TECHNICAL SUPPORT FOR ROCKY MOUNTAIN ARSENAL

Offpost Operable Unit
Endangerment Assessment/Feasibility Study

Final Report

Volume I of VIII
(Introduction)

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PREPARED BY

Harding Lawson Associates
Environmental Science and Engineering, Inc.

PREPARED FOR

PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL

THIS DOCUMENT IS INTENDED TO COMPLY WITH THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969.

THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATION RECORD FOR THIS CERCLA OPERABLE UNIT.

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PREFACE TO THE FINAL ENDANGERMENT ASSESSMENT/FEASIBILITY STUDY

The Rocky Mountain Arsenal Offpost Operable Unit (OU) Endangerment Assessment/Feasibility Study (EA/FS) is presented in eight volumes. The contents of each volume are outlined below. To assist the reader, the complete Table of Contents is included at the beginning of each text volume; appendix volumes include a list of appendixes in the front. Tables and figures for each volume are included at the end of that volume for the sections included in the same volume. The Introduction, EA, FS, and each appendix have separate reference lists.

VOLUME I

- Table of Contents EA/FS - complete Table of Contents for all volumes, followed by List of Tables and List of Figures
- Preface EA/FS - explanation of the organization of the EA/FS report
- Executive Summary - summary of information presented in the EA/FS
- Introduction to the EA/FS - introductory material common to both the EA and the FS, including site history and nature and extent of contamination at the Offpost OU
- Glossary EA/FS - list of acronyms and abbreviations used in the EA/FS

VOLUME II

- Table of Contents EA/FS - complete Table of Contents is included in each volume
- Preface EA - outline of the organization of the EA
- Section 1.0 EA - Identification of Chemicals of Potential Concern
- Section 2.0 EA - Exposure Assessment
- Section 3.0 EA - Toxicity Assessment
- Volume II Tables EA - tables for Sections 1.0, 2.0, and 3.0 of the EA
- Volume II Figures EA - figures for Sections 1.0, 2.0, and 3.0 of the EA

VOLUME III

- Table of Contents EA/FS - complete Table of Contents is included in each volume
- Section 4.0 EA - Human Risk Characterization

- Section 5.0 EA - Ecological Assessment
- Section 6.0 EA - Conclusions
- Section 7.0 EA - References
- Volume III Tables EA - tables for Sections 4.0, 5.0, and 6.0 of the EA
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VOLUME IV

- List of EA Appendixes
- EA Appendixes (A through H) - All Appendixes for the EA

VOLUME V

- Table of Contents EA/FS - complete Table of Contents is included in each volume
- Preface FS - outline of the organization of the FS
- Section 1.0 FS - Feasibility Study Purpose and Organization
- Section 2.0 FS - Development of Remedial Action Objectives and Screening of Technologies
- Volume V Tables FS - tables for Sections 1.0 and 2.0 of the FS
- Volume V Figures FS - figures for Sections 1.0 and 2.0 of the FS

VOLUME VI

- Table of Contents EA/FS - complete Table of Contents is included in each volume
- Section 3.0 FS - Development of Remedial Alternatives
- Section 4.0 FS - Screening of Alternatives
- Section 5.0 FS - Detailed Analysis of Alternatives
- Section 6.0 FS - Selection of the Preferred Sitewide Alternative
- Section 7.0 FS - References
- Volume VI Tables FS - tables for Sections 3.0, 4.0, 5.0, and 6.0 of the FS
- Volume VI Figures FS - figures for Sections 3.0, 4.0, 5.0, and 6.0 of the FS

VOLUME VII

- List of FS Appendixes
- FS Appendixes (A through F) - All Appendixes for the FS

VOLUME VIII

- Response to Comments
- Glossary - list of acronyms used in the responses

EXECUTIVE SUMMARY

This Final Endangerment Assessment/Feasibility Study (EA/FS) is consistent with the National Contingency Plan (NCP), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the regulations implementing the National Environmental Policy Act of 1969 (NEPA), and Federal Facility Agreement (FFA).

ENDANGERMENT ASSESSMENT

An Endangerment Assessment was performed for the Offpost Operable Unit (OU) of Rocky Mountain Arsenal (RMA). The offpost area consists of 27 square miles located to the north and northwest of RMA. The Offpost OU is defined by the Federal Facility Agreement as that portion of the offpost area where the hazardous substances, pollutants, or contaminants from RMA are found, and which is subject to remedial action. On the basis of information existing at the conclusion of the offpost remedial investigation (RI) and the beginning of the EA/FS, the Offpost OU is assumed to be coincident with the offpost area. It is currently characterized by rural agricultural and residential land uses, with some industrial land use. In the future, land use is projected to change to more commercial, industrial, and recreational land use in areas adjacent to RMA, with some areas zoned for residential development (Adams County Planning Commission, 1990). For these reasons, a rural residential scenario (including agriculture), an urban residential scenario (excluding farm animals), and a commercial/industrial scenario were evaluated. An ecological assessment was also performed, due in part to the bald eagle habitat and other sensitive environments in the Offpost OU. The major steps performed in the EA included data evaluation, identification of chemicals of potential concern, exposure assessment, toxicity assessment, human risk characterization, and ecological assessment.

Identification of Chemicals of Potential Concern

Chemicals of potential concern (COCs) were identified by medium. The primary criterion for identification of COCs was a statistically significant increase in concentration in samples

collected from the Offpost OU when compared with samples from locations believed to be unaffected by RMA contamination (i.e., background).

The statistical procedures used in this assessment to determine whether chemical concentrations were elevated above background levels contained several conservative elements when compared with procedures recommended by published guidance. These conservative elements were included to compensate for small sample size and low frequency of detection above certified reporting limits in some of the data sets. The conservative features built into the statistical procedure exceeded published guidance and resulted in the inclusion of four groundwater COCs, two surface-water COCs, and one surface soil COC that would normally have been excluded.

Thirty-four COCs were identified for groundwater, including nine pesticides, five inorganic compounds, and 20 volatile or semivolatile organic compounds. Ten COCs were identified for surface water, including four pesticides, two organic compounds, and four inorganic compounds. Each is also a COC for groundwater, the primary source of offpost surface-water contamination.

The six COCs identified in sediments are all pesticides. These COCs are associated with groundwater and/or surface water that interacts with the sediments in First Creek. Six pesticides were identified as COCs in surface soils.

All of the thirty-four COCs were evaluated for biota; however, only those COCs for which a complete pathway of exposure existed for a specific receptor organism were evaluated in the ecological assessment.

Exposure Assessment

The major elements of the exposure assessment included fate and transport of COCs, characterization of the exposure setting and exposure pathways, quantification of exposure, and an uncertainty analysis of calculated exposure intakes.

Chemicals migrated to the Offpost OU as a result of past operations at RMA, primarily by shallow groundwater and airborne pathways . Contaminant transport by both pathways has been controlled by onpost interim remedial actions. Offpost OU surface water was contaminated primarily by the natural interaction with offpost groundwater. Offpost OU surface soil was

contaminated by the deposition of airborne contaminants, non-RMA-related intentional agricultural application of pesticides, and irrigation practices. Air monitoring data indicate that the air pathway does not contribute to human exposure.

The COCs exhibit great variability in their mobility and persistence in environmental media. Organochlorine pesticides are relatively immobile and persistent, tending to associate with soils and sediments and tending to bioaccumulate in the food chain; the organochlorine pesticides are the only COCs elevated above background levels in soils and sediments. Most of the remaining COCs are mobile in groundwater, and the aromatics and aliphatics are volatile in surface waters. The fate properties of the COCs tend to determine their distribution in the Offpost OU.

Groundwater containing elevated levels of COCs exists north and northwest of RMA in three distinct plumes with characteristically different groundwater quality conditions. These flow paths are referred to as the northern paleochannel, due north of the RMA north boundary; the First Creek paleochannel, paralleling First Creek to the northwest from the RMA north boundary; and the northwest paleochannel, west of the RMA northwest boundary. The northern and First Creek paleochannels comprise the North Plume Group, and the northwest paleochannel is referred to as the Northwest Plume Group. The alluvial flow system transports most of the contamination in paleochannels characterized by coarser sediments. Groundwater traveling through the First Creek paleochannel discharges to First Creek, probably seasonally, resulting in elevated levels of several COCs in First Creek. First Creek discharges to O'Brian Canal. Concentrations of COCs are reduced substantially upon discharge to O'Brian Canal; only two COCs (diisopropyl methylphosphonate [DIMP] and fluoride) are elevated in the Canal.

Land use in the Offpost OU has been predominantly agricultural and rural residential, with localized commercial/industrial land uses and open space. The portion of the Offpost OU north of O'Brian Canal, where irrigation water is available from Burlington Ditch, contains many vegetable and turf farms. A recent change in land use affecting exposure to COCs was the purchase of former residential properties near the intersection of 96th Avenue and Peoria Street by Shell Oil Company. Based on local planning documents, it is expected that development

resulting from encroachment of the Denver suburban fringe from the southwest and the new regional airport to the east will supplant agricultural land uses with residential and commercial/industrial land uses over the next 20 years.

The predominant traditional agricultural land use of the area supports the evaluation of exposure pathways involving consumption of foods produced in the Offpost OU. A complete pathway must have a source, a mechanism of release, a transport medium, an exposure point, a receptor (e.g., humans must be present to be exposed), and an exposure route (e.g., ingestion). The most important pathways considered under the residential reasonable maximum exposure (RME) scenario, including hypothetical future exposure pathways that may not be complete at this time, are direct ingestion of groundwater, inhalation of volatile COCs released from groundwater used for domestic purposes (e.g., showering, cooking), and consumption of vegetables, meat, eggs, and dairy products produced in the Offpost OU. Exposure concentrations in foods were estimated using equilibrium partition models. Predictions by the models were compared to limited site-specific sampling and analytical data, and the model results approximated the limited number of observed concentrations in meat and eggs. Data for milk and vegetables were insufficient to verify the models.

Current and projected future commercial/industrial land uses in zone 5 suggested that exposure pathways consistent with this land use should be evaluated. The most important pathways considered in the RME commercial/industrial scenario are direct ingestion of groundwater and inhalation of volatile COCs from other uses (e.g., showering).

For purposes of the EA, the Offpost OU was subdivided into six geographic zones, each with distinct exposure conditions. Variations in medium-specific exposure concentrations and land and water use were considered in defining these zones, which are shown in Figure ES1. A separate exposure assessment was performed for each zone. Hypothetical future intakes under the RME scenario are greatest in zones 2, 3, and 4, directly north of the RMA north boundary.

Exposure factors used in this EA conformed to U.S. Environmental Protection Agency (EPA) RME guidance wherever applicable factors existed. Where EPA guidance was not

available, RME exposure factors were derived for the 90th percentile of the range of the exposure factor. COC intakes were estimated for lifetime, chronic, and acute exposure durations. The lifetime scenario begins at age 0 and extends for 30 years, considering age-dependent body weight, milk consumption, and direct ingestion of soil. Intakes were estimated for children and adult women to address potentially sensitive subpopulations. The child chronic scenario assumes an exposure duration from ages 1 to 9. Children tend to be exposed at greater rates than adults, so the child chronic scenario represents the RME for chronic noncarcinogenic risk assessment. Commercial/industrial intakes were estimated for adult workers with a 25-year duration.

The RME COC intake estimates include hypothetical exposure pathways that have not been complete for several years (i.e., exposure has not occurred by these pathways). For example, previous residents in zones 3 and 4 and current residents in zone 5 have water supplies other than shallow wells. There are no current residents in zones 3 and 4. Therefore, residential intake estimates in these zones are conservative because the pathways do not represent existing exposures.

A limited quantitative uncertainty analysis was performed to evaluate the possible exposure variation among the potentially exposed population. The uncertainty analysis implies that up to 99 percent of a future exposed population would experience intakes less than the RME. Although there are uncertainties in exposure estimates, the EA generally used conservative approaches to limit the potential for underestimating exposures. Thus, it is reasonable to conclude that the RME falls above the 95th percentile of possible exposures and is thus in the range of exposures consistent with the definition of RME. The uncertainty analysis combines uncertainty in defining exposure concentrations (from monitoring data and models) and variability in hypothetical exposures. The uncertainty analysis process demonstrates that most of the variance in intake estimates can be attributed to variability across the population rather than uncertainty in defining the exposure concentrations.

Toxicity Assessment

Available information on the toxic effects of the COCs, emphasizing information pertinent to the evaluation of subchronic and chronic exposures at relatively low intakes, is summarized in

the toxicity assessment section of the report. Available reference doses and cancer slope factors published by EPA were used in this EA. When chronic reference doses were unavailable from EPA, they were estimated or identified from other sources, particularly the RMA onpost toxicity assessment contained in the Final Human Health Exposure Assessment (Ebasco, 1990).

Two of the COCs, arsenic and benzene, are known human carcinogens (EPA category A). Ten COCs are probable human carcinogens (EPA category B2). Category B2 chemicals have sufficient evidence that the chemical causes cancer in laboratory animals, but insufficient evidence for cancer in humans. Most of the COCs have the potential for noncarcinogenic effects on the liver (hepatic system), and these chemicals were grouped to evaluate the probability of adverse effects on the liver.

The potential effects of the contaminants on terrestrial wildlife, livestock, terrestrial vegetation, and aquatic organisms were also summarized in the toxicity assessment section of this report. Toxicity reference values for biota were developed, which are intended to represent exposure levels that would result in a low probability of adverse effects on a population of nonhuman receptors, rather than to protect every individual animal. The potential for ecological effects was also evaluated by comparing observed tissue concentrations of COCs in biota samples to maximum allowable tissue concentrations, which are summarized in the toxicity assessment and ecological assessment.

Human Risk Characterization

Additive carcinogenic risks for residential hypothetical future exposures at RME intake levels by zone are highest in zones 2, 3, and 4. These zones are south of O'Brian Canal and within approximately one mile of the RMA north boundary. Based on the uncertainty analysis, the hypothetical risks may be overstated by threefold from intake considerations alone. Future hypothetical cancer risks (assuming pathways are complete and without considering additional remediation) in these zones are estimated to be less than 3×10^{-4}. More than 60 percent of the risk in each of these zones is attributable to category B2 and C human carcinogens. Thus, the risk estimate is critically dependent on the extrapolation of toxicological data from animals to humans.

The largest contributor to total carcinogenic risk is dieldrin. Two toxicological profiles discussing both animal and human data are in Appendix F of the EA (page F-1 and F-112).

In addition to RMA-related sources, dieldrin in surface soils north of O'Brian Canal appears to be associated with agricultural practices in the Offpost OU. The hypothetical carcinogenic risk associated with dieldrin in soil resulting from agricultural practices in zones other than zone 3 and 4 is 4×10^{-5}. In addition, naturally occurring arsenic in groundwater contributes approximately 4.4×10^{-5} risk. Summing these two risks yields a 8×10^{-5} risk that is not attributable to RMA.

More than 95 percent of the residential hypothetical carcinogenic risk in each zone is attributable to the following pathways, listed in order of their contribution to risk:

1. Ingestion of shallow groundwater
2. Consumption of homegrown vegetables
3. Ingestion of locally produced milk
4. Inhalation of volatiles via domestic use of shallow groundwater (e.g., showering, cooking)
5. Ingestion of locally produced eggs
6. Ingestion of locally produced meat

Dermal exposures for all media do not contribute significantly to carcinogenic risk for the residential exposure, nor does incidental ingestion of soil and sediments. The oral exposure route for all media accounts for more than 70 percent of total carcinogenic risk, with the remainder predominantly by inhalation.

Groundwater is the dominant source medium contributing to total carcinogenic risk in zones 2, 3, and 4 accounting for 60 to 80 percent of total risk, depending on the zone. In the remaining zones where groundwater concentrations are lower, soil contributes relatively more to total risk (40 to 50 percent), and soil alone contributes a risk from agricultural practices of approximately 4×10^{-5} in all zones. Groundwater, surface water, and soil may contribute to estimated risks via multiple pathways, specifically those involving food production within the Offpost OU. Groundwater and surface water are assumed to be used for irrigation of vegetable

crops and watering of livestock. Each of the food pathways may also accumulate COCs from soil, and these relationships are quantified via the equilibrium partition models.

Hypothetical risks from all carcinogens are added to determine total carcinogenic risk regardless of target organ/system or weight-of-evidence category. The dominant contribution to total carcinogenic risk in all zones is from category B2 and C carcinogens, as previously presented. Carcinogenic risks are also posed by arsenic, a category A human carcinogen.

Hypothetical future noncarcinogenic effects were evaluated for all COCs by calculating a hazard index (HI), which is the estimated intake divided by a reference dose. An HI of greater than 1.0 warrants further evaluation. Children are a potentially sensitive subpopulation in the residential scenario with the largest potential for adverse noncarcinogenic effects, due to higher intakes. Considering the target organ/system potentially affected by each of the COCs, the most probable noncarcinogenic effect would be to the central nervous system (CNS). The maximum hypothetical future additive child chronic HI for CNS toxicants is 4 in zone 4. Hepatic (liver) effects are also a potential, although smaller, risk, with additive chronic HI of 2 in zones 2 and 3.

RME estimates of hypothetical current carcinogenic risks for residential land use are substantially less than future hypothetical risks. No one resides in zones 3 and 4; hence, there is no hypothetical current risk for these zones. Residents in zones 1B and 2 do not use water from the shallow aquifer. Consequently, the domestic use groundwater pathway is not and has not been complete in these zones for several years. Hypothetical current risks in zones 1B and 2 are at least 3 to 4 times lower than the hypothetical future RME estimates.

For the commercial/industrial RME scenario, hypothetical future carcinogenic risks in zone 5 is approximately 3×10^{-5}, with 83 percent of the risk in zone 5 from aldrin, dieldrin, and arsenic. The estimated chronic HIs (liver toxicants) for the commercial/industrial scenario in zone 5 are less than one.

Ecological Assessment

The objective of the ecological assessment was to determine hypothetical adverse affects of COCs on the environment and nonhuman receptors. Two major natural ecosystem types occur in the Offpost OU: terrestrial and aquatic. There is also extensive agricultural use of the area.

Potential hazards to the different ecological components of the Offpost OU were addressed by considering the hazards to terrestrial, aquatic, and agricultural biota separately. Bioaccumulation and direct toxicity endpoints were evaluated for terrestrial and aquatic life. Maximum allowable tissue concentrations (MATCs) were developed to assess risk from tissue residues as a function of bioaccumulation. The predicted tissue concentrations for endrin for the owl and kestrel exceeded the MATC; however, these predicted tissue concentrations are not supported by actual data from lower trophic levels. In addition, exposure concentrations or intakes were compared to acceptable intakes, such as toxicity reference values or reference media concentrations, resulting in a hazard quotient (HQ). The estimated intake of DDE, DDT, aldrin, dieldrin, and endrin for the ecological receptors did not exceed the toxicity reference values. However, an HQ equal to 1 was calculated for the American kestrel for endrin.

The results of the ecological risk characterization indicate that a minimal potential for adverse effects to receptor species in the aquatic and terrestrial foodwebs exist. Species in the agricultural food web are not expected to be at risk because of exposure to the COCs. Plant life, cattle, and chickens will be relatively unaffected based on the results of the risk characterization.

Endangerment Assessment Conclusion

The objectives of the EA were to provide an analysis of risks in the absence of additional remediation (baseline risks) and to provide a basis for determining the need for remedial action at the Offpost OU. The EA for the Offpost OU has identified hypothetical carcinogenic risks that are within the acceptable carcinogenic risks as defined by the revised NCP (EPA, 1990) and the Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions (EPA, 1991). Hazard indices only exceeded 1.0 in some noncarcinogenic exposure scenarios.

Although these findings indicate that the Offpost OU remedial action is not warranted on a risk basis, site-specific factors suggest that remedial alternatives for the groundwater medium should be considered. Accordingly, a Feasibility Study has been prepared as a companion document to the EA for the Offpost OU.

FEASIBILITY STUDY

Based on the results of the EA, the FS concurrently developed and evaluated a range of remedial alternatives consistent with the NCP. Based on the evaluation presented in this FS, the Army selected a preferred sitewide alternative, which is consistent with CERCLA and the NCP. The FS shows that the preferred sitewide alternative meets the statutory requirements of CERCLA and the NCP. The major steps performed in the FS include development of remedial action objectives (RAOs), development and screening of remedial alternatives, detailed analysis of remaining alternatives, and selection of the preferred sitewide alternative.

Development of Remedial Action Objectives

The development of RAOs consisted of three steps:

- Identification of COCs by medium
- Identification of media of concern
- Identification of exposure pathways.

Six media were evaluated in the remedial investigation (RI) for the Offpost OU: groundwater, soil, surface water, sediment, air, and biota. Each medium was evaluated in the Offpost EA with respect to (1) the nature and extent of contamination and (2) potential exposure pathways and associated risk characterization.

The cumulative Offpost OU hypothetical cancer risk is a maximum of 3×10^{-4} on the basis of the RME risks presented in the EA (Volume III, Section 4.0 and Volume IV, Appendix G). Since the Offpost OU cumulative risk is within the acceptable cancer risk range specified by EPA, Offpost OU remedial action is not warranted. The Army, nevertheless, recognizes that there are site-specific factors that suggest remediation of groundwater is preferable to no-action in the

Offpost OU. Groundwater contributes approximately 75 percent of the total hypothetical risk, and the data available showed exceedances of some MCLs in groundwater. Additionally, substantial progress has been made toward the construction and startup of an offpost groundwater treatment system. Since the remaining media contribute a minor amount of risk to the total, the Army concludes that these media do not require development of remedial action objectives (RAOs). On this basis, groundwater was identified as a medium of concern. Soil, surface water, and sediment were identified as not requiring remediation due to the low risk attributable to these media. Air was not identified as a medium of concern because air monitoring data have indicated air quality within the Offpost OU is not affected by contaminants related to RMA. Biota were not identified as a medium of concern. Direct remediation of biota was not included on the basis that it is not effective except by methods that temporarily eliminate receptor species from the contaminated area. However, protection of biota was addressed through the development of ecological criteria for the protection of species potentially at risk.

Groundwater RAOs specify the attainment of preliminary remediation goals (PRGs) for the identified COCs and exposure pathways. In accordance with the NCP, PRGs were developed considering applicable or relevant and appropriate requirements (ARARs), health-based criteria, factors related to technical limitations (e.g., analytical detection limits), land use, and ecological criteria. Final remediation goals will be determined when the remedy is selected and the Record of Decision is issued.

Groundwater exceedances of PRGs were identified in two plume groups, the North Plume Group and the Northwest Plume Group, an area encompassing approximately 590 acres in the Offpost OU. Groundwater alternatives were developed to address the areas of PRG exceedances.

Development and Screening of Remedial Alternatives

Remedial alternatives for the Offpost OU were developed by (1) identifying the media in which COCs were detected at levels exceeding PRGs, (2) calculating the areas and volumes of media exceeding PRGs, and (3) assembling combinations of representative process options into alternatives representing a range of treatment and containment combinations that address the

RAOs. Consistent with the NCP, a range of alternatives for groundwater was developed from no action to complete removal or destruction of contaminants exceeding PRGs.

Use of Groundwater Modeling in Alternatives Development

To aid in the analysis of groundwater alternatives, two numerical models (North Plume Group and Northwest Plume Group) were prepared to simulate the groundwater flow and dissolved chemical transport in the Offpost OU. Due to the approximate nature of the models, and the considerable uncertainty in the conceptual model and hydrogeologic parameters, none of the modeling results should be construed as accurate predictions of future contaminant distribution. Rather, the models and modeling results should be viewed as tools for assessing the relative merits of remedial alternatives. Although there are inherent uncertainties in the groundwater model, this is a tool being used by the FS and predicted differences in remediation timeframes are considered with respect to evaluating alternative effectiveness. Simulations of contaminant transport were made corresponding to the No Action alternative and other configurations for both the North and Northwest Plume Groups. Initial conditions were chosen to reflect the contaminant plumes and to reflect contaminant removal at the North Boundary Containment System (NBCS) and Northwest Boundary Containment System (NWBCS) consistent with attainment of Offpost OU PRGs at the boundary systems.

North Plume Group Alternatives

After screening several extraction/recharge configurations, the following groundwater alternatives were developed for the North Plume Group. The major components of each alternative are also listed.

Alternative No. N-1: No Action

The components are as follows:

- Long-term groundwater monitoring
- Five-year site reviews

This alternative was retained for the detailed analysis step as required by the NCP.

Common to the following alternatives are long-term groundwater monitoring and five-year site reviews, as well as the Army's commitment to provide alternative water (i.e., exposure control) to any identified future users of groundwater exceeding PRGs.

Alternative No. N-2: Continued Operation of the North Boundary Containment System With Improvements as Necessary

The major components are as follows:

- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative was retained for the detailed analysis step.

Alternative No. N-3: Land Acquisition and Use Restrictions

The major components are as follows:

- Land acquisition
- Access and deed restrictions
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative was not retained for the detailed analysis step.

Alternative No. N-4: Interim Response Action A

The major components are as follows:

- Removal of contaminated unconfined groundwater north of the RMA boundary in the First Creek and northern paleochannels, using Interim Response Action (IRA) A groundwater extraction wells
- Treatment of the organic COCs present in the groundwater, using carbon adsorption
- Recharge of treated groundwater to the unconfined flow system (UFS), using IRA A wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS and IRA A as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative was retained for the detailed analysis step.

Alternative No. N-5: Expansion 1 to Interim Response Action A

The major components are as follows:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels, using IRA A groundwater extraction wells
- Expansion 1 of IRA A (additional wells and trenches)
- Treatment of organic COCs present in the groundwater, using carbon adsorption
- Recharge of treated groundwater to the UFS, using wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative was retained for the detailed analysis step.

Alternative No. N-6: Expansion 2 to Interim Response Action A

The major components are as follows:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels, using IRA A groundwater extraction wells
- Expansion 2 of IRA A (additional wells and trenches)
- Treatment of the organic COCs present in the groundwater, using carbon adsorption
- Recharge of treated groundwater to the UFS, using wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative was not retained for the detailed analysis step.

Northwest Plume Group Alternatives

After screening several extraction/recharge configurations, the following groundwater alternatives were developed for the Northwest Plume Group. The major components for each alternative are also listed.

Alternative NW-1: No Action

The major components are as follows:

- Long-term monitoring
- Five-year site review

This alternative was retained for the detailed analysis step as required by the NCP.

Common to the following alternatives are long-term groundwater monitoring and five-year site reviews, as well as the Army's commitment to provide alternative water (i.e., exposure control) to any identified future users of groundwater exceeding PRGs.

Alternative NW-2: Continued Operation of the Northwest Boundary Containment System With Improvements as Necessary

The major components are as follows:

- Continued operation of the NWBCS
- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative was retained for the detailed analysis step.

Alternative No. NW-3: Land Acquisition With Use Restrictions

The major components are as follows:

- Land acquisition
- Access and deed restrictions
- Continued operation of the NWBCS
- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative was not retained for the detailed analysis step.

Alternative No. NW-4: Northwest Plume Groundwater Extraction/Recharge System

The major components are as follows:

- Removal of contaminated UFS groundwater northwest of the RMA boundary, using three groundwater extraction wells
- Treatment of organic COCs present in the groundwater, using carbon adsorption
- Recharge of treated groundwater to the UFS, using five wells
- Continued operation of the NWBCS
- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring

- Five-year site reviews
- Exposure control

This alternative was not retained for the detailed analysis step.

Detailed Analysis of Alternatives

The remaining alternatives (Alternative Nos. N-1, N-2, N-4, N-5, NW-1, and NW-2) were evaluated with respect to the threshold and primary balancing criteria required by the NCP. The criteria are listed below

Threshold Criteria

- Overall protection of human health and the environment
- Compliance with ARARs

Primary Balancing Criteria

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost

Evaluation of the modifying criteria (i.e., the state and community acceptance) is deferred until completion of the state and public comment periods.

A comparative analysis of the remedial alternatives identifying the relative advantages and disadvantages of each alternative was performed. Based on the analysis, a preferred sitewide alternative was selected.

Selection of the Preferred Sitewide Alternative

Using the evaluation of the alternatives with respect to the criteria required by CERCLA and the NCP, the preferred alternative was selected. The preferred sitewide alternative consists of

Alternative No. N-4 (Interim Response Action A) for remediation of groundwater in the North Plume Group and Alternative No. NW-2 (Continued Operation of the NWBCS with Improvements as Necessary) for remediation of groundwater in the Northwest Plume Group.

Redefinition of the Offpost Operable Unit

On the basis of the FS analysis of and selection of the preferred alternative and the Federal Facility Agreement definition of the Offpost OU, the offpost area is not coincident with the Offpost OU. Consistent with the Federal Facility Agreement definition limiting the Offpost OU to that portion of the offpost area where hazardous substances, pollutants, or contaminants from RMA are found at levels subject to remedial action, the Offpost OU is defined as only zones 2, 3, and 4 in the offpost area.

INTRODUCTION TO THE ENDANGERMENT ASSESSMENT/FEASIBILITY STUDY OFFPOST OPERABLE UNIT

The Final EA/FS report complies with guidelines prepared under the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (Title 42, United States Code [USC], Sections 9601-9675), the Superfund Amendments and Reauthorization Act of 1986 (SARA), the revised National Contingency Plan (NCP) (Title 40, United States Code (USC) of Federal Regulations [CFR] Part 300), the regulations implementing the National Environmental Policy Act of 1969 (NEPA), and associated U.S. Environmental Protection Agency (EPA) guidance documents.

This introduction provides background information for the Offpost OU including setting, site history and land use, previous investigations, nature and extent of contaminants, and response actions for the Offpost OU.

SETTING

This section describes the site location, environmental setting, geology, and hydrogeology of the Offpost OU.

Site Location

The RMA National Priorities List (NPL) site is comprised of two OUs: Onpost and Offpost. As shown in Figure 1, the offpost area occupies 27 square miles in southern Adams County, Colorado, and lies north of the Denver metropolitan area and east of Commerce City, Colorado. The offpost area is defined as the area southeast of the South Platte River, north of 80th Avenue, southwest of Second Creek, and north of the north and northwest boundaries of RMA, as depicted in Figure 2. The Offpost OU is defined by the Federal Facility Agreement as that portion of the offpost area where hazardous substances, pollutants, or contaminants from RMA are found, and which is subject to remedial action. Additionally, the Offpost OU includes the surface waters of O'Brian Canal and Burlington Ditch as they extend northeast of Second Creek and the surface

water of Barr Lake. The Offpost OU encompasses rural residential, agricultural, and commercial/industrial areas located north and northwest of RMA.

Environmental Setting

The topography of the Offpost OU is similar to the topography onpost and consists of stream-valley lowlands separated by gently rolling uplands. The maximum local topographic relief in the area is about 300 feet. The elevation above mean sea level (MSL) ranges from approximately 5330 feet at the southern boundary of RMA to about 5030 at the South Platte River.

Cropland and rangeland provide habitat for numerous animal species, including game species such as cottontails, ring-necked pheasants, and mourning doves. Lake and wetland areas at Barr Lake provide feeding, breeding, and roosting areas for waterfowl and endangered species, including the bald eagle.

The climate of the offpost area is characterized by sunny, semiarid conditions. Approximately 37 percent of the total annual precipitation (16 inches) occurs in the spring, with much of this moisture falling as snow in the early spring. Summer is the hottest season and is characterized by scattered local thunderstorms during afternoons and evenings. Approximately 31 percent of the total annual precipitation occurs during the summer season. Winter is the coldest season, during which time approximately 13 percent of the total annual precipitation occurs.

The regional surface drainage is to the northeast toward the South Platte River. Surface water originating south of RMA, on RMA, or in the Offpost OU flows toward the South Platte River. Two major canals, O'Brian Canal and Burlington Ditch, and several smaller ditches flow from southwest to northeast between RMA and the South Platte River. O'Brian Canal receives some drainage from the Offpost OU and RMA where the canal intercepts First Creek. Burlington Ditch may receive surface water infrequently from First Creek.

Geology

Sediments at the land surface in the Offpost OU consist of unconsolidated alluvial and eolian deposits of Pleistocene and Holocene age. The composition of the unconsolidated sediments varies from clays to coarse gravels, and the thickness varies from less than 10 feet to approximately 100 feet. The thickest deposits of unconsolidated sediments occur in paleochannels eroded into the underlying Denver Formation.

The Denver Formation is of late Cretaceous to early Tertiary age, and consists of 250 to 300 feet of interbedded shale, claystone, siltstone, and sandstone, with a regional dip of one-half to one degree to the southeast. The uppermost bedrock unit was subjected to erosion before deposition of the overlying unconsolidated units. Paleochannels incised into the bedrock surface are present in many areas in the Offpost OU.

The presence of paleochannels in the Denver Formation surface has an impact on groundwater flow in the unconfined flow system (UFS). Two such paleochannels, the First Creek and northern paleochannels, are present north of the RMA North Boundary Containment System (NBCS). An additional paleochannel, the northwest paleochannel, is present west of the RMA Northwest Boundary Containment System (NWBCS). Coarse, unconsolidated materials commonly found within these paleochannels provide for preferential groundwater movement in the UFS. Groundwater contaminant plumes that have historically migrated across the RMA boundaries to the Offpost OU are generally confined to these paleochannels.

The Arapahoe Formation lies beneath the Denver Formation at depths of 230 to 300 feet at the RMA north boundary and has a regional dip of one-half to one degree to the southeast. The formation consists of 400 to 700 feet of interbedded conglomerate, sandstone, siltstone, and shale. The upper portion consists predominantly of 200 to 300 feet blue to gray shale with some conglomerate and sandstone beds. The lower portion consists largely of sandstone and conglomerate with less prevalent beds of shale. The lower portion is a source zone for many water supply wells in the area. The Arapahoe Formation is the oldest geologic unit present beneath the site that was investigated in the Offpost Remedial Investigation (RI) and Offpost RI Addendum programs.

Alluvial and eolian Pleistocene and Holocene deposits form much of the ground surface in the Offpost OU. At some locations, Denver Formation units crop out at the ground surface. The Arapahoe Formation is not present at the ground surface anywhere in the Offpost OU.

Hydrogeology

The two principal water-bearing units in the Offpost OU that have been impacted by chemicals originating from RMA are the unconsolidated alluvial deposits and the underlying Denver Formation. The hydraulic properties of these two units, including hydraulic conductivity, porosity, and associated groundwater flow velocities, are distinctly different. Hydraulically, these two units generally behave as distinct hydrostratigraphic units.

Groundwater flow in the Offpost OU area occurs within an UFS that overlies a confined flow system (CFS). The UFS includes groundwater present in the unconsolidated materials overlying the Denver Formation, the weathered upper portion of the Denver Formation, and, near the South Platte River, the weathered upper portion of the Arapahoe Formation.

The CFS includes the deeper portions of the Denver Formation and the underlying Arapahoe Formation. The Final Water RI (Ebasco, 1989), the Final Offpost RI (ESE, 1988a), and the Draft Final Offpost RI Addendum (Harding Lawson Associates [HLA], 1991a) reports provide further information concerning the conceptual model of groundwater flow in the unconfined and confined flow systems (UFS and CFS). On the basis of an evaluation of the distribution of contaminant plumes in the Offpost OU area, the UFS is considered the principal migration route for groundwater contaminants from onpost to the Offpost OU, although some contaminants are present in the CFS in the Denver Formation and isolated occurrences of a few contaminants have been detected in some domestic Arapahoe Formation wells.

Water-level data for the UFS were collected from all Offpost OU monitoring wells during several monitoring events and programs. The UFS potentiometric surface slopes predominantly toward the northwest, indicating groundwater flow in that direction. This information is consistent with the interpretation that the South Platte River is a regional discharge point for the groundwater system in the Offpost OU. Hydraulic gradients in the Offpost OU range from

0.003 to 0.02 ft/ft and average approximately 0.004 to 0.005 ft/ft. The hydraulic gradients are highest in the area immediately downgradient of the NBCS and in the vicinity of O'Brian Canal and Burlington Ditch.

The hydraulic gradient of the UFS near the canals is consistent with that reported in the Final Offpost RI. However, the hydraulic gradient near the NBCS has increased as a result of the installation and operation of recharge trenches in late 1988. Operation of these trenches has increased groundwater recharge in northern portions of Sections 23 and 24, near the northern RMA boundary.

The confined Denver Formation is heterogeneous and consists of interbedded claystones, siltstones, sandstones, and organic-rich (lignitic) intervals. Water-bearing layers of sandstone and siltstone occur in irregular beds dispersed within thick sequences of relatively impermeable material. Individual sandstone layers commonly are lens-shaped and range in thickness from a few inches to as much as 50 feet. Confined aquifer conditions are observed in sandstone layers within the deeper portions of the Denver Formation.

Water-level data collected from three Arapahoe Formation wells installed under the RI Addendum program indicate that the Arapahoe Formation is a confined aquifer. Data generally indicate that the Arapahoe Formation has a northerly to northwesterly regional groundwater flow direction, as presented in the Final Offpost RI.

SITE HISTORY AND LAND USE

This section presents a discussion of former RMA and Offpost OU activities and land uses.

Former Disposal Practices

RMA began operation in 1942. RMA was a site for the manufacture and demilitarization of chemical and incendiary munitions and the manufacture of industrial chemicals, primarily pesticides and herbicides, until 1984. A detailed account of disposal practices associated with these operations is presented in the Onpost Study Area Reports and RI Media Reports for each potential site.

From 1945 to 1950, RMA distilled available stocks of Levinstein mustard, demilitarized several million rounds of mustard-filled shells, and test-fired mortar rounds filled with smoke and high explosives. Also, many different types of obsolete World War (WW) II ordnance were destroyed by detonation or burning.

Colorado Fuel and Iron (CF&I) leased facilities at RMA in 1946. Julius Hyman & Company first leased facilities in 1947, and succeeded to the CF&I leasehold interest, with some modifications and additions in 1949. Shell Oil Company acquired a majority interest in Hyman in 1952, and operated the plant as the Julius Hyman Company until 1954, when the operation became the Shell Chemical Company - Denver Plant.

RMA was selected as the site for construction of a facility to produce Sarin, a nerve agent. The facility was completed in 1953, with the manufacturing operation continuing until 1957 and the munitions-filling operations continuing until late 1969. From 1970 until 1984, RMA was involved primarily with the disposal of chemical warfare material. This disposal included the incineration of TX anticrop agent and mustard agent explosive components, and the destruction of Sarin and related munitions casings by caustic neutralization.

Chemicals were introduced to the RMA environment primarily by the burial or surface disposal of solid wastes, discharge of wastewater to basins, and leakage of wastewater and industrial fluids from chemical and sanitary sewer systems. Munitions were destroyed and disposed of in trenches. Wastewater generated by the Army and private industry in the South Plants and North Plants areas was discharged to a series of unlined evaporation and holding basins (Basins A, B, C, D, and E) and to asphalt-lined Basin F at various times throughout the history of RMA operations.

The primary areas that have contributed to groundwater contamination at RMA include (1) former manufacturing facilities, (2) former waste storage basins, (3) solid waste disposal areas, (4) the chemical sewer system, and (5) locations with in the rail classification yard, and (6) the motor pool area.

Land Use

The current land use within the Offpost OU is predominantly agricultural and rural residential with localized commercial/industrial land uses and open spaces. Areas within the Offpost OU are largely used for rangeland and dryland farming, with some rural residential areas and scattered areas of intensive agricultural use. Certain areas within the Offpost OU are currently zoned and developed for commercial/ industrial activities. Commerce City, which is located west of RMA, is the only urban area in the immediate vicinity of RMA and has recently annexed lands within the Offpost OU. Another geographic feature in the Offpost OU is Barr Lake, a state recreation area.

Farming in the Offpost OU ranges from large grain operations covering square miles to small subsistence farms to vegetable gardens. A number of these farms also maintain livestock. Subsistence and hobby farmers often consume a large part of their diet from locally produced vegetables and livestock produced in the Offpost OU.

Intentional application of pesticides for pest control purposes likely accounts for the presence of some concentrations of pesticides in Offpost OU soil. Many of the pesticides detected in Offpost OU soil are or have been commercially available and may have been applied agriculturally or residentially. These pesticides include cyclodiene compounds and chlorinated hydrocarbon insecticides.

The cyclodiene compounds aldrin, endrin, dieldrin, and isodrin detected in Offpost OU soil have been used as insecticides in areas similar to the Offpost OU from the 1940s to the mid-1970s. Aldrin was used in the early 1950s to protect cotton against boll weevils and in the 1970s for soil application in grain crops and termite control. In Colorado, dieldrin was used to control insects in field vegetable, grain, and fruit crops (Mullins, 1971) and against termites and locusts. Endrin was also used to control a wide range of pests. These insecticides were banned for general uses in 1974 by the EPA. Aldrin and dieldrin may still be used for certain restricted uses such as subsurface insertion for termite control and dipping of nonfood roots.

Evaluation of projected future land use at the Offpost OU indicates that areas of commercial/industrial land use will increase (Adams County Planning Commission, 1987). Rural residential (including agricultural) land use is expected to decrease in the Offpost OU.

PREVIOUS INVESTIGATIONS

As a result of the detection of chemicals in the Offpost OU, the Army initiated a regional sampling of hydrogeologic surveillance program requiring the quarterly collection and analysis of samples from more than 100 onpost and offpost wells and surface-water stations. This program was carried out under the direction of the RMA Contamination Control Program, established in 1974 to ensure compliance with federal and state environmental laws. The objectives of this program were to evaluate the nature and extent of contamination and to develop response actions to control chemical migration. Potential and actual chemical sources were assessed, and chemical migration pathways were evaluated. To minimize offpost discharge of RMA chemicals via groundwater, three boundary containment systems were constructed, one each at the northern, western, and northwestern boundaries of RMA. All three systems are currently in operation to intercept and treat contaminated groundwater and to recharge treated water.

From 1975 to the present, numerous groundwater monitoring programs have been conducted at RMA. The Army designed and implemented the 360 Degree Monitoring Program to monitor regional groundwater and surface water. The Army designed and implemented boundary system monitoring program to support the operation of the boundary control systems. Studies conducted at RMA to assess groundwater and surface-water conditions are discussed below.

The RMA Offpost Contamination Assessment Report (CAR) (ESE, 1987a) incorporated data from several studies to depict the distribution and concentrations of offpost contamination north and northwest of RMA. The scope of this investigation was intended to address critical data gaps required to evaluate a comprehensive set of multimedia exposure pathways. In the mid-1980s, the potential for contamination of private wells was investigated. These were referred to as Consumptive Use (CU) Studies, Phases I, II, and III. The CU Phase I and II studies (ESE, 1985; ESE

1986) addressed the RMA offpost area bounded to the south by East 80th Avenue, to the northwest by the South Platte River, and to the north and east by Second Creek.

In the CU Phase III study (ESE, 1987b), the Army conducted an inventory of privately owned drinking water wells in an area bound by East 80th Avenue on the south, East 96th Avenue on the north, the South Platte River on the west, and RMA on the east. The objectives of the study were as follows:

- Locate all shallow domestic wells (less than 100 feet) in the study area.
- Sample a representative number of the located wells.
- Assess the groundwater quality of the shallow alluvial aquifer.

U.S. Environmental Protection Agency Study Area

In 1981, a random national survey of drinking water systems was conducted by EPA. Several organic chemicals were detected in South Adams County Water and Sanitation District (SACWSD) wells. Additional sampling in 1982 and 1985 confirmed these results. As a result of these findings, EPA began an RI/FS of an area located west of RMA and south of the Offpost OU.

RMA was suspected as one of the potential sources of contaminants in the EPA study area because of the history of waste disposal practices on that site. In response, the Army and EPA built a water supply system for SACWSD. Further investigation by EPA's Field Investigation Team indicated that source areas other than RMA may have been contributing to groundwater contamination detected within the study area. Groundwater monitoring wells installed on the Chemical Sales Company (CSC) property have since confirmed that CSC is a possible source of groundwater contamination west of RMA and south of the Offpost OU.

Comprehensive Monitoring Program

In the mid-1980's, the Program Manager for RMA (PMRMA) developed the Comprehensive Monitoring Program (CMP), a long-term multimedia monitoring program designed to provide data

to facilitate evaluation of response actions. Sample collection under the CMP commenced in 1987, and data from the CMP were used in performing this EA/FS.

Scope of the Remedial Investigations

Based on known areas of onpost and offpost contamination and the predominant groundwater and surface-water flow patterns, the Offpost OU for the Offpost RI/FS is the area between north and northwest boundaries of RMA and the South Platte River. The specific boundaries of the unit are the same as for the Offpost CAR, as shown in Figure 2 and described below:

- Southeast boundary - north and northwest boundaries of RMA
- Southwest boundary - 80th Avenue
- West and northwest boundary - South Platte River
- Northeast boundary - Second Creek

The Offpost OU was originally selected on the basis of a conservative estimate of the area with which RMA chemicals may now or may eventually exist. However, based on current knowledge (HLA, 1991a), most of the Offpost OU is not contaminated by chemicals originating from RMA. The surface waters of Barr Lake have also been included in the Offpost OU because of the potential for contaminant migration through surface-water features.

Several sources of trichloroethene have been documented south of the Offpost OU in or near Commerce City. Also, recent investigations by EPA and the Army along the western sections of RMA have detected the presence of a trichloroethene plume entering Township 35, Range 67W, Section 9 along the southern boundary of RMA. Although trichloroethene has been detected in selected dewatering wells of the Irondale system, no trichloroethene has been detected in the influent or effluent sumps of the system. Because of the potential for multiple trichloroethene sources upgradient of the Offpost OU, trichloroethene detected in the area between 80th and 88th Avenues falls under the jurisdiction of EPA.

The primary objectives of the Offpost RI were to:

- Collect additional data to refine the current understanding of groundwater flow and surface-water patterns, and the nature and extent of contaminants offpost of RMA.

- Evaluate the potential for chemical migration to the Offpost OU in various media, such as groundwater, surface water, sediment, air, and biota.
- Provide additional data necessary, to complete the EA/FS.

The review of past studies provided the data to evaluate wells that have been sampled in the past, use results from previous aquifer tests, to analyze historical onpost and offpost contaminant plumes, and to examine and develop an overall geologic and hydrologic understanding of the Offpost OU. Additionally, biota and air quality information for the Offpost OU were reviewed and used to assess the human and environmental receptors that may be at risk and to define airborne pollutant pathways.

As a result of the review of the past programs and the original Offpost RI program, limitations to the groundwater, soil, surface water, sediment, and biota databases were identified, and appropriate sampling and analysis were completed in the RI Addendum (HLA, 1991g) program. Data collection consisted of compiling new hydrogeologic and chemical data relevant to the Offpost OU. Data were obtained by drilling new wells and borings, collecting groundwater and surface-water samplers for analysis, measuring groundwater levels and surface-water flows, conducting aquifer tests, and obtaining sediment samples for analysis.

Surface-water and sediment samples were collected in the Offpost OU to define chemicals in the media. Samples were collected from streams, creeks, impoundments, and lakes that were suspected pathways for migration of onpost contamination to the Offpost OU. The data were used to evaluate contamination in surface water and sediment as well as to evaluate surface water and groundwater interaction.

Biota and air-quality condition were evaluated using onpost and offpost information collected during past and current studies. Input from the Offpost CAR was used to assess transport of chemicals and impacts on biota in the Offpost OU from onpost conditions. Data from the Air RI Report (ESE, 1988b) were used to assess the potential for migration of airborne chemicals to the Offpost OU.

The water, sediment, biota, and air quality information was organized so that a comprehensive evaluation of RMA chemicals in all media could be made in the Offpost OU. The information collected during the Offpost RI and RI Addendum was integrated with historical data as well as data being collected during other ongoing RMA investigations.

In general, the RI Addendum summarizes new information primarily pertaining to further assessment of the extent of contamination in various media (groundwater, soil, surface water, sediment, and biota) within specific geographic areas. Activities performed in preparation of the RI Addendum include a review of existing data and collection and interpretation of additional field data to address identified data needs.

NATURE AND EXTENT OF CONTAMINATION

This section discusses the nature and extent of contaminants in the groundwater, soil, surface water, sediment, and air media in the Offpost OU as currently understood. The Offpost RI and RI Addendum reports were the primary sources of information for the groundwater, soil, surface water, sediment, and biota media. Another source of information for the groundwater medium was CMP annual groundwater data. The primary source of information on the air medium was the CMP Air Quality Data Assessment Report for 1989 (RLSA, 1990). In determining COCs and exposure point concentrations, the EA used environmental data for the period 1985 to 1991 including these reports.

Groundwater - Semivolatile Organic Compounds

This section provides a summary of the nature and extent of contamination in groundwater in the Offpost OU on the basis of groundwater occurrence in both the UFS and CFS. Diisopropylmethylphosphonate (DIMP), dicyclopentadiene, dieldrin, and endrin are the most widespread and consistently detected semivolatile organic compounds (SVOCs) in groundwater in the Offpost OU of these chemicals.

The most widespread contaminant detected in groundwater in the Offpost OU is DIMP. As Figure 3 illustrates, DIMP is distributed in a continuous plume extending from the RMA north

and northwest boundaries to the South Platte River. Samples from 89 monitoring wells were analyzed for DIMP, which DIMP was above the CRL in 71 of these samples. In general, the highest concentrations of DIMP offpost occur between the RMA northern boundary and the O'Brian Canal. The highest observed concentrations were 5800 micrograms per liter (μg/l) in the First Creek paleochannel, 860 μg/l in the northern paleochannel, and 80 μg/l in the northwest paleochannel.

Current data indicate the distribution of dicyclopentadiene, as shown in Figure 4, is generally limited to the First Creek paleochannel. The maximum concentrations of dicyclopentadiene reported in the Offpost RI Addendum was 600 μg/l.

The distribution of dieldrin is shown in Figure 5. Dieldrin occurs in the Offpost OU north of the northern and northwestern RMA boundaries. The highest concentrations of dieldrin are found in wells located in the First Creek paleochannel, ranging from 0.6 to 0.9 μg/l. Dieldrin plumes are also interpreted in limited areas in the northern paleochannel and in two areas north of the northwestern RMA boundary. Detectable concentrations of dieldrin in the northern paleochannel and northwestern paleochannel ranged from 0.05 to 0.14 μg/l.

The distribution of endrin is shown in Figure 6. The highest concentrations of endrin ranged from approximately 0.25 to 0.75 μg/l for wells immediately north of the northern RMA boundary. The maximum concentration of endrin was 0.748 μg/l from well 37309, located approximately 1500 feet north of RMA. Endrin was also detected in groundwater samples collected from wells in the central portion of the northern paleochannel.

Other SVOCs were detected in groundwater samples from the Offpost OU. The other SVOCs detected include the pesticides atrazine, malathion, and parathion; the organsulfur compounds 4-chlorophenylmethyl sulfone ($CPMSO_2$) and 4-chlorophenylmethyl sulfoxide (CPMSO); and the organchlorine pesticides aldrin, isodrin, chlordane, 2,2-bis (para-chlorophenyl)-1,1-dichloroethene (DDE), and 2,2-bis (para-chlorophenyl)-1,1,1-trichloroethane (DDT).

The distribution of atrazine in the Offpost OU is similar to that of the organochlorine pesticides (OCPs). Atrazine was detected in 21 Offpost OU wells, with the maximum

concentrations occurring in the First Creek (46.0 μg/l) and northern (72.9 μg/l) paleochannels. Atrazine was generally not detected in groundwater samples collected from the Offpost OU off the northwestern RMA boundary, except for two isolated occurrences.

Although CPMSO and $CPMSO_2$ are both organosulfur compounds, their distributions in offpost groundwater differ. CPMSO was generally only found in samples collected from wells installed in the northern paleochannel, whereas $CPMSO_2$ was generally only found in samples collected from wells located in the First Creek paleochannel. CPMSO was generally found at levels higher than those reported for $CPMSO_2$. CPMSO was detected at concentrations up to 82.2 μg/l in the northern paleochannel. $CPMSO_2$ was also detected in the First Creek paleochannel at concentrations up to 21.0 μg/l.

The distribution of the additional OCPs (aldrin, isodrin, chlordane, DDE, and DDT) is similar to the previously discussed distribution of the OCPs dieldrin and endrin. The maximum concentrations of these compounds generally occur in the First Creek paleochannel, usually in the area 500 to 1000 feet north of the NBCS. Generally, only sporadic, isolated occurrences of these compounds were observed in the Offpost OU north of the RMA northwestern boundary.

Groundwater - Volatile Organic Compounds

The volatile organic compounds (VOC) most frequently detected in the Offpost OU include chloroform, chlorobenzene, dibromochloropropane, tetrachloroethene, trichloroethene, 1,2-dichloroethene, carbon tetrachloride, and benzene.

Chloroform occurs primarily downgradient of the NWBCS and in the northern paleochannel, as shown in Figure 7. Chloroform was generally not found in the First Creek paleochannel. Concentrations of chloroform emanating from the northern RMA boundary are higher than concentrations in the Offpost OU north of the northwestern RMA boundary. The highest concentrations of chloroform occur at the north end of the northern paleochannel (200 to 400 μg/l). The highest concentration of chloroform was 19.8 μg/l in the northwestern paleochannel.

The distribution of chlorobenzene is presented in Figure 8. The plumes are confined to localized portions of the First Creek and northern paleochannels. The maximum concentration of chlorobenzene was 38.2 μg/l in a groundwater sample collected from a well located in the northern paleochannel approximately one mile north of RMA. The maximum reported concentration in the First Creek paleochannel is less than 2 μg/l.

The distribution of dibromochloropropane is shown in Figure 9. As shown in Figure 9, dibromochloropropane was generally only found in samples from wells in the northern paleochannel. A few isolated occurrences of dibromochloropropane were observed in the First Creek paleochannel and immediately downgradient of the O'Brian Canal near the northern end of the northern paleochannel. The maximum concentrations of dibromochloropropane ranged from approximately 2 to 7 μg/l in a few wells located in the northern paleochannel. All other detectable levels of dibromochloropropane were less than 1 μg/l.

The distribution of trichloroethene and tetrachloroethene is presented in Figures 10 and 11, respectively. These VOCs are found in the First Creek and northern paleochannels. The highest concentrations of these compounds were detected in samples collected from wells located at the northern end of the northern paleochannel. The concentrations of tetrachloroethene are higher than those reported for trichloroethene. The maximum concentrations of tetrachloroethene were approximately 100 μg/l in two wells located in the northern paleochannel, approximately one-mile north of the RMA boundary. The highest concentrations of trichloroethene in the Offpost OU north of RMA ranged from approximately 5 to 7 μg/l.

Other volatile organic compounds (VOCs) detected in the Offpost OU include benzene, carbon tetrachloride, 1,1,1-trichloroethane, 1,1-dichloroethane, 1,2-dichloroethene, toluene, and xylenes. These compounds were generally found in only a few groundwater samples collected from wells installed in the UFS.

Groundwater - Inorganic Compounds

This section describes the distribution of selected inorganic constituents in groundwater. The inorganics presented below include arsenic, chloride, fluoride, and mercury.

The distribution of arsenic based on data collected in support of the Offpost RI Addendum and for the CMP, is shown in Figure 12. As shown in Figure 12, the distribution of arsenic is sporadic, with detectable levels of arsenic occurring in a number of areas. Arsenic occurs in a plume along the First Creek paleochannel. The maximum concentrations of arsenic in the Offpost OU are 4 to 5 μg/l.

The distribution of chloride is shown in Figure 13. Chloride occurs in plumes in the Offpost OU north of the northern and northwestern RMA boundaries. Chloride concentrations in the First Creek and northern paleochannels generally exceed 250,000 μg/l. The maximum concentrations of chloride occur in the First Creek paleochannel. Offpost of the northwestern RMA boundary, chloride concentrations exceeding 250,000 μg/l occur immediately downgradient of the RMA boundary. Concentrations of chloride below 50,000 μg/l occur only in limited areas (Figure 13).

The distribution of fluoride is presented in Figure 14. Fluoride concentrations generally exceed 3000 μg/l in the First Creek paleochannel and 2200 μg/l in the northern paleochannel. Concentrations average approximately 2000 μg/l in the northwestern paleochannel.

The Final Offpost RI reported mercury in only one offpost groundwater sample. The sample, which was collected from well 37342 located in the First Creek paleochannel, had a mercury concentration of 0.36 μg/l. Data generated during Offpost RI Addendum activities showed detectable levels of mercury in four samples collected from wells located 2000 to 7000 feet offpost of the northwestern RMA boundary. Mercury concentrations in these wells ranged from 0.210 μg/l to 1.64 μg/l. The distribution of these sampling locations does not suggest a mercury plume in the Offpost OU, and detections are considered sporadic. Additionally, data collected under the Fall 1989 CMP show a higher frequency of detection for mercury than reported in the Final Offpost RI. The FY90 CMP reported that field or laboratory contamination existed for those mercury results. Thus, data for mercury are considered questionable and not representative of actual groundwater conditions.

Nature and Extent of Confined Denver Formation Contamination

The nature and extent of the confined Arapahoe formation was evaluated through a sampling program of domestic and monitoring wells. The data and interpretations presented in this section are for groundwater samples collected from 14 offpost confined Denver Formation wells in the Offpost OU. Figure 15 presents the locations of these wells. Additional information concerning the confined Denver Formation groundwater is presented in Section 3.3.2 of the Final Offpost RI report.

Data were examined from the Fall 1989 and Spring 1991 CMP sampling rounds, which represent the two most recent sampling rounds. The data reported detections of the following organic compounds: benzene, chlorobenzene, chloroform, DIMP, dibromochloropropane, phenol, and 1,1,1-trichloroethane. The most frequently detected compounds were DIMP, chloroform, and chlorobenzene. In general, the detections were not consistent from one sampling event to the next for the same well. DIMP was detected most frequently; however, detections occurred in only 11 sampling events out of 42 sampling events. The concentrations of DIMP ranged from 0.443 μg/l to 46.0 μg/l. Chloroform and chlorobenzene detection frequencies were below 10 percent. Chloroform concentrations ranged from 0.631 μg/l to 1.30 μg/l. Chlorobenzene detections ranged from 1.10 μg/l to 51.5 μg/l.

The observed detections indicate sporadic, isolated low-level occurrences of these compounds in the Offpost OU in the confined Denver Formation. The data are not consistent temporally for the same well and do not indicate a spatial or areal trend indicative of a contaminant plume.

Nature and Extent of Confined Arapahoe Formation Contamination

The nature and extent of the confined Arapahoe formation was evaluated through a sampling program of domestic and monitoring wells. Two isolated detections of DIMP and one of chloroform were observed in approximately 30 Arapahoe Formation wells sampled by the Army. The detections do not appear to be representative of overall aquifer conditions. For example, the majority of samples collected from Arapahoe Formation wells did not contain detectable

concentrations of organic compounds. In addition, DIMP and chloroform were not detected consistently from one sampling event to the next.

Surface Soil

This section presents the concentrations and distributions of compounds detected in soil in the Offpost OU. Surface soil includes the upper 2 inches of the soil profile. As shown in Figure 16, the organochlorine pesticides (OCPs) DDT, DDE, aldrin, chlordane, dieldrin, endrin, hexachlorocyclopentadiene, and isodrin were detected above Certified Reporting Limits (CRLs) in surficial soil collected in the Offpost OU. The most widespread and frequently detected OCP was dieldrin. Concentrations of dieldrin detected in samples in the Offpost OU ranged from 2.05 to 250 micrograms per kilogram (μg/kg). DDT, aldrin, endrin, and DDE were also frequently detected, generally in samples where dieldrin was also detected.

Offpost OU suface soil was contaminated by the deposition of airborne contaminants and non-RMA-related intentional agricultural application of pesticides and irrigation practices.

The greatest number of compounds and highest concentrations were observed north of RMA, with a few occurrences to the east and west of RMA. Several reasons may, in part, explain the presence of these compounds north and west of the canals: (1) several of the compounds detected in the surficial soil are or have been available commercially and may have been applied agriculturally or residentially and (2) some areas where samples were collected may have been previously irrigated with surface water and/or groundwater originating from RMA.

Arsenic was detected in approximately 20 percent of the samples at concentrations ranging from 2.61 to 4.62 micrograms per gram (μg/g). The distribution of arsenic was limited to the following detection areas:

- East of RMA
- Immediately north of RMA
- West of the northwest boundary
- Along Burlington Ditch

No identifiable pattern to the distribution is evident.

Mercury was detected in approximately 10 percent of the samples at concentrations ranging from 0.0719 μg/g to 0.325 μg/g. A discernable pattern to the distribution of mercury is not evident.

The concentrations of arsenic and mercury in soil were not statistically evaluated above background as presented in the Offpost EA (Volume II, Section 1.0).

Subsurface Soil

Six subsurface soil samples were collected in the 96th Avenue residential area and analyzed for OCPs, arsenic, and mercury. Subsurface soil samples were collected from approximately 1-foot and 5-foot depths. Only one detection of OCPs was reported in subsurface soil samples. Dieldrin was detected at a concentration of 7.0 μg/kg in a sample collected between 0 and 1 foot. Arsenic was detected above the CRL in one subsurface soil sample at a concentration of 3.59 μg/g in a sample collected between 0 and 1 foot. Mercury was not detected above the CRL in any subsurface soil samples.

Surface Water

Figure 17 presents the distribution of organic contaminants detected in Offpost OU surface water as presented in the Offpost RI Addendum. The concentrations of organic compounds detected in offpost surface-water samples typically have been highest in First Creek near the O'Brian Canal.

DIMP was the organic compound most frequently detected in surface water in the Offpost OU. DIMP was also the most widely distributed compound and was detected in surface-water samples collected from First Creek, O'Brian Canal, and Burlington Ditch at concentrations ranging from 0.532 μg/l to 59.0 μg/l.

The greatest number and highest concentrations of detected OCPs occur in the reach of First Creek between the northern RMA boundary and the confluence with O'Brian Canal.

The maximum detections of arsenic and several other inorganic constituents including chloride and sulfate were found in samples collected from First Creek along the reach between the RMA boundary and the First Creek confluence with O'Brian Canal. Arsenic was detected at concentrations ranging from 2.78 to 280 μg/l in Offpost RI Addendum samples. The concentration of 280 μg/l is considered anomalous and not representative of surface-water quality in the Offpost OU. The maximum concentrations of arsenic are commonly found in surface-water samples collected from First Creek immediately downstream of the onpost sewage treatment plant. Arsenic concentrations of approximately 70 μg/l have been detected at this location (RSLA, 1990).

Groundwater and surface-water interaction is known to occur in the reach of First Creek between the northern RMA boundary and the confluence of First Creek with O'Brian Canal. This interaction has been discussed and documented in the Final Offpost RI and FY90 Surface Water CMP. Comparison of the concentrations of organic compounds detected in surface-water samples with those detected in groundwater samples collected in the vicinity of this reach of First Creek supports the conclusion that contaminated groundwater discharging into First Creek may be the source of organic contamination in surface water. The decrease in number and concentrations of organic compounds in Burlington Ditch and the O'Brian Canal indicates that dilution of surface water by the ditch and canal is occurring. The distribution of arsenic in offpost surface water suggests a source other than groundwater. A potential source appears to be onpost Sewage Treatment Plant discharge to First Creek.

Sediment

Figure 18 presents the distribution of organic contaminants detected in sediment as presented in the Offpost RI Addendum. The following organic compounds had the highest frequency of detection in sediment samples in the Offpost OU: aldrin, chlordane, dieldrin, and dibromochloropropane. The detections were predominantly in samples collected from in First Creek and were generally low concentrations.

Arsenic and mercury were detected at low concentration levels in sediment samples in the Offpost OU. Mercury was detected only in the Burlington Ditch, O'Brian Canal, and Barr Lake samples. Arsenic was detected in sediment samples in the Offpost OU from all water bodies sampled.

Air

Results from onpost RMA air monitoring during 1988 and reported in the CMP Air Quality Data Assessment Report (R.L. Stollar & Associates, 1990) (FY88 Air CMP) indicated that total suspended particulate (TSP) levels at RMA boundaries were below the levels of metropolitan Denver. Asbestos was monitored but not detected. VOCs measured at RMA boundaries appear to present toxic risks similar to those encountered in the urban environment of metropolitan Denver. Levels of SVOCs were detected at negligible and/or regional baseline levels at RMA boundaries. Metal levels were proportional to TSP concentrations and were not elevated.

GROUNDWATER TREATMENT SYSTEMS THAT AFFECT THE OFFPOST OPERABLE UNIT

Three major containment/treatment systems, the Irondale Containment System (ICS), the NBCS, and the NWBCS, have been installed at the RMA boundaries to control the migration of contaminants to offpost areas. All three of the systems are currently in operation to intercept and treat contaminated groundwater and to recharge the treated water. In addition to the boundary control systems, a groundwater intercept and treatment system north of RMA (Groundwater Intercept and Treatment System North of RMA Interim Response Action A [IRA A]) is currently being constructed to provide remediation of alluvial groundwater in the Offpost OU.

Irondale Containment System

The ICS is located at the southern end of the RMA northwest boundary within Section 33 and consists of a hydraulic control system and a carbon treatment system. The ICS became operational in 1981. The majority of the area downgradient of the ICS is contained within the EPA offpost study area, although portions of the downgradient area are within the confines of the

Offpost OU. A review of monitoring data downgradient of the ICS shows contaminant concentrations to be low and probably attributable to the source of contamination within the EPA offpost study area rather than RMA. Therefore, the configuration, operation, and performance of the ICS are not relevant to this study and will not be discussed further.

North Boundary Containment System

The NBCS is located just south of the RMA north boundary in Sections 23 and 24. The NBCS consists of a system of dewatering wells with contaminated groundwater from the unconfined flow system, a soil-bentonite barrier to separate contaminated and treated groundwater and to impede offpost migration of contaminated groundwater, a carbon-adsorption treatment system to remove organic contaminants, and a system of recharge wells and trenches to return treated groundwater to the UFS.

The NBCS was constructed in two phases during 1978 and 1981. Initially a pilot system was installed and became operational in 1978. The pilot system was expanded approximately 1400 feet to the west and 3840 feet to the east in 1981. Recharge trenches were added to the west end of the system in 1988. Additional recharge trenches were added to the east end of the system in 1990. Currently, the soil-bentonite barrier is 6740 feet long and approximately 3 feet wide, with a designed hydraulic conductivity of 1×10^{-7} centimeters per second (cm/sec) or less. The barrier depth varies from 20 feet at the western end to over 40 feet along the eastern extension. The barrier is anchored in the Denver Formation.

Currently, the average flow through the NBCS treatment system is approximately 240 to 250 gallons per minute (gpm) according to the Final Implementation Document for IRA A (HLA, 1991b). All water is treated and recharged to the alluvial portion of the UFS.

Examination of groundwater contaminant distribution patterns indicates that the NBCS is having a significant effect on the distribution of organic compounds in the Offpost OU. The NBCS treatment plant is effectively removing the organic contaminants for which it was designed. Concentrations of organic contaminants above CRLs have not generally been detected in the system effluent. Inorganic contaminants such as chloride and fluoride are not being treated.

Northwest Boundary Containment System

The NWBCS is located along the northwest boundary of RMA in the southeast quarter of Section 22. Construction of the NWBCS began in 1983, and the system became operational in 1984. The purpose of this system was to intercept and remove dibromochloropropane and other organic compounds from a plume of contaminated groundwater originating onpost.

Contaminant bypass was observed at the northeast end of the system in 1988. Recharge was increased at the northeast end in December 1988 to prevent continued contaminant bypass. The system consists of a line of 15 upgradient dewatering wells, a soil bentonite barrier extending approximately two-thirds of the length of the dewatering system, 21 downgradient recharge wells, and a carbon-adsorption treatment facility. Groundwater is pumped from the dewatering wells on the upgradient side of the barrier, treated by carbon adsorption, and returned to the aquifer through recharge wells near the RMA boundary.

An IRA to improve the NWBCS was initiated in 1989. In April 1990, the NWBCS Improvements IRA B(ii) was divided into two phases: NWBCS Short-Term Improvements IRA and NWBCS Long-Term Improvements IRA. The long-term improvements involve a more thorough assessment of the NWBCS and the short-term improvements.

Under the NWBCS Short-Term Improvements IRA, the existing groundwater intercept system was extended both to the southwest and northeast. The soil-bentonite wall was extended across the alluvial channel found northeast of the system to prevent contaminant bypass. Additional extraction wells were added to the existing system to intercept and treat the water in this channel. The northeast extension was completed in July 1990, and recharge rates at the northeast end of the system were reduced. Higher recharge rates resumed in July 1991 at the northeast end of the system. New extraction wells and recharge wells were added to the southwest end of the system and became operational in August 1991.

Interim Response Action A

IRA A addresses contaminant migration north of RMA along two primary contaminant pathways, defined by the First Creek and northern paleochannels.

In the area north of the RMA north boundary, IRA A is being implemented for remediation of contamination in alluvial groundwater in the First Creek and northern paleochannels. The system has been designed to intercept and extract contaminated groundwater from the UFS in each paleochannel, treat the organic fraction of the groundwater, and recharge treated water to the UFS. Groundwater extraction will be achieved by installing and operating well systems. Water will be treated using a granular activated carbon adsorption system and will be recharged to the UFS using a combination of wells and trenches.

The IRA was designed to be flexible to be compatible with the final remedy. Compatibility with the final remedy could be achieved by modifying the system to include the addition of new wells, treatment processes, or additional treatment capacity if necessary. Construction of IRA A began in November 1991.

The groundwater treatment system for IRA A is designed to treat a maximum flow of 720 gpm and an average initial flow of 480 gpm; however, the facilities will be able to accommodate flows less than the average, with a minimum flow of 200 gpm.

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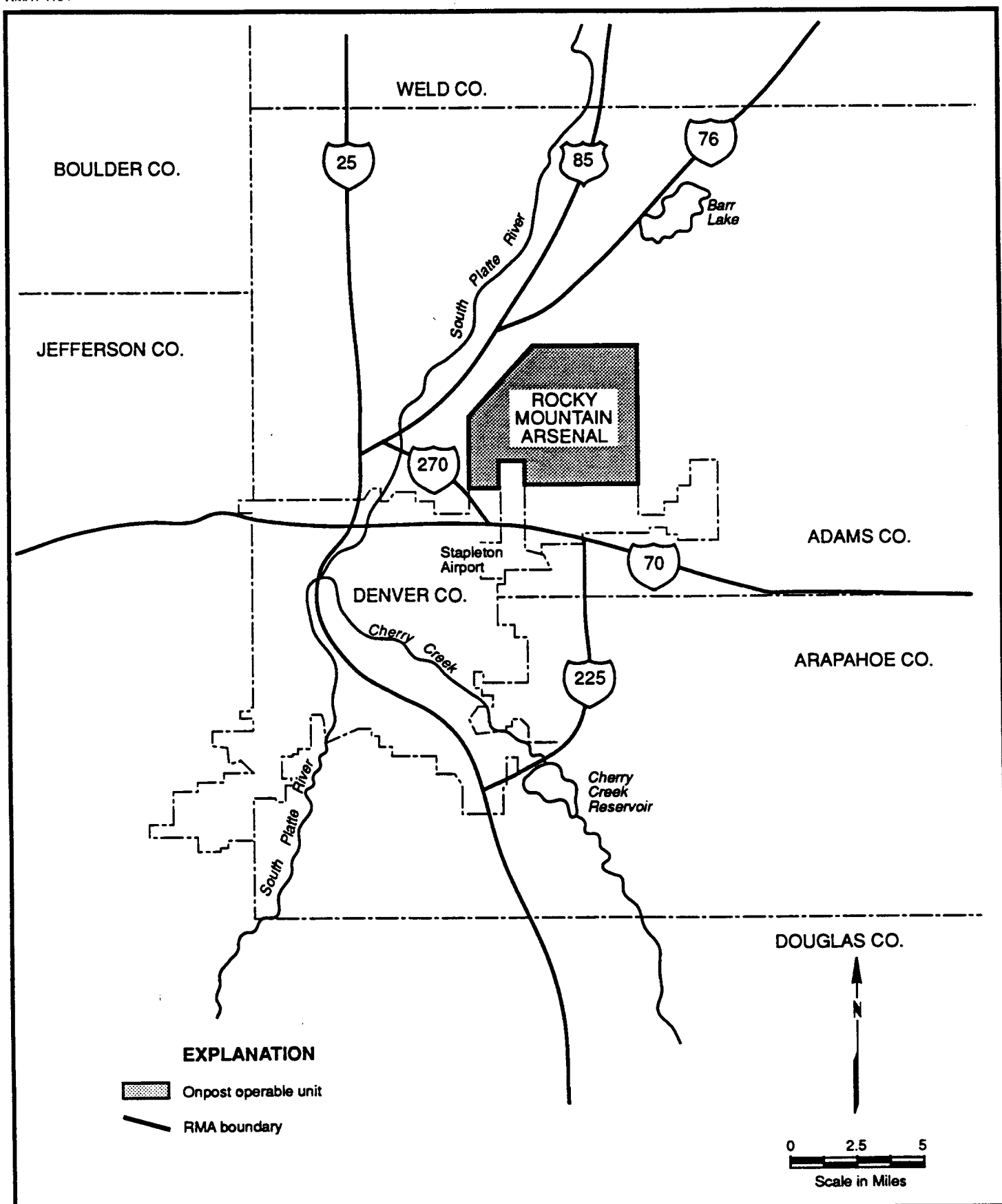

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Rocky Mountain Arsenal

Commerce City, Colorado

Figure 1

LOCATION MAP OF ONPOST OPERABLE UNIT, ROCKY MOUNTAIN ARSENAL

RMA1 1101.1

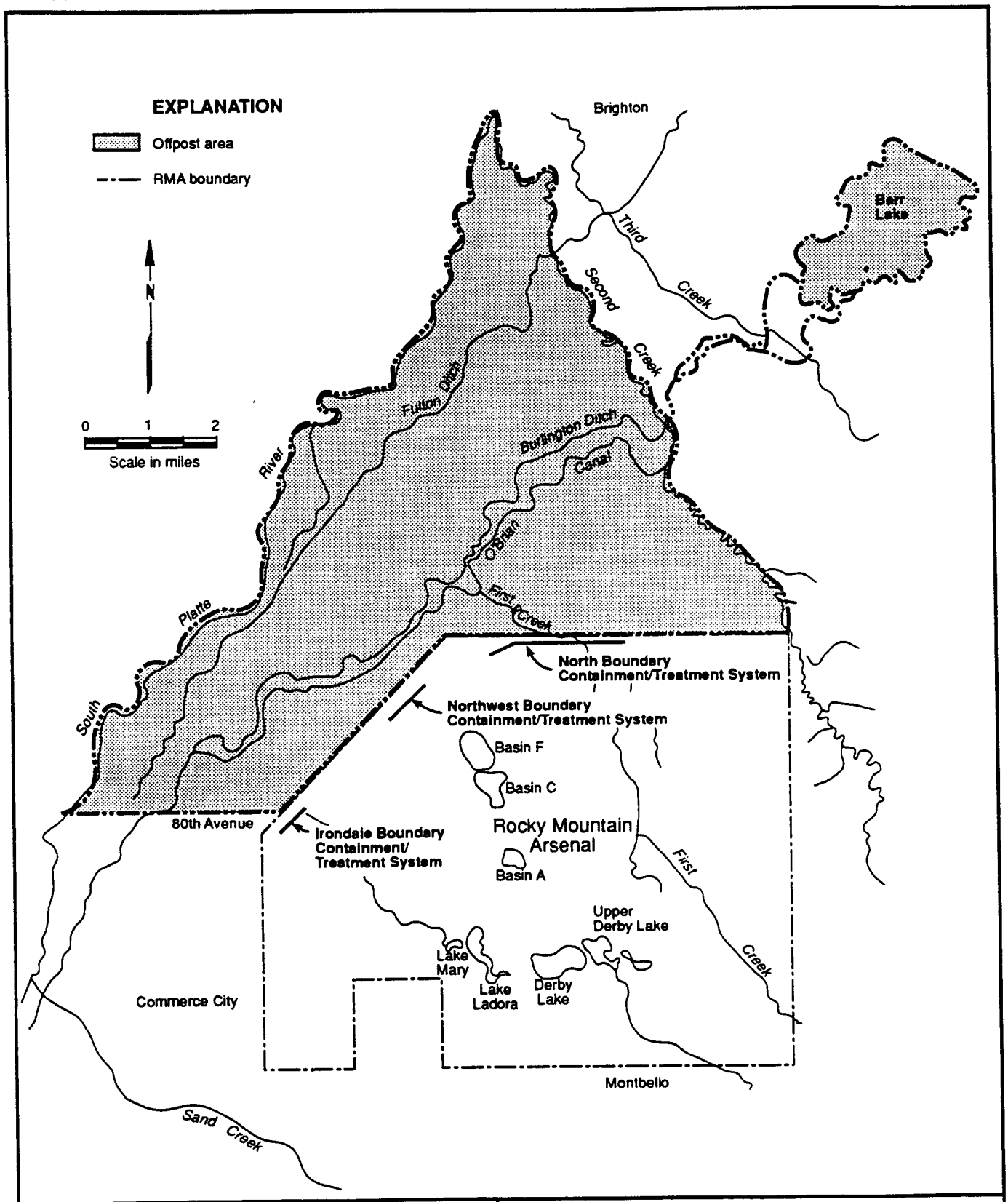

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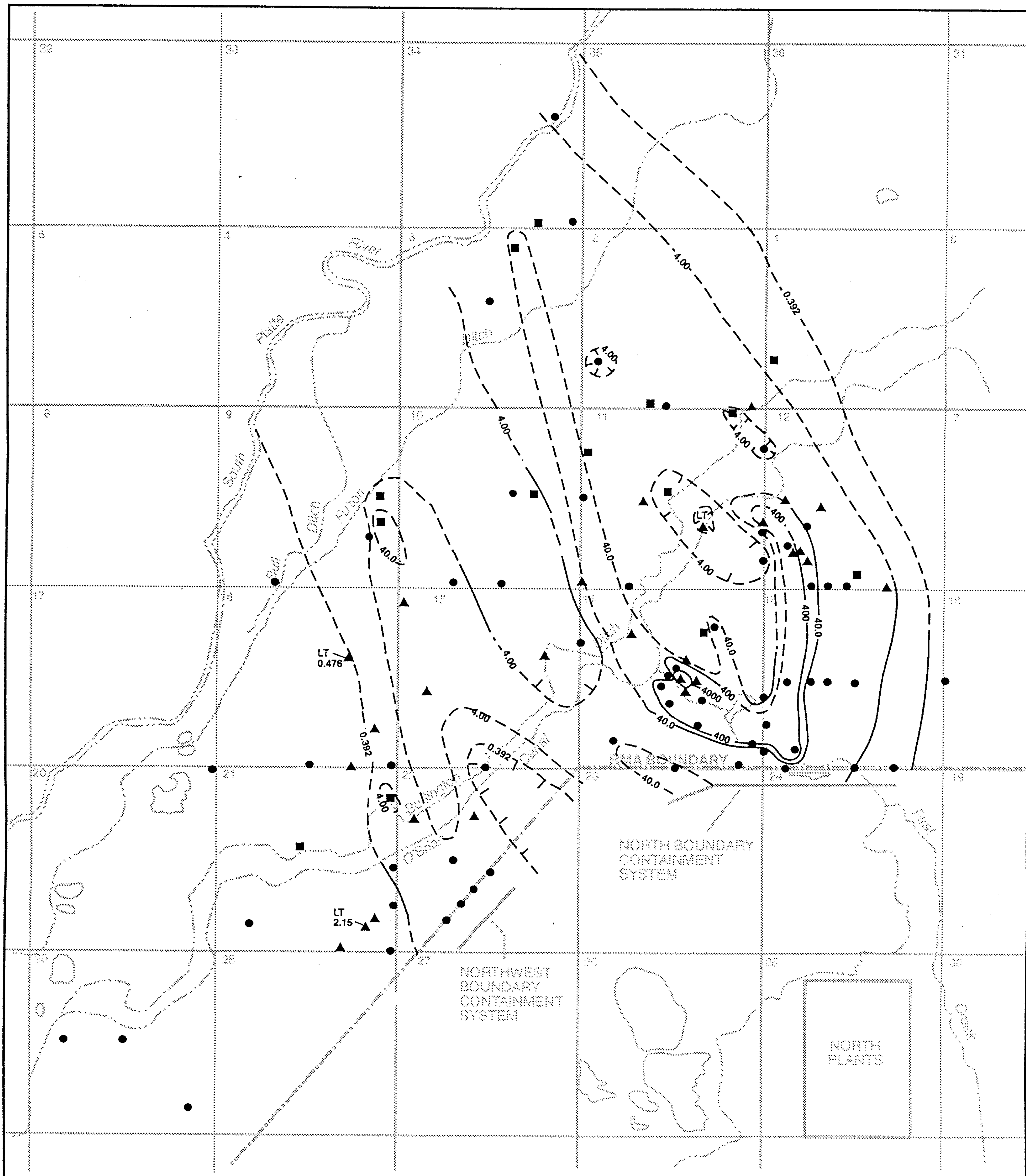
Figure 2

OFFPOST AREA,
ROCKY MOUNTAIN ARSENAL

RMA1 1144



N

0 1500 3000
Scale in Feet

EXPLANATION

Isoconcentration Line, Dashed where Inferred

2.65 ● LT Isolated Detection, in µg/l. Two Values Shown if Sampled Twice. LT - Indicates Analyte was not Detected Above the Certified Reporting Limit.

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990)

● Monitoring Well Sampled Under CMP (Fall 1989)

■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

0.392
4.00
40.0
400
4000

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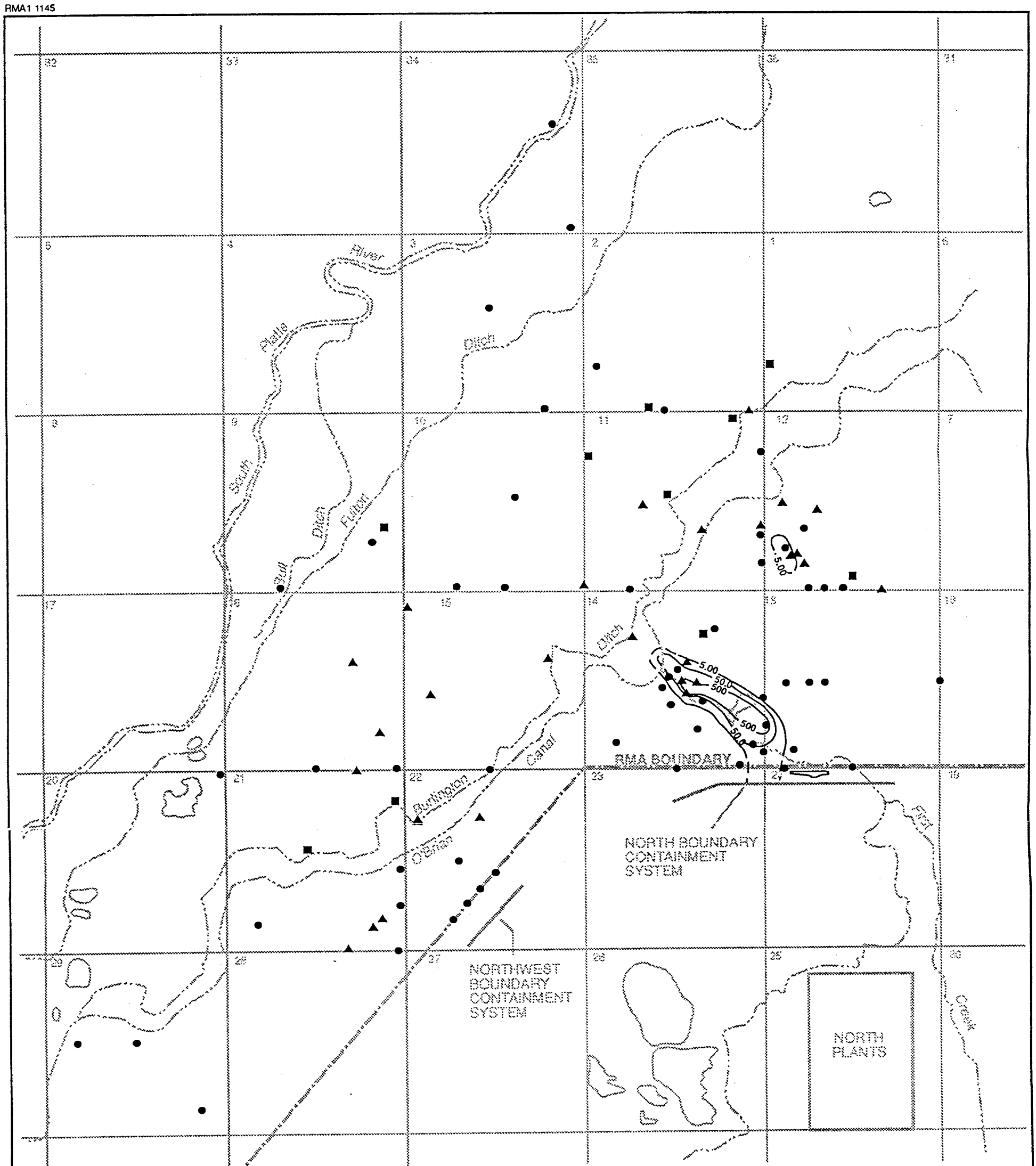
Figure 3

DISTRIBUTION OF DIISOPROPYLMETHYL PHOSPHONATE (DIMP) IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1145



EXPLANATION

- Isoconcentration Line, Dashed where Inferred
- 2.65 ● Isolated Detection, in µg/l
- ▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990)
- ● Monitoring Well Sampled Under CMP (Fall 1989)
- ■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

5.00
50.0
500

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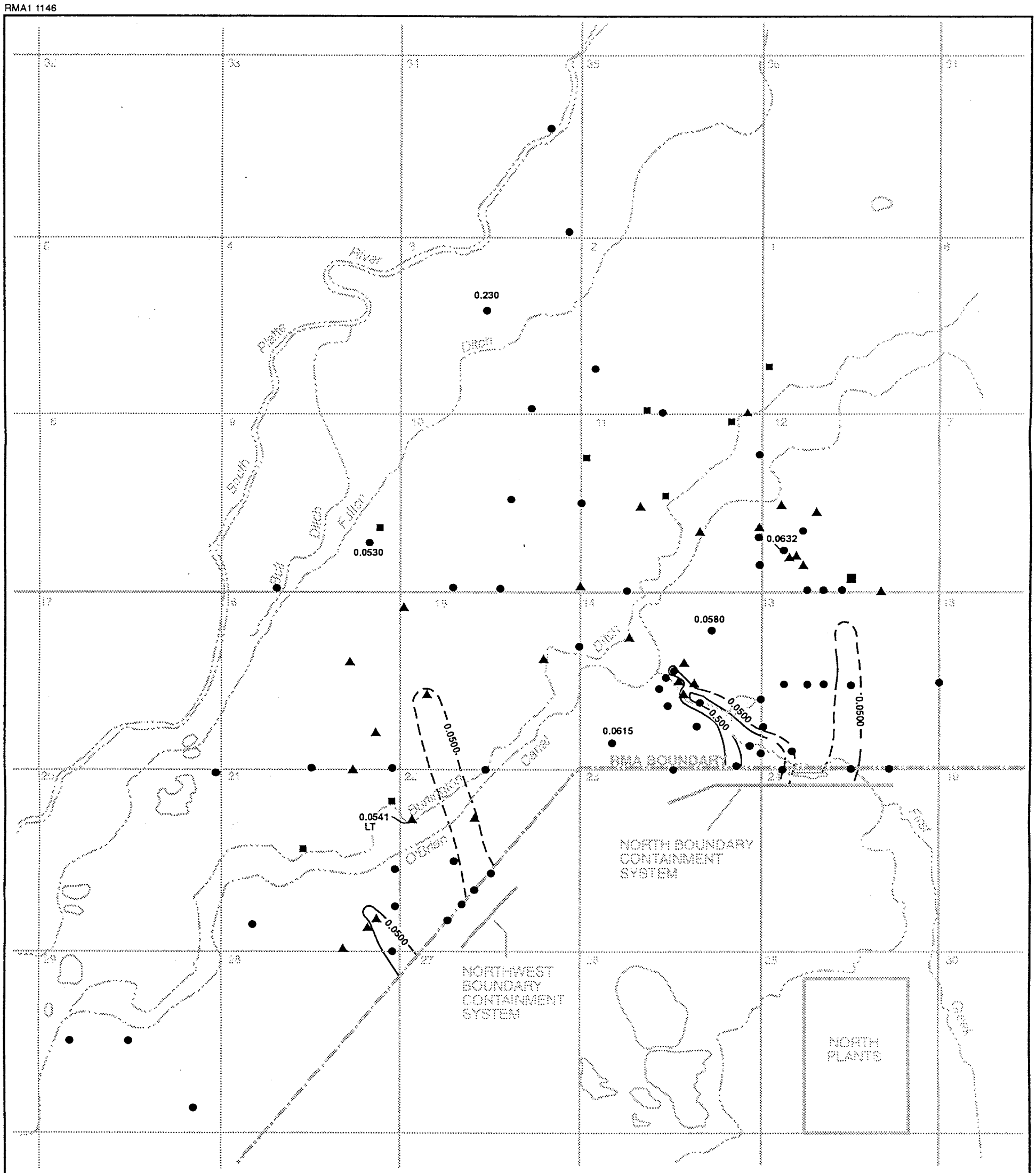
Figure 4

DISTRIBUTION OF DICYCLOPENTADIENE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1146



EXPLANATION

Isoconcentration Line, Dashed where Inferred

2.65 LT — Isolated Detection in µg/l. Two Values Shown if Sampled Twice. LT - Indicates Analyte was not Detected Above the Certified Reporting Limit.

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990)

● Monitoring Well Sampled Under CMP (Fall 1989)

■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

0.0500
0.500
5.00

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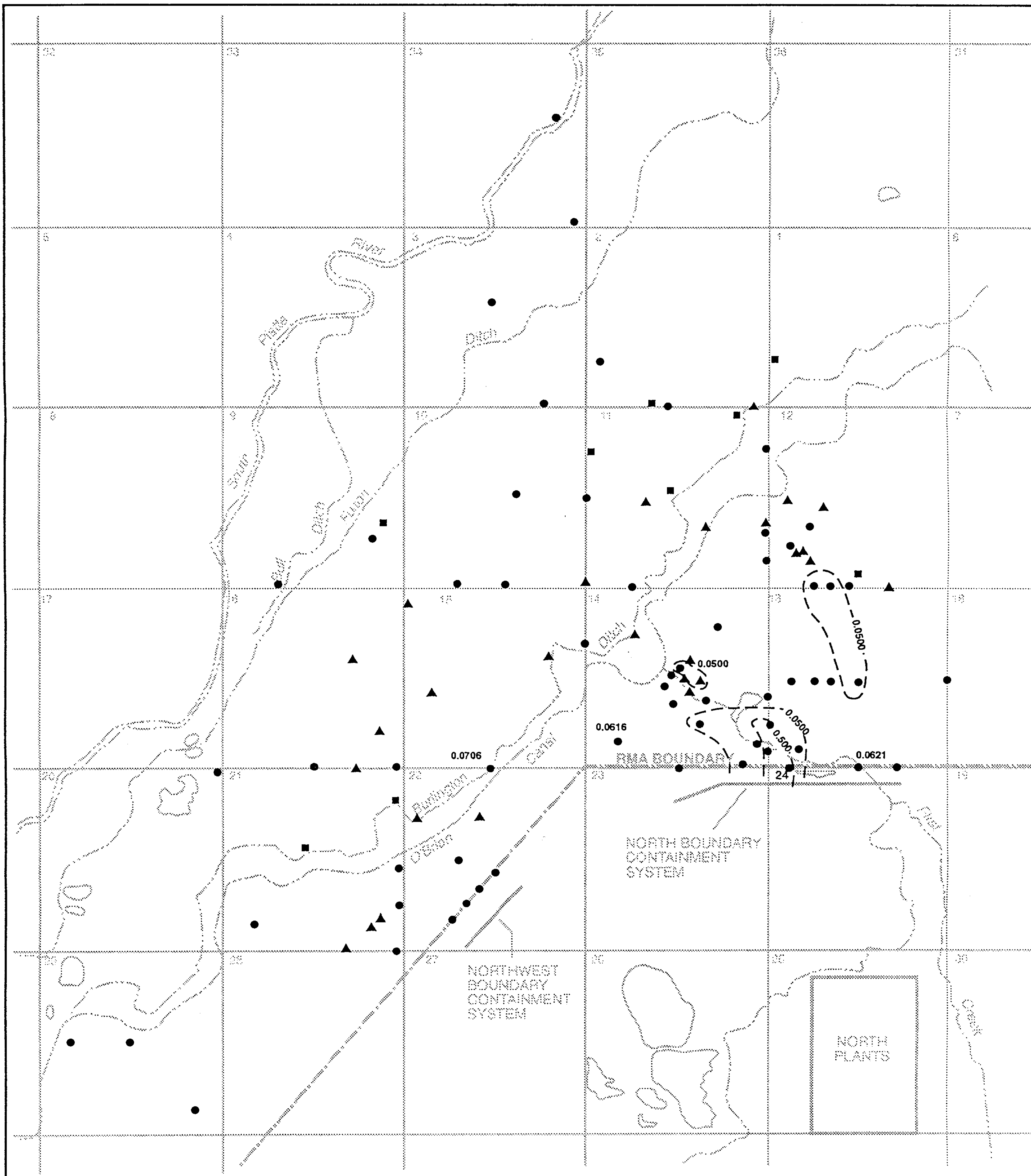
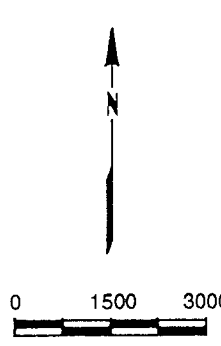
Commerce City, Colorado

Figure 5

DISTRIBUTION OF DIELDRIN IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1147





EXPLANATION

Isoconcentration Line, Dashed where Inferred

2.65 Isolated Detection, in µg/l

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990)

● Monitoring Well Sampled Under CMP (Fall 1989)

■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

0.0500
0.500

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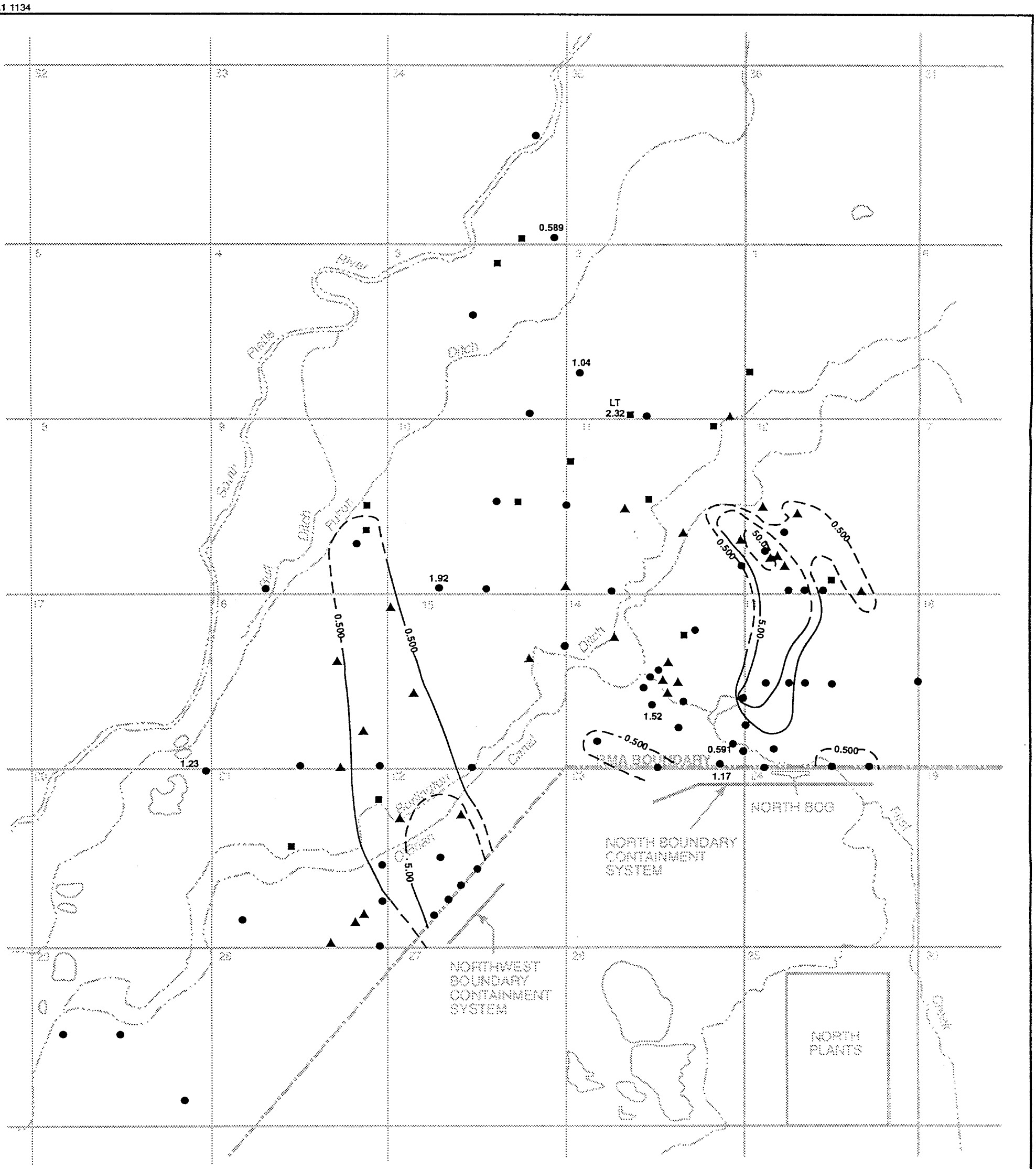
RMA1 1134



EXPLANATION

Concentrations in micrograms per liter (µg/l)

Isoconcentration Line, Dashed where Inferred

2.65 / LT — Isolated Detection, in µg/l. Two Values Shown if Sampled Twice. LT - Indicates Analyte was not Detected Above the Certified Reporting Limit.

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990). February 1991 CMP Data for these Wells were Considered during Construction of Plume Contours.

● Monitoring Well Sampled Under CMP (Fall 1989)

■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)
- 0.500
- 5.00
- 50.0

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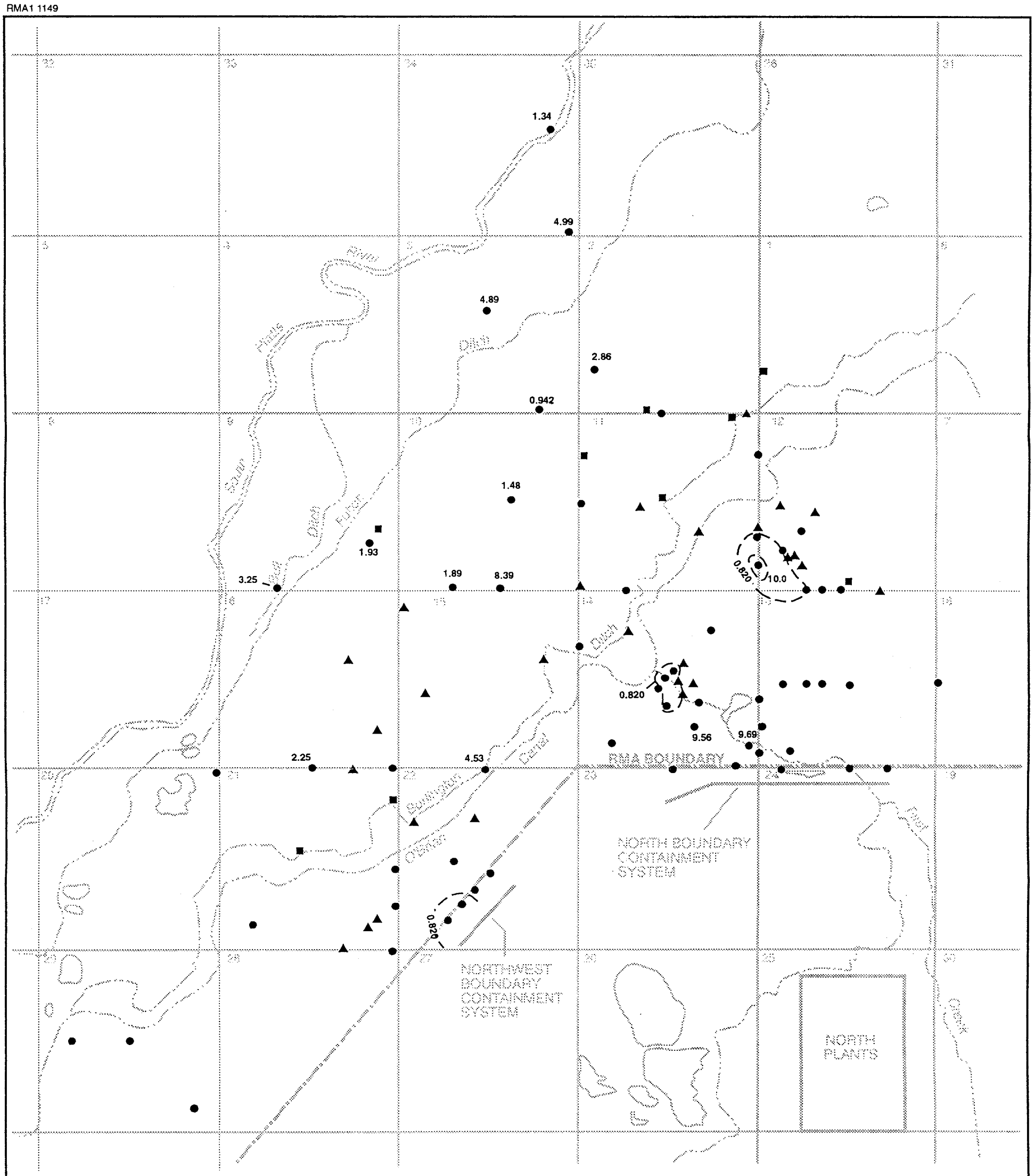
Figure 7

DISTRIBUTION OF CHLOROFORM IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1149



N

0 1500 3000

Scale in Feet

EXPLANATION

- Isoconcentration Line, Dashed where Inferred
- 2.65 — Isolated Detection, in µg/l
- ▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990). February 1991 CMP Data for these Wells were Considered during Construction of Plume Contours.
- ● Monitoring Well Sampled Under CMP (Fall 1989)
- ■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)
- Isoconcentration Value (µg/l)
  - 0.820
  - 10.0

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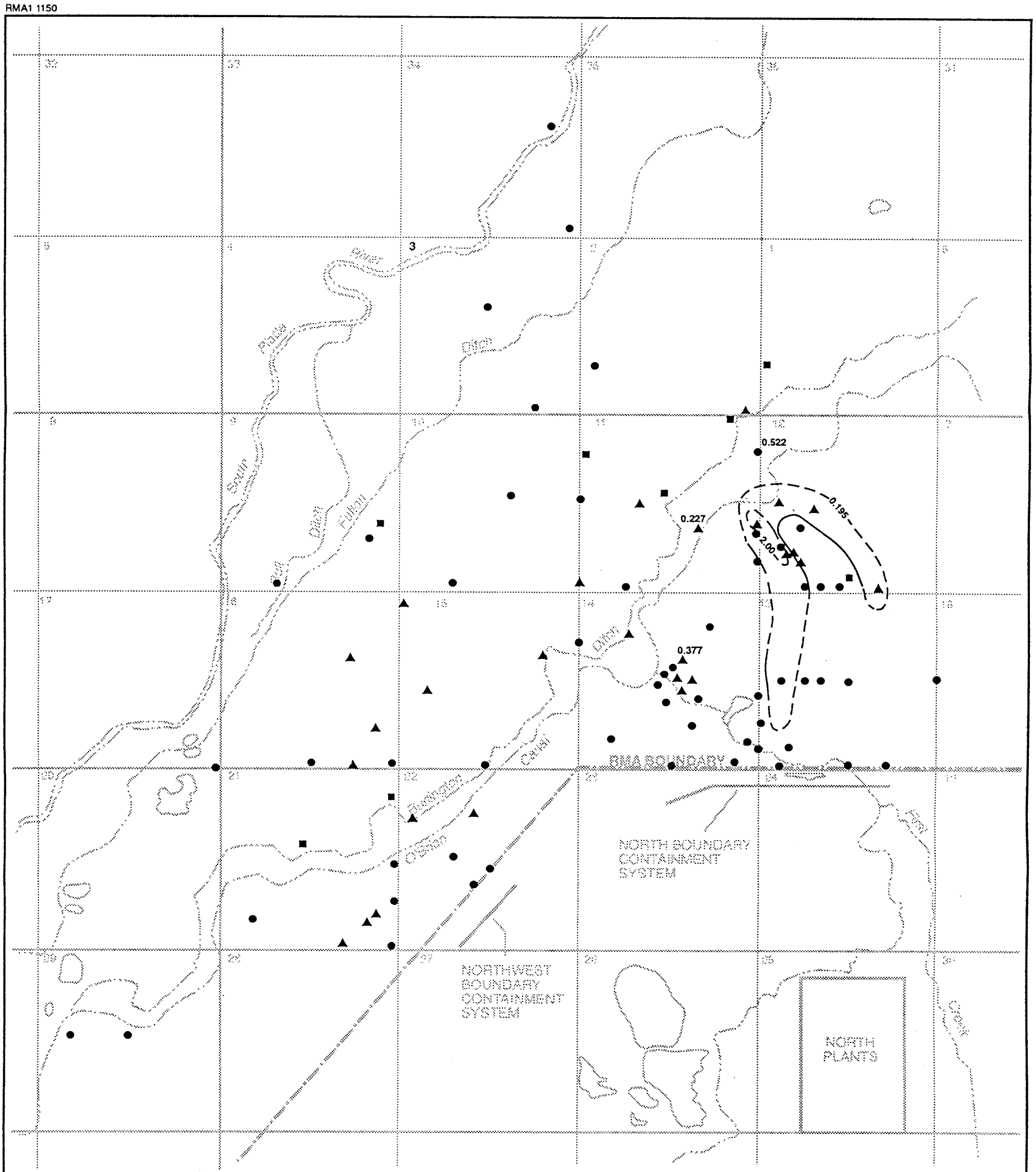
Figure 8

DISTRIBUTION OF CHLOROBENZENE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1150



N

0 1500 3000

Scale in Feet

EXPLANATION

Isoconcentration Line, Dashed where Inferred

2.65 Isolated Detection, in µg/l

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990). February 1991 CMP Data for these Wells were Considered during Construction of Plume Contours.

● Monitoring Well Sampled Under CMP (Fall 1989)

■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

0.195
2.00

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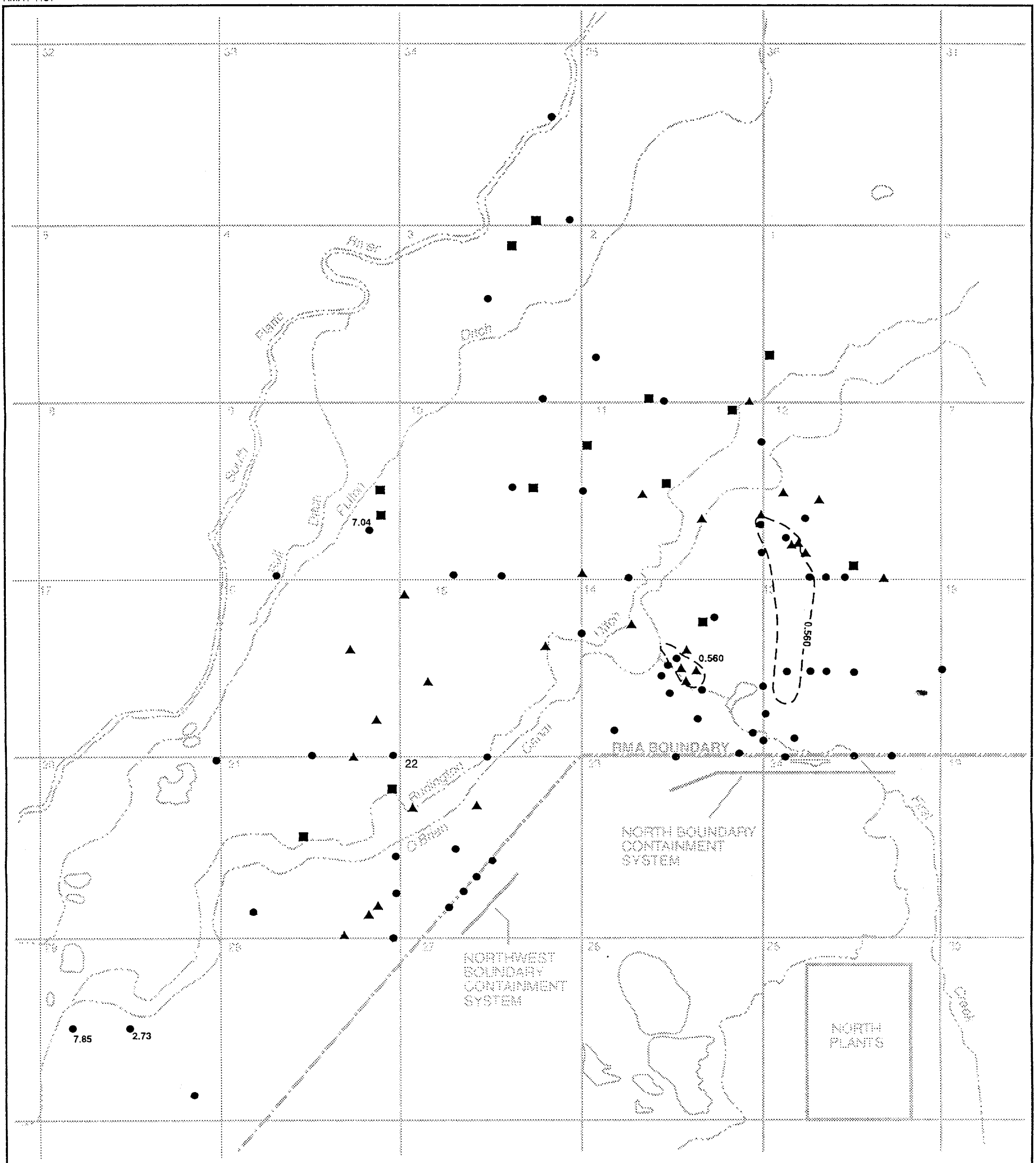
Figure 9

DISTRIBUTION OF DIBROMOCHLOROPROPANE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1151



EXPLANATION

- Isoconcentration Line, Dashed where Inferred
- 2.65 — Isolated Detection, in µg/l
- ▲ Monitoring Well Sampled Under RI Addendum Offpost Program (1989-1990). February 1991 CMP Data for these Wells were Considered during Construction of plume Contours.
- ● Monitoring Well Sampled Under CMP (Fall 1989)
- ■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

0.560

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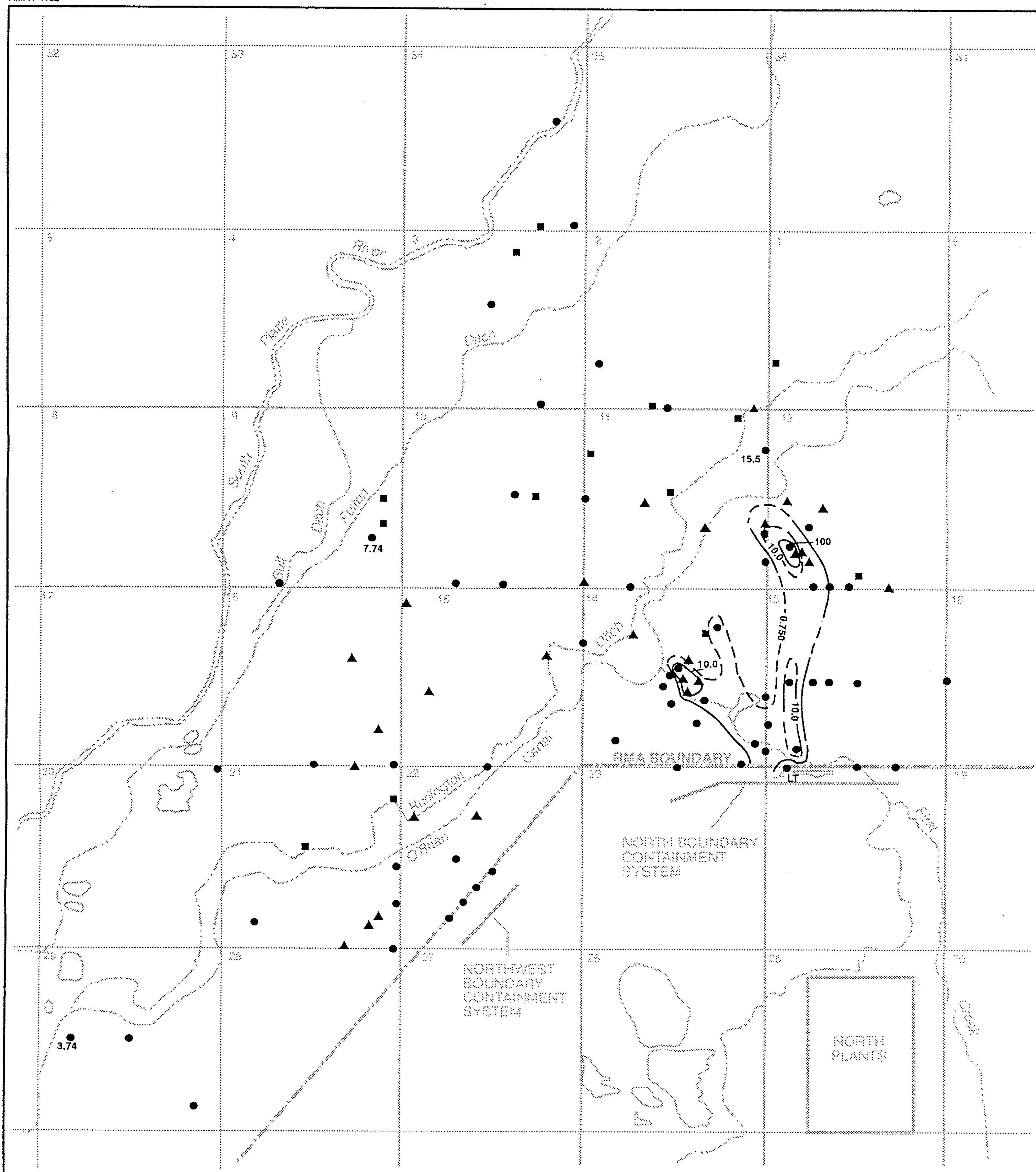
Figure 10

DISTRIBUTION OF TRICHLOROETHENE (TRCLE) IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1152



N

0 1500 3000

Scale in Feet

EXPLANATION

Isoconcentration Line, Dashed where Inferred

2.65 Isolated Detection, in µg/l

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990). February 1991 CMP Data for these Wells were Considered during Construction of Plume Contours.

● Monitoring Well Sampled Under CMP (Fall 1989)

■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

0.750
10.0
100

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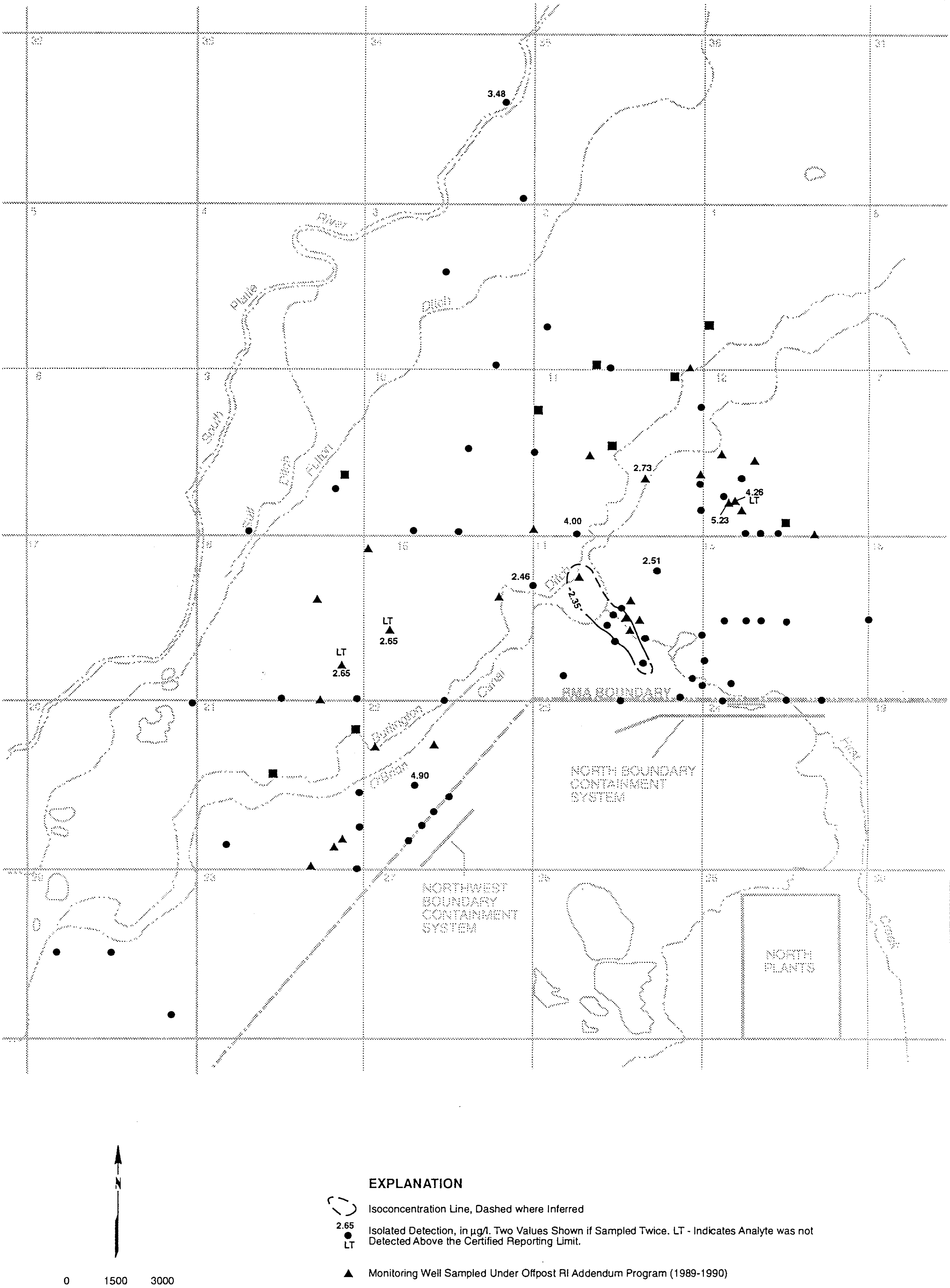
RMA1 1153



EXPLANATION

Isoconcentration Line, Dashed where Inferred

2.65 ● LT — Isolated Detection, in µg/l. Two Values Shown if Sampled Twice. LT - Indicates Analyte was not Detected Above the Certified Reporting Limit.

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990)

● Monitoring Well Sampled Under CMP (Fall 1989)

■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

2.35

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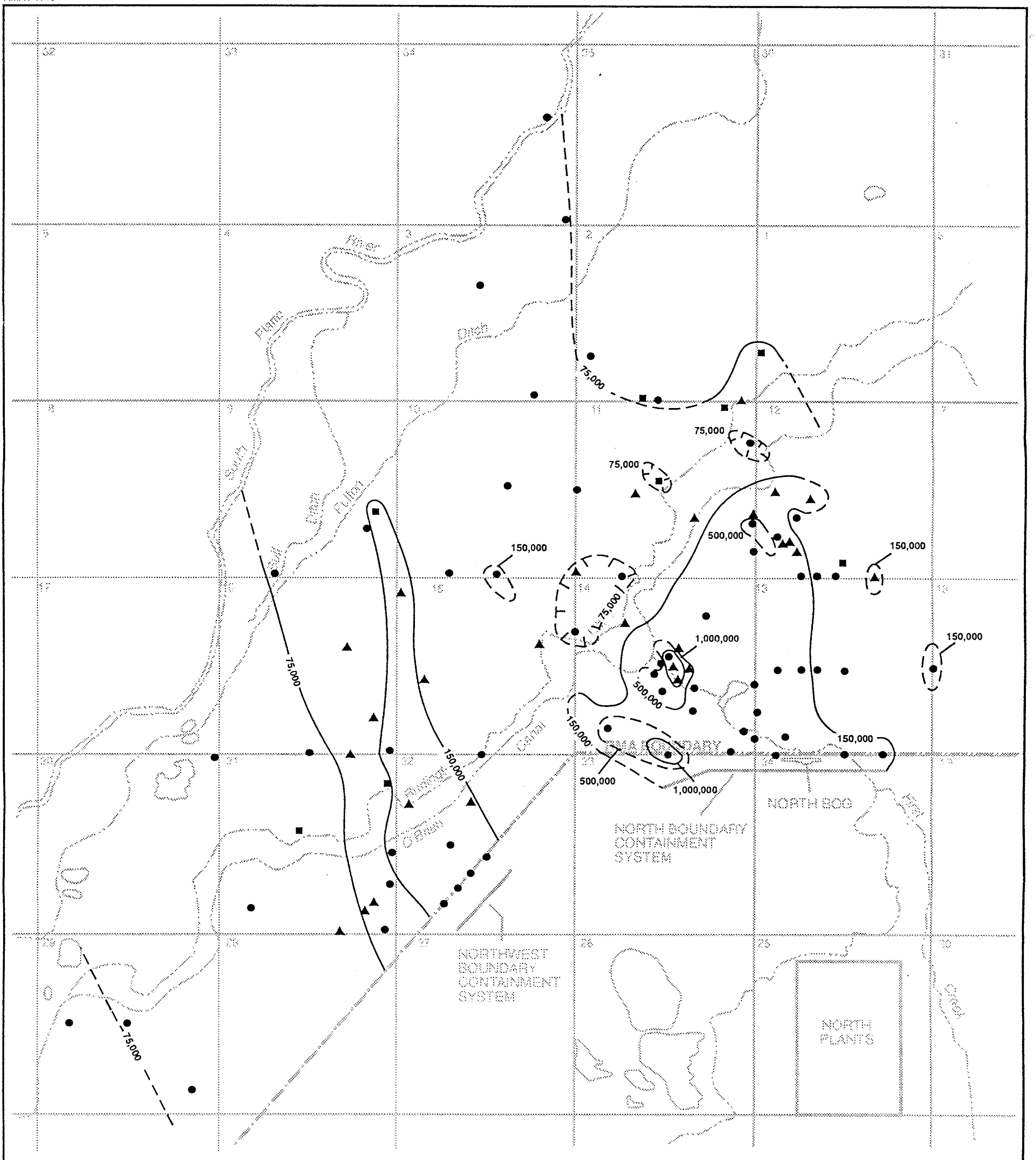
RMA1 1140



EXPLANATION

- Isoconcentration Line, Dashed where Inferred
- ▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990)
- ● Monitoring Well Sampled Under CMP (Fall 1989)
- ■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

75,000
150,000
500,000
1,000,000

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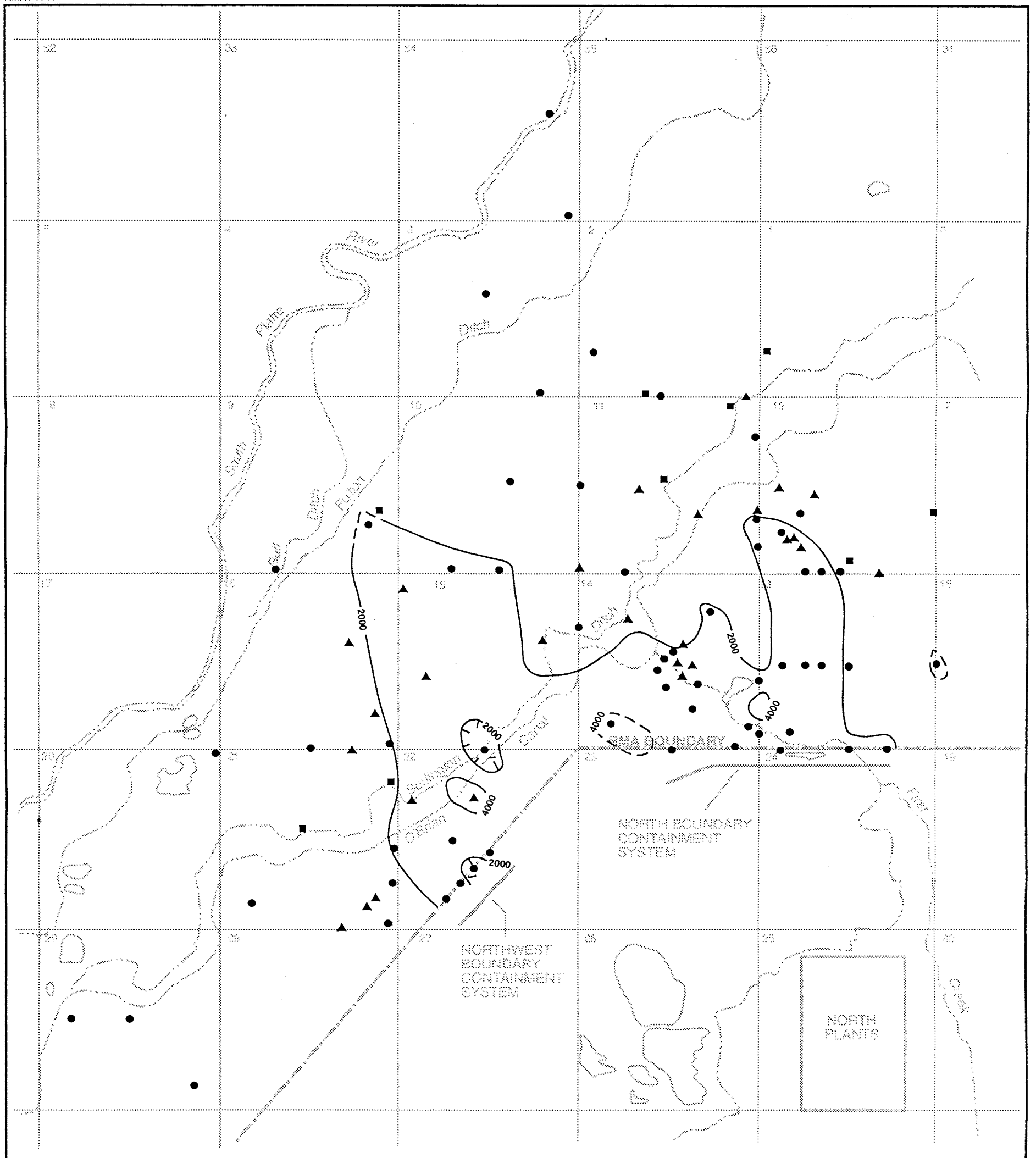
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 13

DISTRIBUTION OF CHLORIDE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1141



EXPLANATION

- Isoconcentration Line, Dashed where Inferred
- 2.65 ● Isolated Detection or Concentration Less Than Lowest Isoconcentration Value, in µg/l
- ▲ Monitoring Well Sampled Under Offpost RI Addendum Program (IRA-A and RI Addendum, 1989-1990)
- ● Monitoring Well Sampled Under CMP (Fall 1989)
- ■ Domestic Well Sampled Under RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

2000
4000

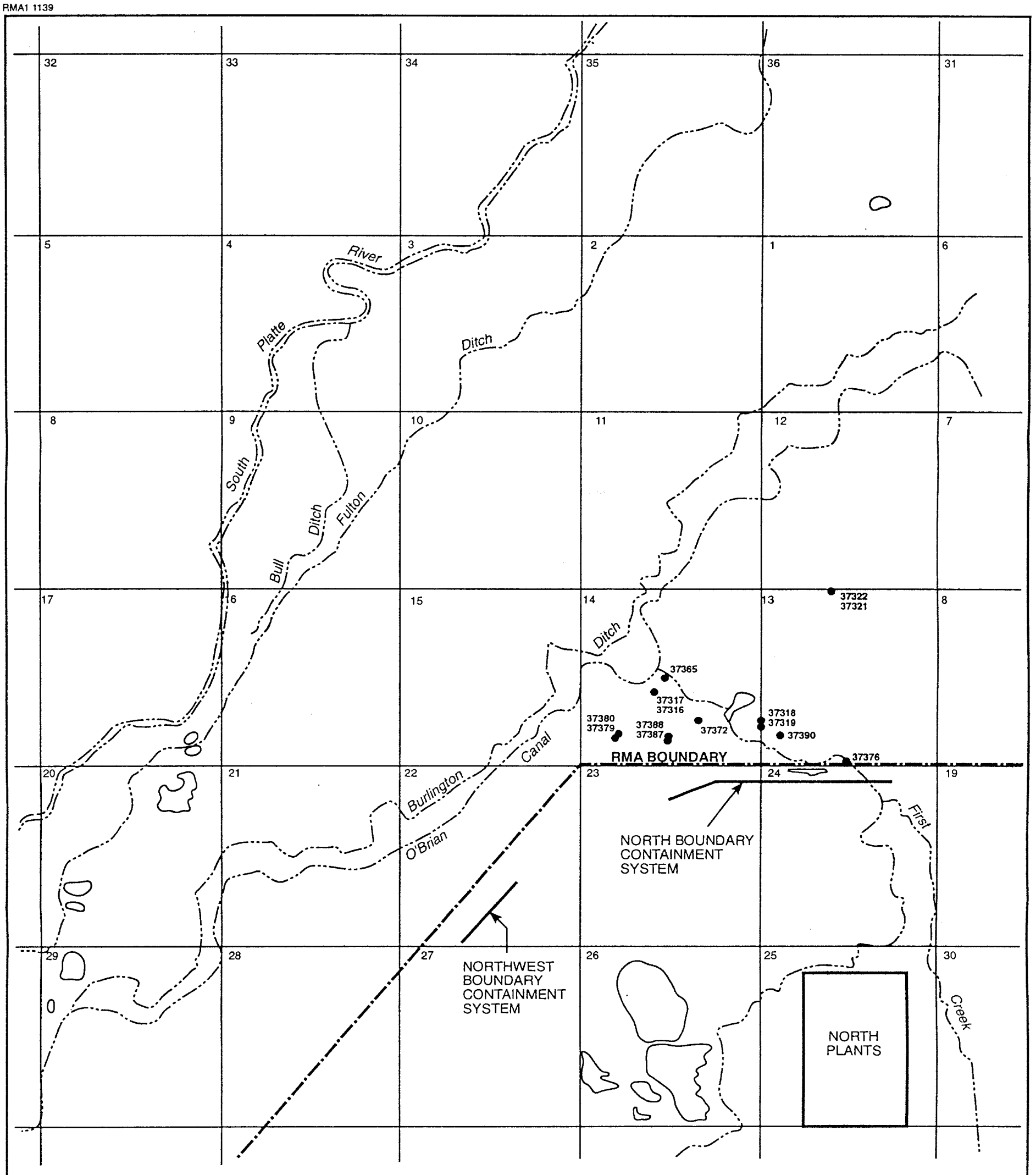
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 14

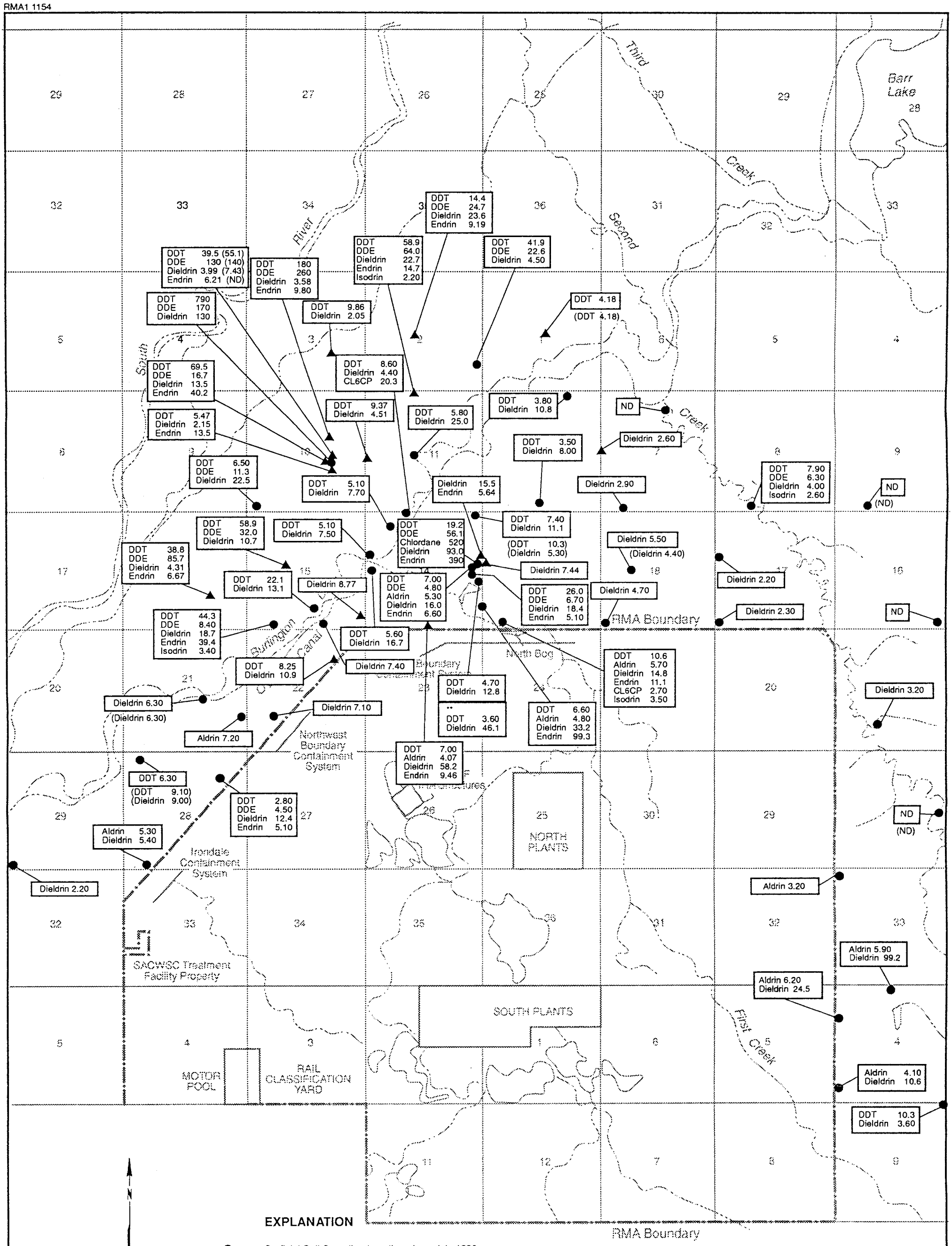
DISTRIBUTION OF FLUORIDE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1139



Prepared for: **Program Manager for** **Rocky Mountain Arsenal** **Commerce City, Colorado**	Figure 15 OFFPOST OPERABLE UNIT CONFINED DENVER FORMATION MONITORING WELL NETWORK

RMA1 1154



EXPLANATION

- ● Surficial Soil Sampling Location, June-July 1990
- ▲ Surficial Soil Samping Location, May 1991
- ( ) Duplicate Sample Results

Concentrations in micrograms per kilogram

- CL6CP Hexachlorocyclopentadiene
- DDT 2,2 - Bis (parachlorophenyl) - 1,1,1 - Trichloroethane
- DDE 2,2 - Bis (parachlorophenyl) - 1,1 - Dichlorethane
- ND Not Detected at or above the Certified Reporting Limit

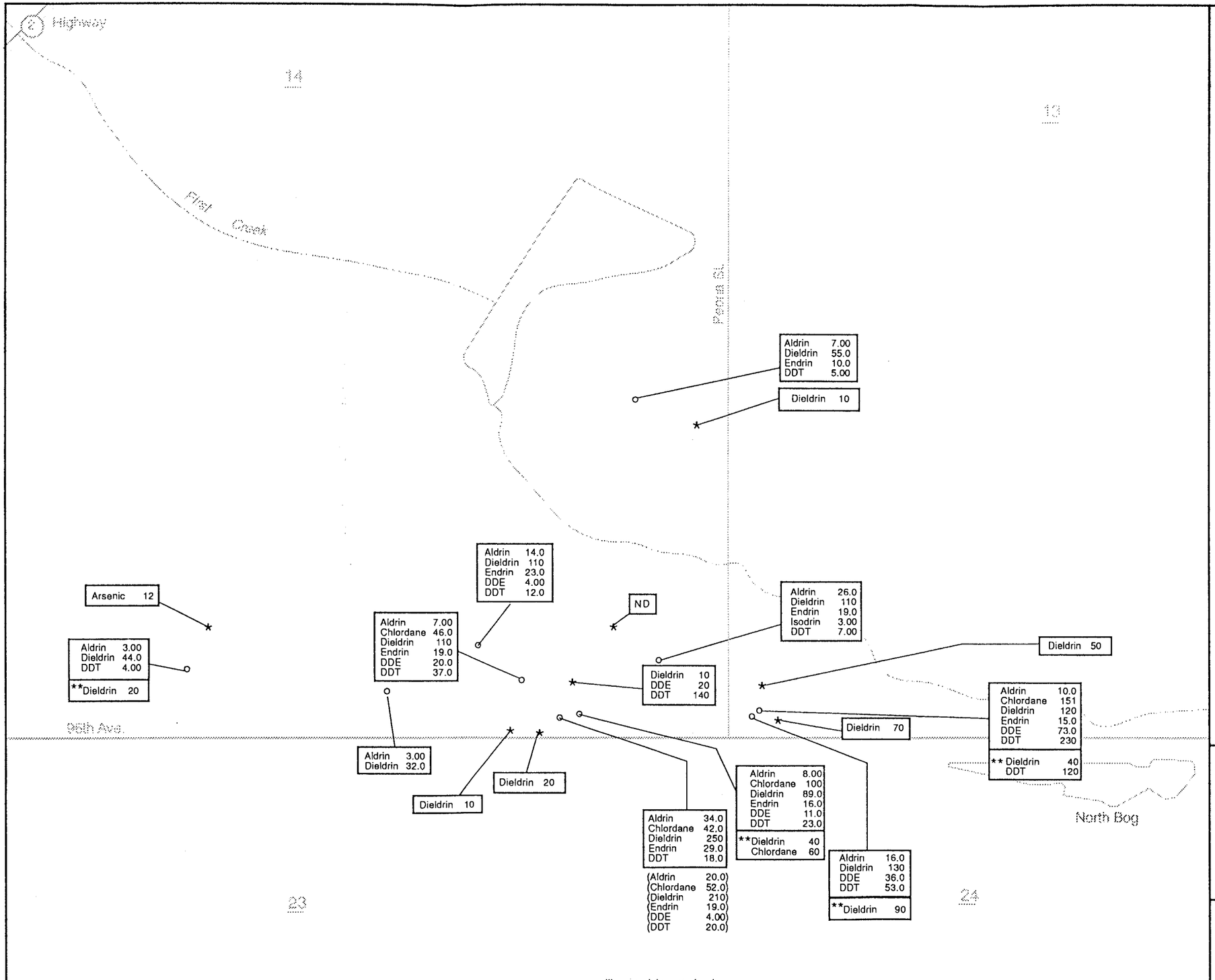
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 16

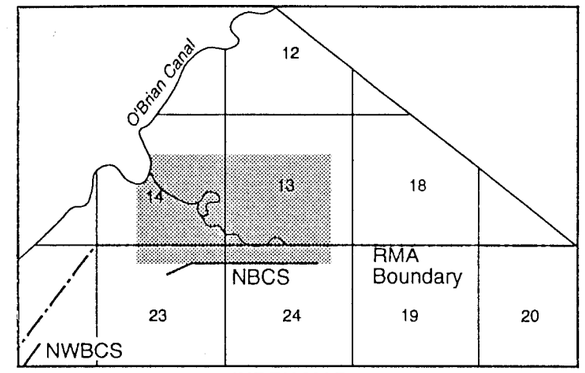
DISTRIBUTION OF ORGANOCHLORINE PESTICIDES DETECTED IN OFFPOST SOIL

RMA1 1194

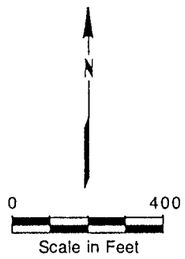


EXPLANATION

- o Surficial Soil Sampling Location, February 1989
- ( ) Duplicate Sample
- ★ CDH Surficial Soil Sampling Location, February 1989
- 13 Section Number
- CDH Colorado Department of Health
- HLA Harding Lawson Associates
- ★★ Indicates CDH Results for Samples Collocated with HLA Samples
- DDT 2,2 - Bis (parachlorophenyl) - 1,1,1 - Trichlorothane
- DDE 2,2 - Bis (parachlorophenyl) - 1,1 - Dichloroethene
- Concentrations in micrograms per kilogram
- ND Not Detected at or above the Certified Reporting Limit



INDEX MAP



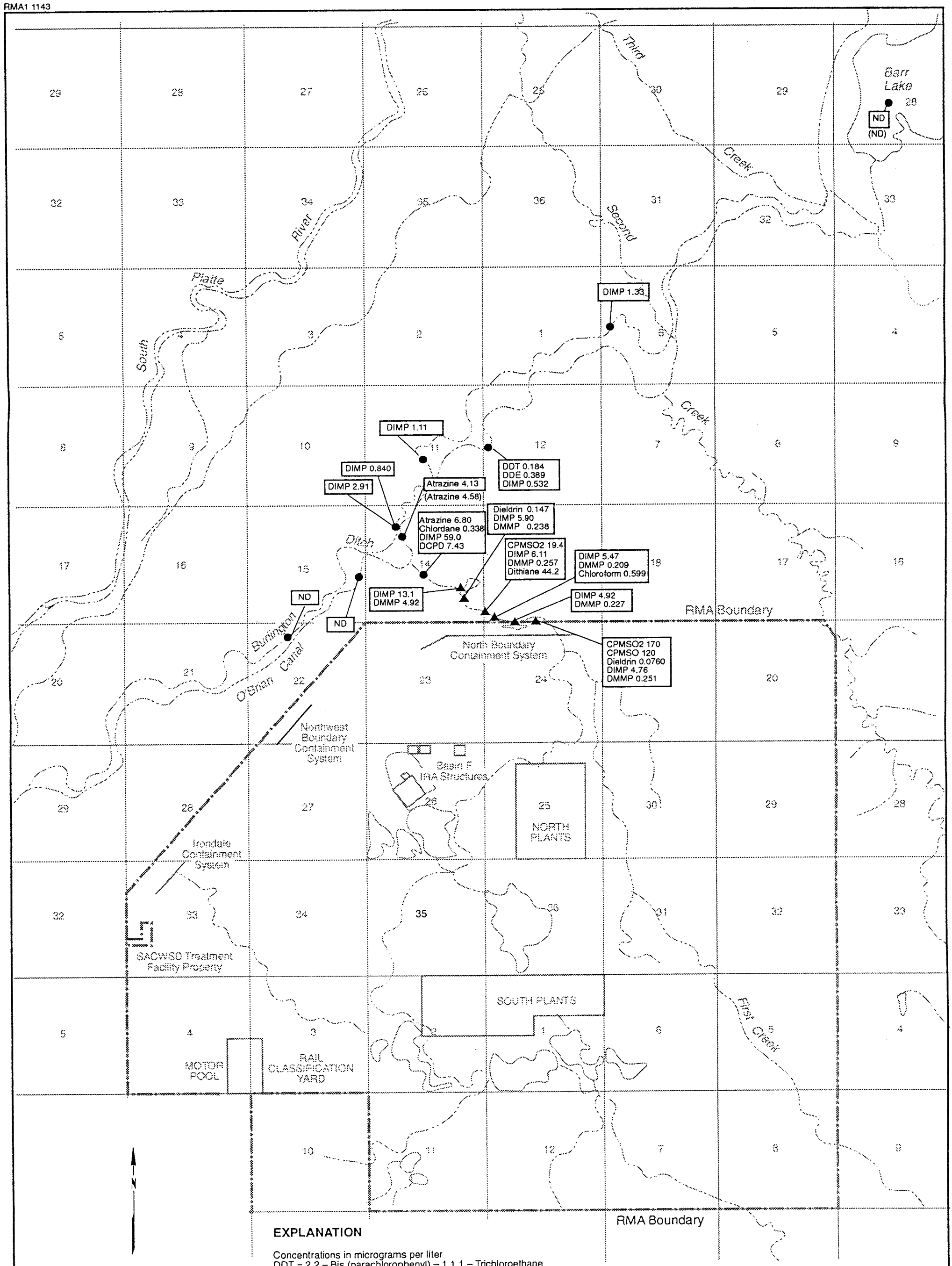
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 17

DISTRIBUTION OF ORGANOCHLORINE PESTICIDES DETECTED IN 96TH AVENUE AREA OFFPOST SOIL

RMA1 1143



EXPLANATION

Concentrations in micrograms per liter
DDT = 2,2 – Bis (parachlorophenyl) – 1,1,1 – Trichloroethane
DDE = 2,2 – Bis (parachlorophenyl) – 1,1 – Dichloroethane
DIMP = Diisopropylmethyl Phosphonate
DMMP = Dimethylmethyl Phosphonate
CPMS = p - Chlorophenylmethyl sulfide
CPMSO = p - Chlorophenylmethyl sulfoxide
CPMSO2 = p - Chlorophenylmethyl sulfone
ND = Not Detected at or above the Certified Reporting Limit

▲ Locations Sampled During RI Addendum Activities, November 1988

● Locations Sampled During RI Addendum Activities, May/June 1990

( ) Duplicate Sample Results

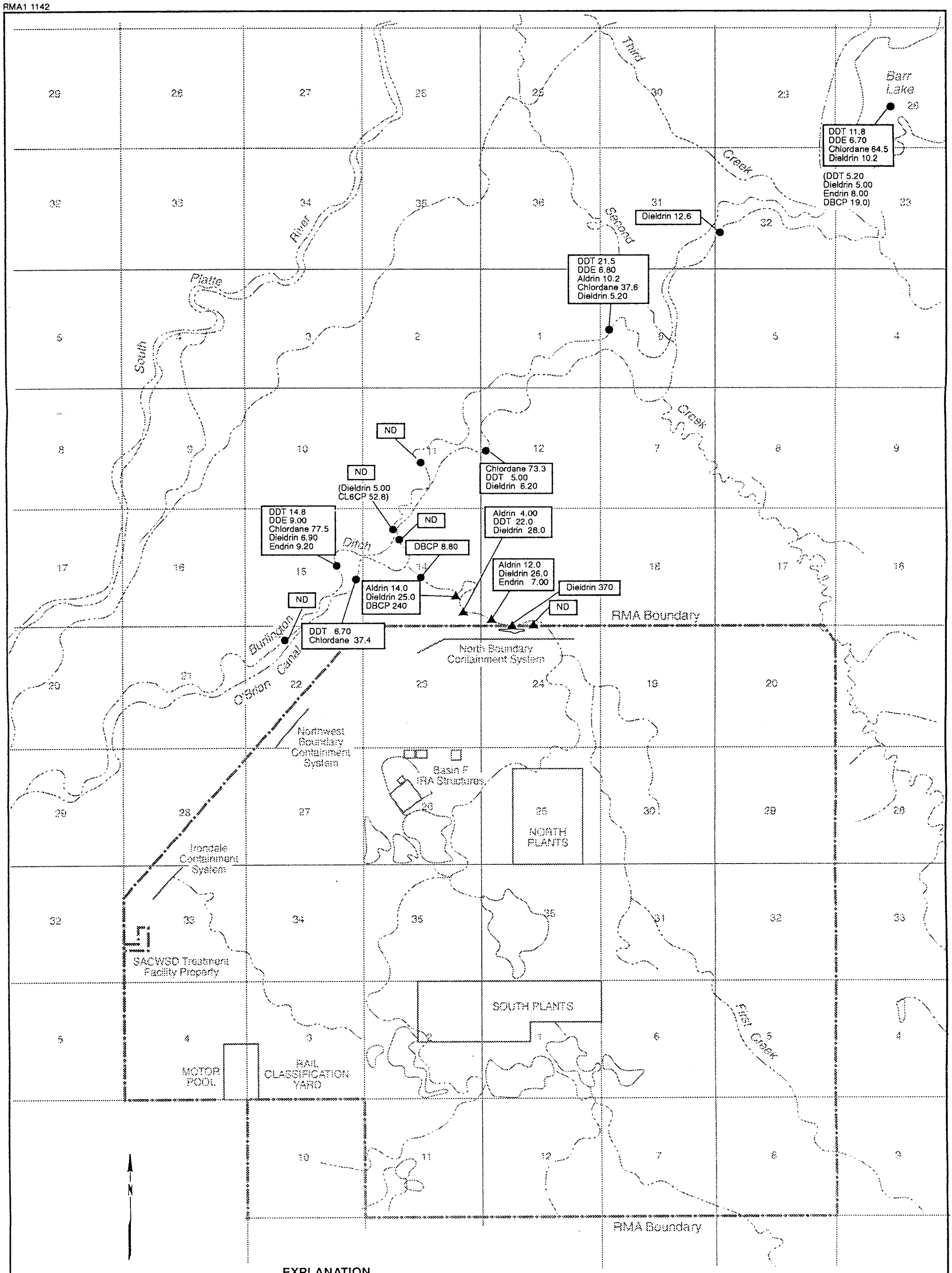
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 18

DISTRIBUTION OF ORGANIC COMPOUNDS DETECTED IN OFFPOST OPERABLE UNIT SURFACE WATER

RMA1 1142



EXPLANATION

Concentrations in micrograms per kilogram
DDT = 2,2 – Bis (parachlorophenyl) – 1,1,1 – Trichloroethane
DDE = 2,2 – Bis (parachlorophenyl) – 1,1 – Dichloroethane
DBCP = Dibromochloropropane
ND = Not Detected at or above the Certified Reporting Limit

▲ Locations Sampled During RI Addendum Activities, November 1988
● Locations Sampled During RI Addendum Activities, May/June 1990
( ) Duplicate Sample Results

Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 19

DISTRIBUTION OF ORGANIC COMPOUNDS DETECTED IN OFFPOST OPERABLE UNIT STREAM-BOTTOM SEDIMENT

GLOSSARY

µg/g	micrograms per gram
µg/kg	micrograms per kilogram
µg/l	micrograms per liter
ABS	chemical-specific absorption factor
ACGIH	American Conference of Government Industrial Hygienists
AChE	acetylcholinesterase
ACL	Alternate Concentration Limit
ADI	acceptable daily intake
AHPA	Archeological and Historic Preservation Act
ANOVA	Analysis of Variance
AOP	advanced oxidation process
APEG	alkali metal polyethane glycol
AQCDs	Air Quality Criteria Documents
ARAR	applicable or relevant and appropriate requirement
ARES	Automated Risk Evaluation System
Army	U.S. Department of the Army
AT	averaging time
ATP	adenosine triphosphate
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
BAC	Biotechnology Advisory Committee
BAF	bioaccumulation factor
BCF	bioconcentration factor
BCRL	below certified reporting level
BCS	Boundary Containment System
BDAT	best demonstrated technology

BDL	below detection limit
BEPA	Bald Eagle Protection Act
BEST	basic extraction sludge treatment
BF	bioavailability factor
BGEPA	Bald and Golden Eagle Protection Act
bgs	below ground surface
BHC	benzene hexachloride
BMF	biomagnification factor
BOD	Biological Oxygen Demand
bw	body weight
C/I	commercial/industrial
CAA	Compliance Assurance Agreement/Clean Air Act
CAR	Contamination Assessment Report
CBSG	Colorado Basic Standards for Groundwater
CCP	Composite Correction Plan (CWA)
CCR	Colorado Code of Regulations
CD	Consent Decree
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF&I	Colorado Fuel and Iron
CFR	Code of Federal Regulations
cfs	cubic feet per second/confined flow system
cfs/mi	cubic feet per second per mile
CHWMA	Colorado Hazardous Waste Management Act
cm	centimeters
cm/sec	centimeters per second
cm/hr	centimeters per hour

cm^2	centimeters squared
CMP	comprehensive monitoring program
CNS	central nervous system
COC	chemical of potential concern
COD	Chemical Oxygen Demand
COE	U.S. Army Corps of Engineers
CPMS	4-chlorophenylmethyl sulfide
CPMSO	4-chlorophenylmethyl sulfoxide
$CPMSO_2$	4-chlorophenylmethyl sulfone
C_r	concentration in plant roots/tubers
CRL	certified reporting limit
CSC	Chemical Sales Company
CTM	cattail marshes
CU	consumptive use
CV	coefficient of variation
C_w	chemical concentration in water
CWA	Clean Water Act
D_a	molecular diffusivities in air
DAA	detailed analysis of alternatives
days/yr	days per year
DBCP	dibromochloropropane
DDD	2,2-bis (para-chlorophenyl)-1,1-dichloroethane
DDE	2,2-bis (para-chlorophenyl)-1,1-dichloroethene
DDT	2,2-bis (para-chlorophenyl)-1,1,1-trichloroethane
DDTR	DDT and its metabolites
DIMP	diisopropyl methylphosphonate
DNA	deoxyribonucleic acid

DOC	dissolved organic carbon
DQO	data quality objective
DRCOG	Denver Regional Council of Governments
DRE	Destruction/Removal Efficiency
DSA	development and screening of alternatives
DSMA	disodium methanearsonate
D_w	molecular diffusivities in water
EA	endangerment assessment
Ebasco	Ebasco Services, Inc.
EC_{50}	median effective concentration
ED	exposure duration
EDB	ethylene dibromide
EF	exposure frequency
EFH	Exposure Factors Handbook
Eh	redox potential
EPA	U.S. Environmental Protection Agency
ERT	Environmental Research and Technology
ESA	Endangered Species Act
ESE	Environmental Science and Engineering, Inc.
ET	exposure time
FF	fallow field
FFA	Federal Facility Agreement
FI	locally produced fraction
FS	feasibility study
ft/day	feet per day
ft/ft	feet per foot
ft/yr	feet per year

FWCA	Fish and Wildlife Coordination Act
FWPCA	Federal Water Pollution Control Act
FWRIR	Final Water Remedial Investigation Report
FY	Fiscal Year
FY88	fiscal year 1988
FY90	fiscal year 1990
g/cm^3	grams per cubic centimeter
g/l	grams per liter
g/day	grams per day
GAC	granulated activated carbon
GC/MS	gas chromatography/mass spectroscopy
GMP	groundwater monitoring program
gpm	gallons per minute
GPS	Groundwater Protection Standards
GWF	grasses and weedy forbs
HA	health advisory
HADs	Health Assessment Documents
HBC	health-based criteria
HDPE	High Density Polyethylene
HEA	Health Effects Assessment
HEAST	Health Effects Assessment Summary Tables
HEEDs	Health and Environmental Effects Documents
HEEPs	Health and Environmental Effects Profiles
HEW	Health Education and Welfare
HI	Hazard Index
HLA	Harding Lawson Associates
HQ	hazard quotient

hr/day	hours per day
HSBAA	Historic Sites, Buildings, and Antiquities Act
HSDB	Hazardous Substance Database
HSWA	Hazardous and Solid Waste Amendments
ICP	inductively coupled plasma
ICS	Irondale Containment System
IRA	Interim Response Action
IRA A	Additional Interim Response Action
IRF	In Situ Radio Frequency
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
ISV	in-situ vitrification
K_{oc}	organic carbon coefficient
K_{ow}	octanol/water partition coefficient
l/day	liters per day
l/kg	liters per kilogram
l/cm^3	liters per centimeter cubed
LAER	Lowest Achievable Emission Rate
lb/acre	pounds per acre
LC_{50}	chemical concentration that is lethal to 50 percent of the exposed population
LD_{50}	chemical dose that is lethal to 50 percent of the exposed population
Ldn	day-night average noise level
LDPE	low-density polyethylene
LDR	Land Disposal Restrictions
LOAEC	lowest-observed-adverse-effect concentration
LOAEL	lowest-observed-adverse-effect level
LOEC	lowest-observed-effect concentration

LOEL	lowest-observed-effect level
m^2/day	square meters per day
MATC	Maximum Allowable Tissue Concentration
MBTA	Migratory Bird Treaty Act
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MER	Colorado Division of Water Resources Master Extract Register
MF	modifying factor
MFO	mixed function oxidose enzymes
mg/kg-bw-day	milligrams per kilogram body weight per day
mg	milligrams
mg/cm^2	milligrams per cubic centimeter
mg/kg/day	milligrams per kilogram per day
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
mg/m^2/day	milligrams per meter squared per day
mg/m^3	milligrams per cubic meter
mi^2	square miles
MKC	Morrison-Knudsen Corporation
MKE	Morrison-Knudsen Engineers, Inc.
MKES	MK-Environmental Services
ml/g	milliliters per gram
MLE	most likely exposure
MOP	Method of Proportion
MP	Malcolm-Pirnie, Inc.
MRL	minimal risk level
MSL	Mean Sea Level

MSMA	monosodium methanearsenate
MTV	mobility, toxicity, and volume
N	nitrogen
NAAQS	National Ambient Air Quality Standards (CAA)
NAS	National Academy of Sciences
NBCS	North Boundary Containment System
NCI	National Cancer Institute
NCP	National Contingency Plan
NEPA	National Environmental Policy Act (1969)
NESHAPS	National Emissions Standards for Hazardous Air Pollutants (CAA)
NHPA	National Historic Preservation act
NIOSH	National Institute for Occupational Safety and Health
nm	nanometers
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no-observed-adverse-effect level
NOAEC	no-observed-adverse-effect concentration
NOEC	no-observed-effect concentration
NOEL	no-observed-effect level
NPDES	National Pollutant Discharge Elimination System (CWA)
NPDWS	National Primary Drinking Water Standards
NPL	National Priorities List (CERCLA)
NRC	National Research Council
NRCC	National Research Council of Canada
NRDAM/COE	Natural Resource Damage Assessment Model for Coastal and Marine Environments
NSPS	New Source Performance Standards (CAA)
NTP	National Toxicology Program
NWBCS	Northwest Boundary Containment System

O&M NBCS	Operation and Maintenance North Boundary Control System
OCP	organochlorine pesticide
OECD	Organization for Economic Cooperation and Development
OHM/TADS	Oil and Hazardous Material/Technical Assistance Data System
OSWER	Office of Solid Waste and Emergency Response
OTSP	organics in total suspended particulates
OU	operable unit
PACT	powder activated carbon treatment
PC	permeability coefficient
PCNB	pentachloronitrobenzene
PEG	polyethylene glycol
PFF	plowed fallow field
PM-10	respirable particulates less than 10 microns in diameter
PMO	Program Managers Office
PMRMA	Program Manager for Rocky Mountain Arsenal
POTW	publicly owned treatment works
ppm	parts per million
PQL	Practical Quantitation Limit
PRG	preliminary remediation goal
PSD	Prevention of Significant Deterioration
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
R	retardation factor
RA	risk assessment
RACT	Reasonably Available Control Technology
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective

RBC	rotating biological contractor
RCC	Resource Conservation Corporation
RCRA	Resource Conservation and Recovery Act
RD/RA	Remedial Design/Remedial Action (CERCLA)
RD	Remedial Design
RfD	reference dose
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RIC	Resource Information Center
RLSA	R.L. Stollar & Associates, Inc.
RMA	Rocky Mountain Arsenal
RME	Reasonable Maximum Exposure
RNA	ribonucleic acid
ROD	Record of Decision
RPM	Remedial Project Manager (CERCLA)
RPO	representative process option
RRC	regulatory risk criteria
RSA	regional statistical area
RTECS	Registry of Toxic Effects of Chemical Substances
SA	skin surface area
SACWSD	South Adams County Water and Sanitation District
SAF	Spatial Adjustment Factor
SARA	Superfund Amendments and Reauthorization Act (1986)
SAS	Statistical Analysis System
SDWA	Safe Drinking Water Act
SEP	Standard Evaluation Procedure
SF	slope factor

SGOT	serum glutamate-oxymate aminotransferase
SIP	State Implementation Plans
SUTRA	Saturated-Unsaturated Transport
SVOC	semivolatile organic compound
TAC	time for exchange of basement air
TBC	to be considered
TCHD	Tri-County Health Department
TCOC	tissue chemicals of concern
TERIS	Teratogen Information System
TG-W	tall grass wetlands
TICs	tentatively identified chemicals
TLV	threshold limit value
TPP	technical program plan
TRCLE	trichloroethylene
TRV	toxicity reference value
TSD	Technical Support Document (or) Treatment, Storage, and Disposal
TSP	total suspended particulates
TSS	total suspended solids
TWA	time-weighted average
UAFS	unconfined alluvial flow system
UF	uncertainty factor
UFS	unconfined flow system
UIC	Underground Injection Control
UL90	upper 90 percent confidence limit on the arithmetic mean
UL95	upper 95 percent confidence limit on the arithmetic mean
USABRDL	U.S. Army Biomedical Research and Development Laboratory
USAF	U.S. Air Force

USC	Unified Soil Classification (or) United States Code
USDA	U.S. Department of Agriculture
USDHEW	U.S. Department of Health Education and Welfare
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTM	universal transverse mercator
USC	United States Code
UV	ultraviolet
VAR	ratio of basement volume to surface air in contact with soil
VLT	very low toxicity
VOC	volatile organic compound
WES	U.S. Army Engineer Waterways Experiment Station
WF	weedy forbs
WHO	World Health Organization
WQC	water quality criteria
WQCA	Water Quality Control Act
WWC	Woodward-Clyde Consultants
°C	degrees Celsius

TECHNICAL SUPPORT FOR ROCKY MOUNTAIN ARSENAL

Offpost Operable Unit
Endangerment Assessment/Feasibility Study

Final Report

Volume II of VIII
(EA Sections 1.0, 2.0, 3.0)

November 24, 1992
Contract Number DAAA15-88-0021
Task RIFS1 (Delivery Order 0001)

PREPARED BY

Harding Lawson Associates
Environmental Science and Engineering, Inc.

PREPARED FOR

PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL

THIS DOCUMENT IS INTENDED TO COMPLY WITH THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969.

THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATION RECORD FOR THIS CERCLA OPERABLE UNIT.

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PREFACE

The Endangerment Assessment (EA) is an element of a combined Endangerment Assessment/Feasibility Study (EA/FS) for the Offpost Operable Unit (OU) and complies with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); the Superfund Amendments and Reauthorization Act (SARA); the revised National Contingency Plan (NCP); and the regulations implementing the National Environmental Policy Act of 1969. Volume I of the EA/FS contains an introduction that includes site history and a summary of the nature and extent of contamination in the Offpost OU. An Executive Summary is also provided in Volume I that presents an overview of the findings from each section and summarizes the hypothetical human and ecological risks associated with the Offpost OU.

PURPOSE AND ORGANIZATION

The primary objectives of this EA are to:

- Provide an analysis of baseline risks and help determine the need for remedial action at a site.
- Provide a basis for determining levels of chemicals that are adequately protective of public health and the environment.

The EA is organized into six major sections plus appendixes. Section 1.0 outlines data evaluation procedures and describes statistical procedures used to identify chemicals of potential concern. Section 2.0 is the exposure assessment, which contains environmental fate properties of the chemicals of concern used in assessing exposure and describes the exposure setting and exposure pathways. Section 2.0 also quantifies exposure point concentrations, exposure factors, and chemical intakes, and presents the results of a limited quantitative uncertainty analysis on chemical intakes. Section 3.0 contains the toxicity assessment for both humans and ecological receptors. Section 4.0 presents the human health risk characterization, and Section 5.0 presents an ecological assessment for the Offpost OU. Section 6.0 provides conclusions of the EA, and Section 7.0 presents the references for the EA.

1.0 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

The initial steps in an endangerment assessment include evaluation of the nature and extent of contamination (Volume I), evaluation of analytical data, and selection of chemicals of potential concern. This section describes the data quality objectives process and procedures used to evaluate the analytical data and identify chemicals of potential concern for affected media in the Offpost Operable Unit (OU).

Data were collected consistent with a conceptual site model developed in 1984 (ESE, 1984) before publication of pertinent U.S. Environmental Protection Agency (EPA) guidance on data quality objectives (DQOs). DQOs are qualitative and quantitative statements established before data collection that specify the quality of the data required to support decisions during remedial response activities (EPA, 1987). Stage 1 of the DQO process is to compile and analyze available information to develop a conceptual site model that describes suspected sources, contaminant pathways, and potential receptors. Stage 2 of the DQO process requires identification of data uses and needs. This evaluation is also in the above-referenced documents. Data needs addressed by the offpost remedial investigation (RI) Addendum (HLA, 1992) were as listed in Table 1.0-1. Stage 3 of the DQO process requires a description of the methods used to obtain data of acceptable quality. These data collection methods were described by HLA (1989), which incorporated other planning documents by reference. The Offpost Contamination Assessment Concept Plan (ESE, 1984) met the substantive requirements of a site conceptual model and included statements equivalent to DQOs, guiding RI activities to collect data sufficient to perform a baseline risk assessment. The site conceptual model was revised during collection of data used in this assessment as new data suggested that such revisions were necessary. These revisions were reflected in the Draft Work Plan for the Offpost RI/endangerment assessment/feasibility study (EA/FS) Study (HLA, 1989). The preliminary conceptual site model is illustrated in Figure 1.0-1 and described below.

The sources of contaminants to the Offpost OU are waste disposal areas onpost. These sources have released and may continue to release contaminants to groundwater, surface water,

and atmosphere. Releases to groundwater as a result of leaching from Basins A and F, as well as other identified onpost source areas, are the predominant sources of Rocky Mountain Arsenal (RMA) contaminants in the Offpost OU. Atmospheric releases as a result of volatilization, reentrainment of dust, and/or atmospheric transport of aqueous-phase aerosols have also been a significant historical source of contaminants now deposited in surficial soils of the Offpost OU. Available evidence indicates that direct surface water releases from the onpost sources have not contributed significantly to contamination observed in the Offpost OU.

Historical releases of contaminants to groundwater from onpost sources have been transported by prevailing groundwater flow to the north and northwest, entering the Offpost OU at RMA's north and northwest boundaries. Several interim remedial actions have been taken to mitigate this source of contamination to the Offpost OU, including implementation of systems to contain, extract, and treat contaminated groundwater at the north and northwest boundaries. The actions have reduced the transport of groundwater contaminants to the Offpost OU.

Contaminants in offpost groundwater are also discharged to surface-water within the Offpost OU. The largest discharge is to First Creek near the north boundary of RMA. Contaminated groundwater may also discharge to the South Platte River or to abandoned gravel pit ponds in the flood plain of the South Platte.

Upon discharge of groundwater to First Creek, surface-water contaminants would be transported to O'Brian Canal. Surface-water flow may also occasionally be diverted to Burlington Ditch. A portion is diverted to Barr Lake. The surface water and bottom sediments interact and are considered together.

Releases of airborne contaminants from onpost sources have been reduced substantially in comparison with historical release rates. As a result, atmospheric concentrations of RMA contaminants are not elevated above background at this time (RLSA, 1990). Past releases have been transported offpost and deposited in surficial soils of the Offpost OU. This is indicated by the consistency of patterns of on- and offpost surficial soil contamination with the climatological wind rose.

Contaminants occurring in surficial soils, groundwater, and surface water may be bioaccumulated by plants and animals in contact with these media, resulting in residues in tissues that may be ingested by organisms at higher trophic levels, including humans. Groundwater is of concern in this regard if used for irrigation or to water livestock. Surface water is the predominant agricultural water supply source in the Offpost OU, but groundwater is used to supplement surface-water supplies and to water livestock on farm parcels south of the canals where surface water supplies are unavailable.

For the purpose of the conceptual site model, the assumption is made that unrestricted use of contaminated groundwater and lands could occur at the most contaminated offpost locations. These include any locations within approximately 1 mile of the north and northwest boundaries of RMA.

Potential exposure pathways identified for the Offpost OU include:

1. Inhalation of vapors released from groundwater and accumulating in structures or when groundwater is used for domestic water supply; inhalation of reentrained surficial soil containing site-related chemicals.

2. Ingestion of groundwater used for domestic supply; of game and agricultural products that have bioaccumulated contaminants from surficial soils; of surface water and groundwater used for agricultural water supply; and incidental ingestion of surface water, surficial soils, and sediments.

3. Dermal exposure to sediments, surface waters, surficial soils, and groundwater used for domestic supply.

Potential receptors include human residents, workers, and other visitors to the Offpost OU and terrestrial and aquatic biota (in First Creek, irrigation canals intercepting First Creek water, and Barr Lake, downstream of the canals).

Data evaluation procedures and statistical procedures for comparison with background concentrations are described. For the purposes of this EA, "background" is defined as chemical concentrations present in the various environmental media in the Offpost OU that are not attributable to contamination from activities at RMA. Chemicals of concern (COCs) were determined for groundwater, surface water, sediment, surface soil, and biota.

1.1 GENERAL SITE DATA EVALUATION CONSIDERATIONS

All data collected offpost after January 1, 1985, and data available upon downloading from the RMA database in August 1990 were originally evaluated for use in this EA, including data from the Offpost RI Addendum. A subsequent data retrieval in May 1992 was used to develop exposure concentrations for surficial soil and groundwater, using samples collected during 1989, 1990, and 1991.

Onpost data were removed from the Program Manager for Rocky Mountain Arsenal (PMRMA) database in a multistep process based on computer-generated maps of RMA and the surrounding offpost area (north to Barr Lake and east, and west approximately 6 miles from the RMA boundaries). Because the mapping database contained coordinates in a mixture of universal transverse mercator (UTM), state planar, and local coordinates, the first step was to convert all coordinates to a common system. State planar units were chosen as the common system. All samples were identified by a site identification, and the location (coordinates) of each site was stored in a separate file. Inconsistencies between site identifications and coordinates in the mapping file were then resolved.

The mapping data set was scanned for anomalies, such as duplicate records based on site identifications, coordinates plotting outside known offpost sampling locations, and unusual location patterns. The first scan revealed a series of sites plotting as a ghost of the onpost area displaced about 4 miles to the northeast. At this point, an updated version of the mapping data set was processed as described previously and used for the remainder of the analysis. Problems detected in the anomalies scan on the new data set were resolved as follows: duplicate records were researched to ensure the same site identification had been used with different site type designations (inconsistencies were corrected) and all sites plotting clearly out of range (and remaining ghost records) were removed. Site coordinates were attached to chemistry records by matching site type and site identification. A list of sites missing location information was generated for each medium and checked to identify sites associated with offpost sampling programs. Location information for these sites was determined from independent sources of

information, particularly the offpost RI report (Environmental Science and Engineering, Inc. [ESE], 1988a), and added to the chemistry and mapping data sets. Finally, sites contained in each chemistry database (groundwater, surface water, sediment, and surficial soil) were plotted on the computer-generated reference map. Offpost sites were verified by visual inspection of the maps and subsetting algorithms relative to RMA boundary coordinates. The final list of offpost sites by medium was then used to create chemistry data sets containing only offpost records.

In general, field duplicates and second column confirmation samples were retained except where both duplicates were reported as less than a Certified Reporting Limit (CRL), in which case, the record with the lower CRL was retained. Gas chromatography/mass spectroscopy (GC/MS) confirmation analyses were retained in the data set although they may be excluded from subsequent evaluations because of an unusually high CRL (to be discussed). Analyses of filtered groundwater and surface-water samples were not used in determining COCs or exposure concentrations.

Records were also checked to ensure that the units of measure used were appropriate to the sample medium. As a result, 50 records having units of micrograms per liter (μg/l) were excluded from the sediment data set. Offpost surficial soil samples collected in February 1989 were erroneously identified in the data set as sediment samples and included in the soil data set.

Because the predominant pathway resulting in surficial soil contamination of the Offpost OU has been through the deposition of airborne contamination (HLA, 1992), surficial soil samples collected from the upper 1 to 2 inches tended to be more contaminated than deeper soil (0.5- to 5.0-foot interval samples were also collected during the RI addendum). To be conservative, the shallower soil sampling interval was used to evaluate surficial soil COCs and exposure concentrations.

Approximately 3000 records from offpost private wells were originally listed in the surface-water file but were identified as tap water samples. This designation may have been based on their point of collection combined with insufficient information on well construction, which prevented identifying the samples as groundwater from a specified depth. Of these

samples, approximately 500 were filtered samples and 500 had no location information. The remainder were used as groundwater samples (2001 records). Major ion chemistry of samples from these wells was used to identify and exclude Arapahoe wells (Tri-County Health Department [TCHD], 1990) because the depth of private wells is not usually known.

Further improvement in the efficiency of subsequent data manipulation was gained by deleting records for analytes that were never detected above the CRL in any offpost sample.

Groundwater quality data collected during the Groundwater Intercept and Treatment System North of RMA Interim Response Action A (IRA A) pilot system testing (January 30 through February 9, 1990) were deleted for two reasons: (1) sampling procedures were inconsistent with the remaining groundwater investigative samples, and (2) inclusion would skew the data set toward a small area and a limited sampling period.

Groundwater data for eight volatile organic compounds (VOCs) from the first quarter of 1990 were excluded because of anomalies when compared with prior and subsequent samples from the same wells. The anomalies were traced to high concentrations of volatiles in a rinsate blank collected on February 28, 1990. The rinsate blank contained 11.4 μg/l benzene, 1.1 μg/l carbon tetrachloride, 90 μg/l chlorobenzene, 193 μg/l chloroform, 16.8 μg/l dichlorobenzenes 0.813 μg/l dibromochloropropane, 2.67 μg/l toluene, and 2.4 μg/l trichloroethene.

Considering that groundwater contamination at RMA is predominantly limited to the alluvial aquifer and upper zones of the Denver Formation (ESE, 1988a), groundwater data were used only for COC identification and exposure concentration estimates if the sample depth (below ground surface) was less than 100 ft. This depth cutoff includes the alluvium and the upper Denver Formation. RMA contamination is virtually nonexistent at greater depths in the Offpost OU. In addition, inorganic chemical background concentrations are substantially different (and generally higher) in the Arapahoe Formation when compared to the alluvium and upper Denver. Thus, comparison to background concentrations is more realistic and conservative if Arapahoe wells are excluded. Sample depth was generally not known for samples from private wells. Private wells have been characterized as alluvial Arapahoe, Denver, or Fox Hills on the basis of characteristic

levels of conductivity and hardness by TCHD (1990). Only samples from wells designated as alluvial or Denver Formation by TCHD (1990) were retained.

Before the various corrections and exclusions described in this section, the original (1985-1990) offpost data set used for identification of COCs and estimation of surface-water and sediment exposure concentrations contained 62,725 groundwater quality data records (one sample + one analyte = one record), 11,841 surface-water records, 2623 sediment records, and 1884 soil records. Of these, 50,107 groundwater records, 3955 surface-water records, 930 sediment records, and 1544 soil records were used to identify COCs and to estimate exposure concentrations in surface water and sediment.

Additional data evaluation steps were performed before estimation of exposure concentrations in groundwater and surficial soil to achieve a more reliable estimate of exposure concentrations in these media. Additional data were collected subsequent to the identification of COCs. It was determined that the most recent data should be used to estimate exposure concentrations in these media that contribute predominantly to chemical intakes. Further, it was noted that groundwater concentrations for some COCs have been declining since 1985 in portions of the Offpost OUs, particularly near the north boundary of RMA. These declines apparently result from the operation of the North Boundary Containment System (NBCS) and the Northwest Boundary Containment System (NWBCS). Considering this trend, only relatively recent data were used to estimate exposure concentrations in groundwater. Inclusion of these data from 1989 through 1991 provides a sufficiently large database to estimate groundwater exposure concentrations reliably.

Before estimation of exposure concentrations in groundwater and surficial soil, chemical analyses performed by GC/MS methods were eliminated for a subset of COCs for which GC/MS methods are insufficiently sensitive to detect (1) concentrations observed in other samples by more sensitive methods and/or (2) reference concentrations (EPA, 1989a). The COCs for which GC/MS analyses were eliminated as insufficiently sensitive were aldrin, chlordane, DBCP, DDE, DDT, dieldrin, endrin, hexachlorocyclopentadiene, isodrin, malathion, and oxathiane. For each of these,

one or more of the following conditions occurred: (1) there were no detections by GC/MS methods; (2) the GC/MS CRLs exceeded the maximum concentration detected by other, more sensitive methods; and/or (3) GC/MS CRLs were substantially higher than reference concentrations (e.g., maximum contaminant levels or concentrations corresponding to a 10^{-6} cancer risk).

Remaining GC/MS analyses were usually performed on a duplicate sample submitted for analysis by other quantitative methods. GC/MS results may be considered semiquantitative for some compounds other than specific analytes of interest; this implies that GC/MS results may be less precise. For this reason, GC/MS analyses that were duplicative of samples analyzed by a quantitative method were eliminated in preference for the quantitative method result. Thus, only nonduplicative GC/MS results were retained and only for those COCs where the method is sufficiently sensitive to detect concentrations routinely observed at the site.

Duplicate samples analyzed by the same method were replaced by a simple average of the duplicate values. When these steps were followed, the groundwater data set used to estimate exposure concentrations (1989-1991) contained 8392 useable records for groundwater COCs.

Additional surficial soil samples collected during 1991 extended the area of offpost sampling approximately one-quarter mile farther north than previous sampling. Additional samples that exhibited anomalously high concentrations of soil COCs were also collected in the immediate vicinity of two prior samples (HA1226WB and HA1231WB). Results from the latter samples clarified that the previously collected samples were unrepresentative of soil concentrations at those locations (HLA, 1992), so results from the two unrepresentative samples were not included in the exposure concentration data sets. The exclusion of these samples was also supported by the results of the Dixon outlier test.

1.2 STATISTICAL PROCEDURES FOR COMPARISON WITH BACKGROUND

Statistical procedures for comparison of current data with background concentrations were developed consistent with Risk Assessment Guidance for Superfund (RAGS) (EPA, 1989a) (particularly Sections 4.4.3, 5.3.2, 5.3.3, 5.7, 5.8, 6.4, and 6.5) and the following sources recommended by RAGS: EPA, 1989b; CH2M Hill, 1988; Barth and Mason, 1984; and Gilbert, 1987.

These procedures were adapted from and are consistent with this guidance; in some cases, modification was required for meaningful application to available site data.

The primary criterion for identifying COCs was that their concentrations at locations of expected maximum RMA-related contamination were statistically elevated above concentrations at sampling locations (sites) where RMA-related contamination is believed to be absent (referred to as reference data sets). The first step was to define reference and RMA-related data sets. Cited guidance recommends that sample size be similar in the reference and RMA-related site data sets. The RMA-related data sets included sampling sites located within the Offpost OU that are affected by RMA contamination.

For surficial soil, the reference data set included 4 agricultural sites approximately 9 miles north of RMA, 11 sites within 1 mile of RMA near the northeast boundary, and 1 site west of RMA. The 4 sites far north of RMA were originally designated as background sites (Figure 1.2-1). The 12 additional sites were subsequently determined to be representative of background conditions as described below.

Both onpost and offpost surficial soil and ambient air monitoring data indicate that airborne contamination from RMA is transported predominantly to the east and north but not significantly to the northeast. This pattern of surficial soil contamination represents the effect of airborne contaminant deposition over the history of RMA. A variety of RMA indicator contaminants, including dieldrin, are not detectable in onpost and offpost surficial soil near RMA's northeast boundary or in the most westerly offpost site. The hypothesis that the 12 additional sites were representative of background contaminant levels was tested by evaluating whether contaminant levels were significantly elevated compared to the four original background sites. The proposed additional background sites were not significantly elevated for any analyte, based on application of the following statistical procedures described by EPA (1989a):

- The Wilcoxon rank sum test if more than 50 percent of the proposed additional background samples exceeded the CRL
- The Method of Proportions (MOP) if less than 50 percent of the proposed additional background samples exceeded the CRL

The significance level used for the one-tailed test was 0.1. Each analyte detected in soil was not significantly elevated in the proposed background sites.

Of the nine detected analytes at the proposed additional background sites, six (arsenic; copper; isodrin; lead; 2,2-bis[para-chlorophenyl]-1,1-dichloroethene [DDE]; and zinc) exhibited mean concentrations slightly but not significantly higher than the mean of the four original background sites; three (chromium; dieldrin; and 2,2-bis[para-chlorophenyl]-1,1,1-trichlorethane [DDT]) had slightly lower mean concentrations at the proposed additional background sites, compared to the original four background sites. Of those with slightly higher means, arsenic exhibited the greatest, nonsignificant relative elevation with a mean of 1.66 μg/g at the proposed additional sites and a mean of 1.25 μg/g at the four original sites (33 percent higher). These concentrations are well within the range of ambient background soil concentrations for arsenic in the western United States (Shacklette and Boerngen, 1984). In conclusion, this evaluation supports the hypothesis that the proposed additional background sites are also representative of background soil concentrations for all analytes, including pesticides, and are not significantly contaminated by RMA sources.

The RMA-related set for surficial soil is the area within 0.5 mile of the intersection of 96th Avenue and Peoria Street, at RMA's north boundary. This zone contains 15 surficial soil sampling sites, similar to the number of sites in the reference data set. This zone was selected considering source characteristics, transport pathways, and the existing distribution of chemicals. Specifically, the climatological wind rose indicates frequent occurrence of high winds from the south and west. Basin F was a suspected historical source of atmospheric chemical release. Of several such sources (including Basin A and the South Plants), former Basin F is nearest to the RMA boundary and the Offpost OU and is directly south of the designated RMA-related area. Evaluation of the existing distribution of chemicals in surficial soil was done by ranking concentrations of nine potential chemicals (seven pesticides and two metals) known to be associated with waste disposal activities at RMA, and all offpost sites were assigned to three strata, the highest one-third, the middle one-third, and the lowest one-third, for each chemical. The RMA-related

zone contained sites from the highest one-third for each of the seven chemicals and contained most of the sites within the highest one-third. Other sites within the highest one-third were randomly distributed and did not follow the spatial patterns expected as a result of transport from known RMA sources. The site locations of the RMA-related and reference surficial soil data sets are shown in Figure 1.2-2.

The zone designated as having the highest concentrations of chemicals in surface water and sediment is First Creek. Reference sites for this comparison were a site on First Creek at the southeast boundary of RMA and two sites on Second Creek upstream of its outlet to O'Brian Canal. Surface-water sites are shown in Figure 1.2-3 and sediment sites are shown in Figure 1.2-4. The watersheds for the reference sites are upstream of all RMA sources. To account for temporal variations, some surface-water sampling dates were deleted from the impacted First Creek data set if samples were not available from the reference data set at approximately the same time. As a result, samples collected in the RMA-related area in November 1988, May 1989, November 1989, and February 1990 were deleted because no corresponding samples were collected at reference sites during these sampling periods. Samples collected at the reference sites in September 1986 were deleted because no corresponding samples were collected in the RMA-related area during this sampling period. Otherwise, all samples collected from November 1985 through April 1990 were used for statistical comparison with background. The number of records was similar in the First Creek and reference surface-water data sets (n = 723, impact; n = 555, reference). For sediment, however, the reference data set was sparse (29 records). The effects of the limited number of records are discussed in Section 1.3.2.

Additional comparisons to reference were made for the irrigation canals that receive flow from First Creek. All samples collected from O'Brian Canal or Burlington Ditch downstream (northeast) of the mouth of First Creek were included in the RMA-related data set for this comparison. All samples collected from O'Brian Canal or Burlington Ditch upstream (southwest) of the mouth of First Creek were used for the reference data set. Site locations for surface water are shown in Figure 1.2-5, and sediment sites are shown in Figure 1.2-6. Sample size was similar

in the contrasted data sets (n = 940, downstream; n = 640, upstream). Comparisons were made only for the chemicals determined to be elevated in First Creek, the only significant potential source of RMA-contaminated flow to the canals.

Barr Lake water quality was also statistically compared with the quality of water in the canals upstream of the mouth of First Creek. The canals are the source of water to Barr Lake. Barr Lake surface-water sites are shown in Figure 1.2-5. Comparisons were made only for those chemicals significantly elevated above reference in both First Creek and the canals. Sample size was similar in the Barr Lake and upstream data sets (n = 616, Barr Lake; n = 640, upstream).

Reference sites for groundwater were defined as those sites where diisopropylmethyl phosphonate (DIMP), dieldrin, and chloroform have not been detected since 1985. These contaminants are characteristic indicators of RMA contamination in groundwater, and the absence of these contaminants indicates negligible RMA impact. DIMP and chloroform are extremely mobile in groundwater and are the most suitable indicators of RMA contamination. Only wells less than 100 feet deep were considered. These well locations tend to be northeast of the north boundary plume, northwest of RMA, between the north boundary and northwest boundary plumes, or southwest of the northwest boundary plume. At the request of Colorado Department of Health (CDH) and EPA, the reference data set was compared to upgradient wells in the southern and eastern tiers of RMA. In nearly all cases, the alternative data set (southern and eastern tiers) means were greater than or nearly equivalent to the reference data set. The only exceptions were chloride and alkalinity means, which were greater in the reference data set.

The RMA-related data set comprises 10 wells near the north and northwest boundaries of RMA having the highest reported concentrations of either DIMP, dieldrin, or chloroform. The number of wells included was determined by the criterion that the RMA-related and reference data sets have a similar number of records (n = 4283, RMA-related; n = 3892, reference). Included wells represent each of the three primary plumes (northern paleochannel, First Creek paleochannel, and northwest paleochannel plumes).

The next step necessary to compare RMA-related and reference data sets was editing of nondetect data with unusually high CRLs following RAGS guidance. An upper 95 percent confidence limit on the arithmetic mean (UL95) was calculated on the basis of either normal or lognormal distribution, according to Gilbert (1987), after substituting half the detection limit for all nondetects. The most representative distribution for estimation of UL95 was selected using the following criteria:

- If the coefficient of variation (CV) is less than 1.2, use normal statistics.
- If CV is greater than 1.2, use the Shapiro and Wilk W test (Gilbert, 1987) to determine whether the normal or lognormal distribution better fits the data (whichever yields the larger value of W).

If UL95 exceeded the maximum detected value, nondetects with an unusually high CRL (greater than the maximum quantified concentration) were deleted from the data set.

The RMA-related and reference data sets were compared in accordance with EPA guidance that addresses data sets with a high frequency of nondetects. Following this guidance, the MOP was used when the frequency of detects in the RMA-related data set was less than 50 percent; the Wilcoxon rank sum test (see also CH2M Hill, 1988) was used when the frequency of hits was greater than or equal to 50 percent but the data fit neither a normal nor lognormal distribution; and parametric analysis of variance (ANOVA) was used when the data fit either a normal or lognormal distribution (90 percent confidence). The Wilcoxon rank sum test and ANOVA procedures were implemented using the Statistical Analysis System (SAS). If lognormal, ANOVA was used to process lognormal transformed data. For both the Wilcoxon and ANOVA procedures, nondetects were substituted as half the detection limit. Each of these procedures yields a Z statistic, which must exceed Z_{1-a} to reject the null hypothesis that the sample means are the same, where "a" is the significance level. For a one-tailed test, $a = 0.1$, $Z > 1.28$ indicates that the RMA-related mean exceeds the reference mean with 90 percent confidence. The referenced guidance generally uses $a = 0.05$ to achieve 95 percent confidence. The confidence level was reduced to 90 percent as a measure of conservatism (the null hypothesis is more likely to be rejected resulting in more COCs with $a = 0.1$ than with $a = 0.05$). This conservative approach was

adopted upon consideration of the small sample size for some data sets (lack of power) and the low frequency of detection for most of the data sets for most analytes.

In all, more than 125 media per analyte data set comparisons (i.e., 125 RMA-related data sets versus 125 reference data sets) were performed to develop lists of COCs by media. There were approximately 40 comparisons for which none of the methods recommended by the cited guidance were technically applicable. None of the methods presented in the cited guidance documents is recommended when there is a very low frequency of detection (total number of detections less than five or frequency of detection less than 10 percent). As a practical matter, such cases are of little interest because it may reasonably be assumed that if the frequency of detection is less than 10 percent, the chemical is not significantly elevated. In a few cases, however, this condition resulted from small sample size (i.e., number of detections less than five, but frequency of detection greater than 10 percent). To avoid eliminating a COC because of small sample size, a modification of the MOP was developed to evaluate such data sets, and this modification was applied only if the basic MOP indicated that the chemical was not significantly elevated.

The modified MOP was based on the assumption that the frequency of detection in both RMA-related and reference data sets would stay the same if more samples were collected. The total number of detects was increased to five while the ratio of detections to total samples collected was kept the same in both data sets. For example, the detection frequency for chlordane in the First Creek surface-water samples was 2/5, while chlordane was not detected in three reference samples (Table 1.3.2-1). By the MOP, which may not be valid for this data set, $Z = 1.26$ and the chemical is not significantly elevated ($Z < 1.28$). By the modified analysis, it is assumed that the RMA-related detection frequency is 5/13, while the reference is 0/8. Then $Z = 2.01$ and the null hypothesis is rejected. This procedure was only applied when the number of detects was less than five, but the frequency of detection in the RMA-related set exceeded 10 percent.

1.3 SELECTION OF CHEMICALS OF CONCERN

The primary criterion used in identifying COCs was the statistical comparison with site-specific background concentrations. In rare instances, additional criteria were considered. Additional criteria are recommended in RAGS Section 5.8 (EPA, 1989a), and the most substantive recommendation is to consider degradation products of chemicals detected. Additional criteria that were considered in this assessment were documented association with RMA activities and presence above background in an interacting medium; for example, hydrophobic chemicals detected at elevated concentrations in surface water were assumed to be elevated in sediments. The reference data set for sediments was relatively sparse, suggesting the need to consider factors beyond the simple statistical comparison. Regional background data for metals in surficial soil were considered in addition to site-specific data. Consideration of regional background data for metals in surficial soil was also prudent given the relatively sparse site-specific reference data set for metals in surficial soil. After comparison with applicable or relevant and appropriate requirements (ARARs), certain major cations detected at elevated concentrations in groundwater and surface water were eliminated as COCs, considering the low toxicity and status as essential human nutrients.

In the following sections, the results of the statistical comparison with background are presented, followed by additional descriptions, by media, leading to identification of lists of COCs that were used for the quantitative risk assessment.

1.3.1 Groundwater

The statistical comparison of RMA-related groundwater sampling locations with reference sampling locations is summarized in Table 1.3.1-1. All analytes detected above CRLs in the RMA-related data set are included in Table 1.3.1-1 except pH, alkalinity, total organic carbon, and total suspended solids. These analytes are of interest primarily with respect to fate and transport and remedial actions evaluation.

Sample size is not a problem in contrasting the groundwater data sets. The average sample size is n = 56 in both RMA-related and reference data sets. No background data are available for

bis(2-ethylhexyl)phthalate, dichlorobenzene, iron, or manganese. Benzothiazole, cyanide, vapona, malathion, parathion, and supona data sets are relatively sparse because of the recent addition of these analytes to the target analyte list for water.

The Z statistic is a criterion for significant elevation above background. If $Z < 1.28$, the null hypothesis that the RMA-related and reference data sets are drawn from the same population cannot be rejected with 90 percent confidence. $Z < 0$ indicates that the chemical is more prevalent in the reference data set than in the RMA-related data set, but the significance of this finding has not been evaluated and probably results from chance. Contaminants with $Z > 1.64$ are elevated with 95 percent confidence. All contaminants significantly elevated with 90 percent confidence are also elevated with 95 percent confidence, with the exception of atrazine, toluene, malathion, and xylene. Ethylbenzene and toluene were found to be significantly elevated even though the frequency of detection in the RMA-related data set is less than 10 percent, a situation in which the MOP may not be valid.

The statistical comparison was not performed for chloroform, DIMP, and dieldrin insofar as the procedure for defining the reference and RMA-related data sets was based on the absence and presence of the chemicals, respectively. Thus, they have been presumed to be COCs.

The detection frequency exceeded 50 percent in the RMA-related data set for only a few chemicals: calcium, chloroform, chloride, dichlorobenzene, DIMP, dieldrin, iron, fluoride, potassium, magnesium, manganese, sodium, nitrate, sulfate, and zinc.

COCs for the groundwater medium are identified in Table 1.3.1-2. The list is based primarily on a finding of significant elevation above background (Table 1.3.1-1). Only differences between the COCs and the chemicals found to be significantly elevated are described in the following paragraphs.

Bis-(2-ethylhexyl) phthalate is not considered a COC for several reasons. There are no site-specific background data for comparison, but this chemical is ubiquitous in the environment (Agency for Toxic Substances and Disease Registry [ATSDR], 1989a) and is frequently detected in environmental samples as a result of contamination by sampling hardware containing polyvinyl

chloride (PVC) or other plastics. This chemical was not detected in blanks taken for quality assurance purposes. The frequency of detection in the RMA-related data set was less than 10 percent (1 sample out of 11) and the single detection was not confirmed by subsequent sampling of the same well. Bis-(2-ethylhexyl)phthalate has not been identified as a chemical associated with waste disposal at RMA (PMRMA, 1988).

Calcium, iron, potassium, magnesium, and sodium are not considered COCs because of their very low toxicity and essentiality to human nutrition (Table 1.3.1-3). Consumption of 2 liters per day (l/day) of water at the UL95 in any of the characteristic groundwater plumes (Section 2.4.1) would not result in ingestion of the recommended daily allowances/intakes for any of these chemicals. Further, the observed concentrations do not exceed ARARs established for these chemicals.

There are no pertinent background data for dichlorobenzene. However, because of the high frequency of detection of this anthropogenic chemical in the RMA-related data set, it was selected as a COC.

DDT and hexachlorocyclopentadiene were elevated at confidence levels slightly less than the criterion of 90 percent. Their detection frequency exceeded 15 percent, and they are known to be associated with disposal practices at RMA; hence they were included as COCs.

1.3.2 Surface Water/Sediment

The statistical comparison with reference for the surface water of First Creek is presented in Table 1.3.2-1. Contrasted data sets have an average n=14 and are sufficient for comparison in most cases. The modified MOP (Section 1.2) was used for atrazine, chlordane, and mercury as a conservative approach when the total number of detections was less than five, but the frequency of detection in the RMA-related data set exceeded 10 percent. In this circumstance, it is possible that the small sample size might result in an inability to detect a significant elevation. In the modified MOP, the sample size is increased artificially in both the RMA-related and background data sets while the frequency of detection is maintained in both until the total number of

detections reaches five. This modification resulted in a finding that chlordane is significantly elevated but did not affect the negative finding for atrazine or mercury.

The Shapiro and Wilk W test indicated that sulfate data were lognormally distributed with 90 percent confidence; therefore, parametric ANOVA was used to contrast ln-transformed data sets for that constituent.

The frequency of detection in the RMA-related (First Creek) data set exceeds 50 percent for only a few chemicals: calcium, chloride, DIMP, fluoride, potassium, magnesium, sodium, nitrate, and sulfate. Arsenic and potassium are elevated with 90 percent confidence but not at 95 percent confidence.

The results presented in Table 1.3.2-1 were used as the basis to select the COCs identified in Table 1.3.2-2. Potassium, magnesium, and sodium are not considered COCs because of their low toxicity and because they are essential human nutrients. Comparison to drinking water intakes is not pertinent because First Creek is not a potential potable water supply.

DDE is considered a COC in surface water because it is elevated with 86 percent confidence, is a degradation product of DDT (a COC), and is a COC in groundwater that discharges to First Creek.

COCs for surface water are also of concern in groundwater, consistent with the findings of the RI (ESE, 1988a) that groundwater discharge to First Creek is the primary transport mechanism whereby RMA-related chemicals reach offpost surface water.

First Creek discharges to O'Brian Canal, and First Creek's flow may also be diverted occasionally to Burlington Ditch. The canals receive little if any groundwater discharge because the canal stream beds are well above the water table. Thus, the only significant source of RMA contaminants to the canals is discharge from First Creek (see Section 1.2), and it is pertinent to evaluate whether COCs in First Creek are also elevated in the canals. A statistical comparison of chemical data from O'Brian Canal and Burlington Ditch downstream of the mouth of First Creek with chemical data from upstream of First Creek is summarized in Table 1.3.2-3. Only the COCs identified in First Creek were evaluated in this comparison. Downstream data sets average n = 22,

while the average size of the reference data set is n = 16. The data sets are of sufficient size for meaningful comparisons. Only chloride and sulfate exhibit a frequency of detection greater than 50 percent, permitting application of the Wilcoxon rank sum test. Only DIMP and fluoride are significantly elevated with 90 percent confidence. These chemicals are also evaluated with 95 percent confidence.

Part of the flow of O'Brian Canal is diverted to Barr Lake and is the primary supply of water to Barr Lake. Thus, it is pertinent to evaluate whether COCs in the canals (DIMP and fluoride) are significantly elevated in Barr Lake. This evaluation is summarized in Table 1.3.2-4, where it is shown that neither of these chemicals is significantly elevated in Barr Lake.

Surface-water sediments interact with overlying waters and may be a source of chemicals to surface waters from past releases. Statistical comparison of First Creek sediments to reference sediments is hampered by a very sparse reference sediment data set. For those chemicals detected in First Creek sediments (aldrin, arsenic, cadmium, chromium, copper, dibromochloropropane, dieldrin, endrin, lead, DDT, and zinc), only two to five sediment samples are available that are representative of background conditions on comparable water bodies (First Creek and Second Creek). Furthermore, these samples were collected in 1986 and 1987, and the analytical procedures used at that time resulted in relatively large CRLs for organochlorine pesticides (OCPs). None of the OCPs was detected above CRLs in the reference samples, but the CRLs were higher than the maximum quantified concentration in any of the sediment samples from First Creek. Consequently, the reference data set for comparison with First Creek sediment is not sufficient to address whether First Creek sediment is elevated for OCPs. Consequently, other criteria were considered in determining whether OCPs are COCs in First Creek sediments. These criteria include frequency of detection in First Creek sediment and status as a COC in surface water combined with a high organic carbon partition coefficient (K_{oc}). A chemical that is elevated in surface water would also be expected to be elevated in associated sediments if it tends to adsorb to sediments.

Excluding GC/MS confirmation samples with unusually high CRLs, the frequency of detection of OCPs in First Creek sediments is aldrin, 30 percent; dibromochloropropane, 20 percent; dieldrin, 50 percent; endrin, 11 percent; and DDT, 10 percent. Chlordane and DDE were not detected. Dieldrin, DDE, and DDT are COCs in surface water and are very hydrophobic (Section 2.1). DDE is a degradation product of DDT, a COC in surface water that was also detected at 10 percent frequency in sediments. Considering these factors, aldrin, dibromochloropropane, dieldrin, endrin, DDE, and DDT are considered COCs in the sediment of First Creek.

Although the reference data sets for metals in sediments are relatively sparse, they do not show the unusually high CRLs exhibited by the reference sediment OCPs data. Considering the small sample size of the sediment reference data sets for metals, however, Table 1.3.2-5 presents additional supporting data not presented for the other media. In addition to detection frequency, the RMA-related and reference data sets are compared with respect to mean and standard deviation of the mean, and maximum concentrations. The same statistical procedures were used as for other comparisons, and it was determined that metals are not elevated above background in First Creek sediment. In addition, it is shown that means are not higher in the RMA-related data set, but instead tend to be lower although the differences are probably not significant. Also, the maximum concentrations tend to be higher in the reference data sets than in the RMA-related First Creek data set. These additional comparisons establish confidence in the finding that First Creek sediments are not elevated for metals.

Analogous to the upstream/downstream comparison performed for water of O'Brian Canal and Burlington Ditch, Table 1.3.2-6 compares sediment of O'Brian Canal downstream of First Creek to sediment upstream. Burlington Ditch sediments were excluded from this comparison to achieve similar sample size in the contrasted data sets. Burlington Ditch is likely to be less contaminated by First Creek discharges than O'Brian Canal; therefore, this exclusion is conservative. Table 1.3.2-6 shows that none of the COCs in First Creek sediment are significantly elevated in O'Brian Canal sediment. Furthermore, aldrin, dibromochloropropane, endrin, and DDE have not been detected in O'Brian Canal sediment.

Barr Lake is a depositional environment that may be more likely than O'Brian Canal to retain residues of past discharges of contaminated sediment. Thus, the statistical comparison is extended to Barr Lake although O'Brian Canal sediment is not significantly elevated. This analysis is summarized in Table 1.3.2-7. The analysis is hampered by small sample size, requiring the modified MOPs to evaluate dibromochloropropane. The finding that dibromochloropropane is possibly elevated in Barr Lake is unlikely because a duplicate sample failed to confirm the presence of dibromochloropropane (HLA, 1992).

1.3.3 Surficial Soil

The statistical comparison of surficial soil data from the RMA-related area near the intersection of 96th Avenue and Peoria Street with a reference data set (Section 1.2) is summarized in Table 1.3.3-1. Sample size averages 18 data points in RMA-related and reference data sets and is sufficient for a meaningful comparison. Even though the conservative modification of the MOP (see Section 1.3) was used for isodrin, it was not found to be elevated.

Although copper, lead, and zinc were found to be significantly elevated with respect to the site-specific reference data set, the RMA-related area data set appears to be completely consistent with regional reference data. For copper, the RMA-related area mean, 11 milligrams per kilogram (mg/kg) and maximum 12.9 mg/kg, can be compared with the mean and maximum for western United States soil reported by Shacklette and Boerngen (1984) of 27 mg/kg and 300 mg/kg, respectively. Shacklette and Boerngen (1984) estimate the mean for lead to be 20 mg/kg and the maximum to be 700 mg/kg. The RMA-related area data set exhibits a mean lead content of 28 mg/kg and maximum of 40.6 mg/kg. Similarly, the RMA-related area mean concentration for zinc of 65 mg/kg is identical to Shacklette and Boerngen's western United States mean. Considering these regional data, copper, lead, and zinc do not appear to be elevated and are not considered COCs for soil. The remaining significantly elevated chemicals from Table 1.3.3-1 (i.e., aldrin, chlordane, dieldrin, endrin, DDE, and DDT) are considered to be COCs for offpost surficial soil.

1.3.4 Biota

Tissue samples of terrestrial and aquatic animals were analyzed for seven target analytes (aldrin, dieldrin, endrin, DDT, DDE, mercury, and arsenic) for biota. The criteria for the selection of the target analytes were given in Section 3.2.2.3 of the Biota RI report (ESE, 1989b). These criteria include the presence of target analytes in RMA soil and the tendency to bio-accumulate. The CRLs for these compounds were mg/kg (equivalent to parts per million [ppm]): arsenic 0.25; mercury, 0.05; aldrin, 0.013; dieldrin, 0.018; endrin, 0.036; DDE, 0.063; and DDT, 0.132 ppm. These CRLs are slightly lower for pesticides than were achieved during the Biota RI (ESE, 1989b), the primary source of background (reference) data. Background levels for these contaminants are not adequately defined for all species by site-specific data; therefore, a quantitative evaluation of the contaminant levels in these biota samples is not feasible.

When compared with background levels from onpost and offpost controls, where available (ESE, 1989; Section 4.3), arsenic levels in prairie dogs and earthworms may be elevated above their respective background levels. For example, arsenic was detected above the CRL in one of five offpost prairie dog samples but was not detected in any of 23 control samples from the Biota RI. The mean arsenic content of five offpost earthworm samples was 1.49 mg/kg, and the mean of 10 controls from the Biota RI was 0.85. Both ANOVA and the Wilcoxon rank sum test indicate that the offpost earthworm arsenic concentrations are significantly elevated above the control data. Arsenic is not expected to be elevated in these species because it is not elevated in the offpost soil to which the species would be exposed. Arsenic levels exceed CRLs in the aquatic organisms, algae, and crayfish. No background data for these species are available for comparison. Arsenic is identified as a COC in groundwater and surface water.

Mercury was detected at concentrations above CRLs in earthworms and fish. The Wilcoxon rank sum test was used to compare earthworm mercury tissue levels offpost with control data reported in the Biota RI, and mercury was not significantly elevated. The mean of offpost mercury levels in fish tissue, 0.080 mg/kg, is less than the mean of fish control samples from the Biota RI, 0.122 mg/kg. Mercury is not significantly elevated in any offpost abiotic media.

Dieldrin in the offpost controls for fish were consistently below the CRL, and two of the four offpost fish samples exceeded 0.031 mg/kg, the CRL achieved during the Biota RI.

Dieldrin was detected offpost in cattle and chicken tissues, including eggs, for which there are no pertinent site-specific control data. Comparisons to relevant tissue data from various United States locations reported in the technical literature suggests, however, that the samples from the Offpost OU may be elevated above background. Background levels in chicken livers are reported from 0.01 to 0.04 ppm (Severson, 1978; Onley and others, 1975), in fat from 0.01 to 0.22 ppm (Graves and others, 1969; Severson, 1978; Onley and others, 1975; Kan and Jonker-den Rooyen, 1978), in chicken breast muscle from 0.01 to 0.016 ppm (Putnam and others, 1974; Onley and others, 1975), and in eggs from 0.006 to 0.05 ppm (Cummings and others, 1966; Kan and Jonker-den Rooyen, 1978; Severson, 1978; Driver and others, 1976). All these data are at least 15 years old. The background levels are believed to be decreasing due to the restricted use of this pesticide. The various tissue levels for dieldrin in chicken at the Offpost OU are liver 0.023, fat 0.23, muscle <0.018, and egg 0.018 ppm. The difference between control from literature and the onpost operable unit area may not be significant, but the lack of relevant control data makes definitive comparison impossible.

Cattle fat dieldrin levels in Ontario cattle were 0.003 ppm in 1986 to 1988 (Frank and others, 1990), and the levels in the meat, fish, and poultry group of the U.S. Department of Agriculture (USDA) total diet study were 0.0012 ppm from 1978 to 1982 (Gartrell and others, 1986). These levels are substantially lower than dieldrin levels detected in two cow fat biopsies collected from a farm near the RMA north boundary (see RI Addendum). Dieldrin is a COC in groundwater, surface water (First Creek), and surficial soil.

In summary, although a rigorous statistical comparison to site-specific controls was not feasible for most biota tissue data, arsenic and dieldrin may be elevated in tissue samples collected in the Offpost OU.

1.4 SUMMARY

COCs have been identified for each environmental medium. If a sample collected in areas affected by RMA contained a significantly elevated level of a particular chemical in comparison with samples believed to be unaffected by RMA, that chemical was identified as a COC. Additional selection criteria were as follows:

1. The presence of degradation products of COCs.
2. Chemicals significantly elevated in surface water were presumed to be significantly elevated in associated sediment if their fate properties indicated a tendency to adsorb to sediment. This criterion was used, in part, because of the low number of sediment samples and the presence of unusually high CRLs in the background data set.
3. After comparison with ARARs, several essential human nutrients were eliminated as COCs because of their low toxicity at observed concentrations.
4. Documented association of the chemical with RMA activities.

The procedures used contained several conservative elements:

1. A significance level of 0.1 rather than 0.05 was used for the one-tailed test, as indicated in cited guidance; use of a higher significance level compensates, in part, for the lack of power in analyzing small data sets and data sets having a low frequency of detection (less than 10 percent for many contaminants). This conservative decision resulted in the inclusion of four additional groundwater COCs, one surface-water COC, and one soil COC.
2. A modification to the MOP was applied to address small data sets having a detection frequency greater than 10 percent. This conservative procedure resulted in the inclusion of one additional surface-water COC.

Thirty-four COCs were identified for the groundwater medium, including pesticides (aldrin, chlordane, dibromochloropropane, DDE, DDT, dieldrin, endrin, isodrin, and malathion), metals (arsenic and manganese), halogenated aliphatics (carbon tetrachloride, chloroform, 1,2-dichloro-ethane, tetra-chloroethene, and trichloroethene), major anions (chloride, fluoride, and sulfate), substituted benzenes (benzene, chlorobenzene, dichlorobenzene, ethylbenzene, toluene, and xylene), sulfur-containing organics (4-chlorophenylmethyl sulfide [CPMS], 4-chlorophenylmethyl sulfoxide [CPMSO], 4-chlorophenylmethyl sulfone [$CPMSO_2$], dithiane, and oxathiane), atrazine, dicyclopentadiene, hexachlorocylcopentadiene, and DIMP.

Ten COCs were identified for the surface-water medium. Of these, nine are also COCs for groundwater, the source of offpost surface-water contamination. DDT was significantly elevated in surface water and sediment, but not in groundwater. The surface-water COCs include one metal (arsenic), four pesticides (chlordane, DDE, DDT, and dieldrin), three major anions (chloride, fluoride, and sulfate), dicyclopentadiene, and DIMP. None of the volatile chemicals, the halogenated aliphatics, nor the substituted benzenes was significantly elevated in surface water.

COCs in sediments are all pesticides (aldrin, dibromochloropropane, dieldrin, endrin, DDE, and DDT). In addition to being associated with groundwater and/or surface water that interacts with the sediment in First Creek, these chemicals are persistent and have a tendency to adsorb to sediment.

Surface water and sediment COCs were identified by comparing First Creek with background sampling locations. A statistical comparison with groundwater reference concentrations was also performed for the irrigation canals downstream of the mouth of First Creek and for Barr Lake. Only the COCs identified in First Creek were evaluated for the canals because the canals receive First Creek's discharge but are not affected by groundwater discharges. With respect to water samples, only chemicals elevated in the canals were evaluated in Barr Lake because the canals are Barr Lake's water source. The results of these surface-water and sediment comparisons follow:

- The canal waters contained DIMP and fluoride at levels significantly elevated above background concentrations.
- Chemicals significantly elevated in the canals are not significantly elevated in Barr Lake.
- COCs in canal sediments are not significantly elevated above reference levels.
- Barr Lake sediments are not significantly elevated above reference for any sediment COCs.

Six pesticides (aldrin, chlordane, dieldrin, endrin, DDE, and DDT) were identified as COCs in surficial soil. These chemicals have low volatility and are persistent in soil. These properties favor their deposition from the atmosphere and long-term retention in soil.

Rigorous statistical comparisons were not feasible for all species, tissues, and contaminants sampled from offpost biota. In some cases, comparison with background was limited to non-site-specific values reported in the technical literature. These comparisons indicate that dieldrin and arsenic may be elevated in some offpost biota tissues.

1.5 UNCERTAINTIES

Uncertainties potentially affecting the identification of COCs include:

1. Insufficient or potentially inappropriate reference data sets for comparison
2. Lack of appropriate statistical procedures for data sets with low frequency of detection
3. Limited statistical "power" (potential for a false negative conclusion) for data sets with limited number of samples and/or low frequency of detection

These uncertainties may generate conservative or nonconservative errors. Wherever possible, such uncertainties were resolved conservatively, i.e., COCs were added rather then deleted where such uncertainties were apparent.

The reference data sets were generally sufficient for groundwater, surface water, and surface soil. The reference data set for groundwater was taken from the offpost area at locations potentially downgradient of RMA sources. This data set was compared with an alternative upgradient data set, however, and shown to be similar in mean concentrations and frequency of detection to the alternative data set. The reference groundwater data were sparse ($n < 10$) for atrazine, bis(2-ethylhexyl)phthalate, benzothiazole, dichlorobenzenes, cyanide, iron, manganese, vapona, malathion, parathion, and supona. Of these 11 chemicals, four were retained as COCs. The remaining seven had very low frequency of detection in the affected wells with the exception of iron, which was eliminated for other reasons. The reference surface-water data were sparse for atrazine and chlordane. Chlordane was retained and atrazine was deleted based on frequency of detection (chlordane, 40 percent; atrazine, 25 percent), using the modified MOP. The reference data sets for surficial soils were generally sufficient and appropriate, and all organic chemicals with detection frequency greater than 12 percent were retained.

The validity of the modified MOP used for data sets where n_d was less than five and detection frequency greater than 10 percent is questionable. For such small data sets, conservative or nonconservative errors would occur. The modified MOP was used, however, only when MOP would have deleted the chemical, so it was used to include rather than exclude chemicals.

For small comparison data sets, the "power" of the statistical tests to avoid false negative conclusions is low. Power is not readily quantified for either the WRS or MOP tests. This potential problem was addressed, in part, by accepting lower confidence (90 percent rather than 95 percent). Power increases as confidence decreases.

Overall, these estimates are not expected to have a significant effect on cumulative risk estimates. COCs with potential to add significantly to cumulative risk at observed maximum concentrations are all included as COCs.

2.0 EXPOSURE ASSESSMENT

The primary objective of the exposure assessment is the estimation of an RME expected to occur under both current and future land-use conditions. The RME intake is intended to represent the highest exposure that is reasonably expected to occur in the Offpost OU. In this assessment, RME intakes are calculated for each pathway, and then pathways are added for each COC.

This section provides information that is considered pertinent in assessing the potential risk to human health and the environment in the Offpost OU. The information is presented in four parts. First, the COCs that were identified for the offpost area in Section 1.0 are further described, including physical and chemical properties and probable environmental fates. Second, the offpost area is described, including major characteristics and land uses considered pertinent to assessing potential risk. Land uses of the offpost area are discussed, with particular emphasis on the importance of agricultural land use and potentially exposed populations. Rationale is provided for developing a residential scenario and a commercial/industrial scenario for exposure assessment. Third, an evaluation of potential exposure pathways is presented, including associated rationale for inclusion in or exclusion from this EA. Finally, estimates of chemical intakes are presented for both the residential scenario and the commercial/industrial scenario. A limited quantitative uncertainty analysis is also presented.

2.1 PROPERTIES AND PROBABLE ENVIRONMENTAL FATES OF CHEMICALS OF CONCERN

COCs listed in Section 1.0 for the Offpost OU have diverse physical and chemical properties and probable environmental fates. In the offpost area, each COC is significantly elevated in groundwater, but only a few of the COCs are elevated in other media. This section addresses, by medium, the probable environmental fate of the COCs that are elevated.

This section is organized into two subsections. Section 2.1.1 quantifies the equilibrium partitioning properties of each COC. Section 2.1.2 qualitatively reviews general findings from the technical literature regarding the potential fate of the COCs, in particular addressing

transformation processes affecting the chemicals. The discussion is organized by chemical groups having similar fate characteristics to avoid redundancy and to highlight the transformation relationships among some of the COCs.

The equilibrium partition coefficients discussed in Section 2.1.1 are used in Section 2.4.3 to estimate exposure concentrations in media/locations that were not sampled during the RI or where available sampling and analytical data are insufficient to reliably estimate exposure concentrations. For example, indoor air was not sampled, so a model was used to estimate indoor air concentrations resulting from volatilization of contaminants from the water table. The model's input parameters include chemical diffusivities in air and water and the Henry's Law constant, which expresses equilibrium partitioning behavior between air and water. Food crops were not sampled, so concentrations in crops are estimated using a model requiring the chemical octanol/water partition coefficient (K_{ow}) as input. Because limited sampling of beef fat at a hot spot of surficial soil contamination is inadequate for defining meat exposure concentrations throughout the Offpost OU, a bioaccumulation model for cows is used to estimate meat exposure concentrations. The bioaccumulation model requires an equilibrium partitioning coefficient relating concentration in feed to concentration in tissue.

As described in the previous paragraph, the intake estimates to be derived in Section 2.4 are directly related to the equilibrium partition coefficients presented in Section 2.1.1. Conversely, intake estimates derived in this document are calculated on the basis of observed concentrations in environmental media, and the finding that exposure concentrations will either persist or decline slowly during the assessment period under the baseline condition (Section 2.3). Considering this approach, transformation processes are not quantified, but they are reviewed qualitatively to provide additional perspective and as a basis for evaluating the uncertainties inherent in the assessment.

2.1.1 Equilibrium Partitioning Properties of Chemicals of Concern

Physical-chemical properties and equilibrium partitioning model input parameters that are required in this assessment are as follows:

1. Henry's Law constant (H; dimensionless)

2. Molecular diffusivities in air and water, D_a and D_w, respectively, in square meters per day (m^2/day)

3. Equilibrium partition coefficient relating concentration in soil aqueous phase, C_w, to concentration in plant roots and tubers, C_r (fresh weight basis): $K_{wr} = C_r/C_w$ (liters per kilogram (l/kg)

4. Equilibrium partition coefficient relating concentration in soil aqueous phase, C_w to concentration in stems, leaves, or other aboveground plant parts, C_p (fresh weight basis): $K_{wp} = C_p/C_w$ (l/kg)

5. Equilibrium partition coefficients relating concentration in bulk soil, C_s (dry weight basis), to concentration in plant tissues (C_p and C_r, fresh weight basis): $K_{sp} = C_p/C_s$ and $K_{sr} = C_r/C_s$ (dimensionless)

6. Equilibrium partition coefficient relating concentration in cattle feed, C_p (wet weight basis), to concentration in meat, C_m (fresh weight basis): $K_{pm} = C_m/C_p$ (dimensionless)

7. Equilibrium partition coefficient relating concentration in cattle feed to concentration in whole milk, C_d: $K_{pd} = C_d/C_p$

8. Equilibrium partition coefficient relating concentration in soil to concentration in chicken eggs, C_e: $K_{se} = C_e/C_s$ and

9. Equilibrium partition coefficient relating concentration in water to concentration in fish edible tissue, C_f (fresh weight basis): $K_{wf} = C_f/C_w$ (l/kg)

To estimate these model input parameters, it was necessary in some cases to rely on relationships between these parameters and other physical-chemical properties. These supplementary parameters included solubility, S milligrams per liter (mg/l); vapor pressure, V_p (torr); K_{ow} (dimensionless); and adsorption coefficient to soil/sediment expressed either as K_d (ratio of solid phase concentration in milligrams per kilogram (mg/kg) to aqueous phase concentration in mg/l or $K_{oc} = K_d/f_{oc}$, where f_{oc} is the organic carbon content of the soil expressed as a fraction of dry weight.

2.1.1.1 Information Sources

To obtain representative values of the parameters for the classical physical and chemical environmental properties, including H, K_{wf}, S, V_p, K_{ow}, and K_{oc}, a limited number of comprehensive review documents were consulted. In some cases where these sources provided widely divergent estimates for a few primary chemicals (e.g., aldrin, dieldrin, DIMP, chloroform, and

arsenic), primary sources were reviewed to verify the summary documents. Summary or secondary references that were used included Ebasco (1990), Rosenblatt and others (1975), Miller and others (1976b), Verscheuren (1983), Callahan and others (1979), Lyman and others (1982), Davies and Dobbs (1984), Hansch and Leo (1979), Sangster (1989), EPA (1986a), and Kenaga (1980).

The primary method used to estimate plant uptake factors (K_{wp}, K_{wr}, K_{sp}, and K_{sr}) was the semi-empirical regression relationships developed by Briggs and others (1982 and 1983). This method was used for all chemicals except the OCPs, for which sufficient experimental data are available, and the metals, for which the primary reference was Baes and others (1984). Baes and others (1984) provides data on K_{sp} and K_d. It was necessary to assume that $K_{sp} = K_{sr}$ for the metals. Baes and others (1984) also provides a basis for estimating K_d, and K_{wp} was calculated using $K_{wp} = K_{sp}K_d$.

Briggs and others (1982) provides a relationship between K_{wr} and K_{ow}, while Briggs and others (1983) provides an equation for estimating K_{wp} from K_{ow}. Estimates of K_{sp} and K_{sr} were not required parameters for any chemicals except the OCPs (the only COCs in soil), and experimental results from the primary technical literature were used to estimate these parameters.

The primary method used to estimate the cattle bioaccumulation factors, K_{pm} and K_{pd}, was proposed by Kenaga (1980), who provided alternative methods on the basis of either K_{ow} or S. The regression equation based on K_{ow} was preferred based on theoretical considerations, but the regression equation based on S was used if available data on solubility indicated that this property was more reliably defined than K_{ow}, as when experimental values of solubility were available but experimental data were not available for K_{ow}. It was also determined that Kenaga's predictions based on K_{ow} are so strongly correlated with predictions based on S ($r = 0.84$) that there is no benefit (reduction of uncertainty) in averaging alternative estimates based on K_{ow} and S. The solubility regression was used for CPMS, CPMSO, $CPMSO_2$, dibromochloropropane, dicyclopentadiene, dithiane, endrin/isodrin, and oxathiane.

Travis and Arms (1988) was reviewed as a potential alternative to Kenaga (1980) but was determined to yield similar estimates, was not demonstrably better supported than Kenaga (e.g., most of the data used by Travis and Arms are cited to Kenaga), and was found to be structured in a manner that was inconsistent with procedures adopted here.

Baes and others (1984) was used to estimate K_{pm} and K_{pd} for manganese. Primary experimental literature was consulted to estimate these parameters for aldrin/dieldrin, arsenic, chlordane, DDE/DDT, and DIMP, considering the availability of such data and the importance of the associated chemicals and pathways to the overall estimate of risk.

The equilibrium partition coefficient relating soil concentrations to chicken egg concentrations was estimated for aldrin/dieldrin only because dieldrin was the only COC detected above the CRL in an egg sample from the Offpost OU, and no published estimation method could be identified. K_{se} of aldrin/dieldrin was estimated by the formula:

$$K_{se} = f_{ps} K_{pc}$$

where:

f_{ps} = ratio of soil ingestion to feed ingestion by chickens

K_{pc} = equilibrium partition coefficient relating dieldrin concentration in whole eggs to aldrin and dieldrin concentration in feed

Parameter f_{ps} was determined to be 3 percent ± 1 percent by analysis of data reported by Putnam and others (1994). K_{pc} for dieldrin was determined to be 1.6 ± 0.2 based on Cummings and others (1988), Kan and Jonker-den Rooyen (1978), Driver and others (1877), Graves and others (1969), Waldrion and Nabor (1974), Kan and Tuinstra (1976). Thus K_{se} = 0.05 (best estimate), while the upper 90 percent confidence limit used in RME calculations is 0.087. These values were found to be consistent with the limited site-specific data (Section 2.4.2 for further discussion).

2.1.1.2 Data Evaluation

The physical and chemical data and equilibrium partition coefficients presented in this section are generally assumed to be intensive parameters, meaning that they are assumed to have a

single unique value. This value is not known precisely, however, and different sources report different values, reflecting imprecision in the measurement or estimation procedures. The best estimate of this true value is assumed to be represented by the mean, and the uncertainty in that estimate is represented by the standard deviation of the mean, which is frequently referred to as the standard error.

If the reported values fit a normal distribution, the best estimate of the mean is the sample mean or average, while the standard deviation of the mean is the standard deviation of the distribution of reported values divided by the square root of the number of observations (Gilbert, 1987). If, conversely, the reported values fit a lognormal distribution, as is often the case with environmental data, or any data with large variability for a parameter whose value must be greater than zero, the best estimate of the mean may not be the traditional sample mean. Gilbert (1987) recommends alternative formulas for estimating the mean of such data sets.

In this analysis, the normal procedures for estimating the mean and standard error were used when the coefficient of variation (standard deviation divided by the mean) was less than 1.2, as recommended by Gilbert (1987). In that case, the distribution of t was used to estimate confidence limits on the mean. When the coefficient of variation exceeded 1.2, the Shapiro and Wilk W test was used to determine whether the data better fit a normal or lognormal distribution. If the data were lognormal, Gilbert's equations 13.7 through 13.14 appropriate for lognormal distributions were used. Regardless of the procedure used to estimate means and confidence limits, the most likely exposure estimate (MLE) is the mean and the RME is the upper 90th percent confidence limit UL90. Where relevant experimental data exist, the RME is set equal to the maximum experimental value when the UL90 exceeded the maximum experimental value. Any exceptions to these procedures are noted in the tables providing the results. Further discussion of the basis of the RME is in Section 2.4.

Estimates of several equilibrium partition coefficients for many of the chemicals were based in whole or in part on empirical regression equations relating the partition coefficient to another property of the chemical, usually the K_{ow}. For many parameters, five to ten estimated values

were commonly reported in the literature, but only one or two experimental values were found. When experimental data and regression relationships were used, the mean of all estimates based on regression equations was included with the experimental data points as a single additional data point. The objective of this procedure was to weight experimental values more heavily than estimated values. When no experimental data were available for a required input parameter, the method of Campbell (1982), which combines method error and propagated error into an overall error estimate, was used to estimate uncertainty. In such cases, the UL90 was calculated using the cumulative normal distribution, Z.

Several equilibrium partition coefficients were calculated as a product or quotient of two or more estimated terms (e.g., $K_{pm} = K_{pa}f_m$, where K_{pa} is the partition coefficient from feed to adipose tissue and f_m is the fat content of meat expressed as a fraction). The relative uncertainty in the result of such calculations is given by the square root of the sum of squares of the relative uncertainties of the inputs (Barford, 1967).

2.1.1.3 Results

Parameter values, estimated by application of these procedures and using the previously identified references, are presented in Tables 2.1-1 through 2.1-12. Table 2.1-1 presents Henry's Law constants for all organic groundwater COCs. These MLEs are provided for informational purposes to indicate the tendency of these chemicals to volatilize from water. Henry's law constant was only used in a screening-level analysis to demonstrate that volatilization from groundwater is not a significant exposure pathway in the Offpost OU (Section 2.3 and Appendix A). Calculations were performed only for chloroform and dibromochloropropane because these are the chemicals with the greatest risk potential by this pathway, considering their volatility, concentrations in groundwater, and toxicity. Consequently, RME values are presented for these chemicals only. For the same reason, Table 2.1-2 presents estimated molecular diffusivities in air and water for chloroform and dibromochloropropane only.

Table 2.1-3 presents solubility and vapor pressure values for all organic groundwater COCs. These values were used to calculate Henry's Law constants to supplement published values of the

Henry's Law constant. Solubility values were used to estimate K_{pa} values for some chemicals as noted.

Octanol/water partition coefficients (K_{ow}) are presented in Table 2.1-4 for all organic COCs. These values were used to calculate other parameters. Note that the only measured value for aldrin or dieldrin was anomalously low (log K_{ow} = 3.01) in comparison to all published estimates. Consequently, this value was weighted equally to other estimated values, rather than equal to the mean of estimated values.

K_{oc} is summarized in Table 2.1-5 for chemicals identified as significantly elevated in soil or sediment. Soil adsorption coefficients, K_d, are also presented for metallic COCs because these were used to estimate K_{wp} and K_{wr}. Note that the K_d of arsenic was treated as an extensive parameter because of uncertainty regarding the speciation of arsenic in offpost water. An extensive parameter was defined as one that is assumed to vary throughout the Offpost OU (Section 2.4.5). As an extensive parameter, the distribution of reported values was used rather than the mean and uncertainty in the mean. The literature reviewed tends to support the hypothesis that arsenic adsorption best fits a Freundlich isotherm, which indicates a substantial increase in adsorption with decreasing water concentration. Concentrations of arsenic in offpost water are substantially lower than concentrations used in any of the experiments reviewed, so the Freundlich isotherms indicated by those experiments were extrapolated to the lower concentrations observed offpost. The result of this extrapolation is that the estimated adsorption coefficient for this assessment is higher than any reported experimental values.

Plant uptake coefficients based on soil solution concentration, K_{wr} and K_{wp}, are presented in Tables 2.1-6 and 2.1-7 for all COCs. Plant uptake coefficients based on bulk soil concentration, K_{sr} and K_{sp}, are presented in Tables 2.1-8 and 2.1-9 for all COCs in offpost surficial soil. K_{sr} and K_{sp} are treated as extensive parameters because they vary with soil organic carbon content, which varies throughout the Offpost OU. The variability in soil organic carbon content is not large when compared to the uncertainty in K_{wr} and K_{wp}; therefore, this procedure does not substantially increase uncertainty in K_{sr} and K_{sp}.

Equilibrium partition coefficients used to estimate bioaccumulation by cattle from feed are presented in Tables 2.1-10 and 2.1-11 for all COCs. Fish bioaccumulation coefficients, K_{wf}, are presented for informational purposes for surface-water COCs in Table 2.1-12. The equilibrium partition coefficient relating concentration in soil to concentration in chicken eggs for aldrin/dieldrin, K_{se}, is based on Putnam and others (1974). The MLE value is 0.049 and the RME value is 0.087.

2.1.2 Offpost Environmental Fate of Chemicals of Concern

This section describes the potential environmental fate of the COCs for the Offpost OU. Chemicals with similar fate characteristics are grouped as follows for this discussion:

1. OCPs: aldrin/dieldrin, endrin/isodrin, chlordane, and DDT/DDE
2. Benzene compounds: benzene, chlorobenzene, dichlorobenzenes, toluene, xylenes, and ethylbenzene
3. Halogenated aliphatic compounds: carbon tetrachloride; chloroform; tetrachloroethene; trichloroethene; 1,2-dichloroethane; and dibromochloropropane
4. Compounds containing sulfur: CPMS, CPMSO, $CPMSO_2$, oxathiane, and dithiane
5. Compounds containing phosphorus: DIMP and malathion
6. Ionic chemicals: arsenic, manganese, chloride, fluoride, and sulfate
7. Miscellaneous compounds: dicyclopentadiene, atrazine, and hexachlorocyclopentadiene

These classifications are based primarily on chemical structure, but physical and chemical properties and the media of concern were also considered. The following sections provide a detailed description of the environmental fate of each of these groups of COCs, including persistence, volatility, mobility, fate, and bioaccumulation.

2.1.2.1 Organochlorine Pesticides

The compounds in this category are aldrin/dieldrin, endrin/isodrin, chlordane, and DDT/DDE. Aldrin/dieldrin are grouped because (1) aldrin is transformed to dieldrin under diverse environmental conditions, particularly upon uptake by plants and animals; (2) they have similar physical-chemical properties; and (3) they were commonly detected together in the

Offpost OU. Similar relationships exist for endrin/isodrin (endrin is a transformation product of isodrin) and DDT/DDE.

The OCPs are COCs in offpost soil, groundwater, sediment, and surface water. These compounds are usually persistent in the environment. The primary cause for the persistence of these compounds can be inferred from their similar physical-chemical properties: low vapor pressure, low aqueous solubility, and high octanol/water partition coefficients (Tables 2.1-3 and 2.1-4). In addition to these properties, the OCPs are relatively resistant to biotic and abiotic transformation processes and are persistent and immobile in environmental media in comparison with other COCs offpost.

The manufacture and use of these OCPs in the United States has been severely restricted during the past two decades. Chlordane manufacture and commercial use has been banned since 1988 (ATSDR, 1988a). Although DDT is still manufactured, use has been restricted to public health emergencies since 1972 (ATSDR, 1989b). Currently, neither aldrin nor dieldrin are manufactured, and their use is severely restricted (ATSDR, 1987a). The manufacture and use of endrin ceased in 1986 (ATSDR, 1989c). However, because of the persistence of these pesticides, residual amounts are still detected in soil and food from past use.

The terrestrial fate of OCPs is often similar. Volatilization of OCPs from soil has been recognized in some cases to be an important elimination pathway, despite low vapor pressures.

Various studies on volatilization of DDT and isomers have been conducted. Volatilization half-lives reported in the Installation and Restoration Program Toxicity Guide (IRP), 1989 include the following: 432 to 2300 days for DDT applied to soil at depths ranging from 1 to 10 centimeters (the half-life increased with depth); conservative estimates of 4 to 4.7 years for DDT applied to agricultural loam soil with crops; and estimates of 21 to 110 days for tropical soil. DDE volatilization rates from soil are similar to rates for DDT but usually slightly higher (IRP, 1989).

Chlordane has a half-life ranging from 2 to over 8 years in soil (IRP, 1989) and is expected to persist for many years in homes treated for termites (ATSDR, 1988a).

Aldrin is expected to volatilize faster than dieldrin although volatilization from soil is not as extensive as volatilization from water bodies. Higher soil organic carbon content, low temperatures, and pesticide sequestration in aged soil (time passed after application of a chemical) is expected to reduce volatility rates. In general, volatilization from wet soil was found to be faster than volatilization from dry soil. Volatilization also occurs at a faster rate from surface-water bodies than from soil.

Upon release to the atmosphere, the OCPs are dispersed either in the vapor phase or adsorbed to dust particles. The dust particles can be deposited to earth surfaces by both wet and dry processes. The OCPs are susceptible to various atmospheric abiotic transformations, including hydroxylation and photodegradation.

Photo-oxidation and reactions with hydroxyl radicals have been observed with DDT although little is known regarding the rates of these reactions. Laboratory studies indicate that DDT may be rapidly destroyed in the ionosphere (ATSDR, 1989b).

Aldrin photolysis results primarily in dieldrin and to a lesser extent in photoaldrin and photodieldrin. Dieldrin photolysis resulted in photodieldrin (Ebasco, 1990; ESE, 1989a).

Few data are available regarding environmental chlordane photolysis although evidence indicates that photolysis occurs at a relatively rapid rate in the presence of photosensitizers, such as acetone and rotenone (IRP, 1989). Chlordane is expected to exist primarily in the vapor phase and to a minor extent is adsorbed to dust particles. Chlordane undergoes oxidation, photodegradation, and hydroxylation reactions in the atmosphere. Some of these reactions, such as those with atmospheric hydroxyl ions, can be quite rapid, with predicted half-lives of about 1.3 days (ATSDR, 1988a).

Few data are available regarding endrin photodegradation although evidence indicates that ultraviolet light degradation occurs in the atmosphere (ATSDR, 1989c). Reported degradation process end products are delta keto endrin and endrin aldehyde (Ebasco, 1990).

The mobility of these pesticides in the soil is usually minor, and leaching from soil should be minimal due to relatively high K_{oc} values. Chlordane has been found to remain in the top

20 centimeters of most soil, at the same concentration in some instances, for more than 20 years (ATSDR, 1988a). Endrin revealed minor leachability in the laboratory (ATSDR, 1989c). Pesticide removal from soil or sediment by water systems is expected to increase with higher aqueous (dissolved) organic carbon content. In one study, DDT sorption to freshwater sediment was reduced by 75 percent in the presence of 6.95 mg/l of dissolved organic carbon (humic acid) (IRP, 1989). In another experiment, the apparent DDT water solubility was increased two to five times in the presence of 100 mg/l of humic and fulvic acids (IRP, 1989).

Abiotic and biotic transformation of pesticides in soil/water systems occurs in the environment. DDT is known to hydrolyze with half-lives of 81 days to 12 years at pH values of 9 to 5. The hydrolysis rate increases with pH, with the end product being DDE (IRP, 1989). DDE is resistant to hydrolysis, having a half-life of over 120 years at pH 5 (IRP, 1989). DDT is photolyzed to DDE when exposed to sunlight; DDE is also photolyzed. Chlordane is also susceptible to photolysis (IRP, 1989). Although photolysis could be a significant elimination pathway for the pesticides in soil and surface water, photolysis usually does not occur because these compounds are often sequestered by solid particles, such as organic carbon compounds (IRP, 1989).

Biodegradation has been reported to occur for these pesticides although, in general, data are not available about the end products and the factors determining the kinetics of these processes. Limited evidence on the biodegradation of chlordane has been reported in studies revealing that biodegradation seemed to occur more rapidly in the upper soil layers. Degradation half-lives in natural soil are expected to be approximately two to four years (IRP, 1989).

DDT has been reported to degrade with half-lives of 10 to 14 years in aerobic soil as compared to 28 to 33 days in moist anaerobic soil. The end products for the aerobic and anaerobic processes are DDE and dichlorodiphenyldichloroethane (DDD), respectively. The aerobic process is considered to be predominantly abiotic (IRP, 1989). Microbial DDE degradation is expected to be insignificant (IRP, 1989).

Microbial dieldrin degradation is slow with the end products being similar derivatives, such as dihydroxydihydro aldrin. Aldrin biodegradation is faster (approximate half-life of 1 year) with dieldrin as the end product (Ebasco, 1990; Lichtenstein and others, 1970; ATSDR, 1989).

Endrin has been reported to biodegrade in water and soil. Endrin biodegradation seems to be more rapid and is accomplished by a larger soil bacteria spectrum when compared to other persistent pesticides (ATSDR, 1989c).

Based on their octanol/water partition coefficients, these pesticides are expected to be present in Offpost OU plants and animals. DDT and metabolites have accumulated significantly in freshwater and marine plankton, invertebrates, and fish (ATSDR, 1989b). According to surveys of large populations exposed to OCPs, DDT has been detected in dietary animal fat and milk. Dairy products, meat, fish, and poultry were the major DDE sources in the diet (IRP, 1989). Significant bioconcentration and biomagnification is expected at sites contaminated with DDT and DDE (Ebasco, 1990).

Some crops are able to absorb chlordane from soil, and chlordane can concentrate in oils, meat, milk, and eggs (IRP, 1989). Chlordane accumulates in the skin of root vegetables and has a tendency to accumulate at high concentrations in aquatic and terrestrial organisms (Ebasco, 1990).

Endrin has been detected at significant concentrations in a variety of fish throughout the United States and has also been detected in domestic and imported food and feed commodities (ATSDR, 1989c). Endrin uptake by plants seems to vary with species. Root crops (such as potatoes) showed higher soil chemical concentrations, whereas pasture crops had lower concentrations. Endrin and isodrin bioconcentration and biomagnification are expected (Ebasco, 1990). Conflicting results as to isodrin plant uptake from isodrin-treated soil have been reported. In one case, no isodrin residues were detected in soybeans, corn, and oats. In another study, isodrin was detected in carrot leaves, and endrin was detected as a conversion product (residue) (Ebasco, 1990).

Aldrin and dieldrin bioaccumulation and biomagnification are possible. Upon uptake by plants and animals, aldrin converts rapidly to dieldrin. Dieldrin can also be bioaccumulated. Both

aldrin and dieldrin were found in fish and invertebrates exposed to water contaminated with aldrin. Similarly, in a model terrestrial ecosystem, aldrin and dieldrin were detected in corn growing in aldrin-treated soil at concentrations higher than associated soil levels. A vole exposed to this ecosystem exhibited similar results (ATSDR, 1987a). Dieldrin uptake levels from soil by potatoes, beets, and pasture crops have been reported to depend on species (Ebasco, 1990). Appreciable bioconcentration and biomagnification levels in aldrin/dieldrin-contaminated sites are possible (Ebasco, 1990).

The relationship between soil aging and bioavailability for OCPs could be important in risk characterization of the ecological and human populations in the Offpost OU. Not all the contaminant mass in a plant or soil sample is available to a receptor. Recent research on the soil contaminant extractability by conventional chemical analyses indicates that the total pesticide fraction present in soil that is amenable to extraction by standard analytical extraction procedures may decrease with aging (Calderbank, 1989). Processes that may account for this phenomenon are diffusion into the sorbent fraction of the soil (e.g., soil organic carbon) or chemical bond formation. In the diffusion process, it may be assumed that the pesticide is ultimately available under a slow diffusion-limited process. If chemical binding alters the strength of the attraction to the sorbent, the pesticide may not be available under environmental conditions and may be considered irreversibly bound.

Quantification of the effect of aging on organochlorine compound bioavailability from plant or soil matrices would be complex and is not feasible based on available information. Evaluating possible associations between the extraction procedure used to determine soil concentrations and biological absorption processes would be necessary. It must be recognized that the routine extraction procedures used in the RI would not be expected to recover all the aged pesticides from the soil. The official analytical methods used for soil pesticide analyses offpost were 40 to 80 percent efficient in recovering pesticides from freshly spiked soil. If a more rigorous procedure had been used, it might be possible to identify that only a portion of the pesticide

recovered may be bioavailable. Given the less rigorous procedures used, it is not clear that a bioavailability correction is appropriate to estimate bioaccumulation by plants and animals.

In summary, the soil aging effect and bioavailability seem to be reasonable and valid considerations in the development of exposure models used in risk characterization. Currently available information is not sufficient, however, to determine the magnitude of any correction that may be required in the context of the available soil analytical data.

2.1.2.2 Benzene Compounds

The compounds included in this category are benzene, chlorobenzene, dichlorobenzenes, toluene, xylenes, and ethylbenzene. The common benzene ring and the small degree of substitution exhibited by these compounds account for their similar physical-chemical properties. Generally, these compounds have moderate K_{ow}, K_{oc}, aqueous solubilities, and vapor pressures. Benzene shows approximately an order of magnitude higher solubility and vapor pressure and a lower octanol/water partition coefficient and organic soil carbon adsorption coefficient than the other compounds in this category. Some of these compounds are significantly elevated in groundwater offpost and are expected to be mobile in the environment. Pathways of concern are volatilization, adsorption to organic material, biodegradation (aerobic and anaerobic), and abiotic degradative processes (hydrolysis, oxidation, and other chemical reactions).

Benzene is manufactured extensively in the United States at a rate of about 1 to 1.5 billion gallons per year, with the synthetic plastic and rubber manufacturing industry being the major user (ATSDR, 1989d). More than 90 percent of benzene is obtained from petroleum residues. Benzene is used as a solvent and in phenylphenol production, diphenyl oxide, and nitrochlorobenzene (ATSDR, 1989d). Chlorobenzene manufacture is declining due to its replacement in phenol production and the demise of DDT manufacturing activities. Dichlorobenzenes are used for various industrial purposes, primarily as solvents and/or in chemical synthesis in deodorizers and as moth repellents. 1,3-Dichlorobenzene has minimal usage as a pesticide (IRP, 1989). Toluene is usually isolated from petroleum compounds, and its production and use are extensive. The major use of toluene is in the improvement of gasoline octane ratings (ATSDR, 1988b). Xylenes are

typically obtained from petroleum products and are primarily used in chemical synthesis and as solvents (ATSDR, 1989e). Ethylbenzene is usually obtained by alkylating benzene with ethylene and is primarily used in styrene production (ATSDR, 1989a).

The benzene compounds are expected to exhibit a like degree of volatility in the Offpost OU environment. They have dimensionless H values in the 0.1 to 0.3 range at 25°C (Table 2.1-1). An arbitrary order of volatility based exclusively on H values will be (in descending order with the more volatile first) ethylbenzene, toluene, benzene, xylenes, chlorobenzene, and dichlorobenzenes.

Volatilization of these benzene compounds from groundwater through soil is expected to be a minor elimination route. Upon groundwater discharge to surface water, volatilization of these compounds is rapid. Once benzene, xylenes, toluene, and dichlorobenzenes are released into the atmosphere, they are expected to hydroxylate quickly (ATSDR, 1988b; 1989d; 1989e; 1989f). Ethylbenzene is known to undergo extensive reactions in the atmosphere with hydroxide and nitrate radicals and atomic oxygen (ATSDR, 1989a). Dichlorobenzene has the lowest H values (Table 2.1-1), which suggests that the volatilization rates are lowest when compared to the other compounds in this category. Ethylbenzene is at the other extreme and is presumed to be the most volatile.

Adsorption to aquifer sediment, particularly the organic fraction, is also expected to have a minor effect on transport of these contaminants. The K_{oc} values are a good measure of the extent of adsorption to organic soil fractions. The benzene compounds show a K_{oc} range of about 50 to 1700 l/kg (Ebasco, 1990; EPA, 1986a). The order of this range is parallel to the log K_{ow}, another indicator of adsorption to organic soil. Based on these parameters, the order of adsorption to soil (from lowest to highest) appears to be: benzene < toluene < chlorobenzene < xylenes < ethylbenzene < dichlorobenzenes. The K_{ow} and K_{oc} values of these compounds are generally two orders of magnitude smaller than for the OCPs.

Another parameter useful in evaluating the mobility of compounds in the soil/water complex of a groundwater system is aqueous solubility. The solubility of the benzene compounds ranges from about 100 to 1600 mg/l (Table 2.1-3). The order of solubility values parallels the log K_{ow}

and K_{oc} order in reverse. The order from highest to lowest is: benzene > toluene > chlorobenzene > xylenes > ethylbenzene > dichlorobenzenes.

Based on these parameters, at one extreme benzene with the smallest K_{oc} and highest water solubility is expected to be the most mobile in the groundwater system. At the other extreme, dichlorobenzenes are the least mobile. Disregarding adsorption characteristics of these compounds to nonorganic soil particles, the predicted order of mobility from highest to lowest is expected to be benzene > toluene > chlorobenzene > xylenes > ethylbenzene > dichlorobenzenes. To summarize, the benzene compounds are expected to show a moderate degree of mobility in the soil/water groundwater system except in the case of benzene, where a greater mobility level is expected. This mobility will decrease as the soil organic content increases.

Both chemical and biological degradation may affect the persistence of benzene compounds. The chemical processes of interest are hydrolysis and other chemical reactions that can occur in the groundwater system. The biological processes of concern are mediated by the microbial populations (either aerobic or anaerobic) of the groundwater system.

Chemical reactions of benzene compounds, such as hydrolysis and oxidation, have been reported to be insignificant. Available data indicate that chemical degradation of benzene in water is also insignificant (ATSDR, 1989d). Similar results are reported for chlorobenzene, toluene, ethylbenzene, xylenes, and dichlorobenzenes (IRP, 1989; ATSDR, 1988b, 1989a, 1989e, 1989f).

Biodegradation of the benzene compounds is of greater significance in the environment than chemical degradation. The biodegradation rate depends on acclimation of relevant strains of microbial populations under the proper environment (temperature, nutrient level, etc.). In general, it has been found that benzene compounds are biodegraded in laboratory experiments with isolated strains of microbes. The extrapolation of laboratory results to real field conditions is rarely straightforward. For the soil/water media of the offpost aquifers, important considerations include the levels of relevant degrading microbial strains that have adapted to the media and the amount of oxygen available. Although dissolved oxygen content of offpost groundwater was not

measured during the RI, the alluvial system offpost is expected to be aerobic. The presence of contaminants that undergo oxygen-demanding biodegradation processes would reduce the oxygen content. Oxygen levels may be lower in the Denver Formation.

Aerobic and anaerobic benzene biodegradation has been documented both in laboratory and in-situ conditions. Aerobic biodegradation seems to occur more rapidly than anaerobic biodegradation. Reported anaerobic transformation end products are catechols that can undergo ring fission (ATSDR, 1989d). There are many reported results for benzene. Two relevant examples are (1) one set of laboratory results found 99 percent anaerobic degradation in 120 weeks, and (2) an in-situ anoxic biological study reported complete benzene removal from a hydrocarbon-contaminated aquifer in 6 months (ATSDR, 1989d).

Toluene has been reported to undergo aerobic degradation by many species of microorganisms. In one study, rapid toluene biodegradation (90 percent lost in seven days) was reported in a shallow aquifer (ATSDR, 1988b). No data on anaerobic degradation have been reported.

Chlorobenzene is known to undergo biodegradation (ATSDR, 1989g; IRP, 1989). Biodegradation has been observed in acclimated cultures and in natural environments. Reportedly, in most cases of chlorobenzene biodegradation, the degrading organisms are expected to be detected at low levels and decrease with depth from the surface (IRP, 1989).

Xylenes are known to biodegrade in laboratory and field conditions; however, quantitative data are limited, especially in groundwater systems. Based on the structural similarity of xylenes to toluene and ethylbenzene, inferences can be made as to their biodegradability (IRP, 1989). Some reports indicate that, in general, biodegradation of xylenes in most aquatic systems will be poor to moderate (ATSDR, 1989e).

Ethylbenzene is known to biodegrade both aerobically and anaerobically (ATSDR, 1989a; IRP, 1989). The aerobic degradation rate is more rapid than anoxic degradation based on various field and laboratory observations (ATSDR, 1989a). It is expected that at greater depths from the surface, the decreasing levels of degrading microbial colonies and increased anoxic conditions will retard biodegradation (ATSDR, 1989a).

Although dichlorobenzenes have been observed to biodegrade in various cases, the consensus indicates that, in general, biodegradation is not expected to be a significant elimination pathway from the groundwater system (ATSDR, 1989f; IRP, 1989). Aerobic biodegradation was observed to be faster than anaerobic in some studies. Certain studies on biodegradation rates of chlorinated compounds indicate that the presence of chlorine on a benzene ring retards microbial action. In addition, the more halogenated the compound, the more resistant to microbial activity (ATSDR, 1989f; IRP, 1989). Therefore, dichlorobenzene biodegradation is always expected to be slower than chlorobenzene degradation.

2.1.2.3 Halogenated Aliphatic Compounds

The compounds included in this category are carbon tetrachloride, chloroform, tetrachloroethene, trichloroethene, 1,2-dichloroethane, and dibromochloropropane. These compounds are small open-chain (one to three carbon atoms) halogenated aliphatics exhibiting similar physical-chemical properties. In general, they have moderate to low K_{ow} and K_{oc} values, moderate to high aqueous solubilities, and high H values and vapor pressures. Dibromochloropropane displays approximately one order of magnitude lower H and vapor pressure than the remaining compounds in this category. Halogenated aliphatics are significantly elevated in groundwater offpost. Dibromochloropropane has also been found to be elevated in sediment. Halogenated aliphatics are expected to be mobile in the environment. Pathways of concern are volatilization, adsorption to organic material, biodegradation (aerobic and anaerobic), and abiotic degradative processes (hydrolysis, oxidation, and other chemical reactions). For the particular case of dibromochloropropane in sediment, further pathways of concern are adsorption to sediment, volatilization from surface water, and bioconcentration/biomagnification in freshwater organisms.

These halogenated aliphatic compounds, with the exception of dibromochloropropane, are currently in extensive use. Carbon tetrachloride is currently produced by chlorinating low molecular weight hydrocarbons and is used primarily in the production of chlorofluorocarbons F-11 and F-12 (ATSDR, 1988c). Chloroform is produced ordinarily by chlorinating methyl

chloride and is primarily used in the production of fluorocarbon-22 (ATSDR, 1989h). Tetrachloroethene is currently manufactured in the United States, although domestic production is predicted to decline in the future. Tetrachloroethene is used extensively as a solvent in dry cleaning and textile industries as well as in metal cleaning (ATSDR, 1987b). Trichloroethene is also manufactured in the United States although use appears to be declining. Trichloroethene is used primarily for vapor degreasing of fabricated metal parts in the automotive and metal industries (ATSDR, 1988d). 1,2-dichloroethane is typically synthesized by chlorinating ethylene and is used primarily as a synthetic agent in vinyl chloride production (ATSDR, 1988e). Dibromochloropropane was used primarily as a nematocidal fumigant, but production and use have declined. EPA has banned the use of dibromochloropropane with a few minor exceptions (EPA, 1987a).

Volatilization is expected to be an important elimination route for all of these compounds with the exception of dibromochloropropane. Table 2.1-1 shows the H values for these compounds, ranging from approximately 0.2 to 1.0, with the high H values indicating the expected higher degree of volatility of these compounds, especially carbon tetrachloride and tetrachloroethene. The exception is dibromochloropropane, which is approximately one order of magnitude smaller than other chemicals in this category. Based on H values, the predicted order of volatility (from highest to lowest) is carbon tetrachloride > tetrachloroethene > trichloroethene > 1,2-dichloroethane > chloroform > dibromochloropropane.

Carbon tetrachloride is most prevalent in the atmosphere, where it resides for long periods. It does not degrade in the troposphere, and it forms chlorine radicals in the stratosphere. Carbon tetrachloride volatilization from groundwater through unsaturated soil is expected to be important (ATSDR, 1988c). Carbon tetrachloride has the highest H value of all the COCs at the offpost area.

Chloroform volatilization from groundwater is expected to be a minor elimination route. When in the atmosphere, it undergoes slow degradation by hydroxyl radicals (ATSDR, 1989h).

Tetrachloroethene is known to volatilize from surface water and soil, and it reacts slowly with hydroxyl radicals in the troposphere (ATSDR, 1987b). The volatilization from groundwater is predicted to be an important process, similar to carbon tetrachloride, based on the high H value.

Trichloroethene and 1,2-dichloroethane are expected to volatilize to a small extent from groundwater. When in the atmosphere, they undergo moderate to slow reactions with hydroxyl radicals (ATSDR, 1988d;). Dibromochloropropane is a heavy compound that is not expected to volatilize (Callahan and others, 1979); therefore, evaporation from groundwater is not expected to be significant at RMA.

The mobility of the halogenated aliphatics in the soil/water complex of the offpost aquifers is expected to be moderate to rapid. The compounds show moderate to high solubilities and moderate to minimal K_{oc} values. These physical-chemical properties are useful predictors of the mobility of the halogenated compounds. Based on these values (Table 2.1-3) (Ebasco, 1990; EPA, 1986a), the following order of environmental mobility (from most to least mobile) can be predicted for the halogenated aliphatics: 1,2-dichloroethane > chloroform > dibromochloropropane > tetrachloroethene> trichloroethene> carbon tetrachloride. For instance, 1,2-dichloroethane, with the highest aqueous solubility and smallest K_{ow} and K_{oc} values, is expected to be the most mobile in the offpost aquifers. In general, the mobility of these compounds decreases with increasing soil organic matter content, decreasing temperature, and increasing water hardness and decreases with increasing amount of dissolved organic matter content of the soil water (IRP, 1989).

Halogenated aliphatics degradation is typically abiotic or biotic. Abiotic degradation of these compounds is slow or insignificant. Carbon tetrachloride is calculated to have an extremely long abiotic hydrolysis half-life of approximately 7000 years at a 1 ppm concentration (ATSDR, 1988c). Chloroform showed a half-life of more than 3000 years in water at pH 7 and 25°C (ATSDR, 1989h). Tetrachloroethene hydrolyzes very slowly. At elevated temperatures (150°C), trichloroacetic acid and hydrochloric acid have been identified as end products. Laboratory tests indicate abiotic hydrolysis half-lives on the order of months to years (IRP, 1989). Similarly, the

abiotic hydrolysis for trichloroethene and 1,2-dichloroethane is not expected to be significant (ATSDR, 1988d; 1988e), and the abiotic dibromochloropropane hydrolysis is expected to be slow (EPA, 1987a). The following half-lives (in years) have been reported for abiotic hydrolysis or dehydrohalogenation at 20°C: chloroform (1.5, 704), carbon tetrachloride (7000), 1,2-dichloroethane (50), tetrachloroethene (0.7, 6), trichloroethene (0.9, 2.5), dibromochloropropane (35) (Vogel and others, 1987).

Biotic halogenated aliphatic transformations are more rapid than abiotic transformations. Generally, in microbial transformations, the more halogenated compounds undergo more rapid reduction and slower oxidation processes (Vogel and others, 1987). End products of reduction processes usually have a lower degree of halogenation than parent compounds. End products of oxidation are usually alcohols or epoxides (Vogel and others, 1987). In general, conflicting reports exist in the literature regarding the occurrence and extent of microbial degradation of halogenated aliphatics (IRP, 1989).

Not much is known about carbon tetrachloride biodegradation. One report indicates that based on availability of natural bacteria that degrade carbon tetrachloride in the environment, biodegradation of carbon tetrachloride is not significant (IRP, 1989). Chloroform has been observed to biodegrade both aerobically and anaerobically (ATSDR, 1989h). It is reported that carbon tetrachloride has a shorter anaerobic biodegradation half-life than chloroform. Tetrachloroethene and trichloroethene have been observed to biodegrade at a slow rate (Wood and others, 1985). Under normal environmental conditions, biodegradation of these compounds is regarded as the main transformation process, especially for trichloroethene. Trichloroethene end products have been identified as vinyl chloride and dichloroethylene (ATSDR, 1988d); however, vinyl chloride has not been detected in the Offpost OU. Slow to moderate aerobic biodegradation of 1,2-dichloroethane has been reported (IRP, 1989; ATSDR, 1988). Dibromochloropropane undergoes slow biodegradation in soil (Ebasco, 1990).

Dibromochloropropane is the only halogenated aliphatic that is also found in sediment in the offpost area. Volatilization from surface water is expected to be a major elimination route. Based

on the low K_{oc} value of dibromochloropropane, the adsorption to sediment is not expected to be extensive. Because of its low K_{oc} value, it is expected to bioaccumulate or biomagnify significantly (Ebasco, 1990).

2.1.2.4 Compounds Containing Sulfur

Compounds containing sulfur included in this category are CPMS, CPMSO, $CPMSO_2$, 1,4-dithiane (dithiane), and 1,4-oxathiane (oxathiane). These five compounds are monocyclic: the first three contain benzene rings, the remaining two contain alkyl rings with heteroatoms (sulfur, oxygen). These compounds are significantly elevated in groundwater offpost. Pathways of concern are volatilization, adsorption to organic material, biodegradation (aerobic and anaerobic), and abiotic degradative processes (hydrolysis, oxidation, and other chemical reactions).

CPMS, CPMSO, and $CPMSO_2$ have been used as intermediates in the production of the herbicide Planavin (Ebasco, 1990). Planavin is no longer produced in the United States (Hazardous Substances DataBank [HSDB], 1991). Oxathiane is a volatile and water-soluble heterocyclic compound (Ebasco, 1990). Dithiane is a decomposition product of mustard gas (Ebasco, 1990).

The physical-chemical properties of the chemicals in this category span a broad range. Based on the K_{ow}, they can be grouped (from highest to lowest) as: CPMS > CPMSO, $CPMSO_2$ > dithiane > oxathiane. CPMS has a log K_{ow} of 3.2; CPMSO, $CPMSO_2$, and dithiane are on the order of 1; and oxathiane has a log K_{ow} of -0.2. The K_{oc} of CPMS is one order of magnitude higher than CPMSO and $CPMSO_2$. The grouping of the compounds based on solubility values is the same as for K_{ow} (from lowest to highest): CPMS > CPMSO, $CPMSO_2$ > dithiane > oxathiane. CPMS has a solubility value two orders of magnitude lower than CPMSO, $CPMSO_2$, and dithiane; the latter three have a value one order of magnitude lower than oxathiane. The solubility values range from 12 mg/l (CPMS) to 20 grams per liter (g/l) (oxathiane). The H values follow a similar pattern. The order of values (from highest to lowest) is: CPMS > $CPMSO_2$, dithiane > CPMSO > oxathiane. The range of values is not as large as those observed previously. The values are generally small, ranging from 0.045 (CPMS) to 0.0001 (oxathiane). From this information the compounds could be divided into three subgroups: (1) CPMS; (2) CPMSO, $CPMSO_2$, dithiane; and

(3) oxathiane. CPMS is the most nonpolar and most volatile, and oxathiane is the most polar and least volatile.

Experiments on the environmental volatilization of sulfur compounds have not been found in the available literature; therefore, only inferences can be made regarding volatility rates from groundwater based on the physical-chemical properties of these compounds. This pathway is not expected to be significant (Ebasco, 1990).

The mobility of sulfur compounds in the groundwater system is expected to be a major pathway for the majority of these chemicals. All the sulfur compounds, with the exception of CPMS, have low K_{ow} values and high water solubilities, which causes rapid mobility in the water system with a small degree of adsorption to soil. Similar expectations have been expressed regarding this pathway although no experimental verifications have been made (Ebasco, 1990).

Few data are available about the stability of sulfur compounds in aqueous systems. Based on the presence of electron-rich moieties in these compounds, some degree of hydrolysis may be expected although the rate of such reactions and end products is unknown. CPMS is reported to undergo oxidation, and dithiane is reported to oxidize to form sulfoxides and sulfones (Ebasco, 1990). Microbial degradation of CPMS, CPMSO, and $CPMSO_2$ have been reported to occur, but the extent of the reactions and the nature of the degradation products is unknown (Ebasco, 1990). No direct evidence of biotic degradation is provided for dithiane and oxathiane (Ebasco, 1990).

2.1.2.5 Compounds Containing Phosphorus

The compounds containing phosphorus included in this category are DIMP and malathion. Both are long-branched chains containing oxygen and phosphorus atoms. Malathion also contains sulfur atoms. Malathion and DIMP have been detected at significant levels in offpost groundwater; DIMP has also been detected at significant concentrations in offpost surface water. Pathways of concern are volatilization, adsorption to organic material, biodegradation (aerobic and anaerobic), and abiotic degradative processes (hydrolysis, oxidation, and other chemical reactions). Additional pathways of concern for DIMP, which is also detected in surface water, are adsorption to sediment.

Malathion is used primarily as an acaricide and insecticide on fruits, vegetables, and ornamental plants. Formulations are made with malathion alone or in combination with other insecticides and fungicides (IRP, 1989). Spanggord and others (1979) report that DIMP produces nerve gas as a byproduct.

These compounds have moderate to low K_{ow} and K_{oc} values, and low H values. The aqueous solubilities vary significantly; DIMP shows a high aqueous solubility and malathion a moderate solubility. Based on these physical-chemical properties, volatilization is not expected to be a major pathway. Based on K_{oc} values, DIMP is expected to be fairly mobile in the groundwater system.

Malathion volatilization from the groundwater system is expected to be insignificant. Various laboratory or field tests and modeling have shown that losses due to volatilization were negligible (IRP, 1989). Similarly, DIMP volatilization is not considered an important elimination route (Ebasco, 1990). A low H value and very high aqueous solubility may account for its significant presence in offpost surface water.

Because malathion has a moderate solubility and K_{oc} value, it is expected to be moderately mobile in the groundwater system. There are few studies on the soil sorption of malathion, probably due to its instability in water media (IRP, 1989). For low organic carbon soil, such as clay, the extent of sorption may depend on soil surface area, cation exchange capacity, and degree of hydration (IRP, 1989). DIMP is expected to be highly mobile in the environment (Ebasco, 1990) because of the low K_{oc} value and very high aqueous solubility. Based on these physical-chemical properties, DIMP adsorption by sediment in contact with surface water is not expected to be significant. These expectations coincide with the fact that DIMP was detected in significant amounts in offpost surface water but not in offpost sediment.

Malathion and DIMP have different abiotic and biotic degradation patterns. Malathion is degraded significantly by hydrolysis. The hydrolysis rate depends significantly on pH and temperature. For pH range, 6 to 8 half-lives on the order of 10 to 1000 hours have been reported at 20°C. Hydrolysis products are 0,0-diethylphosphorodithioic acid and fumaric acid and its ethyl

esters (IRP, 1989). Hydrolysis half-lives have been reported to range from 0.5 to 21 weeks at 20°C for the 6 to 8 pH range for heterogeneous systems (mostly solid with significant moisture). The hydrolysis rate increases with pH for this range (IRP, 1989). Malathion has been observed to be significantly biodegraded. In many instances, it is expected that biodegradation will compete with hydrolysis as the major elimination pathway. Aerobic degradation, fungal biodegradation, and natural surface-water biodegradation have been observed to occur (IRP, 1989).

Conversely, DIMP appears quite stable in aqueous systems. Significant hydrolysis or photolysis reactions are not expected to occur. Studies were conducted in hot aqueous solutions to assess the DIMP hydrolysis patterns. The degradation process was slow at temperatures as high as 80°C. Based on these studies, a half-life of approximately 530 years was estimated for DIMP at 10°C (Ebasco, 1990). No photolysis was observed for DIMP in aqueous solutions exposed up to 232 hours to light with wavelengths greater than 290 nanometers (nm) (Ebasco, 1990). Aquatic biodegradation was not observed for DIMP in acclimated cultures from RMA (Ebasco, 1990). Microbial degradation in the groundwater and surface water is expected to be a nonexistent or insignificant elimination pathway. Although DIMP uptake has been observed in experiments in plants such as radishes grown in hydroponic solutions, it is expected that, in general, appreciable DIMP bioconcentration and biomagnification will not take place in offpost surface water (Ebasco, 1990).

2.1.2.6 Ionic Chemicals

Ionic chemicals include arsenic, manganese, fluoride, chloride, and sulfate. The compounds are detected at significant concentrations in offpost groundwater and surface water, with the exception of manganese, which has been detected in offpost groundwater only.

Arsenic is detected in various oxidation states. The -3 oxidation state is rare and occurs under very reducing conditions as arsine gas. The 0 oxidation state is also rare and is found in certain mineral deposits. The +3 and +5 oxidation states are the most common, forming complex minerals or dissolved as salts in water (EPA, 1979a). Arsenic, as total arsenic, has been detected in offpost groundwater and surface water.

Arsenic occurs in the environment as a result of natural forces and human activities. These natural forces include volcanoes and the weathering of rocks containing arsenic. Human arsenic-producing activities include metal smelting, glass manufacture, pesticide production, and fossil fuel burning (ATSDR, 1989i).

Volatilization is not expected to be a major elimination route. Arsine, the inorganic form, could undergo volatilization and is only found in extremely reducing areas. Methylated forms of arsenic, such as trimethylarsine, may undergo volatilization (ATSDR, 1989i).

Sorption of arsenic to soil and sediment is a complicated process making the fate of arsenic in offpost areas difficult to predict. Based on chemical analysis, the geochemical conditions at the site may inhibit arsenic because arsenic was not detected at significant concentrations in sediment. Arsenic sorbs to clays, aluminum hydroxide, iron oxides, and organic material. Some general conclusions indicate that sorption is more prevalent in aerobic, acidic, fresh water (EPA, 1979a).

The chemistry of arsenic in aquatic systems is usually complex: oxidation-reduction, ligand exchange, precipitation, and adsorption occur simultaneously. Typical forms of arsenic present in water are arsenite, arsenate, methylarsonic acid, and dimethyl arsenic acid. Arsenious acid and arsenic acid are the prevalent forms in aerobic water. In natural water, it has been observed that speciation of arsenic is associated with the resident biota. No evidence has been found that photolysis plays a significant role in the chemistry of arsenic (Callahan and others, 1979).

Microbial mediated methylation of arsenic compounds occurs in both aerobic and anaerobic media (Callahan and others, 1979). Reduction is also possible by fungi, yeasts, bacteria, and algae (ATSDR, 1989i). Arsenic compounds are accumulated by biota to a small extent, and in general, biomagnification and bioaccumuluation are not expected to be significant (Callahan and others, 1979).

Manganese has been detected in offpost groundwater. The main use of manganese is in the metallurgical industry, particularly steel production (EPA, 1984a).

The aqueous chemistry of manganese is quite complex. Manganese occurs at various oxidation states: +2, +3, +4, +5, +6, and +7. The most common states are +2 and +4 (EPA, 1984a).

The +2 (Mn^{+2} species) and +4 (MnO_2) forms are more stable in reducing and oxidizing media respectively (Adriano, 1986). Due to lower oxygen content, groundwater has different chemical equilibration among manganese compounds than surface water. Some studies have concluded that the free manganese ion is usually predominant even if complexes with organic matter are occurring (EPA, 1984a).

Volatilization of manganese compounds is not expected to be a significant elimination route. Sorption to soil is difficult to predict due to the complex chemistry of the compound. Microbial mediated oxidation and reduction have been observed (EPA, 1984a).

Fluoride has been detected in significant amounts in offpost groundwater and surface water. Sources of fluoride are both anthropogenic and natural and include volcanic, wind transfer, agricultural, and industrial sources (Ebasco, 1990; Bodek and others, 1988).

Volatilization from groundwater is not expected to be a major elimination pathway, but volatilization from surface water may be significant. Fluoride entrapment in windblown dust is a source of fluoride atmospheric content (Bodek and others, 1988). Fluoride volatilized in aerosols (e.g., hydrofluoric acid) may enter the atmosphere. Volatile fluorine compounds in the atmosphere may be hydrolyzed to form acids, possibly reentering surface water by deposition (Bodek and others, 1988).

In natural water, fluoride is expected to be in the F^- form because of its high electronegativity. F^- is the only oxidation state of fluoride found in natural aqueous systems. In natural water, fluoride is expected to exist as the uncomplexed, free ion, although it is known to complex with aluminum, beryllium, and iron ions (Bodek and others, 1988). The most common fluoride salts (e.g., calcium fluoride) have low solubilities and the sorption to soil is difficult to predict. Sorption appears to depend on pH and soil characteristics (Bodek and others, 1988).

In the literature reviewed, no information was found on microbial activities related to fluoride. Fluorides are easily transferred through most food chains, but knowledge on biomagnification is lacking (Ebasco, 1990).

Chloride has been detected at significant concentrations in the offpost groundwater and surface water and is a very common ion in the environment. The source of chloride can be natural or related to industry. Volatilization of chloride salts is not expected to be a major elimination route.

In natural water, the chloride ion does not undergo redox reactions. The chemistry of the ion is mostly dissolution, precipitation, and complexation. Chlorine (Cl_2) is found only at low pHs. Cl_2, OCL^-, and HOCL are unstable or metastable in natural aqueous systems. Chloride complexes with various heavy metals (cadmium, lead, and mercury), increasing the speciation, mobility, and apparent solubility of these metals. Chloride should be highly mobile in the groundwater system because sorption to soil is minimal (Bodek and others, 1988).

Sulfate has been found in significant amounts in offpost groundwater and surface water. Sources of sulfate are natural and industrial. Volatilization of sulfate is not expected to be a significant elimination pathway.

Although the redox reactions of sulfate are numerous, with sulfur oxidation states ranging from -2 to +6, it is expected that in natural water, sulfate will be the predominant form. Sulfate forms ion pairs with various cations, although in freshwater systems, most sulfate is expected to be detected as the free ion.

Microorganisms play an important role in mediating sulfate redox reactions. Sulfate reduction is expected to occur in anaerobic media, leading to the formation of hydrogen sulfide. In aerobic media, oxidation of sulfur compounds to sulfate is known to occur (Bodek and others, 1988).

The mobility of sulfate in the groundwater system is expected to be significant although predicting the extent is difficult. Sulfate can be adsorbed to soil, dissolved, or precipitated. The nature of the soil and pH are important factors. In general, soil retention of sulfate is unstable. It is less mobile than chloride, but more mobile than strongly retained anions, such as phosphate (Bodek and others, 1988).

2.1.2.7 Miscellaneous Compounds

This category contains chemicals difficult to classify in any of the previous groups. Dicyclopentadiene possesses the basic carbon skeleton of some chlorinated aliphatics but is not chlorinated. Hexachlorocyclopentadiene is a cyclical halogenated aliphatic. Atrazine is a heteroaromatic (nitrogen as a heteroatom) with amine groups.

Dicyclopentadiene (used as a common precursor during pesticide manufacturing processes) has been detected in offpost groundwater and surface water. Dicyclopentadiene has a high H value in contrast to chlorinated pesticides, a moderate to minimal K_{oc}, and minimal aqueous solubility. Based on physical-chemical properties, dicyclopentadiene is expected to exhibit minimal environmental mobility in the groundwater system and significant volatilization from water. Significant photodegradation is expected to occur in the atmosphere (Ebasco, 1990).

Experimental evidence shows that microbial degradation, hydrolysis, and direct photolysis of dicyclopentadiene are minimal. Spanggord and others (1979) observed this compound to be significantly volatile and to undergo a small degree of indirect photolysis and oxidation. Based on physical-chemical properties, dicyclopentadiene is not expected to significantly bioconcentrate or biomagnify (Ebasco, 1990).

Atrazine (used as a selective herbicide [Merck, 1976]) has been found in the offpost groundwater. Atrazine has an extremely small H value and a minimal solubility and K_{oc} value. Based on physical properties, atrazine is not expected to volatilize, adsorb to organic soil, or dissolve in water at any significant rate. Perhaps this is indicative of a tendency to leach easily through soil or accumulate as free-phase without extensive environmental mobility. Hydrolysis has been reported as a possible elimination pathway and could be significant. Increasing acidity or alkalinity appears to enhance hydrolysis of this compound (Ebasco, 1990). Information was unavailable regarding the atrazine biodegradation in the environment.

Hexachlorocyclopentadiene has been found in the offpost groundwater. Hexachlorocyclopentadiene is used in chlorinated pesticides manufacturing and in flame retardants (EPA, 1984d). Hexachlorocyclopentadiene has a high H value, large K_{oc}, and minimal aqueous solubility and is

expected to volatilize to some extent from groundwater and to have minimal environmental mobility. Hydrolysis is reported as a significant elimination pathway. Hydrolysis half-lives in the range of 3 to 11 days, at pHs of 5 to 9, and temperatures ranging from 25 to 30°C have been reported (Ebasco, 1990). A variety of soil microorganisms are known to metabolize hexachlorocyclopentadiene (Ebasco, 1990).

2.1.3 Uncertainties

Uncertainties associated with understanding of the environmental fate of COCs include:

1. Quantification of equilibrium partition coefficients used to estimate intakes.
2. Potential for COC concentrations to decline over a chronic exposure duration as a result of degradation processes. These processes were not quantified in this assessment.

Equilibrium partition coefficients have been defined with greater precision for those chemicals/coefficients with potential to affect the final risk estimate. The most uncertain parameters include plant and animal uptake of volatile chemicals, but even the conservative estimates of those parameters provided in this section, incorporating approximately order-of-magnitude uncertainty factors, do not result in significant contributions to total cumulative risk (see Section 4). The most substantial uncertainty associated with bioaccumulation factors for the OCPs (which do affect the total risk estimate) relates to the fact that most experimental studies used to define these parameters were conducted after fresh application of the pesticide. There is limiting evidence suggesting that soil-bound pesticides become less bioavailable with age in the soil although virtually all of that evidence applies to pesticides that are not similar to the chlorinated insecticides contributing to risk in the Offpost OU.

It is likely that OCPs in soil and volatile chemicals in groundwater biodegrade over periods of years or decades. Generic data on the rates of these processes is not sufficient, however, to estimate degradation rates at this site. As a result, this process has not been quantified in this assessment with the consequent potential to overestimate exposure and risk.

2.2 CHARACTERIZATION OF EXPOSURE SETTING

This section presents a summary of the site conditions and characteristics, including a description of contamination in the Offpost OU and the nature of the land uses Offpost that could affect populations potentially exposed to chemicals originating from RMA. The purpose of this section is to discuss the major characteristics of the Offpost area that are considered pertinent to assessing the potential risk to human health and the environment in the Offpost area.

Section 2.2.1 summarizes the major site characteristics that affect contaminant migration, including the site setting and historical land use, environmental setting. Sampling and analytical results and conclusions from the RI are also summarized. Section 2.2.2 characterizes the potentially exposed populations at the Offpost OU.

2.2.1 Site Characteristics Affecting Contaminant Migration

The following subsections briefly discuss site conditions pertinent to understanding the assessment of potential risk to human health and the environment. The discussion of site characteristics summarizes the general characteristics of the Offpost OU, including geographic setting, site boundaries, current and historical land uses, and the operational status of IRAs affecting the Offpost OU. The discussion of environmental setting presents a general overview of the natural site characteristics and habitats, local climate, and surface-water hydrology. The remaining sections present an overview of the media sampled and their locations and a summary of the conclusions from the RMA Offpost OU RI program regarding contaminant distribution and migration in the Offpost area.

2.2.1.1 Site Description and History

This section briefly describes the physical characteristics and site history of the Offpost OU. The Offpost area is defined as the area southeast of the South Platte River, north of 80th Avenue, southwest of Second Creek, and north of the north and northwest boundaries of RMA. Additionally, the Offpost area includes the surface water of O'Brian Canal and Burlington Ditch, as they extend northeast of Second Creek, and the surface water of Barr Lake. The Offpost OU is

defined as that portion of the Offpost area where hazardous substances, pollutants, and contaminants from RMA are found (EPA, 1989b). The Offpost OU encompasses rural residential and industrial areas located north and northwest of RMA. The current land use is predominantly characterized as rural residential/agricultural. Areas within the Offpost OU are largely used for dryland farming, with some rural residential areas and scattered areas of intensive agricultural use.

Farming in the Offpost area ranges from large grain operations covering square miles to small subsistence farms to vegetable gardens. A number of these farms also maintain livestock. Subsistence and hobby farmers may consume a significant fraction of their diet from locally produced vegetables and livestock.

To address the groundwater contamination, the U.S. Department of the Army (Army) constructed and is continuing to operate groundwater remediation system IRAs for remediation of contamination at the RMA boundaries. Two of these IRAs, the NBCS and the Northwest Boundary Containment System (NWBCS), are being operated to mitigate migration of groundwater contaminants across the north and northwest RMA boundaries into the Offpost OU. The performance of these IRAs over the past several years has been assessed under various onpost programs and under the Offpost RI program. Recent upgrades to the NBCS and NWBCS have recently been completed and have enhanced the performance of the IRAs. Operation and monitoring of these systems over the past several years shows that they are having a beneficial impact on groundwater quality Offpost. An additional interim response action (IRA A) is under construction by the Army north of RMA immediately southeast of O'Brian Canal. Operation of this system will have a beneficial impact on groundwater quality offpost and will continue to mitigate migration of groundwater contamination to downgradient areas offpost.

2.2.1.2 Environmental Setting

The South Platte River forms the northwest boundary of the Offpost OU. The area within the Offpost OU is largely rangeland and dryland agriculture. Rural residential developments are scattered throughout the Offpost area. Commerce City, which is located west of RMA, is the only major urban area in the immediate vicinity of RMA. Commerce City has recently annexed land

within the Offpost OU. Cropland and rangeland provide habitat for numerous animal species, including such game species as cottontails, ring-necked pheasants, and mourning dove. Lake and wetland areas at Barr Lake provide feeding, breeding, and roosting areas for waterfowl and endangered species, including the bald eagle.

The climate of the offpost area is characterized by sunny, semiarid conditions. Approximately 37 percent of the total annual precipitation (16 inches) occurs in the spring, with much of this moisture falling as snow in the early spring. Summer is the hottest season and is characterized by scattered local thunderstorms during afternoons and evenings. Approximately 31 percent of the total annual precipitation occurs during the summer season. Winter is the coldest season, during which time, approximately 13 percent of the total annual precipitation occurs.

As described in the RI, the regional surface drainage is to the northeast toward the South Platte River (ESE, 1988a). Surface water originating on RMA or in the Offpost OU flows toward the South Platte River (Figure 1.2-1). Two major irrigation canals, O'Brian Canal and Burlington Ditch, and several smaller ditches flow from southwest to northeast between RMA and the South Platte River. O'Brian Canal receives some drainage from the Offpost OU and RMA where it intercepts First Creek. Burlington Ditch may receive surface water infrequently from First Creek.

2.2.1.3 Sampling Locations and Media

The following section provides an overview of the results of the remedial investigations. The RI for the Offpost OU consisted of two principal phases of work. The first phase focused on contamination in groundwater, surface water, and sediment offpost. The results from those activities were reported in the Final RI for the Offpost OU (ESE, 1988a). As described in Section 1.1.2, further investigations were subsequently undertaken to provide additional data for groundwater, surface water, and sediment, and data for additional media, including shallow subsurface soil and biota. The results from the subsequent program were reported in the RI Addendum Report (HLA, 1992).

Samples collected by the Army provided a database sufficient for conducting this EA and FS. Numerous groundwater samples from monitoring wells were assessed to identify groundwater

contamination emanating from RMA and flowing northwest toward the South Platte River. Data evaluated in this report include information generated under the Offpost RI program and the ongoing comprehensive monitoring program (CMP). The database used in the assessments consisted of the most recently available and certified data available from the RMA database.

During the RI Addendum, a number of surface-water samples were collected from the principal surface-water bodies in the Offpost OU, including O'Brian Canal, Burlington Ditch, First Creek, and Barr Lake. These samples have provided sufficient data to assess the probable sources and migration routes for contaminants in surface water in the offpost area. Sediment samples were also collected at a number of locations along the same surface-water bodies. In most cases, sediment samples were collected at locations collocated with the surface-water sampling locations to permit assessment of the relationships between the nature and extent of contamination in each medium.

Approximately 80 surficial soil samples were collected from areas offpost. The sampling locations were selected based on evaluation of preliminary surficial soil data from onpost samples and data from a few samples collected near the RMA north boundary. Shallow subsurface soil samples were collocated with a selected number of surficial soil samples. These subsurface soil samples provided data for assessing the vertical distribution of contaminants in surficial soil samples.

Biota samples were collected from the Offpost OU near East 96th Avenue and Peoria. This area was selected because data from other media indicated the highest concentrations of chemicals that could be of concern to various biota were located in that area. The types of biota samples collected included aquatic vertebrates and invertebrates, terrestrial vertebrates and invertebrates, and a limited number of livestock samples. To the extent practicable, biota samples were collocated with samples collected from other media to permit assessment of the impact of contaminants derived from RMA on the biotic community.

2.2.1.4 Summary of Offpost Operable Unit Contamination

Contaminants from RMA have entered the Offpost OU by a variety of mechanisms, including advective transport with the groundwater and transport by high wind events. The resulting offpost contamination consists of several principal contaminants detected relatively consistently in a number of media. However, many of the contaminants for which analyses were performed were detected only sporadically or in only a selected medium. For example, DIMP was detected primarily in groundwater and surface-water samples. In contrast, dieldrin was detected in essentially all media.

The extent of groundwater contamination from RMA has been well-documented by the Army in the RI and RI Addendum reports and in the various annual reports prepared under the CMP. Groundwater flow in the unconfined aquifer is the principal pathway for migration of contaminants to the offpost area. The highest concentrations of contaminants in offpost groundwater occur between the RMA boundary and O'Brian Canal. As described in Volume I, contamination occurs primarily in three plumes: the northern paleochannel, the First Creek paleochannel and the northwest boundary plume. The principal contaminants detected in the groundwater include DIMP, dieldrin, chloroform, dicyclopentadiene, tetrachloroethene, and a few inorganic species, including chloride and fluoride. Other contaminants are present in the groundwater, but are generally detected sporadically or at levels near their respective CRLs .

Surface-water samples were collected from a number of offpost locations. The highest concentrations were identified in samples collected along First Creek in areas where groundwater is discharging to the surface-water system. In general, the contaminants detected in the surface-water samples were similar to those detected in the groundwater samples from the same area. However, concentrations in the surface-water samples were generally lower than the levels in groundwater. The principal contaminant detected in surface-water samples was DIMP.

Sediment samples were collected at locations generally corresponding to surface-water sampling locations. The contaminants detected in these samples consisted of the OCPs. Generally, the contaminants detected in the sediment samples are those with a high affinity to organic

carbon. Contaminants commonly detected in surface-water samples but not in sediment include DIMP and chloroform. Detectable concentrations of contaminants, including OCPs and metals, were reported for samples from the canals upgradient of the confluence with First Creek, suggesting a source of these contaminants other than RMA.

Surficial soil samples were collected from approximately 80 locations offpost. The contaminants detected in these samples generally decreased with distance from the RMA boundary although a few anomalously high concentrations were detected at a few locations. The most commonly detected contaminant was dieldrin. A few other contaminants were also detected in the samples, including DDT, DDE, and other OCPs. Significantly high concentrations of a few contaminants at one or more locations, including chlordane immediately north of the RMA north boundary, have been attributed to historical agricultural or other residential use and not associated with migration from RMA (HLA, 1992). The former property owner of the land where sample HA1227WB is located indicated to Army contractors performing soil sampling that he had applied insecticides to his property. Additionally, samples collected from a background area several miles north of RMA had detectable levels of OCPs, which also indicates a residual background level for some of these contaminants due to historical commercial uses of some of these compounds.

Biota samples were collected from a variety of wildlife species and from livestock. Samples were collected from the area immediately north of RMA because of the generally higher concentrations detected in sampled media from that area. The types of contaminants detected in biota samples were generally consistent with the types of contaminants detected in onpost biota samples. The most commonly detected contaminants included dieldrin and arsenic.

2.2.2 Potentially Exposed Populations

This section describes the prevailing land uses in the Offpost OU and provides demographic data describing the population present. Groundwater and surface water uses are also described.

2.2.2.1 Residential Land Use

Population and land use trends were assessed for existing and projected changes in population and land use for the Offpost OU. The objectives of the analysis were to summarize the results of the most recent population projections made by the Denver Regional Council of Governments (DRCOG) and to determine the implications of the various master plans from Commerce City, Adams County, and the new Denver International Airport on specific study areas of the Offpost OU.

2.2.2.1.1 Procedures

For purpose of demographic and land use assessment, the Offpost OU was subdivided into two Land Use Areas by zones of groundwater contamination and differences in land and water use. These study areas were defined in advance of the final identification of zones of groundwater contamination presented in Section 2.4.1 and do not overlay simply on those zones. For the most part, however, the zones of groundwater contamination occur in Land Use Areas I and II as used in this section.

Land Use Area I incorporates the area from the RMA north boundary on the south and the O'Brian Canal on the west and northwest; the eastern boundary parallels Second Creek (approximately 0.75 mile west of Second Creek) to the O'Brian Canal (Figure 2.2.2.1.1-1).

Land Use Area II is the area bounded by the O'Brian Canal on the east, the Platte River on the west, 105th Avenue on the southwest, 92nd Avenue and the O'Brian Canal on the southeast, 112th Avenue and the O'Brian Canal on the northeast, and the junction of the Platte River and 124th Avenue on the northwest.

The principal data set used in this analysis was DRCOG's Traffic zones 2010 Data Set. The traffic zone data are unofficial and are not published by DRCOG; however, their Traffic zones 2010 Data Set was used because traffic zones are the smallest geographical unit for which DRCOG develops estimates of current and future population, households, and income figures.

The traffic zone data set delineates 1488 traffic zones for the Denver-Boulder metropolitan area. These traffic zones were created by DRCOG primarily for transportation planning and

modeling. Traffic zone boundaries usually follow major highways, streets, roads, railroad tracks, rivers, and section lines. The second major purpose of the traffic zones was to divide the regional statistical area (RSA) into smaller planning zones. The Denver-Boulder metropolitan area consists of 51 RSAs. They were created to closely approximate metropolitan area growth in population and employment for planning and forecasting purposes. RSAs include sufficient geographical area to reflect general growth trends yet are small enough to analyze and define the dynamics of those trends.

RSAs usually include populations of 40,000 to 50,000 and are subdivided into traffic zones. There is no set of spatial requirements for traffic zones except that their boundaries do not cross census tract boundaries and are kept sufficiently small in area to locate the specific dynamics of growth, such as major residential and commercial development projects that may cause large increases in population and employment within the RSAs.

Each RSA and traffic zone is apportioned a current population count in addition to a forecasted population estimate. A top-down method for population is used to distribute the total metropolitan area population throughout the RSAs according to each RSA's historical and anticipated growth patterns. Each RSA is apportioned a current and forecast population estimate, which is then apportioned to traffic zones within the respective RSA. DRCOG develops the regional and RSA population estimates; however, municipal and county planning departments are responsible for allocating current and forecasted population estimates to each traffic zone. Local planning departments allocate population estimates to traffic zones so that forecast population estimates closely coincide with future land use development and annexation plans. Even though local planning departments are responsible for allocating current and future population estimates, the total population of all traffic zones may not exceed the total population of the respective RSA.

The assumptions made by DRCOG in its 1985 population estimates (revised September 27, 1989), 1995 population forecasts (revised April 1988), and 2010 population forecasts (revised May 31, 1988) included the following:

1. The traffic zone population was considered to be evenly distributed throughout the traffic zone. Therefore, if the study areas did not include a complete traffic zone or

more than one traffic zone, the percentage of traffic zone area included in the study area was applied to the current and forecasted population estimates to derive the study area population figures.

2. Earlier and 1988/1989 traffic zone population forecasts assumed that the new airport would be constructed east of RMA where it is now under development.

3. A potential planning constraint for future development of the study area was the 65 decibel day-night average noise level (Ldn) contour, which has now been determined for aircraft activity at the new airport. The 65 Ldn contour was not expected to encompass any area within the Offpost OU, and the Airport Environs Concept Plan supports this prior assumption. Even the 60 Ldn failed to encroach upon the Offpost OU study area; therefore, development activities within the study area will remain unaffected by noise constraints from the new airport.

4. The possible construction of a major transportation route along East 96th Avenue, accessing the new airport appears to increase the likelihood of commercial/industrial land use in the Offpost OU.

In addition to identifying and summarizing the latest government figures for total population growth in the study area, this analysis sought to determine the percentages of the study area's population that were children, women of childbearing age, and elderly. These population subgroups were considered somewhat more susceptible to environmental contamination than the population as a whole. Neither the DRCOG Traffic zone data set nor updated government population publications detailed population characteristics in the format necessary to update the 1980 U.S. Census. Therefore, the 1980 U.S. Census was used to determine the study area's percentage of susceptible population subgroups relative to state and national averages. The relevant population characteristics for the four census tracts that encompass the study area were combined to determine the percentage of susceptible persons living in the study area relative to the state and national percentages.

Future land use forecasts for the study area were derived primarily from the Airport Environs Concept Plan (Adams County, City of Aurora, City of Brighton, City of Commerce City, 1990), augmented by the Adams County Future Land Use Plan (May 1987). Together, these two land use projections were reconciled and mapped out on the study area where the percentages of each land use category were determined for each zone within the study area.

2.2.2.1.2 Results

Based on methods and data sources discussed above, population and land use trends were projected by study area to the year 2010. Results for population and land use are summarized in Tables 2.2.2.1.2-1 and 2.2.2.1.2-2, respectively. Large percentage increases in population and significant changes in predominant land use are expected during this period. These changes are expected because the Offpost OU lies at Denver's urban fringe with urban land uses at its southern edge. Also, development of the new international airport to the immediate east-southeast of the Offpost OU may be expected to encourage industrial and commercial development.

Currently, Land Use Area I, where the highest levels of RMA-related contamination are detected, is sparsely populated, with an estimated 1985 population of 121. The population is expected to increase to 512 by the year 1995 and to 1725 by 2010. Land use is projected to change during this period from predominately agricultural use (83 percent) to a mix of industrial, commercial, and residential use (90 percent) by the year 2010, as shown in the existing and future 2010 land use maps produced in the Airport Environs Concept Plan. Figure 2.2.2.1.2-1 illustrates the future land use as projected by planning jurisdictions contributing to the Airport Environs Concept Plan.

Land Use Area II is located downgradient of known contaminant sources in an area heavily used as agricultural land under irrigation. Contamination concentrations are significantly lower than in Land Use Area I. Land Use Area II is forecast to experience an annualized growth rate of 4.9 percent for the period 1985 to 1995 and 5.4 percent from 1995 through 2010, with its population increasing from 825 in 1985, to 1333 in 1995, to 2915 in 2010. Land use is projected to change during this period from 84 percent irrigated agricultural acreage to nearly 60 percent urbanized and 40 percent open space and floodplain.

In summary, the population of the affected portions of the Offpost OU (Land Use Areas I and II) is forecast to increase from 950 persons in 1985 to 4640 persons by 2010. Land use is

projected to change over the same 25-year period from 80 percent agricultural and open space/floodplain to 72 percent urbanized by 2010.

Susceptible subgroups in the Offpost OU population were examined using the 1980 U.S. Census population characteristics for the four census tracts that encompass the combined study areas. In Table 2.2.2.1.2-3, the percentage of children under 15 years of age, the percentage of women aged 15 to 44, and elderly people 65 years of age and older were identified for the Offpost OU and compared to similar percentages for such subgroups in the state and national populations. Examination of these percentages revealed that a proportionately higher number of children and a proportionately lower number of elderly inhabited the combined study areas in 1980 compared to their state and national averages. Women of childbearing age were somewhat more numerous in the Offpost OU than their proportion nationally but fewer than their proportion statewide.

Institutional land uses, such as health care facilities, residential care facilities, nursing homes, elementary schools, hospitals, and daycare homes, in which potentially sensitive subpopulations congregate, were surveyed throughout the Offpost OU. Two schools and one daycare home were identified.

2.2.2.2 Commercial/Industrial Land Uses

The land use in portions of the Offpost OU is changing. During 1991, the new Denver airport began construction, and negotiations progressed between the City and County of Denver and commercial airlines to the point that uncertainty about the future of the new Denver airport was substantially diminished. The current land use and zoning, along with the future land use for the Offpost area, were reviewed to determine whether the residential exposure scenario was appropriate for these areas. EPA guidance allows for exposure scenarios other than residential when the land uses warrant (EPA, 1989a, 1990, 1991a).

The current land use for the 96th and Peoria area is abandoned residential. The area coinciding with the northwest paleochannel is currently occupied by industrial complexes, including Purina Mills, United Facilities, Burlington Northern Automotive Terminal, Western Ash

Company, Delta Petroleum, and others. A small proportion of the this area is used for agriculture, but it has no residences.

An additional geographic feature that may influence future land use is the floodplain of First Creek. The 100-year floodplain of First Creek has been mapped by the Urban Flood Control and Drainage District. Approximately two-thirds of the acreage of the property now owned by Shell lies within the floodplain. Approximately 250 acres of this area may also qualify as wetlands which, together with the floodplain, make residential development even more unlikely.

Portions of the Offpost OU are within either the Commerce City or Adams County zoning jurisdictions. The zoning for both jurisdictions was compiled into one map and is shown in Figure 2.2.2.1.2-1. A substantial amount of the central portion of the Offpost OU is zoned for industrial use. Future land use plans for the area have been evaluated by local planning agencies with jurisdiction and have been published in the Airport Environs Plan (Adams County, 1990). Figure 2.2.2.1.2-1 displays the proposed future use of the offpost area. Affected areas of the offpost are planned to be industrial with open space/floodplain planned for the floodplain of First Creek. In addition, Adams County and Commerce City planners have proposed a realignment of East 96th Avenue through the area, moving it approximately 0.25 mile north and enlarging it for airport traffic. Consistent with projected commercial and industrial land use plans, Shell Oil Company purchased all these properties during 1991 and relocated the residents. Shell has indicated that only commercial/industrial, or remediation uses of these properties will be permitted (Shell, 1991).

As a result of this evaluation, an exposure scenario has been included in the EA to account for the probable commercial/industrial land uses in the offpost. The potentially exposed populations in the commercial/industrial scenario are commercial/industrial workers.

The commercial/industrial group consists of adults employed in a variety of occupational activities that are commensurate with a predominantly indoor industrial setting. These activities

include warehousing, light manufacturing, and maintenance facilities. Currently, these activities occur in the northwest portion of the Offpost OU.

2.2.2.3 Qualitative Assessment of the Likelihood of Occurrence of the Selection of Future Land Use for the Offpost Endangerment Assessment/Feasibility Study

Sections 2.2.2.1 and 2.2.2.2 provide the background discussion on current and future land use for the Offpost OU. The purpose of this section is to evaluate the information within the context of EPA guidance, and to select the most probable land use scenarios for the EA/FS.

Evaluation of land use for the Offpost OU considered the following sources for guidance and pertinent information:

1. The National Contingency Plan (NCP)
2. Risk Assessment Guidance for Superfund (RAGS)
3. Local city and county planning documents, including Adams County (1990)

The NCP states:

> The analysis for potential exposures under future land use conditions is used to provide decision-makers with an understanding of exposures that may potentially occur in the future. This analysis should include a qualitative assessment of the likelihood that the assumed future land use will occur. The reasonable maximum exposure estimates for future uses of the site will provide the basis for the development of protective exposure levels.
>
> In general, a baseline risk assessment will look at a future land use that is both reasonable, from land use development patterns, and may be associated with the highest (most significant) risk, in order to be protective. The assumption of residential land use is not a requirement of the program but rather is an assumption that may be made, based on conservative but realistic exposures. An assumption of future residential land use may not be justifiable if the probability that the site will support residential use in the future is small (NCP preamble [55 FR 8710] Remedial Investigation-baseline risk assessment).

The discussion above indicates that it is within the guidance to select a future land use other than residential before a record of decision.

For assessing potentially exposed populations, RAGS guidance requires an assessment of current land use and activity patterns and likely future land use. In applying the NCP language above, RAGS cites an example: "If the site is industrial and is located in a very rural area with a

low population density and projected low growth, future residential use would probably be unlikely" (EPA, 1989a). The portion of the Offpost OU near east 96th and Peoria already is industrial because of construction and operation of IRA A in this area.

From the data presented in Sections 2.2.2.2 and 2.2.2.3, the most likely future land uses for the Offpost OU are as follows:

- Residential/agricultural for the Offpost OU exclusive of the portions described below
- Commercial/industrial for subject parcels occupying the SE 1/4 of Section 14 and the SW 1/4 of the SW 1/4 of Section 13, Range 2S, Township 67W, 6th P.M.

A summary of the qualitative assessment of the likelihood of occurrence of these future land uses includes the following findings:

- Current land use in the subject parcels is abandoned residential with industrial activities planned for construction and operation of remedial treatment facilities
- The completion of the new Denver Airport and its proximity to the offpost OU will stimulate growth, particularly along the East 96th Avenue corridor, and the growth is most likely to include commercial and industrial development
- Future land use as projected by Adams County and Commerce City includes commercial, industrial, and open space in the subject land parcels
- Transportation agencies have mapped an enlargement and realignment of E. 96th Avenue to handle increased traffic to the new Denver Airport, and the realignment is positioned within the subject land parcels
- Floodplains and wetlands occur in the subject parcels and would tend to prevent the construction of buildings in these areas but may promote recreational uses
- For the remaining Offpost OU, residential and agriculture are the most likely future land uses.

2.2.2.4 Water Use

This section describes existing use of groundwater and surface water and projected future use of groundwater.

2.2.2.4.1 Existing Groundwater Use

Intensive surveys to identify water supply wells and water users were conducted by various parties including the Army, Shell Oil Company, Colorado Department of Health, and TCHD (ESE,

1985; 1986; 1987; TCHD, 1990). Based on the results of these surveys, no residences are currently using alluvial groundwater that contains concentrations of COCs above EPA MCLs as their primary water system. Continuing efforts have been made to identify and communicate with occupants of all residences overlying the chemical-containing plumes.

Although groundwater that is contaminated in excess of regulatory standards is not used for drinking or cooking, it may be used for other domestic and sanitary purposes at some residences. Groundwater containing RMA-related chemicals below regulatory standards is used for drinking and other domestic activities. Groundwater in the RMA vicinity is also being used to water livestock and crops that are sold for human consumption. The remainder of this section presents recent findings of surveys of well water use in the Offpost OU.

Wells in the Offpost OU were inventoried by ESE in 1985 and 1986 to support a sampling and analysis program of private wells. There were 656 permitted wells in this area in 1985, according to the Colorado Division of Water Resources Master Extract Register (MER).

In 1986, property ownership maps of the Consumptive Use Phase II study area (Figure 2.2.2.1.1-1) were acquired from the Adams County Tax Assessor's Office in Brighton, Colorado (ESE, 1986). The Consumptive Use Phase II study area approximately coincides with Offpost OU Areas I and II and represents an area directly downgradient of documented RMA sources (Figure 2.2.2.1.1-1). Telephone contact was attempted with all landowners in that area to determine whether wells existed on their properties, whether the wells were permitted, the depth of each well, and the use(s) of the water. As a result, it became apparent that approximately 29 percent of all wells in the Offpost OU were not included in the MER. Applying this factor, a minimum of 700, and more likely 900 to 1000, wells exist in the Offpost OU.

These data were used to estimate the number and use of wells in each of the Offpost OU study areas. Well use information from the MER is summarized in Table 2.2.2.4.1-1. Well Use Codes 0, 1, 3, 7, and 8 include potable use. These data are considered unreliable, however, because the MER-permitted use may not be the actual well use. In applying for a permit, uses may have been listed that were not current uses but may be potential future uses. Also,

information provided by the MER is not current. MER data indicate that 33 permitted potable wells are in Land Use Area I and 89 permitted potable wells in Land Use Area II. In addition to human use, many wells are permitted as livestock water supplies (Well Use Codes 2 and 3). Land Use Areas I and II showed 6 and 17 of these wells, respectively. Also, some wells in the offpost OU are designated as irrigation wells (Well Use Codes 6 and 7). Although no irrigation wells are permitted in Land Use Area I, Land Use Area II contains wells permitted for this use.

Actual well use may be estimated from the data compiled for the three phases of the Consumptive Use Survey (ESE, 1985, 1986, 1987) and the more recent survey by TCHD (1990). It is important to note that the Consumptive Use Survey data set is very biased because wells were selected on the basis of proximity to RMA, direction from known RMA source areas, and well use (uses resulting in human exposure were prioritized). This sample represents approximately 20 percent of all wells in the Offpost OU. These data are summarized in Table 2.2.2.4.1-2. A preliminary estimate of the number of wells in the Offpost OU according to the MER and Consumptive Use Survey is presented in Table 2.2.2.4.1-3.

To obtain an accurate and dated well inventory in the study area, TCHD conducted a multiphase well investigation north of RMA in 1989 (TCHD, 1990). Following the release of news statements and bulk mail introductory notification, TCHD conducted telephone and door-to-door surveys as well as water sampling and testing for conductivity and hardness (to characterize the wells as shallow/alluvial or deep/bedrock). Residents/property owners who were not available during regular working hours and/or had unavailable telephone numbers were sent follow-up letters and self-addressed, stamped postcard questionnaires. After-hours telephone calls were also attempted. If no contact was made with a resident/property owner after several attempts, a well assessment was made on the basis of review of the available records in the Adams County Tax Assessor's Office and State Engineer's Office, field observations, discussions with former residents (if possible), and/or former data reported by ESE. A TCHD data summary is presented in Table 2.2.2.4.1-4.

The TCHD survey provides the most comprehensive data set for the well use analysis in the Offpost OU. Overall, information was obtained for more than 95 percent of the properties in the TCHD survey area, including almost 600 properties and 400 wells that were not previously identified. Considering the shortcomings inherent in each of the databases, some uncertainty still remains regarding the total number of wells in the Offpost OU. An attempt has been made to combine data from the TCHD survey with data from the previous studies to estimate the total number of wells used for purposes that may result in human exposure in each of the study areas. This summary is presented in Table 2.2.2.4.1-5.

Land Use Area I, the most contaminated area, has the fewest wells, which is consistent with the low population and the dominance of dryland agriculture in this area. The data presented in Table 2.2.2.4.1-5 are consistent with the land use and demographic data.

Of the 837 wells estimated to be in the Offpost OU, 132 wells are potable water sources in Land Use Areas I or II, the areas of greatest concern. In addition, approximately 30 nonpotable wells in Land Use Areas I and II are used for cooking and/or nonconsumptive purposes (bathing, laundering, washing dishes, and sanitation). Of the 162 wells that are used for domestic purposes, approximately 27 percent are alluvial wells, and 73 percent are deep aquifer wells (Arapahoe, Denver, or Fox Hill). Conversely, approximately 80 percent of the irrigation and livestock wells draw water from the alluvial aquifer. Approximately 62 percent of the total number of wells in the Offpost OU are completed in the alluvial aquifer.

Konikow (1977) estimated that total pumpage from the alluvial aquifer for irrigation, by far the largest volumetric use of water in the Offpost OU, was 550 gallons per minute (gpm). According to the RI (ESE, 1988a), this pumping rate has probably declined in recent years to approximately 300 gpm or less.

Irrigation systems in the Offpost OU primarily use groundwater to supplement surface-water supplies, presumably due to pumping costs and ditch water availability. In general, the land is not irrigated in areas where canal water is not available. However, several exceptions to this rule were documented during the consumptive use surveys (ESE, 1985, 1986, 1987). A farm with

property in Sections 22 and 28 includes at least two parcels that are irrigated exclusively by wells. The larger of these parcels is located in Section 22 less than 0.5 mile from the northwest RMA boundary. The farm with property in Sections 22 and 28 grows a variety of vegetable crops, some of which are sold through a retail outlet in Irondale. The majority of produce from this farm, however, is distributed to major grocery chains throughout Colorado and adjacent states.

Vegetables are also grown for local sale at various locations in the offpost OU. Both parcels are irrigated entirely with groundwater from wells on the two properties. The wells are 25 and 12 feet deep. Produce raised and sold on these parcels includes corn, cucumbers, eggplant, green beans, various peppers, acorn squash, zucchini, red and green cabbage, cauliflower, red beets, and tomatoes.

Livestock in the Offpost OU are primarily watered with groundwater (ESE, 1989b). Based on data obtained from the Adams County Extension Service in 1987, approximately 52,000 head of feed cattle were quartered at two large feedlots in Land Use Area I; 15,000 sheep and 300 hogs were raised in Land Use Area II near Hazeltine Heights. Recent field observations indicate that feedlot operations have been significantly curtailed in those areas. Livestock count can vary seasonally and from year to year.

2.2.2.4.2 Projected Future Use of Groundwater

In keeping with the demographic projections presented in Section 2.2.2.1, additional demands will be placed on the groundwater resource as a source of municipal water supply. South Adams County Water and Sanitation District (SACWSD) plans to develop alluvial wells at locations downgradient of or within known contaminant plumes originating from RMA (SACWSD, 1991). The first well field planned for development is approximately 0.5 mile from the northwest boundary containment system in an area where groundwater is uncontaminated. Pumpage at the proposed new well field could potentially affect operation of the NBCS and draw contamination toward the municipal well, further spreading the contaminant plume over a wider area in the Offpost OU (ESE, 1988b); however, ESE (1988a) presented results of a groundwater model simulation that indicated the well would not be affected by RMA chemicals. New wells are

planned in the Rolla and Hazeltine areas, which are downgradient of RMA contaminant sources in Land Use Area II.

If commercial/industrial and residential development supplant agricultural land uses to the extent indicated by projections of the various local planning agencies, total water demand on the alluvium may not increase as rapidly as population because agricultural irrigation currently uses a large volume of water in the Offpost OU. Furthermore, if municipal supplies are provided for the growing population as planned by SACWSD, it may be assumed that future residents will not be exposed to chemicals in the alluvial aquifer via domestic use of water because the municipal suppliers will be required to treat the water before delivery to comply with the Safe Drinking Water Act.

2.2.2.4.3 Surface-Water Use

Surface-water uses vary substantially for different water bodies included as part of the Offpost OU. Irrigation canals are used principally for agricultural water supply but also provide habitat for aquatic biota and riparian vegetation. Barr Lake provides a significant, unique habitat for aquatic biota, waterfowl, and predatory birds. It is stocked with gamefish and used as a recreational fishery. Waterfowl hunting is permitted, but swimming and wading are prohibited at Barr Lake State Park. Historically, Barr Lake has been adversely affected by bacterial contamination due to raw sewage discharge to the South Platte River, the lake's source. Barr Lake water is also used for irrigation downstream.

The Offpost OU contains 2500 to 2700 acres of irrigated farmland (Konikow, 1977). Most of this land is supplied primarily by the various irrigation ditches that traverse the Offpost OU. Irrigation water use is estimated at approximately 4000 to 6000 gpm as an annual average (Konikow, 1977; ESE, 1988a). Irrigation water use is seasonal, peaking in the summer. Irrigated crops in the Offpost OU may include a wide variety of vegetable crops, including beans, beets, cabbage, cauliflower, celery, cucumbers, eggplant, melons, peppers, squash, and tomatoes, as well as corn, alfalfa, and sorghum. Several turf and sod farms in the Offpost OU are irrigated.

Although livestock are watered primarily by well water in the Offpost OU, surface water may be used where available.

2.3 EXPOSURE PATHWAYS

An exposure pathway consists of four elements: (1) a source and mechanism of release, (2) a transport medium, (3) a point of potential human contact with the contaminated medium, and (4) an exposure route, such as ingestion at the contact point (EPA, 1989a). The following subsections and Figure 2.3-1 present an updated site conceptual model including potential sources, release mechanisms, and pathways and provide justification for inclusion in or exclusion from the EA.

2.3.1 Potential Sources, Release Mechanisms, and Transport Media

The sources of contaminants to the Offpost OU are waste disposal areas onpost. These sources have released and may continue to release contaminants to groundwater, surface water, and the atmosphere. Atmospheric releases that resulted from volatilization, reentrainment of dust, and/or atmospheric transport of aqueous-phase aerosols have also been a historical source of contaminants now deposited in surficial soil of the Offpost OU. Use of groundwater for irrigation may have affected surface soil concentrations in areas south of O'Brian Canal. Available evidence indicates that direct surface-water releases from the onpost sources do not contribute significantly to contamination in the Offpost OU (ESE, 1988a). Potential sources are discussed below by medium. Please note that use of the term "significant" refers to the statistical evaluation of whether a chemical concentration is elevated with respect to background as presented in Section 1.3.

2.3.1.1 Groundwater

Historical releases of contaminants to groundwater from onpost sources have been transported by prevailing groundwater flow to the north and northwest, entering the Offpost OU at RMA's north and northwest boundaries. Several IRAs have been implemented to mitigate this source of contamination to the Offpost OU, including the interim remediation of Basin F and

implementation of systems to contain, extract, and treat contaminated groundwater and recharge treated water at the north and northwest boundaries. The contamination that has already reached the groundwater of the Offpost OU may continue to pose potential for exposure for an extended period of time if offpost remedial actions are not implemented.

Groundwater contaminants in the Offpost OU are transported to the north and northwest of RMA. During transport, the most important fate processes are expected to be lateral dispersion and advective mixing with less contaminated groundwater at the edges of plumes, dilution by recharge of less contaminated surface water from O'Brian Canal and Burlington Ditch, dilution by recharge of irrigation water from the irrigated land northwest of the canals, adsorption to aquifer material, and biotransformation. Application of groundwater for irrigation may transport groundwater contaminants to surficial soils, particularly south of the canals where canal water is unavailable for irrigation.

Recharge of surface water from O'Brian Canal, Burlington Ditch, and applied irrigation water in the irrigated farmland northwest of the canals appears to play a significant role in reducing groundwater contamination northwest of these irrigation canals. Groundwater concentrations of COCs decline substantially as groundwater moves under the canals in a northwesterly direction, particularly along the First Creek and northern paleochannels. Estimates of the water balance of the offpost alluvial aquifer, based on groundwater models developed for the RI (ESE, 1988a), as well as an earlier model by Konikow (1977), illustrate the importance of this recharge. Approximately 200 to 300 gpm of groundwater is being recharged to the alluvial aquifer at the RMA north boundary, and approximately 185 gpm is being recharged at the northwest boundary. This estimate approximates the flow of contaminated groundwater from RMA before implementation of the boundary containment systems. This flow passes through contaminated portions of the aquifer and may be leaching adsorbed contaminants from aquifer sediment.

Although First Creek receives some contaminated discharge from the alluvial aquifer, this discharge is seasonal. Recharge-discharge relationships vary along the course of First Creek

through the Offpost OU. Available information suggests that First Creek north of RMA loses approximately 80 gpm on average. Adding this flow to the amount crossing the boundaries, the contaminated flow south of and underflowing the canals is approximately 500 gpm.

Konikow (1977) estimated that approximately 2000 to 3000 gpm of surface water, used as irrigation water, recharges contaminated portions of the alluvial aquifer, and the canals may lose a similar amount. Recharge from the canals may not be uniform along their length, as indicated by the significant extension of the northwest plume north of the canals. Along the First Creek and northern paleochannels, concentrations of COCs decline rapidly with distance north of the canals, as might be observed at the leading edge of a plume that is continuing to migrate downgradient. Average linear velocities for contaminated groundwater in paleochannels upgradient of O'Brian Canal were estimated in the RI report (ESE, 1988a) to be 4 to 7 feet per day, indicating that groundwater currently underflowing O'Brian Canal left the north boundary two to six years ago. Because contaminants have been migrating across the north boundary for much longer than two to six years, the current contaminant distribution must represent a nearly steady state response to prevailing fate and transport processes that are profoundly influenced by the canals and not by the leading edge of plume. Thus, substantial downgradient expansion of the plumes is not expected in light of the boundary containment systems.

Several groundwater COCs are hydrophobic and are expected to be adsorbed by aquifer materials (e.g., aldrin, arsenic, chlordane, dicyclopentadiene, DDE, dieldrin, endrin, and isodrin). Many remaining COCs are relatively mobile in groundwater systems. The chlorinated aliphatic COCs (carbon tetrachloride; chloroform; 1,2-dichloroethane; tetrachloroethene; and trichloroethene) are subject to dechlorination (Section 2.1) under anaerobic conditions, while the aromatic contaminants (ethylbenzene, toluene, and xylenes) are readily biodegraded under aerobic conditions. The persistence of each of these contaminants during transport from onpost sources suggests that natural biotransformation processes may not be vigorous enough to substantially reduce groundwater concentrations. It is possible that the introduction of microbes or nutrients

with recharging irrigation also contributes to significant reductions in concentration of some contaminants northwest of the canals.

2.3.1.2 Surface Water and Sediment

Contaminants in offpost groundwater are also discharged to surface water within the offpost OU. The most significant discharge, resulting in significantly elevated levels of COCs in surface water, is into First Creek near the north boundary of RMA. Contaminated groundwater may also discharge to the South Platte River or to abandoned gravel pit ponds in the floodplain of the South Platte, but available data indicate that these potential discharges would not result in significant contamination of these water bodies. Groundwater concentrations near potential discharge points in the South Platte floodplain are much lower than at the point of discharge to First Creek, and the dilution capacity of the South Platte is much greater than that of First Creek. Groundwater COCs are not elevated in the South Platte at locations of maximum potential impact, compared with sampling locations upstream of potentially contaminated groundwater discharge (ESE, 1988a; HLA, 1992).

If groundwater were discharged to First Creek, surface-water contaminants would be transported to O'Brian Canal where substantial dilution occurs. The average flow of First Creek is approximately 500 gpm, and O'Brian Canal averages approximately 65,000 gpm, resulting in 130:1 dilution of any contaminants received from First Creek (ESE, 1988a). Surface-water flow in First Creek may also be diverted occasionally to Burlington Ditch.

Surface-water COCs range from relatively soluble ions, such as chloride, fluoride, and sulfate, to relatively hydrophobic and environmentally persistent OCPs, such as DDE, DDT, and dieldrin. No volatile contaminants were significantly elevated above background. DIMP and the major ions are transported and diluted. The hydrophobic contaminants, which also include chlordane and dicyclopentadiene, are expected to associate strongly with suspended and bottom sediment. In fact, DDE, DDT, and dieldrin are also significantly elevated in the bottom sediment of First Creek. Other sediment COCs include aldrin, dibromochloropropane, and endrin, which are not significantly elevated in surface water. The surface water and bottom sediment interact

and should not be considered independently. All the surface-water and sediment COCs are relatively persistent in environmental systems.

2.3.1.3 Atmospheric

Releases of airborne contaminants from onpost sources have been reduced substantially in comparison with historical release rates. As a result, atmospheric concentrations of RMA contaminants are not significantly elevated above background at this time (RLSA, 1990). Past releases have been transported offpost and deposited in surficial soil of the Offpost OU. This is indicated by the consistency of patterns of on- and offpost surficial soil contamination and the climatological wind rose. The strongest winds are usually from the south, and the most prevalent wind direction is from the west. Consistent with this climatology, surficial soil contamination is observed extending from known RMA air sources. Surficial soil contamination does not extend to the northeast boundary of RMA, nor to the south and west.

Surficial soil COCs are limited to the nonvolatile OCPs. The low vapor pressure of the OCPs causes them to be associated with aerosols, which are preferentially deposited by both dry and wet processes, and their environmental persistence results in their continued presence in surficial soil. Although other, more volatile contaminants may have been released from onpost sources during the course of operations at RMA, the low volatility and environmental persistence of the OCPs have caused them to be selected as surficial soil COCs.

2.3.1.4 Biotic

Contaminants occurring in surficial soil, groundwater, and surface water may be bioaccumulated by plants and animals in contact with these media, resulting in residues in tissues that may be ingested by organisms at higher trophic levels, including humans. Groundwater is of concern in this regard if used for irrigation or to water livestock. Surface water is the predominant agricultural water supply source in the Offpost OU, but groundwater is used to supplement surface-water supplies and to water livestock on farm parcels south of the canals where surface-water supplies are unavailable.

The substantial control of groundwater and airborne releases from onpost sources indicates that concentrations of COCs in the Offpost OU will decline even if offpost remedial actions are not taken. Due to the relative persistence of several COCs in both groundwater and soil systems, however, current concentrations may persist for years or may decline slowly.

2.3.2 Potential Exposure Points

Potential points of exposure to RMA contamination are widespread in the Offpost OU. The most significant routes of exposure have been mitigated by exposure controls (e.g., no longer use of the alluvial aquifer) in areas with the highest groundwater concentrations of COCs. Exposure to COCs in surficial soil contamination has also been mitigated by relocation of residents from the area near the intersection of 96th Avenue and Peoria Street where surficial soil concentrations are highest. It would be imprudent, however, to assume that exposure controls will be effective indefinitely, considering possible future residential land use and the lack of binding restrictions on water use in the future. Therefore, a clear distinction should be drawn between existing exposure points and pathways and potential future exposure points and pathways.

For the residential scenario, the assumption was made that unrestricted use of contaminated groundwater and land could occur at the most contaminated offpost locations. These include any locations within approximately 1 mile of the north and northwest boundaries of RMA. To support definition of representative exposure concentrations for distinct potential exposure points, six zones having characteristic and distinct groundwater contaminant levels are defined in Section 2.4.1.

Similarly, a hot spot of surficial soil contamination was identified within 1/2 mile of the intersection of 96th Avenue and Peoria Street. While the traditional land use for this area has been residential, land use projections, including the proposed upgrading of 96th Avenue as an east-west corridor to the new airport, suggest that the most likely use of this land in the future may be commercial/industrial. However, this assessment will assume that urban residential land use is possible.

Surface-water concentrations were higher in First Creek than other surface water bodies during 1986 through 1990, creating a potential exposure point for nonhuman receptors and a direct-contact human pathway associated with wading. First Creek does not support a recreational fishery; Barr Lake is the most likely point of human exposure to bioaccumulated residues in fish tissue. Because COCs are not significantly elevated in Barr Lake, consumption of contaminated fish is not a complete exposure pathway.

2.3.3 Potential Exposure Pathways and Routes

Potential exposure pathways identified for the Offpost OU include the following:

1. Inhalation of vapors and particulates, including vapors in basements and vapors from domestic use of shallow groundwater other than ingestion
2. Dermal exposure to sediment, surface water, surficial soil, and shallow groundwater used for domestic supply
3. Incidental ingestion of shallow groundwater used for domestic supply; game and agricultural products that have bioaccumulated contaminants from surficial soil; surface water and shallow groundwater used for agricultural water supply; and surface water, surficial soil, and sediment

As discussed in Section 1.1, shallow groundwater refers to groundwater less than 100 feet below ground surface, which includes the alluvium and the upper Denver Formation under unconfined flow conditions. RMA-related contamination is virtually nonexistent at greater depths, and exposure to such groundwater has not been quantified.

In the remainder of this section, the above information will be integrated to assemble a list of potentially complete exposure pathways for the Offpost OU.

2.3.3.1 Inhalation Route

Complete pathways that may result in exposure by the inhalation route are summarized in Table 2.3.3.1-1.

One potential pathway may involve vapor accumulation in residences or other structures as a result of volatilization from underlying groundwater. This existing exposure pathway is complete, regardless of groundwater use. However, the exposure resulting from vapor accumulation is much

less than the exposure from domestic groundwater use. Use of groundwater for domestic supply involves the same pathway at the same exposure point; consequently, deletion of this pathway from the quantitative assessment would not significantly reduce the final estimates of exposure and risk associated with contaminated groundwater. These assertions were demonstrated by a conservative screening level analysis using a fate and transport model describing this pathway (EA Appendix A). The analysis is summarized in the following paragraphs.

Considering their volatility, concentrations in groundwater, and toxicity, chloroform and dibromochloropropane pose the greatest risk by the inhalation pathway. Sample calculations presented in Appendix A, using RME parameters, indicate that exposure to chloroform and dibromochloropropane by inhalation pathway is much less than the exposure that would result from domestic water use. The analysis was performed using the following conservative assumptions regarding the environmental setting:

1. The water table is 8 feet below ground surface (bgs) (tenth percentile of actual groundwater depths in the area having highest concentrations of volatile COCs).
2. The moisture content of the unsaturated zone is 3.7 percent (tenth percentile of moisture contents expected in the unsaturated zone offpost).
3. The water table is in fine sand; in the most contaminated area, the alluvial aquifer is semiconfined (ESE, 1988a) and may be situated in finer-grained materials (e.g., silty sand and sandy silt). Fine-grained materials would increase the thickness of the capillary fringe, a nearly saturated zone above the water table that reduces the flux of volatile chemicals from the water.
4. A house with a basement would be situated at a location where all these adverse conditions occur simultaneously (unlikely).
5. The floor of the basement is dirt or is cracked so that it presents no resistance to the influx of volatile chemicals.
6. Physical-chemical properties, such as diffusivity and Henry's Law constant, were input at the upper 90 percent confidence limit based on reported values and enhancing estimated volatilization rate.
7. An individual will spend an average of 8 hours per day in the basement over a chronic exposure duration (30 years).

Under these assumptions, which all tend to increase the estimated indoor exposure, exposure to chloroform by this pathway would be 4 percent of the inhalation exposure that would result

from domestic use of the groundwater in the home. Exposure to dibromochloropropane from this pathway would be less than 3 percent of the inhalation exposure that would result from domestic use. Because this assessment is predicated on the assumption that domestic use of groundwater could occur and because it is quantified, exposure from the basement vapor pathway will be much less than that from the domestic use pathway involving groundwater at the same geographic exposure point. Inclusion of this basement vapor pathway in the quantitative assessment would not increase risk estimates significantly, considering that those estimates are presented to one significant figure. Consequently, this pathway was not considered further in the quantitative exposure assessment.

Volatile chemicals are released from water used in the home for all purposes (e.g., showering, dishwashing, laundry, toilets), resulting in exposures by the inhalation route. Approximately 200 gallons of water pass through an occupied residence daily. A portion of the volatile chemicals present in this water is released to the air, and occupants inhale a fraction of those chemicals. The remaining, and major, portion of these volatile chemicals delivered through the water system exits the residence with the water and as a result of structural ventilation. Andelman (1985) presented experimental data and reasonable exposure assumptions indicating that the intake through the inhalation route is approximately equal to intake through the ingestion route when domestic water contains volatile chemicals. Consequently, exposure by inhalation was quantitatively evaluated.

Surficial soil of the Offpost OU is contaminated by OCPs that have low volatility and bind tightly to soil particles (Section 2.1). Soil particles containing OCPs may be reentrained into the breathing zone by high winds, vehicular traffic, and tillage, resulting in inhalation exposure. Some of the inhaled particles may penetrate the lungs, and a large fraction will be trapped in the upper respiratory system, cleared, and ingested. Available toxicological information does not indicate that the exposure route (inhalation versus ingestion) markedly affects the toxic effects of the OCPs. A conservative screening level model of exposure to dust is presented in Appendix B. The results indicate a maximum one-day exposure to 8 milligrams of soil per day, and a long-term average exposure of 2.5 milligrams of soil per day. This contact rate is much less than contact

rates associated with incidental direct soil ingestion (100 to 200 milligrams soil per day), which will be shown in Section 2.4.3 to result in significantly lower exposure than pathways involving bioaccumulation by agricultural products. Consequently, this pathway is demonstrated to result in much less exposure than other quantified pathways involving soil at the same exposure point. Consequently, the pathway was not evaluated further in the quantitative assessment.

Waste disposal areas onpost are documented to release vapors and aerosols containing COCs (RLSA, 1990). These emissions may be transported by wind to the Offpost OU, resulting in exposure by the inhalation route. However, RLSA (1990) also documents that the atmospheric concentrations of all chemicals associated with RMA source emissions are reduced to ambient background levels at the RMA boundary. Consequently, no detectable COCs are in outdoor ambient air of the Offpost OU associated with this pathway, and it was not quantified.

2.3.3.2 Dermal Route

Complete pathways that may result in exposure by the dermal route are summarized in Table 2.3.3.2-1.

Direct contact with contaminated surficial soil is likely under all potential land uses; therefore, this pathway was quantified.

Direct contact with contaminated sediment in First Creek is possible, and this pathway was quantified. Concentrations of COCs in sediment of O'Brian Canal were not significantly elevated above background levels (Section 1.4). Consequently, this pathway was not complete with respect to the canals. Direct contact with sediment of Barr Lake is not feasible, considering the depth of the water and the prohibition of swimming.

Direct contact with contaminated surface water of First Creek is possible, and this pathway was quantified. Direct contact with canal water is expected to be unlikely and, in the worst case, infrequent. The physical setting of the canals and the presence of treated sewage effluents make them unattractive for wading or other contact activities. If infrequent exposure by dermal absorption were quantified, the resulting risks would be very low in comparison with other pathways to be quantified. COCs except fluoride and DIMP in O'Brian Canal northeast of its

confluence with First Creek are not present in the canals. Consequently, this pathway was not quantified for the canals. The water of Barr Lake, where direct-contact recreation is prohibited because of the presence of treated sewage effluents, is not significantly elevated for any COC. Consequently, the direct-contact pathway was not quantified in Barr Lake.

Direct contact with groundwater used domestically is likely. Exposure, however, is expected to be much less than other quantified pathways involving groundwater at the same point of exposure. Exposure by direct contact is adequately accounted for by the contact rate assumed for domestic use of groundwater. This was demonstrated by a sample calculation using dermal exposure during showering compared with ingestion intake. The ratio of dermal intake in domestic use to ingestion intake is as follows:

$$\frac{\text{Dermal Intake}}{\text{Ingestion Intake}} = \frac{SA \times PC \times ET \times CF}{IR} = 0.0015$$

where:

SA = 18,150 cm^2 (average adult total body surface area)

PC = 8.4 x 10^{-4} cm/hr (recommended default value [EPA, 1989a])

ET = 0.2 hr/day (90 percentile shower duration, [EPA, 1989c])

CF = 10^{-3} l/cm^3

IR = 2 l/day

Dermal intake during showering is 0.15 percent of ingestion intake (i.e., much less than another quantified pathway involving the same medium at the same exposure point); hence it will not be quantified.

2.3.3.3 Ingestion Route

Complete pathways that may result in exposure by ingestion are summarized in Table 2.3.3.3-1.

Incidental ingestion of contaminated surficial soil is likely under all potential land uses; therefore, this pathway was quantified.

Incidental ingestion of contaminated sediment of First Creek is possible in association with wading or recreational activities; therefore, this pathway will be quantified. Sediment of the canals is not significantly elevated for any COC, and incidental ingestion of Barr Lake sediment is infeasible considering the depth of the water as well as the prohibition of swimming.

Cattle and other livestock raised for human consumption may bioaccumulate contaminants from surface water or groundwater used for watering the livestock, from forage grown in contaminated surficial soil or irrigated by contaminated surface water or groundwater, and by direct ingestion of soil while grazing. Bioaccumulated residues may be present in meat and milk. This was documented to be a complete pathway in the Offpost OU, and cow fat tissue samples appear to be elevated above background levels for dieldrin. This pathway was quantified, using cattle as the representative species for development of a bioaccumulation model.

Chickens may bioaccumulate contaminants by incidental ingestion of surficial soil during feeding. This exposure pathway would not occur in commercial poultry management. In hobby/subsistence farming, it is likely that chickens would be kept primarily for egg production rather than meat production. Eggs sampled in the Offpost OU contained dieldrin at levels that may be elevated above background. Consequently, bioaccumulation resulting in dieldrin contamination of chicken eggs was quantified in this assessment.

Vegetable crops and fruits grown for human consumption may contain COCs because of uptake of COCs from contaminated surficial soil and surface water or groundwater for irrigation. A major portion of the Offpost OU is presently irrigated and used for production of edible vegetables. Consumption of homegrown vegetable crops is documented to occur in the Offpost OU. Fruit production is much less likely to occur, considering climate and prevailing agricultural practices in the area. Although tomatoes are scientifically classified as a fruit, for the purposes of this EA, they will be considered as a homegrown vegetable crop. In fact, fruit production is such a minor contribution to the agricultural economy of the area that fruit production statistics are not kept by local agricultural economists. Exposures through fruit consumption are expected to be less than other quantified pathways (meat, eggs, dairy, and vegetable) involving the same media at

the same exposure points. Consequently, intake through consumption of potentially contaminated vegetable crops was quantified, but exposure by ingestion of fruit crops was not quantified.

Fish may bioaccumulate COCs from surface water and sediment. The only surface-water body supporting an important fishery in the Offpost OU is Barr Lake, a stocked recreational fishery. First Creek is intermittent and does not provide habitat for edible fish. The canals are also intermittent but are documented to contain fish typical of the South Platte River. There is no evidence that the canals are used as a fishery. The canals' physical setting and the presence of treated sewage effluent may discourage such use. Nor are COCs present in the canals that would bioaccumulate in fish.

Game animals such as pheasants or rabbits may bioaccumulate COCs from their diet, soil, or surface water. Available data indicate that the edible tissues of pheasants and other biota do not contain COCs above background levels offpost (HLA, 1992; ESE, 1989b). Consequently, this pathway was not quantified.

At this time, most of the area overlying identified zones of contaminated alluvial groundwater (Section 2.4.1) is supplied by individual domestic wells. Many of these wells were completed in the alluvial aquifer. Residences whose wells are contaminated above guidance levels established by the Army in consultation with the State of Colorado have been supplied with alternative water, thereby substantially mitigating existing exposures by this pathway. Commerce City plans to annex unincorporated portions of the Offpost OU and develop a municipal water supply system supplied by alluvial wells. The South Adams County Water and Sanitation District also intends to develop alluvial supplies during the next 20 years. There is insufficient water in the contaminated areas of the alluvial aquifer to supply such municipal systems, and the treated water would be required to meet maximum contaminant levels. However, it has been conservatively assumed that domestic use of untreated alluvial water might occur; therefore, this pathway was quantified.

Incidental surface-water ingestion during direct contact recreation is possible. Exposure is most likely in First Creek, which has higher exposure concentrations than other surface water of

the Offpost OU, and is more attractive and accessible than the canals. Swimming is not feasible in First Creek, however, and exposure during wading is expected to be much less than other quantified pathways involving surface water of First Creek.

2.3.4 Uncertainties

In predicting future land and water use for the Offpost OU, conservative assumptions of residential land use and potable use of alluvial groundwater were made for locations where such use is not occurring now. There is ample evidence, however, that residential land use is unlikely in certain portions of the Offpost OU in the foreseeable future, so these assumptions may be unrealistically conservative.

Exposure to COCs that may have accumulated in fruits such as apples, pears, or cherries is possible but not quantified. Fruit production in the region is much less than vegetable production, and quantification of uptake by this pathway is highly uncertain given available scientific information. Nonetheless, one or more residents may be exposed via this unquantified pathway. Assuming that fruits would have similar tissue concentrations to vegetables, inclusion of this pathway would not increase total RME intakes by more than 10 percent.

2.4 QUANTIFICATION OF EXPOSURE

This section presents estimates of potential chemical intake for both the residential and the commercial/industrial scenarios on the basis of exposure pathways, equilibrium partitioning theories, existing data, and patterns of contamination in the offpost area. In addition, the agricultural food chain models are further developed into intake equations, and intakes are calculated and summarized. The results of a limited uncertainty analysis on the exposure intake estimates are also presented.

Potentially sensitive subpopulations under the rural residential scenario include residents whose diets include above average (RME) fractions of locally produced foods including vegetables, meat and milk products, and eggs. Children among such families are also shown to represent a potentially sensitive subpopulation because their exposure may be somewhat higher, relative to

body weight, than adults. The RME estimates explicitly represent both of these sensitive subpopulations. This is accomplished by using RME (e.g., 90th percentile) estimates for home-grown fraction of these dietary components in both adult and child chronic scenarios for noncarcinogenic endpoints and the lifetime scenario for assessment of carcinogenic endpoints.

To define the RME exposure, conservative estimates are used for all parameters used to estimate intakes (with the exception of body weight and skin surface area, per EPA, 1989a). Specific statistics used include:

- Upper 95 percent confidence limits of the arithmetic mean (for exposure concentrations calculated from monitoring data, EPA, 1989)
- Upper 90 percent confidence limits of the mean value for other parameters, (e.g., equilibrium partition coefficients used to estimate exposure concentrations in foods; see Section 2.1.1 and 2.4.2.2)
- 90th percentiles for exposure factors such as food and water ingestion rates (see Sections 2.4.2.3 and 2.4.5.4)

The rationale for using these distinct statistics for different categories of inputs is based primarily on EPA (1989), which recommends use of upper 95 percent confidence limits of the arithmetic mean for exposure concentrations calculated from monitoring data and 90th or 95th percentiles for exposure factors. By logical extension, upper confidence limits of the arithmetic mean are also appropriate when estimating exposure concentrations in foods using equilibrium partition coefficient models. Upper 90 percent confidence limits were selected for partition coefficients, which are then multiplied by upper 95 percent confidence limits of soil, groundwater, or surface water concentrations, because the probability that both the abiotic media concentration and the partition coefficient would exceed their upper 95 percent confidence limits is very small (much less than 1 percent chance of occurrence). Combining upper 95 percent confidence limits would probably result in an unreasonably conservative RME estimate. The use of upper 90 percent confidence limits for equilibrium partition coefficients is shown to be sufficiently conservative by the quantitatively uncertainly analysis (see Section 2.4.5.5.2). The uncertainty analysis also supports the decision to base RME intakes on 90th percentiles of exposure factors insofar as the RME intakes typically exceed the 98th percentile result from the

uncertainty analysis. Notwithstanding the support provided by the uncertainty analysis, however, the use of this assessment of specific statistics as input to the RME exposure assessment is consistent with EPA guidance.

Finally, the combined RME intake reflecting multiple pathways is calculated by summing the RME intakes for each pathway. This degree of conservatism is not required by EPA (1989a), which permits RMEs for some pathways to be combined with average estimates for other pathways. In this assessment, a clear basis for exercising this option was not apparent. It will be shown, for example, that carcinogenic risk is dominated by the potential future domestic use of groundwater in some zones and by consumption of homegrown foods in other zones. So long as a dominant pathway is assumed to be at RME intake levels, assigning average intakes to other pathways would not substantially alter overall intakes, risks, or the substantive findings of this assessment.

2.4.1 Identification of Zones Having Distinct Exposure Concentrations and/or Pathways

The Offpost OU is a large, heterogeneous area with a variety of characteristics that can affect exposure levels. Specifically, distinct zones exhibit distinct exposure concentrations of COCs in groundwater, surface water, and surficial soil, including hot spots where contaminant levels are higher than the average for the entire Offpost OU. In addition, population density, land use, and water use varies throughout the Offpost OU. The greatest population densities are associated with urban land use in the southwestern portion of the Offpost OU, an area with low levels of RMA-related chemicals. Water use is distinctly different north of the irrigation canals, where surface water is available for agricultural water use, in contrast to south of the irrigation canals, where dryland agriculture is dictated by the unavailability of ditch water.

Considering these factors, the Offpost OU has been subdivided into six zones with distinct exposure conditions. Each of these zones constitutes a distinct exposure assessment. Some zones represent hot spots of groundwater, surface-water, and/or soil contamination as compared to the other areas of the offpost area. The primary factor used to define the zones was the pattern of COC concentrations in groundwater. Five zones having distinctly different groundwater

contamination patterns were the starting point in defining the exposure zones. In addition, the spatial pattern of COCs in surficial soil was used to refine the boundary of one of the five groundwater zones. Two of the groundwater zones include the most contaminated surface-water body, First Creek. Differences in water use north and south of the canals were considered in further disaggregating groundwater zones that straddle the canals.

Figure 2.4.1-1 schematically delineates the dominant patterns of groundwater contamination of the Offpost OU. A broad area, extending from the north and northwest boundaries of RMA to the South Platte River, exhibits varying levels of COCs. The maximum downgradient extent of this contamination area is defined primarily by relatively low levels of DIMP (i.e., DIMP in excess of CRLs). Slightly elevated levels of chloride and other mobile groundwater COCs, such as chloroform, have also been observed within this area and more than 2 miles from RMA.

Within this inclusive area of RMA-related groundwater contamination, three distinct plumes exhibiting the highest concentrations of characteristic RMA chemicals occur: the northern paleochannel, the First Creek paleochannel, and the northwest paleochannel. The latter two plumes emanate from RMA's north boundary and bifurcate, following paleochannels where the alluvial aquifer is relatively thick and contains coarser sediment.

The plumes having higher concentrations of RMA chemicals exhibit characteristically different levels of particular COCs. The northern paleochannel is characterized by relatively elevated levels of carbon tetrachloride, chloroform, CPMSO, and dibromochloropropane. Carbon tetrachloride, detected in the northern paleochannel at a maximum concentration of 11.5 μg/l, was not detected elsewhere. Maximum concentrations of chloroform are more than an order of magnitude greater in the northern paleochannel than elsewhere in the Offpost OU, while maximum concentrations of CPMSO and dibromochloropropane are approximately five times greater in this area than elsewhere.

The First Creek paleochannel of groundwater contamination is so designated because the paleochannel along which groundwater flows in this area is aligned with First Creek. Groundwater in the First Creek paleochannel is characterized by aldrin, dieldrin, 1,2-dichloroethane,

dichlorobenzenes, dicyclopentadiene, DIMP, DDE, and high levels of total dissolved solids (e.g., sodium and chloride). The maximum concentration of DIMP observed in the First Creek paleochannel is more than five times the maximum observed in any other location in the Offpost OU. Maximum concentrations of chloride in excess of 1000 mg/l were observed along the First Creek paleochannel.

Within 0.5 mile of the north boundary, and upgradient of the locale where the First Creek and northern paleochannels bifurcate, levels of some of the more mobile groundwater contaminants have been reduced by the operation of the NBCS system (ESE, 1988a). This area exhibits somewhat lower concentrations of mobile chemicals but relatively high levels of less mobile chemicals, such as the OCPs. This area, although somewhat difficult to define on a map, is considered to have distinct groundwater quality characteristics.

The northwest boundary plume contains only a few chemicals at significantly elevated concentrations, particularly chloroform, chlorobenzene, arsenic, and dieldrin. Most COCs are not observed in this area.

Beyond this complex pattern of groundwater contamination, offpost surface water and surficial soil also exhibit characteristic patterns of contamination. The most contaminated offpost surface-water body during 1985-1990 was First Creek, which extends from RMA's north boundary to O'Brian Canal in a northwesterly direction. Thus, the spatial pattern of surface-water contamination was consistent with a pattern observed in the groundwater. First Creek discharges to O'Brian Canal, where significantly elevated levels of DIMP and fluoride have been observed (1985-1990).

The distribution of COCs in surficial soil contamination is relatively uniform over most of the Offpost OU within about 1 mile of RMA to the northwest, north, and east, with the exception of a limited area within approximately 0.5 mile of the intersection of 96th Avenue and Peoria Street, where soil concentrations are higher. This area immediately north of the NBCS has experienced a reduction in groundwater concentrations of relatively mobile groundwater chemicals since commencement of full-scale operation of the containment system in 1982

(ESE, 1988a). Thus, this limited zone may be distinguished from both the northern paleochannel and the First Creek paleochannel on the basis of both groundwater and surficial soil contaminant distributions. The high spatial density of surficial soil sampling was also used to distinguish this zone.

The existing contaminant distribution in groundwater, surface water, and surficial soil, as well as differences in land and water use, were considered in mapping six zones where exposures are expected to be distinct from each other (Figure 2.4.1-2). The outermost boundary shown in Figure 2.4.1-2 is the extent of known contamination associated with RMA, defined as the Offpost OU by the Federal Facility Agreement (EPA and others, 1989b).

Zone 1 is an area with relatively low levels of COCs in groundwater and surficial soil; it is further subdivided into zones 1A, 1B, and 1C. Zone 1B is the portion of zone 1 south of O'Brian Canal with no permanent surface-water features. The area has a mixture of dryland agriculture, residential, and open space land use. No surface-water supply is available for agricultural use; therefore, water for livestock or small gardens would be supplied by groundwater. Zones 1A and 1C are portions of zone 1 north of O'Brian Canal. The area is predominantly irrigated farmland, with residential, industrial, and commercial land use. Irrigation supply is predominantly by ditch water, though groundwater is used to supplement available surface-water supplies. A distinct boundary between zones 1A and 1C has not been mapped. The distinction between these zones is based on whether the ditch water used for irrigation is collected upstream or downstream of the mouth of First Creek. Low levels of RMA-related contamination have been detected downstream in O'Brian Canal (zone 1A, northeast). Upstream (zone 1C, west) ditch water is expected to be unaffected by RMA-related contamination. Rural residential land use characterizes the exposure scenario expected to result in reasonable maximum exposure levels now and probably in the future.

Zone 2, south of O'Brian Canal, is an area of relatively high levels of COCs in groundwater, low levels of COCs in surficial soil, and no permanent surface-water features. Zone 2 is also referred to as the northern paleochannel for groundwater. The area is used for dryland

agriculture, open space, and residential land use. A rural residential land use is expected to result in maximum exposure levels under existing and probable future conditions. Agricultural water supply for livestock and small garden watering would be exclusively from groundwater.

Zone 3, south of O'Brian Canal, is an area of relatively high concentrations of OCP COCs in surficial soil, groundwater, and surface water. Zone 3 has traditionally been used for dryland agriculture and residential land but has recently been purchased by Shell Oil Company and is expected to be unoccupied for an indeterminate period of time, at least until completion of remedial activities. First Creek flows through zone 3.

Zone 4, south of O'Brian Canal, is an area of relatively high concentrations of COCs in groundwater and surface water and relatively low levels of COCs in surficial soil. Zone 4 has traditionally been used for dryland agriculture, open space, and residential land, but has recently been purchased by Shell Oil Company and is expected to be unoccupied until completion of remedial activities. First Creek flows through zone 4, also referred to as the First Creek paleo-channel for groundwater contaminant transport.

Existing human exposure in zones 3 and 4 are negligible. The most probable future land uses are commercial/industrial and/or urban residential (no farm animals). Of these probable future land uses, urban residential is expected to result in higher exposure levels.

Zone 5, south of O'Brian Canal, is an area with moderate concentrations of COCs in groundwater and relatively low concentrations of COCs in surficial soil contamination. No permanent surface-water features are in zone 5. The land is primarily used for dryland agricultural and commercial use. Ditch water is not available; therefore, agricultural water supply for livestock is assumed to be provided by alluvial groundwater. Zone 5 is part of the northwest boundary plume. The reasonable maximum exposure scenario for zone 5 is commercial/industrial.

Zone 6 is the extension of the northwest boundary plume to the north of O'Brian Canal, exhibiting moderate levels of COCs in groundwater and relatively low concentrations of COCs in surficial soil contamination. Predominant land uses are irrigated farmland and residential and commercial use. Irrigation water is primarily supplied by available ditch water although alluvial

groundwater may be used as a supplement. Ditch water in zone 6 is not expected to be contaminated by RMA. The rural residential land use results in reasonable maximum exposure levels now and in the foreseeable future.

In summary, portions of the Offpost OU containing RMA-related chemicals have been defined so that within each zone, exposure conditions are expected to be similar to but distinct from the other zones. This procedure permits this assessment to address hot spots of contamination and the diversity of land and water use in the Offpost OU. All the complete exposure pathways identified in Section 2.3 are assumed to be complete in zones 1, 2, and 6 except those associated with direct contact with surface water and sediment. In these zones, a rural residential land use involving consumption of homegrown vegetables, milk, meat, and eggs results in RME exposures under existing and probable future conditions.

Anticipated changes in land use in zones 3 and 4 and the purchase of property by Shell Oil Company are expected to substantially reduce the potential for human exposure by all pathways in these zones. The degree of reduction appropriate for consideration in this risk assessment depends on the extent that access is restricted and the permanence of land use changes. For purposes of the EA, it was assumed that urban residential land use is possible in the future. In the urban residential land use, it is assumed that exposure to meat, dairy, and eggs would not occur but that vegetable gardens are possible. It appears more likely, however, that such use will be prevented at least until completion of the final remediation. In addition, plans for improvement of 96th Avenue as an access road for the proposed regional airport may result in predominantly commercial/industrial land use in these zones. As mentioned in Section 2.2.2.2, zone 5 is zoned industrial over the majority of its area, is currently developed for industrial uses, and is projected as industrial land use for the future.

2.4.2 Exposure Assessment Procedures and Exposure Point Concentrations

This section describes the procedures and resulting exposure point concentrations to be used in the exposure assessment. The procedures used to estimate RME concentrations are based on and are consistent with RAGS (EPA, 1989a). For media and locations with adequate monitoring

data, the RME concentrations are the UL95 but not greater than the maximum observed concentration. Models based on equilibrium partition coefficients were used to estimate exposure concentrations for media with insufficient sampling and analytical data, particularly agricultural products. The RME concentrations calculated using food chain models were based on UL95 concentrations in associated abiotic media (groundwater, surface water, and soil) in conjunction with RME values of the equilibrium partition coefficients (Section 2.1).

Existing concentrations (data collected from 1985 through 1991) appear to be decreasing in some media. For the human health risk assessment, data collected from 1989 through 1991 were assumed to represent future concentrations conservatively over the maximum exposure duration (30 years) for soil and groundwater (Section 2.3). The substantial treatment and control of groundwater contaminant migration across RMA boundaries indicate that concentrations will decline as indicated in Volume VII, Appendix E. CMP data indicate that groundwater concentrations of certain COCs have been decreasing since 1985. ESE (1988a) also demonstrated that concentrations of some chemicals in groundwater near RMA's north boundary declined substantially during 1982 and 1983, shortly after full-scale operation of the NBCS was implemented. Improvements were made to the NBCS and/or the northwest boundary containment system in 1988, 1990, and 1991 under the Boundary System Improvements IRA program. These recent improvements have also caused subsequent declines in groundwater concentrations in the Offpost OU.

2.4.2.1 Statistical Procedures Used to Evaluate Monitoring Data

Monitoring data sets were defined from the zones of the Offpost OU where exposure conditions were believed to be similar but distinct from other zones (Section 2.4.1). The exposure concentration is given by the UL95 but not greater than the maximum positively quantified concentration in the data set. The algorithm used in calculating the UL95 is described as follows:

1. Replace all values listed as less than the CRL by one-half the CRL (EPA, 1989a).
2. Determine goodness of fit to normal and lognormal distributions, using the Shapiro and Wilk W test (Gilbert, 1987). The Shapiro and Wilk test can be used to test lognormality by taking the natural logarithms of the data, and then testing for normality.

3. If the coefficient of variation (standard deviation divided by the mean) is less than 1.2, use normal procedures (e.g., equation 11.6 of Gilbert, 1987; see also Gilbert, p. 164, for the coefficient of variation criterion).

4. If the coefficient of variation exceeds 1.2, select the distribution type (normal or lognormal) that fits the data according to the Shapiro and Wilk W test. Then use Gilbert equation 11.6 for normal or Gilbert equation 13.13 for lognormal.

5. If the UL95 exceeds the maximum detected concentration, verify whether this is the result of nondetect data with unusually high CRLs, delete all nondetects where the CRL is greater than the maximum detect, and repeat steps 2 through 4.

6. Exposure concentration equals UL95 or maximum detect, whichever is smaller.

2.4.2.2 Model Used to Estimate 30-Year Groundwater Exposure Point Concentration

Concentrations of contaminants in the groundwater in the Offpost OU will continue to decline with the operation of boundary containment systems. It is difficult, however, to make an accurate estimate of the rate of decline because many of the processes affecting contaminant fate and transport are poorly understood (Section 1.4, Appendix E of the FS) and are, therefore, not modeled. The purpose of this section is to provide a conservative illustrative example of expected future groundwater concentration declines.

In the interest of simplifying the analysis, future decline estimates are made for only two major risk drivers, aldrin and dieldrin, and only in the groundwater zones 3 and 4. The FS modeling results presented in Appendix E of the FS (Figure E17) are used to estimate a decline rate for each compound and each zone. Appendix E of the FS estimates the retardation coefficients for dieldrin to range from 2 to 5. An average retardation coefficient of 3.5 for both dieldrin and aldrin is used for this analysis. Consistent with the methodology presented in Appendix E of the FS, the NBCS effluent concentrations of aldrin and dieldrin are assumed to be one-half the CRL of 0.05 μg/l for each compound. Actual values will be much lower, considering the affinity of dieldrin and aldrin to adsorb to carbon. In addition, the operation of the Offpost IRA A intercept and treatment system was not considered in this analysis. This system should accelerate contaminant declines in the Offpost OU by a considerable margin.

The rate of decline of the UL95 exposure point concentration value is assumed to be directly proportionate to the rate of decline of the simulated maximum concentration of dieldrin in the FS

North model. This assumption is conservative because the UL95 value (which is assumed to be more representative of concentrations throughout the zone) will tend to decline more rapidly than the maximum value. Existing data indicate that the majority of the contaminant mass is in areas of relatively high permeability, which will tend to clean up more rapidly.

The future exposure point concentration values are calculated as follows:

$$UL95_t = \frac{Cmax_t}{Cmax_{t=0}} \times UL95_{t=0}$$

where:

$UL95_t$ = Upper 95th percentile confidence limit of the mean at time t

$Cmax_t$ = Maximum concentration in the FS North model at time t

$Cmax_{t=0}$ = Initial maximum concentration in the FS North model

$UL95_{t=0}$ = Initial upper 95th percentile confidence limit of the mean

2.4.2.3 Models Used to Estimate Concentrations in Agricultural Products

Limited sampling of agricultural products was performed as part of the RI. Cattle tissue samples included a variety of tissues from a cow that had died after ingesting a length of rope and fat biopsies collected from two healthy cattle. Each of these cattle had been kept near the intersection of Peoria Street and 96th Avenue, an area with relatively high soil, surface-water, and groundwater COC concentrations. Samples of chicken tissues, including eggs, were also collected from the same location, with most samples from an unhealthy animal. These samples are insufficient for estimation of exposure concentrations in eggs, meat, and milk throughout the Offpost OU. Samples of vegetable crops were not collected as part of the RI.

Equilibrium partitioning models were used to estimate exposure concentrations in vegetables, eggs, meat, and milk. These models assume that the crops or livestock have bioaccumulated chemicals from the environment and exhibit equilibrium tissue concentrations in response to the levels of COCs in the soil, feed, and/or water. This approach is acceptable under current

Superfund guidance (EPA, 1989a). Food chain model equations used in this assessment are described below.

2.4.2.3.1 Chicken Eggs

It was assumed that chicken eggs will attain an equilibrium concentration of a chemical directly proportionate to the concentration in soil when the chicken is fed by scattering feed on the ground. It was assumed that the feed was purchased commercially and contributes relatively little to the chicken's total exposure. In this case it was assumed that:

$$CF_e = K_{se}C_s \qquad (2.4.2\text{-}1)$$

where:

CF_e = the concentration of chemical in whole egg (mg/kg)

K_{se} = equilibrium partition coefficient

C_s = concentration in surficial soil (mg/kg)

Virtually all studies identified in the technical literature addressed bioaccumulation from contaminated feed. Cases of soil exposure have not often been studied because this scenario does not occur in modern commercial poultry management. A study by Putnam and others (1974) provided the only data on bioaccumulation from contaminated soil. This pathway was evaluated for aldrin/dieldrin alone because dieldrin was the only COC detected in eggs from the Offpost OU. The RME dieldrin concentration in eggs was estimated to be 1.7 μg/kg.

2.4.2.3.2 Vegetables

The model equation used to estimate exposure concentrations in vegetables for most COCs is as follows:

$$\begin{aligned} CF_v &= C_{gw}[RF \times K_{wr} + (1 - RF)(f_eK_{dep} + K_{wp})]GWF \\ &+ C_{gw}[RF \times K_{wr} + (1 - RF)(f_eK_{dep} + K_{wp})](1 - GWF) \\ &+ (C_s/5)[RF \times K_{sr} + (1 - RF)K_{sp}] \end{aligned} \qquad (2.4.2\text{-}2)$$

where:

CF_v = concentration of chemical in vegetables (mg/kg)

C_{gw} = chemical concentration in groundwater applied as irrigation water (mg/l)

RF = fraction of total homegrown vegetable consumption comprised of roots/tubers

K_{wr} = equilibrium partition coefficient relating chemical concentration in roots/tubers (expressed on a fresh weight basis) to concentration in the soil aqueous phase (l/kg)

f_e = fraction of total consumption of aboveground plant parts comprised of exposed produce (not grain)

K_{dep} = 10 x I/M (l/kg) [(where I is interception storage (cm); M is the mass of aboveground plant parts per unit area (kg/m^2)]

K_{wp} = equilibrium partition coefficient relating chemical concentration in aboveground plant part (expressed on a fresh weight basis) to concentration in the soil aqueous phase (l/kg)

GWF = fraction of total irrigation water supply derived from groundwater

C_{sw} = chemical concentration in surface water applied as irrigation water (mg/l)

C_s = chemical concentration in surficial soil (mg/kg)

K_{sr} = equilibrium partition coefficient relating chemical concentration in roots/tubers (expressed on a fresh weight basis) to concentration in the bulk soil

K_{sp} = equilibrium partition coefficient relating chemical concentration in aboveground plant parts (expressed on a fresh weight basis) to concentration in the bulk soil

Procedures used to estimate the chemical specific partition coefficients, K_{wr}, K_{wp}, K_{sr}, and K_{sp}, and the values used in this assessment were presented in Section 2.1.1.

This equation was based on the following assumptions:

1. Contributions to residue levels in plants via root uptake from irrigation water, deposition of spray irrigation on exposed surfaces, and root uptake from residual soil contamination were considered to be additive.

2. The water quality of the soil aqueous phase was assumed to be approximately equivalent to that of the applied irrigation water.

3. Chemical mass deposited on exposed plant surfaces was assumed to be the residue after evaporation of the intercepted spray.

4. Deposited materials were assumed not to be absorbed.

5. Aboveground vegetative tissue was assumed not to be rinsed before consumption.

6. Concentrations of COCs in the root zone soil was assumed to be approximately one fifth the concentration measured in surficial soil (depth interval = 0.1 foot).

Assumption 1 is not realistic for chemicals with high soil adsorption coefficients, requiring a modification for chemicals discussed later in this section. Assumptions 2 and 3 may be unnecessarily conservative for volatile COCs that may volatilize during irrigation water use and before absorption by plants. Assumption 4 is nonconservative, but its nonconservative effects are expected to be counteracted by assumption 5. Assumption 6 is supported by available monitoring data, the fate and transport properties of surficial soil COCs, and the probable mechanism (airborne deposition) that led to surficial soil contamination of the Offpost OU (HLA, 1992).

Plants are known to bioaccumulate chemicals from the soil and through the roots from aqueous nutrient solutions. There is considerable evidence that bioaccumulated residue levels vary across distinct plant tissues (e.g., reproductive tissues, leaves/stems, and roots/tubers). In this assessment, a distinction was made between aboveground plant parts and roots/tubers. This distinction appears important for hydrophobic pesticides, for which this pathway is a relatively important contributor to total exposure in this assessment. Consequently, the model equation was based on separate estimations of chemical concentrations in edible roots and tubers (C_r) and in aboveground plant parts (C_p).

The concentration of chemicals in a long-term average diet of a variety of vegetables (CF_v) was estimated as a diet-weighted average of C_r and C_p ($CF_v = RF \times C_r + [1-RF] \times C_p$), where RF is the fraction of homegrown root/tuber vegetables compared to total consumption of homegrown vegetables. Tables 2.1-6 through 2.1-9 show that bioaccumulated residue levels are expected to be greater in roots/tubers than in aboveground plant parts (i.e., $K_{wr} \geq K_{wp}$ and $K_{sr} \geq K_{sp}$). Thus, a conservative estimate of CF_v results from a conservatively high estimate of RF. Consistent with data on consumption of homegrown vegetables (EPA, 1989c; Section 2.4.3), a reasonable maximum estimate (90th percentile) of RF is 0.51.

It was assumed that C_r and C_p (concentration in root and aboveground plants, respectively) are the result of additive contributions from (1) applied irrigation water and (2) residual contamination of the bulk soil:

$$C_r = C_{r,w} + C_{r,s}$$

$$C_p = C_{p,w} + C_{p,s}$$

where:

w and s subscripts represent the contribution from water and soil.

$C_{r,w}$ and $C_{p,w}$ are directly related to the concentration in the soil aqueous phase, C_w (Briggs and others 1982, 1983).

$$C_{r,w} = K_{wr}C_w$$

$$C_{p,w} = K_{wp}C_w \qquad (2.4.2\text{-}3)$$

where:

C_w = concentration in the soil aqueous phase, assumed to be equivalent to applied irrigation water (i.e., $C_w = C_{iw} = GWF \times C_{gw} + [1\text{-}GWF]\, C_{sw}$)

An additional contribution to uptake via the roots is uptake from chemicals based on the depth-averaged concentration in the root zone.

$$C_{r,s} = K_{sr}C_s/5$$

$$C_{p,s} = K_{sp}C_s/5$$

Surficial soil concentrations were divided by 5 to estimate a depth-averaged concentration in the root zone. The soil COCs are strongly adsorbed to soil particles (Section 2.1) and are not expected to be readily leached through the soil column. Most of the available surficial soil data are from the upper 0.1-foot interval of soil from untilled areas. A limited number of collocated and nearby samples composited from 0.5-foot cores contained less than one-fifth of the 0.1-foot sample, or nondetectable levels of COCs, indicating that virtually all surficial soil contamination is limited to the upper 0.1-foot interval. Only the upper 0.1-foot interval samples were used to estimate surficial soil concentrations because they were more numerous, had greater

concentrations, and had a higher detection frequency. Consequently, it is appropriate to divide the concentrations by 5 to estimate the average concentration in a 0.5-foot-depth root zone.

It was further assumed that spray irrigation would result in the deposition of chemical residues on the aboveground plant parts in addition to the amount taken up by the roots. A simplified model of the deposition process was based on two principal assumptions:

1. Deposited chemicals were the residual left after evaporation of the intercepted spray.
2. Deposited materials were not absorbed and aboveground vegetative tissue was not rinsed before consumption.

The model of the spray irrigation/deposition process was based on the following concept: when irrigation water is applied via spray, a specific amount of water is retained by the leaves and stems (interception storage, Donigan and Davis, 1978). After irrigation, the intercepted water evaporates, leaving behind 100 percent of the contaminant as residue. This contaminant may be washed off by subsequent irrigation but is replaced by an equivalent mass. The residue is neither lost by volatilization or photolytic degradation, nor is it absorbed by the plant. This simple model was the only available method that can be applied using available data for all COCs. It combines both conservative and nonconservative assumptions, which are presumed to counterbalance one another. This assumption is very conservative for volatile COCs. Grain was assumed to be protected by husks, so this term was not added to the portion of total vegetable consumption contributed by grain. Thus, the term $f_e K_{dep} C_w$ was added to equation 2.4.2-3 to estimate the additive effect of accumulation from applied irrigation water resulting from root uptake and foliar deposition.

It was necessary to modify the basic plant uptake model represented by equation 2.4.2-2 for organochlorine pesticides and heavy metals (specifically aldrin/dieldrin, arsenic, chlordane, DDE/DDT, endrin/isodrin, and manganese). Because of the tendency of these COCs to adsorb to soils (see Table 2.1-5), one of the fundamental assumptions used in the derivation of equation 2.4.2-2 is not satisfied: the concentration of these COCs in the soil aqueous phase would not be approximately equivalent to that of the applied irrigation water under any realistic

irrigation scenario. If these chemicals were applied via irrigation water, they would adsorb to the soil, causing little increase in soil aqueous phase concentrations even after many years of irrigation.

To illustrate, consider the following realistic hypothetical situation. Existing soil concentration after tillage is $C_s = 0.1 \mu g/gm$ in a root zone of depth, d = 20 cm. The chemical has a $K_d = 1000\ cm^3/gm$. The root zone aqueous-phase concentration would be $C_w = C_s/K_d = 0.1\ (\mu g/gm)/1000\ (cm^3/gm) = 0.1\ \mu g/l$. The total mass of chemical in the soil per unit area is given by $C_s \times p \times d = 0.1\ \mu g/gm \times 1.7\ gm/cm^3 \times 20\ cm^3/cm^3 = 3.4\ \mu g/cm^2$. Application of irrigation water at a rate, I = 60 cm/yr (0.06 $l/cm^2/yr$), containing chemical concentration, $C_{iw} = 1 \mu g/l$ would add $I \times C_{iw} = 0.06\ \mu g/cm^2/yr$, a negligible addition to the existing mass in the root zone (3.4 $\mu g/cm^2$), and most of this annual chemical addition to the root zone would be adsorbed with a similar negligible effect on the aqueous-phase concentration. Specifically, the aqueous-phase concentration would increase by $(I \times C_{iw})/(p \times d \times K_d) = 1.8 \times 10^{-3}\ \mu g/l/yr$. In this scenario, assuming no losses of chemical from the root zone irrigation, water must be applied at 60 cm/yr for approximately 500 years before the soil aqueous-phase concentration would reach the level (1 $\mu g/l$) in the irrigation water. In fact, consideration of plausible half-lives for the chemical in soil would dictate that concentrations would never reach that level. Qualification of such loss terms is complicated and highly uncertain, so a conservative assumption has been made that such hydrophobic chemicals are persistent in soil.

Assuming no losses of chemical from the root zone, the concentration is increasing linearly with time under constant irrigation additions. Targeting a 30-year exposure duration, the average incremental aqueous phase concentration is simply given by the concentration after 15 years, i.e. [15 (yr) x I (cm/yr) x C_{iw} ($\mu g/l$)]/[p (gm/cm^3 x d (cm) x K_d (cm^3/gm)]. If this term is introduced into the foregoing derivation of equation 2.4.2-2, K_{wp} and K_{wr} may be replaced by the relationships, $K_{wp} = K_{sp}K_d$ and $K_{wr} = K_{sr}K_d$, resulting in an alternative formula for hydrophobic COCs:

$$CF_v = C_{iw}[RF \times \{(15 \times I)/(p \times d)\}K_{sr} + (1 - RF)(f_e K_{dep} + \{(15 \times I)/(p \times d)\}K_{sp})] + (C_s/5)[RF \times K_{sr} + (1-RF)K_{sp}]$$

Similar revisions were applied for hydrophobic COCs (aldrin/dieldrin, arsenic, chlordane, DDE/DDT, endrin/isodrin, and manganese) in subsequent equations for concentration in meat and dairy products.

2.4.2.3.3 Beef

Cattle kept in the Offpost OU may bioaccumulate COCs from drinking water supplies (surface and/or groundwater), direct ingestion of contaminated soil while grazing, and residues that have bioaccumulated in forage. The predicted concentration in beef was estimated using the following equation:

$$\begin{aligned} CF_m &= C_{gw} K_{pm} GWF (K_{wp} + I_{pwm}) \\ &+ C_{sw} K_{pm}(1 - GWF)(K_{wp} + I_{pwm}) \\ &+ C_s K_{pm}(K_{sp}/5 + I_{ps}) \end{aligned} \qquad (2.4.2\text{-}4)$$

where:

CF_m = concentration of the chemical in beef (mg/kg, fresh weight)

K_{pm} = equilibrium partition coefficient relating chemical concentration in beef (fresh weight) to concentration in feed (fresh weight)

I_{pwm} = ratio of water consumption (l/day) to feed consumption (kg/day) by beef cattle (l/kg)

I_{ps} = the ratio of direct soil ingestion to feed consumption by cattle

The model assumed that absorption was similar regardless of the medium ingested and that feed/forage may have been contaminated by uptake from soil or irrigation water.

A contribution to meat levels from feed/forage is given by (Kenaga, 1980):

$$C_{m,p} = K_{pm}C_p$$

where the concentration in feed is estimated by the following:

$$C_p = C_{gw}GWF \times K_{wp} + C_{sw}(1 - GWF)K_{wp} + (C_s/5)K_{sp}.$$

The contribution to chemical concentrations in meat from water supply is given by:

$$C_{m,w} = K_{pm}C_wI_{pwm}$$

where:

$$C_w = C_{iw} = C_{gw}GWF + C_{sw}(1\text{-}GWF)$$

For hydrophobic chemicals (see previous subsection: Vegetables), the concentration in the soil aqueous phase is not equal to that of the applied irrigation. The effect of the modified plant uptake model for those COCs is that K_{wp} in equation 2.4.2-4 is replaced by $(15I/pd)(K_{sp}) = 26.4\ K_{sp}$.

The contribution to chemical concentrations in meat from direct soil ingestion was given by the following equation and based on the assumption of equal absorption by soil and feed/forage ingestion:

$$C_{m,s} = K_{pm}C_sI_{ps}$$

The assumption that absorption is the same regardless of the medium ingested is required because nearly all data on bioaccumulation by cattle result from studies where the chemical was administered with the feed.

Finally, equation 2.4.2-4 was derived by combining all routes of exposure and rearranging the routes to highlight the contributions from groundwater, surface water, and soil:

$$CF_m = C_{m,p} + C_{m,w} + C_{m,s}$$

2.4.2.3.4 Dairy

The concentration in whole milk (CF_d) was estimated by the following:

$$\begin{aligned} CF_d &= C_{gw}K_{pd}GWF(K_{wp} + I_{pwd}) \\ &+ C_{sw}K_{pd}(1 - GWF)(K_{wp} + I_{pwd}) \\ &+ C_sK_{pd}(K_{sp}/5 + I_{ps}) \end{aligned} \qquad (2.4.2\text{-}5)$$

where I_{pwd} is analogous to I_{pwm}, only for dairy cattle

For hydrophobic chemicals (aldrin/dieldrin, arsenic, chlordane, DDE/DDT, endrin/isodrin, and manganese), K_{wp} is replaced by $26.4\ K_{sp}$ in equation 2.4.2-5.

The derivation and basis of equation 2.4.2-5 is identical to 2.4.2-4. Values for the chemical-specific parameters used in equations 2.4-4 and 2.4-5 are provided in Section 2.1.1.

2.4.2.4 Summary of Nonchemical-specific Parameters

The models presented for estimation of chemical concentrations in agricultural products require two categories of input parameters: chemical-specific (Section 2.1.1) and nonchemical-specific (summarized in Table 2.4.2.4-1 and below).

2.4.2.4.1 Groundwater Fraction Used for Irrigation (GWF)

The fraction of applied irrigation water that comprises groundwater varies within the Offpost OU, depending on the availability of more economical surface-water supplies. North of the irrigation canals, groundwater is used only to supplement available surface-water supplies. ESE (1988a) summarizes the findings of two groundwater modeling studies supporting an estimate of GWF ranging from 0.05 to 0.20, leading to a best estimate of 0.1 and an RME of 0.16 (90th percentile of triangular distribution with minimum of 0.05 maximum of 0.2 and mode 0.075). This value was applied in zones 1A, 1C, and 6 (Section 2.4.1). Along First Creek and the First Creek impoundment, it is possible that groundwater or surface water might be used for agricultural water supply. GWF may range from 0.0 to 1.0 in zones 3 and 4, with a best estimate of 0.5 and an RME of 0.9 (90th percentile of a uniform distribution with minimum of 0 and maximum of 1). In zones 1B, 2, and 5, there are no permanent surface-water features. In these areas, it was assumed that all agricultural water supply would be from groundwater sources, with GWF = 1.0.

2.4.2.4.2 Fraction Exposed (f_e)

The fraction of consumption of homegrown aboveground vegetables, excluding corn, that are exposed was calculated from data presented by EPA (1989d). Corn comprises 38 percent of homegrown aboveground vegetables ingested; therefore, the best estimate of f_e is 0.62. The variability in individual diets supports the use of 1.0 as an RME value for f_e.

2.4.2.4.3 Partition Coefficient Deposited from Spray (K_{dep})

This parameter represents the concentration in aboveground plant parts resulting from the interception of spray on plant leaves and stems, with subsequent evaporation and chemical

residues. K_{dep} was estimated using data on interception storage from Donigan and Davis (1978) and data on yield per acre from Knisel (1980). The best estimate for K_{dep} is 2.4 l/kg, and a reasonable maximum estimate is 3.5 l/kg.

2.4.2.4.4 Cattle Water/Feed Intakes (I_{pwm} and I_{pwd})

These parameters are defined by dividing daily water ingestion by daily feed ingestion for beef and dairy cattle, respectively. MLE and RME values are presented in Table 2.4.2.4-1.

2.4.2.4.5 Cattle Feed/Soil Intake (I_{ps})

This parameter is the ratio of incidental soil ingestion to forage ingestion by grazing cattle. No distinction has been made between beef and dairy cattle. The best estimate for I_{ps} is 0.01, and an RME is 0.014.

2.4.2.5 Sample Calculations and Comparison With the Available Monitoring Data

A sample calculation for one zone is presented below to clarify the calculation procedure and sources of information. This zone was selected considering the availability of site-specific data so that comparisons could be made between the calculated and observed concentrations. Agricultural samples were collected only in zone 3 near the intersection of 96th Avenue and Peoria Street. Typically, only dieldrin was detected above the CRLs in these samples. Dieldrin may accumulate in plant and animal tissues following exposure of the biota to either aldrin or dieldrin (aldrin is readily converted to dieldrin in biota) (Section 2.1.2). Thus, concentrations of aldrin and dieldrin in abiotic media were added for input to the models, with the resultant tissue concentration assumed to be dieldrin. MLE and RME exposure concentrations of aldrin plus dieldrin in surficial soil, surface water, and groundwater of zone 3 are presented in Table 2.4.2.5-1. Chemical-specific parameters pertinent to aldrin/dieldrin are summarized in Table 2.4.2.5-2.

The estimated dieldrin concentration in eggs was estimated as follows:

MLE: $C_e = K_{se}C_s = 0.049 \times 0.093 = 0.005$

RME: $C_e = 0.087 \times 0.126 = 0.011$

One sample of eggs was collected and analyzed for pesticides. Dieldrin, the only COC detected, was quantified at 0.018 mg/kg. The model RME estimate is slightly lower than the single observed value. It is possible that background dieldrin in the feed, or other routes of exposure, contributed to the dieldrin levels in the eggs. The deviation between estimated and observed levels was small and indicated consistency with the food chain model.

The dieldrin concentration in meat is estimated as follows:

$$\text{MLE: } CF_m = C_{gw}K_{pm}GWF(26.4\ K_{sp} + I_{pwm}) + C_{sw}K_{pm}(1 - GWF)(26.4\ K_{sp} + I_{pwm}) + C_sK_{pm}(K_{sp}/5 + I_{ps})$$

$$= 0.00014 \times 0.63 \times 0.5\ (1.85 + 0.93) + 0.00067 \times 0.63 \times 0.5\ (1.85 + 0.93) + (0.093 \times 0.63\ (0.07/5 + 0.01)$$

$$= 0.0001 + 0.0006 + 0.0014$$

$$= 0.0021 \text{ mg/kg}$$

$$\text{RME: } CF_m = 0.00026 \times 0.75 \times 0.9\ (3.7 + 1.2) + 0.0026 \times 0.75 \times 0.1\ (3.7 + 1.2) + (0.126 \times 0.75\ (0.14/5 + 0.014)$$

$$= 0.0009 + 0.0010 + 0.0040$$

$$= 0.0058 \text{ mg/kg}$$

Fat biopsies were collected from two cattle from zone 3. The resultant concentrations of dieldrin in the fat were 0.053 and 0.078 mg/kg, respectively (beef averages 19 percent fat [USDA, 1990]). Because dieldrin partitions predominantly to fatty tissue, the estimated concentration in beef is 0.19 x 0.053 = 0.010, and 0.19 x 0.078 = 0.015. Similar to the results for eggs, the limited monitoring data exhibits somewhat higher concentrations than the model predicted values. Other pesticide results are consistent with the model estimated values (i.e., none were detected and the model estimates for other COCs were less than the CRL). For example, the estimated concentration of DDE in beef is 0.0033 mg/kg (implying 0.017 mg/kg in beef fat), and both cow fat biopsies exhibited less than 0.063 mg/kg of DDE.

The dieldrin concentration in whole milk can be estimated as $CF_d \sim CF_m(K_{pd}/K_{pm})$, a relationship that can be derived from equations 2.4.2-4 and 2.4.2-5. (This relationship is approximately valid for aldrin/dieldrin because $K_{wp} >> I_{pwd} > I_{pwm}$ and $K_{sp} >> I_{ps}$.)

MLE: $CF_d = 0.0021\ (0.13/0.63) = 0.00043$ mg/kg

RME: $CF_m = 0.0058\ (0.15/0.75) = 0.0012$ mg/kg

No samples of milk from the Offpost OU were analyzed for dieldrin. Samples were analyzed for dibromochloropropane, however, which were all less than 0.195 mg/kg. Concentrations were estimated using the proposed model, which predicted a maximum RME concentration of dibromochloropropane in milk of 1×10^{-6} mg/kg in milk (zone 2).

No vegetable samples were collected from the Offpost OU for chemical analysis; therefore, food chain models were used to predict exposure concentrations in vegetables. Sample calculations for dieldrin in zone 3 are as follows:

$$\text{MLE: } CF_v = C_{gw}[RF \times 26.4\ K_{sr} + (1 - RF)(f_e K_{dep} + 26.4\ K_{sp})]GWF + C_{sw}[RF \times 26.4\ K_{sr} + (1 - RF)(f_e K_{dep} + 26.4\ K_{sp})](1 - GWF) + (C_s/5)[RF \times K_{sr} + (1 - RF)K_{sp}]$$

$$= 0.00014\ [(0.30 \times 9) + 0.70\ (0.62 \times 2.4) + 1.85)]0.5 + 0.00067\ [(0.30 \times 9) + 0.70\ (0.62 \times 2.4) + 1.85]0.5 + (0.093 / 5)[(0.30 \times 0.34) + (0.70 \times 0.07)]$$

$$= 0.0004 + 0.0017 + 0.0028$$

$$= 0.0049 \text{ mg/kg}$$

$$\text{RME: } CF_v = 0.00026\ [(0.51 \times 17.2) + 0.49\ (3.5 + 3.7)]0.9 + 0.0026\ [(0.51 \times 17.2) + 0.49\ (3.5 + 3.7)]0.1 + (0.126 / 5)[(0.51 \times 0.65) + (0.49 \times 0.14)]$$

$$= 0.003 + 0.003 + 0.010$$

$$= 0.016 \text{ mg/kg}$$

These values are higher than national average concentrations in vegetables as reported by Gartrell and others (1986), who found less than 0.002 mg/kg in potatoes and leafy vegetables. Concentrations in the Offpost OU would be expected to be higher than national averages because aldrin and dieldrin are significantly elevated above background in surface water, groundwater, and surficial soil.

2.4.2.6 Results

Exposure concentrations in groundwater are provided in Tables 2.4.2.6-1 through 2.4.2.6-6. A list of wells used to characterize each zone is contained in Appendix C. Most COCs exhibited

the highest exposure concentrations in zones 2, 3, and 4. The only exception was trichloroethene whose exposure concentration was highest in zone 6. The frequency of occurrence of organic COCs averaged about 13 percent with higher frequency of occurrence in zones 2, 3, and 4. There are more than 30 samples per COC in zones 1, 2, 4, and 5, with a maximum of 61 samples per COC in zone 1. Zone 3 has 24 samples per COC and zone 6 only 17.

Although zones 2, 3, and 4 are contiguous and directly downgradient of the north boundary, there are important distinctions among the relative proportions of COCs in these zones. For example, chloroform and dibromochloropropane exposure concentrations are substantially higher in zone 2 (northern paleochannel) than in zones 3 and 4; groundwater exposure concentration of dieldrin is much higher in zone 3 than in zones 2 and 4; and DIMP is predominantly associated with the First Creek paleochannel (zone 4).

Frequency of occurrence is relatively low in groundwater zone 1, where organic COCs average only 7 percent frequency of detection above CRLs. Atrazine, benzene, isodrin, DDE, and xylenes were detected in less than 2 percent of the groundwater samples in zone 1. With such a low frequency of occurrence, the exposure concentrations were heavily influenced by the CRL (exposure concentrations will be approximately one-half the CRL) because nondetects are replaced with one-half the CRL. The true exposure concentration may be much less than the calculated value in such instances.

Figures 2.4.2.6-1 and 2.4.2.6-2 show the estimated future groundwater exposure point concentrations (UL95) for a 30-year period. The minimum UL95 value shown on these figures is 0.025 μg/l, which is the assumed NBCS effluent concentration. The estimated future UL95 values are also depicted in Table 2.4.2.6-7. The average values for dieldrin over the 30-year period are 0.057 μg/l and 0.027 μg/l in zones 3 and 4, respectively. The 30-year average values for aldrin in zones 3 and 4 are 0.027 μg/l and 0.036 μg/l, respectively.

Exposure concentrations in First Creek and downstream portions of the irrigation canals are listed in Table 2.4.2.6-8. Exposure concentrations of COCs in First Creek were typically about one-half of corresponding groundwater exposure concentrations in zones 3 and 4, where ground-

water discharges to First Creek. Exposure concentrations were higher in First Creek than in the associated groundwater for arsenic and dieldrin. Because both of these contaminants tend to associate with sediment, the higher concentrations in First Creek may be attributable to suspended material. The surface-water samples were not filtered before analysis.

Exposure concentrations in the soil of the Offpost OU and sediment of First Creek are shown in Table 2.4.2.6-9. All the soil and sediment COCs are pesticides. First Creek, a shallow and intermittent stream, flows through zones 3 and 4.

Further evaluation of the distribution of OCPs in surficial soils indicates that the distribution of the organic contaminants correlates to the dominant wind directions at RMA in zones 3 and 4 but does not follow the trend of decreasing concentrations with distance from RMA in other zones. Several of the compounds detected are or have been commercially available and may have been applied by residential and/or agricultural practices in the surrounding rural area. The patterns indicate that a mechanism of windblown contaminants alone does not account for levels of OCPs in soils outside zones 3 and 4. Instead, agricultural or residential application or use of contaminated irrigation water may be responsible for the observed distributions of OCPs in surficial soil (HLA, 1992). The RI Addendum indicates that a concentration gradient exists north of RMA, decreasing by an order of magnitude within approximately 0.5 miles of the north boundary (HLA, 1992). The concentration gradient loses definition at this point.

North of the canals in particular, it appears that portions of sections 2, 10, 11, and 15 may have been affected by agricultural practices, including intentional application of OCPs, or by irrigation from Burlington Ditch. The presence of dieldrin and other OCPs in Burlington Ditch sediment upstream of First Creek (HLA, 1992) indicates that there are other sources of irrigation water contamination upstream of the Offpost OU.

For these reasons, it is difficult to attribute OCP concentrations in soils to RMA, other than in zones 3 and 4. Soil samples collected outside zones 3 and 4 average 9.5 μg/kg dieldrin, which is approximately equal to the 8 μg/kg dieldrin concentration identified in the RI as the anthropogenic (non-RMA) background concentration for dieldrin (HLA, 1992). Anomalous

samples HA1226WB and HA1231WB were excluded from this average based on the RI Addendum (HLA, 1992). This lends further support to the conclusion that dieldrin soil concentrations outside zones 3 and 4 are due to sources other than RMA. However, in accordance with EPA guidance, the contribution to risk of background concentrations of dieldrin will be quantified in the risk characterization.

Surficial soil concentrations in zone 3 were typically greater than sediment concentrations in First Creek, suggesting that a significant portion of the observed pesticides detected in the sediment may be derived from atmospheric deposition, the apparent pathway resulting in surficial soil contamination, or erosion and runoff from the surrounding soil. Groundwater discharging to First Creek may also contribute to observed levels of pesticides in sediment. Clearly, however, the sediment of First Creek does not represent a hot spot when compared with the surrounding soil.

Exposure concentrations in agricultural products were calculated in each zone in which the pathway is complete for each COC except chloride, nitrate, fluoride, and sulfate. The proposed modeling approaches are not applicable to anionic COCs because they are not bioaccumulated. The results are documented in Appendix C and summarized in Tables 2.4.2.6-10 through 12, which show the maximum estimated exposure concentration and the zone in which it occurs. DIMP was estimated to have the highest exposure concentration of any COC in vegetables (in zone 4) at 22 mg/kg. The highest vegetable concentrations were calculated to occur in zones 2, 3, or 4 for all COCs. Vegetables were predicted to have the highest exposure concentrations of any food product for all COCs. Concentrations in meat are typically higher for the organic compounds than concentrations in dairy products because meat has a higher fat content. However, manganese, an inorganic, was estimated to have the highest concentration of any COC in meat and dairy products.

As documented in Appendix C, calculated exposure concentrations in agricultural products vary throughout the Offpost OU for all COCs, and only the maximum calculated values are presented in Table 2.4.2.6-10 through Table 2.4.2.6-12.

2.4.3 Estimation of Chemical Intakes

Intakes of COCs were estimated for acute, chronic, and lifetime exposure durations in accordance with the RAGS (EPA, 1989a) and supplemental guidance issued March 25, 1991 (EPA, 1991a, Office of Solid Waste and Emergency Response (OSWER) Directive 9285.6-03). The objective of the exposure assessment was to estimate the RME for each pathway as characterized in the referenced guidance. For each of these scenarios, intakes were summed separately by exposure route (i.e., dermal, inhalation, and ingestion). The exposure assessment was structured to address potentially sensitive subpopulations, including children and women of childbearing age. Specifically, RME intakes for a rural residential exposure scenario were estimated for the following subpopulation/duration combinations:

1. Lifetime: age 0 to 30, male/female statistics combined, for evaluation of carcinogenic risks
2. Acute adult female: reasonable maximum one-day exposure to be used as an upper bound on subchronic exposure
3. Chronic adult: male/female statistics combined, for evaluation of chronic noncarcinogenic risks
4. Acute child: reasonable maximum one-day exposure for children age 1 to 9, male/female statistics combined, to be used as an upper bound on subchronic exposure
5. Chronic child: male/female statistics combined, for evaluation of chronic noncarcinogenic risks

As presented in Section 2.4.1 (see also related information in Sections 2.2.2.2 and 2.2.2.3), the Offpost OU has been subdivided into zones within which exposure conditions are similar. The rural residential scenario is assumed to be the land use scenario that leads to RME intakes in zones 1, 2, and 6. The urban residential scenario is assumed to be the land use scenario that will lead to RME intakes in zones 3 and 4, and the commercial/industrial scenario is assumed to be the land use scenario that will result in RME intakes in zone 5. The pathways that have been quantified for each of these land use scenarios are summarized in Table 2.4.3-1. The rural residential scenario would also have included the direct exposure pathways related to surface water and sediment, but those pathways are not complete in zones 1, 2, or 6.

Intakes were estimated using the following equations presented from RAGS (EPA, 1989a).

RAGS Exhibit 6-11: Ingestion of Chemicals in Drinking Water

$$\text{Intake} = CW \times IR_w \times EF \times ED / (BW \times AT)$$

where:

CW = chemical concentration in water (mg/l)

IR_w = ingestion rate (l/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days)

RAGS Exhibit 6-13: Dermal Contact with Chemicals in Water

$$\text{Absorbed Dose} = CW \times SA \times PC \times ET \times EF \times ED \times FC_w / (BW \times AT)$$

where:

SA = skin surface area available for contact (cm^2)

PC = chemical-specific dermal permeability constant (cm/hr)

FC_w = volumetric conversion factor for water (1 l/1,000 cm^3)

ET = exposure time (hours/day)

RAGS Exhibit 6-14: Ingestion of Chemicals in Soil and Sediment

The equation was modified to incorporate BF in accordance EPA (1989a, Appendix A)

$$\text{Intake} = CS \times IR_s \times BF \times FC_s \times FI \times EF \times ED / (BW \times AT)$$

where:

CS = chemical concentration in soil (mg/kg)

IR_s = ingestion rate (mg soil/day)

BF = bioavailability factor, a ratio of chemical absorption when the chemical is ingested with soil compared to absorption in other matrices

FC_s = a conversion factor (10^{-6} kg/mg)

FI = fraction ingested from contaminated source (FI = 1)

RAGS Exhibit 6-15: Dermal Contact with Chemicals in Soil and Sediment

$$\text{Absorbed Dose} = CS \times FC_s \times SA \times AF \times ABS \times EF \times ED / (BW \times AT)$$

where:

AF = soil to skin adherence factor (mg/cm^2)

ABS = chemical-specific absorption factor

Exhibit 6-18 (Ingestion of Contaminated Vegetables) was modified to accommodate use of available data pertaining to consumption of homegrown vegetables.

$$\text{Intake} = CF_v \times IR_v \times EF \times ED / (BW \times AT)$$

where:

CF_v = chemical concentration in homegrown vegetables (mg/kg)

IR_v = consumption rate of homegrown vegetables (kg/day)

Exhibit 6-19 (Ingestion of Contaminated Meat, Eggs, and Dairy Products) was modified to accommodate use of available data pertaining to consumption of meat, dairy, and eggs and was applied separately for each of these food products.

$$\text{Intake} = CF_m \times IR_m \times EF \times ED / (BW \times AT)$$

where:

CF_m = chemical concentration in locally produced beef (mg/kg)

IR_m = ingestion rate (kg/day)

$$\text{Intake} = CF_e \times IR_e \times EF \times ED / (BW \times AT)$$

where:

CF_e = chemical concentration in locally produced eggs (mg/kg)

IR_e = ingestion rate (kg/day)

$$\text{Intake} = CF_d \times IR_d \times EF \times ED / (BW \times AT)$$

where:

CF_d = chemical concentration in locally produced milk (mg/kg)

IR_d = ingestion rate (kg/day)

In the equations for intakes by food consumption, the contaminated fraction term (FI as presented in the original RAGS Exhibits 6-18 and 6-19) was omitted here but is implicitly included in the definition of food consumption rates because these are defined as consumption of locally produced foods.

An alternative approach, used by EPA in the development of RCRA corrective action levels and to support OSWER Directive 9360.1-01 (EPA, 1987b) for provision of alternative water supplies during implementation of final remedial actions, was adopted to estimate inhalation intake resulting from use of domestic groundwater containing volatile chemicals. It was assumed that residents inhale the equivalent mass of chemicals contained in 2 liters of water per day when domestically using water containing volatiles. Therefore, it was assumed that inhalation intakes are approximately equal to ingestion intakes. This assumption is supported by Andelman (1985) and Andelmann and others (1986) and EPA (1987b). Volatile chemicals are defined by OSWER Directive 9360.1-01 (EPA, 1987b). Thus, inhalation intakes are estimated by:

$$\text{Inhalation Intake} = CW \times CR \times EF \times ED / (BW \times AT)$$

where:

CR = contact rate by inhalation route (2 l/day)

The previous equations contain three input parameter categories:

1. Exposure concentrations:

   CW, CS, CF_v, CF_m, CF_e, CF_d

2. Chemical-specific parameters:

   PC, ABS, BF

3. Exposure factors:

   IR_w, EF, ED, BW, AT, SA, IR_s, FI, AF, IR_v, IR_m, IR_e, CR, FC_w, FC_s

Exposure concentrations are presented in Section 2.4.2 and Appendix C. The chemical-specific environmental fate properties of the COCs presented in Section 2.1.1 were used primarily to estimate the exposure concentrations, CF_v, CF_m, CF_e, and CF_d, as presented in Section 2.4.2.

The additional chemical-specific parameters relate to absorption by dermal pathways as described below.

2.4.3.1 Chemical-specific Parameters

The default value recommended by RAGS (EPA, 1989a) was used for the permeability constant for dermal contact with water, PC = 8.4 x 10^{-4} centimeters per hour.

The absorption factor for dermal contact with soil and sediment, ABS, was defined as the product of an absorption factor for the pure compound and a soil-matrix effect. The absorption factors were estimated from information presented in ATSDR (1988a, 1989b) for aldrin, dieldrin, dibromochloropropane, and DDT, ranging from 0.10 to 0.13. The absorption factor for endrin was assumed to be the same as aldrin and dieldrin, based on structural similarities. The matrix effect was assumed to be 0.15, based on Hawley (1985). The resulting ABS values used in this assessment are presented in Table 2.4.3.1-1. The chemicals listed in this table are the COCs for soil and/or sediment, the only relevant media for this exposure pathway.

The bioavailability factor for soil ingestion, BF, characterizes the relative gastrointestinal absorption efficiency of a soil-adsorbed chemical compared with the absorption efficiency of the chemical as administered in studies used to define the dose-response relationship (EPA, 1989a; Shu and others, 1988). Data indicate that rats and guinea pigs absorb substantially less dioxin when administered dioxin-contaminated soil orally compared to dosing procedures commonly used in toxicity studies (e.g., in corn oil, ethanol, or by gavage [Shu and others, 1988; Umbreit and others, 1986; Poiger and Schlatter, 1980]). These studies indicate that the BF for dioxin is between 0.25 and 0.50.

No experimental studies designed to define this parameter have been identified for any COC in this assessment. Richardson and Robinson (1971) reported data suggesting 90 percent dieldrin absorption in pesticide manufacturing workers who were apparently exposed to dieldrin-containing dusts. It is likely that soil adsorption is an important process affecting the BF, and dioxins and polybrominated biphenyls are similar to OCPs in their tendency to adsorb to soil (EPA, 1986a). Consequently, the RME and MLE BF for the OCPs are 0.9 and 0.3, respectively.

2.4.3.2 Exposure Factors

Exposure factors are defined to estimate the RME and generally were selected as the 90th percentile of the distribution of the parameter among the exposed population. Exceptions to this rule occur for body weight (BW) and skin surface area (SA), where 50th percentiles were used as recommended by RAGS (EPA, 1989a). BW always appears in the denominator of intake estimation equations, so selection of a 90th percentile would be nonconservative. In most cases, one or more of the exposure factors in the numerator of the equation (food or water ingestion rates) are expected to be correlated with BW, and selection of a 90th percentile for parameters in the numerator, combined with the 50th percentile of BW, results in an RME estimate. Skin surface area is strongly correlated with body weight (EPA, 1989a), so it is most appropriate to choose the 50th percentile because SA and BW appear as a ratio.

RME values of the exposure factors and the reference sources are presented in Tables 2.4.3.2-1 through 2.4.3.2-3. The following paragraphs describe the interpretation of information in the referenced sources used to define these values.

Ingestion Rate, water (IR_w): The Exposure Factors Handbook (EFH) (EPA, 1989d) presents data from numerous sources supporting the conclusion that the average water ingestion rate (MLE) among adults is approximately 1.4 l/day, and the commonly used value of 2 l/day approximates a 90th to 95th percentile water ingestion rate (RME). Insufficient information is provided on the range or distribution of water ingestion rates among children. It was assumed that variability in water ingestion rates is similar among children and adults, and thus the ratio of RME to MLE would be the same. Some of the same sources cited by EPA (1989d) also provide typical or average water ingestion rates for children (ages one to nine) ranging from 0.4 l/day to 0.8 l/day with an average from three sources of 0.547 l/day (MLE). Therefore, the RME water-ingestion rate for children is (2/1.4) x 0.547 = 0.78 l/day.

Ingestion Rate, soil (IR_s): RAGS (EPA, 1989a) recommends use of 100 and 200 mg/day as RME estimates for adults and children, respectively. These values are supported by several published studies including Binder and others (1986), Clausing and others (1987), Calabrese and

others (1989), Stanek and others (1989), and van Wijnen and others (1989). In estimating lifetime intakes (for carcinogenic risk assessment) and chronic childhood intakes, a time-weighted average (TWA) intake is calculated. This approach is more accurate when intakes vary substantially with age and body weight. Intakes by the soil ingestion pathway vary substantially with age because they are proportionate to the soil ingestion rate divided by body weight; and children, with relatively small body weights, ingest more soil than adults, so this ratio is much larger.

Ingestion Rates: vegetables, meat, eggs, dairy products (IR_v, IR_m, IR_e, IR_d): All the food ingestion rates are intended to represent the 90th percentile among the represented population for the indicated exposure duration. The primary information source for defining the distribution of consumption of various foods was Pao and others (1982). Pao and others (1982) was the preferred source because it is the only recent report providing detailed information on the distribution of consumption rates across a large sample of the American population (30,770 individuals). The source for the homegrown fraction is RAGs and EHF (EPA, 1989a, EPA 1989d).

In 1991, EPA issued guidance as a supplement to RAGS specifying values to be used for adult chronic exposures for IR_v, IR_m, and IR_d. These new recommended values were used in this assessment (Table 2.4.3.2-1). The recommended values are not substantially different from values estimated from Pao and others (1982) and EFH as shown by the following comparison:

Chronic Adult	EPA, 1991	Pao, 1982; EPA, 1989d (as described)
IR_v	0.080 kg/day	0.077 kg/day
IR_m	0.075 kg/day	0.113 kg/day
IR_d	0.300 kg/day	0.455 kg/day

Although the recently recommended EPA (1991a) estimates were used for adult chronic intake estimation (and lifetime exposures where they were assumed equal to adult chronic), the Pao/EFH method was used for all other populations/exposure durations.

Exposure frequency and duration parameter values are presented in Table 2.4.3.2-2. For lifetime and chronic exposures, the exposure frequency was generally set to 350 days/year, as

recommended by EPA (1991a), which allows for two weeks per year away from the residence. For pathways involving direct exposure to surface water or First Creek sediment, exposure frequency was set at 62 days/year. This is the number of days per year when the climatological normal maximum daily air temperature exceeds 80°F at Stapleton International Airport (National Oceanic and Atmospheric Administration [NOAA, 1989]).

Exposure duration for adult chronic and lifetime exposure scenarios was set at 30 years, which is approximately the 90th percentile for occupation of a residence location and the value recommended by EPA (1989a). For chronic childhood scenarios, the exposure duration was set at nine years. This is approximately the minimum exposure duration considered to represent a chronic exposure (EPA, 1989a), and selection of a minimum value is conservative for this scenario because the exposure duration is targeted on the age range during which maximum exposure per body weight occurs (one to ten years). If a longer exposure duration were used, the estimated intakes (per body weight) would be reduced by averaging in periods of adolescence, when exposure to soil contamination and dairy products is lower.

Acute scenarios are designed to represent a RME for one day. Exposure duration (ED) equals 0.00274 days, and locally produced fraction (FI) equals 1. The 90th percentile food consumption rates for one day were used, and dermal exposure to surface water was assumed to occur.

Averaging time is set equal to ED (x 365 days per year) for evaluation of chronic noncarcinogenic health effects, and 70 years (x 365 days per year) for evaluation of carcinogenic risks, as recommended by RAGS (EPA, 1989a). Averaging time is set to 0.00274 days (ED) for the acute scenario.

Body weight and skin surface area parameters are presented in Table 2.4.3.2-3. Values are 50th percentiles as recommended by EPA (1989a) for the designated populations. Childhood ranges from age one to ten in this assessment. For estimation of intakes by the dairy products and direct soil ingestion pathways, age-specific body weights were used to calculate a time-weighted TWA intake as presented in Table 2.4.3.2-1a. Skin surface areas represent 50th percentile

estimates of the surface area of hands and arms for the specified population (Anderson and others, 1985). Data on soil adherence factors is summarized by Sedman (1989), supporting a best estimate of 0.51 milligrams per square centimeter (mg/cm^2) and an RME (maximum of three values reported by Sedman) of 0.9 mg/cm^2.

2.4.3.3 Results

Intakes estimated according to the procedures described herein are documented in Appendix D. For most COCs, intakes were predicted to be highest in zones 2, 3, and/or 4, where exposure concentrations are highest.

Among volatile COCs, zone 2 chloroform intakes are highest. Lifetime intakes of chloroform by pathway and groundwater zone are illustrated in Figure 2.4.3.3-1. Ingestion and inhalation intakes are approximately equivalent and greater than dermal intakes. Exposure concentrations in groundwater, the only abiotic medium in which chloroform is significantly elevated, are much greater in zone 2 than elsewhere, resulting in much higher intakes in zone 2 than elsewhere in the Offpost OU. Oral intakes result predominantly from direct ingestion of groundwater (85 percent), while inhalation intakes are exclusively from the assumed domestic use of shallow groundwater as the primary residential water supply.

Lifetime intakes of dieldrin were found to exceed all other OCPs, (except in zone 4, where chlordane is highest), and dieldrin intakes are greatest in zones 2, 3, and 4, as illustrated in Figure 2.4.3.3-2. More than 99 percent of dieldrin intake was predicted to result from ingestion exposure in these zones. In contrast to chloroform, several exposure pathways contribute significantly to dieldrin lifetime intakes. Under the rural residential scenario of zone 2, vegetables, milk, eggs, groundwater, and meat pathways each contribute more than 10 percent of the total intake. Under the urban residential scenario evaluated in zones 3 and 4, vegetable intake comprises more than 75 percent of total intake, and groundwater ingestion contributes most of the remainder.

Chronic (adult and child) intakes of DIMP in zone 4 are higher than any organic COC regardless of zone. In zone 4, the RME chronic intake by children was found to be

0.25 milligrams per kilogram per day (mg/kg/day), and the adult chronic RME intake was 0.16 mg/kg/day. Exposure due to DIMP results predominantly from ingestion of drinking water (83 percent of total intake) because DIMP is not volatile and does not bioaccumulate readily into foods.

Chronic child intakes exceeded chronic adult (female) intakes, averaging about 80 percent higher for most chemicals. At most, the ratio of chronic child intakes to chronic adult intakes for a given chemical and zone was found to be approximately 4. High values of this ratio were observed for the OCPs, which have relatively high exposure concentrations in dairy products and soil compared to other media. Children were predicted to experience significantly higher exposure by these pathways than adults. As a result, it would be sufficient to evaluate chronic noncarcinogenic effects in children only because this subpopulation experiences the RME.

Acute (one-day) intakes typically exceed chronic (nine-year average) intakes in children by a factor of 5, although the ratio is variable among chemicals due to relative importance of specific pathways. For some pathways (e.g., ingestion of dairy products, soil, and groundwater), exposure is represented as relatively steady from day to day, and for other pathways (e.g., dermal exposure to sediment and surface water, ingestion of homegrown meat and vegetables), exposure may vary substantially from day to day or seasonally. Acute to chronic ratios in adults are slightly less, averaging about 3.

Due to lack of pertinent data and guidance, a separate subchronic exposure scenario has not been defined. Intakes over subchronic exposure durations are expected to be less than acute intakes and greater than chronic intakes. Both acute and chronic intakes will be compared to subchronic reference doses (RfDs) in the risk characterization section (4.1) to evaluate subchronic health effects.

2.4.4 Estimation of Chemical Intakes for Commercial/Industrial Scenario

The exposure assessment equations developed by EPA (EPA, 1989a) were used to calculate the chemical intakes for the following commercial/industrial (C/I) scenario pathways: domestic use of water, dermal exposure to soil, and ingestion of soil. A description of the equations is in

Section 2.4.3 of this document. Where appropriate, the input parameters for the equations were adjusted to conform to current EPA guidance (EPA, 1990a). The C/I RME and MLE input parameters used in the equations are presented in Tables 2.4.4-1 and 2.4.4-2, respectively.

It was assumed that C/I workers would use the shallow groundwater for drinking and showering at the work site. Based on the information presented in Section 2.2.2.2, the types of occupational activities observed could cause workers to be exposed to surface soil through dermal contact and ingestion.

2.4.4.1 Estimation of Chemical Intakes

Calculated chronic RME intakes for the commercial/industrial scenario are contained in Appendix D.

In zone 5, chloroform and arsenic contribute the greatest carcinogenic intakes through the groundwater pathway. Additionally, chloroform and manganese contribute the greatest noncarcinogenic intakes by the groundwater pathway.

The MLE chemical intakes for the C/I scenario are approximately 27 percent less than the intakes calculated using RME intake parameters.

2.4.5 Uncertainty Analysis (Residential)

A limited quantitative uncertainty analysis was performed on exposure intakes. The purpose of this uncertainty analysis is to provide additional information on the range of intakes that may exist among the potentially exposed population and the degree of conservatism inherent in the RME intake estimate. The results may be used to evaluate whether the RME intake is reasonable or to determine the protectiveness of alternative cleanup objectives if the feasibility study determines that it is not feasible to achieve the RME intake.

The RME for purposes of the uncertainty analysis is defined as the 95th percentile from the distribution of exposures. This value is used in comparison with the deterministic RME estimates calculated in Section 2.4.

2.4.5.1 Preliminary Sensitivity Analysis

To limit the scope and level of effort of the uncertainty analysis, a preliminary sensitivity analysis was conducted to identify those parameters whose uncertainty or variability was sufficient to affect the intake estimate. The sensitivity analysis addressed oral and inhalation intakes of arsenic, chloroform, dieldrin, and DIMP in an adult chronic exposure scenario. These chemicals were chosen because it was anticipated that they would contribute significantly to risk and because they have distinct physical chemical properties that are representative of most other COCs. In this analysis, all parameters were set at RME levels as a base case intake estimate. Then each individual parameter was independently adjusted to an MLE value (mean for intensive variables, 50th percentile for extensive variables), and all other parameters were maintained at the RME value. The relative difference from the base case was used as a measure of the sensitivity to uncertainties in the input parameter.

The preliminary sensitivity analysis was conducted separately for each contaminated medium (e.g., all pathways derived from groundwater were summed and considered independently of all pathways derived from soil and surface water) because exposure concentrations for the media had not been determined at the time the preliminary sensitivity analysis was performed. In addition, the plant uptake model and groundwater volatilization models were revised after the preliminary sensitivity analysis. As a result, the sensitivity analysis findings may not be applicable to the final intake equations. To address this potential problem, two steps were taken:

1. Distributions were used in the uncertainty analysis for additional parameters not originally identified as sensitive. In the final uncertainty analysis, only Ipwd, Ipwm, Ips, and IRs were held constant. Each of these parameters had sensitivity of less than 4 percent in the preliminary sensitivity analysis.

2. A final sensitivity analysis using exposure concentration sensitivity and final intake equations was performed for oral and inhalation intakes, combining all media and pathways to verify parameter sensitivity.

The final results confirmed the selection of parameters for distributional input to the uncertainty analysis. Each of the fixed parameters exhibited sensitivity of 2 percent or less in the final analysis. The most sensitive parameters are summarized in Table 2.4.5.1-1.

2.4.5.2 Additional Scoping Considerations

It was infeasible and unnecessary to characterize quantitatively the uncertainty in every intake estimate reported in Appendix D (more than 1000 chemical/route-specific intake estimates are presented). The uncertainty analysis was limited to the critical chemicals that present the greatest risk of carcinogenic and noncarcinogenic effects within each zone. The chemicals of greatest concern are described by zone in Section 4.1.1. The selected chemicals and exposure scenario for each zone are as follows:

Zone 1B: Dieldrin (lifetime)

Zone 2: Chloroform (lifetime)

Zone 3: Dieldrin (child chronic and lifetime)

Zone 4: Arsenic (lifetime), DIMP (child chronic)

Zone 6: Dieldrin (lifetime)

These intake estimates significantly affect the overall assessment of potential health effects in each of the zones, address several of the COCs of greatest concern, and encompass the variety of uncertainties that contribute to overall uncertainty in the exposure assessment. Dieldrin contributes significantly to risk in zone 4, but the dieldrin results in zones 3 and 4 are similar, so findings of the uncertainty analysis in zone 3 can be extended to characterize uncertainty qualitatively regarding zone 4. Zone 5 has a similar mixture of COCs to zone 6 although uncertainty regarding exposure concentrations in zone 6 is probably greater because less data are available in zone 6. Relative contributions to exposure from various chemicals are similar in zones 1A, 1B, and 1C because the same chemical data sets are used; only the water use differs. Zone 1B was selected because exposure and risk estimates are higher than in 1A and 1C. Lessons learned from characterizing the uncertainty in the selected intake estimates can be extrapolated qualitatively to characterize overall uncertainty in the exposure assessment.

Residential intake estimates presented in Appendix D and summarized in Section 2.4.3 represent an RME estimate as defined by EPA (1989a). The RMEs were calculated by defining conservative values for selected input parameters to the intake estimation equations. It is expected

that less than or equal to 5 percent of the exposed population will have intakes exceeding these estimates. The use of conservative values for each input parameter in the intake estimation equation implies a certain degree of correlation between inputs that tend to produce an intake estimate that is more conservative than any of the inputs. For example, it is assumed that the individual who consumes homegrown vegetables at a rate greater than 90 percent of the general population also consumes locally produced meat and dairy products at a rate greater than 90 percent of the population and resides at a location with above average exposure concentrations, spending most of the time at home. Although this situation may occur, it is less likely in aggregate than the probability of any occurrence of these conditions separately.

2.4.5.3 Procedures

The uncertainty analysis was performed using @RISK®, software commercially available from Palisade Corporation, Newfield, NY. The software was tested before application by input of simple formulas involving products and sums of well-characterized parameter distributions and verifying that the outputs conformed to those expected from first order error analysis (Barford, 1967). Additional testing was conducted to verify that the Latin hypercube sampling technique supported by @RISK® produced similar results to the Monte Carlo sampling option and to determine the minimum number of Latin hypercube samples (iterations) required to achieve stable results at the 95th and 99th percentiles of the output distribution. Based on these preliminary tests of the software, Latin hypercube sampling was used consistently in this analysis with 500 iterations per simulation.

Input to @RISK® is structured like a Lotus 1-2-3 spreadsheet. In any of the cells, a formula representing a statistical probability distribution can be entered. The intake estimation equations are entered as formulas involving products and sums of other cells that may contain constant values or distributions. An uncertainty analysis is performed by repeating the calculation of the formulas for a user-specified number of iterations (n). During each iteration, a value is randomly sampled from the distribution specified within each cell, and that value is entered in the cell. Each of the randomly selected input values is then combined according to the intake estimation

formula, resulting in a randomly generated intake estimate for that iteration. The value is stored, and another iteration begins. Each iteration produces a randomly generated possible intake. At the end of a simulation, n possible intake values have been generated, and the data are processed to present the probable distribution of intakes.

2.4.5.4 Determination of Input Parameter Distributions

Input parameters can be categorized as (a) those affecting the estimate of the exposure concentration, which are usually chemical-specific and (b) those characterizing the degree of exposure and the variability among members of the population at risk that are not chemical-specific, for example:

$$\text{Intake (mg/kg/day)} = \text{Concentration (mg/kg)} \times \text{Exposure Rate (day}^{-1}\text{)}$$

It was intended that the uncertainty analysis be based on the same concepts and evaluation of distributions used to define the RME input parameters. To the extent this intention was implemented effectively, the uncertainty analysis would be consistent with the RME analysis: input parameter distributions would have a 90th or 95th percentile equivalent to the RME input parameter, and the distribution of resultant intakes would represent the full range of uncertainty and/or variability associated with the RME intake estimates. Consequently, the sources of information used to define the input parameter distributions are the same as those provided in previous subsections of the exposure assessment to define the RME parameters. Note that the information sources used to define exposure factors, such as consumption of vegetables in this analysis as well as the RME estimates, are largely limited to nationwide statistical summaries and are not based on local regional data.

For chronic RME intake estimates it was assumed, consistent with EPA (1989a), that the RME of the long-term average exposure concentration is the UL95 of the mean concentration from pertinent monitoring data. This allows a 95 percent confidence that the true mean is less than this value. In this uncertainty analysis, variables whose RME value is based on the upper

confidence limit of the mean are referred to as intensive variables. The assumption is made that such variables have a unique true value, but the value is uncertain.

Alternatively, parameters used to define the exposure rate, such as water and food ingestion rates, exposure frequency and duration, and body weight and skin surface areas are considered to be extensive variables. These are parameters whose values are known to vary among the exposed population. For example, it is known that over a long-term average, some individuals consume more meat than other individuals, some buy all meat at the grocery store, and others consume beef raised at their residences. It is an objective of the remedial decision process to protect individuals with above-average exposure. EPA (1989a) recommends that RME input parameters for intake estimation be based on the 90th or 95th percentile of the distribution of such parameters. This value is distinctly different from (greater than) the UL95. For example, it is known with a high degree of confidence that the average duration of residency at a single location is less than 15 years; however, roughly 10 percent of the population reside at the same location for more than 30 years (EPA, 1989d). The 90th percentile of the distribution of exposure duration is 30 years, and this value is used as the RME.

As an example of the difference between the procedures for handling intensive and extensive variables, consider the following hypothetical values reported for a parameter: 7, 2, 6, 9, 8. The mean is 6.4, and the standard deviation is 2.7. The standard deviation of the mean (standard error) is $2.7 / 5^{0.5} = 1.21$. The data set is presumed to be sampled from a normal distribution because the median (7) is approximately equal to the mean, and the standard deviation is less than the mean. The UL90 of the mean is given by (Gilbert, 1987, equation 11.6):

$$UL90 = 6.4 + 1.53(1.21) = 8.3$$

The 90th percentile of the distribution could be estimated (McClave and Dietrich, 1985) as:

$$\text{90th percentile} = \text{mean} + Z_{0.4} \times \text{standard deviation}$$

$$90\text{th} = 6.4 + 1.28(2.7) = 9.9$$

If these data characterized an intensive parameter, the RME would be 8.3 and the parameter would be represented in the uncertainty analysis by the uncertainty in the mean as a normal distribution with a mean of 6.4 and a standard deviation of the mean (standard error) of 1.21. If these data characterized an extensive variable, the RME would be 9.9 and the parameter would be represented in the uncertainty analysis by its variability as a normal distribution with a mean of 6.4 and a standard deviation of 2.7.

Not all input parameter distributions were assumed to be normal, however. The lognormal distribution was selected for many input parameters, and others were defined empirically as a cumulative distribution rather than fit to any specified shape. In general, exposure concentrations and parameters used to estimate exposure concentration (e.g., equilibrium partition coefficients) were treated as intensive, and the RME was defined as an upper 90 or 95 percent confidence limit of the mean. Parameters used to estimate exposure rates were treated as extensive, and the RME was defined as the 90th percentile of the distribution. Input parameter distributions used in the uncertainty analysis are presented in Appendix E. As previously stated, the sources of information used to define the distributions are identical to those documented earlier, where the RME values were presented.

2.4.5.5 Results

Results of the uncertainty analysis of each of the intake estimates are presented in detail in Appendix E. Selected results and a summary are presented as follows. First, distributions of several of the nonchemical-specific exposure factors that are used for all intake estimates will be reviewed, followed by selected chemical-specific input parameters, selected results for intake estimates, and a quantitative summary of the overall findings. Refer to Appendix D for more detail.

2.4.5.5.1 Input Parameters

An interesting feature of the uncertainty analysis that differs slightly from the RME analysis is the relationship between exposure duration and the age of residency in the Offpost OU as

represented in the uncertainty analysis for lifetime intake estimates. The RME results from residency for 30 years beginning on the first birthday. Exposure by direct ingestion of soil is highest from age one to six, and exposure to dairy products is also highest during childhood. In the uncertainty analysis ED is treated as an extensive variable with a cumulative distribution defined in the EFH (EPA, 1989d). In addition, the age of establishment of residency is treated as a uniform random variable over the range 1 to 70 years ED. Thus, if exposure duration during an iteration was randomly determined to be 40 years, the age of immigration to the Offpost OU may be anywhere from 1 to 30 years, with uniform probability within that interval. As a result, only a fraction of the iterations during an uncertainty analysis of a lifetime intake will actually include childhood, representing the range of ages among the potentially exposed population. In the child chronic scenario, this logic is not followed. The intention is to represent a sensitive subpopulation defined by age. Exposure duration is set as a constant at nine years (less than seven years is not considered a chronic exposure duration [EPA, 1989a]; longer would not represent childhood), and the cycle starts at the first birthday (to maximize direct soil ingestion).

The effect of these contrasting procedures is best illustrated by comparing the distribution of IR_d, ingestion of dairy (milk) products in the child chronic scenario, with the same parameter in the lifetime scenario (Figure 2.4.5-1). Most children regularly consume milk, and the distribution derived from Pao and others (1982) is roughly lognormal. Many adults, however, consume very little milk (Pao and others, 1982) although the few who do may consume larger quantities than children. Of course, the lifetime scenario also frequently selects a portion of the exposure duration during childhood. The means of the two distributions (expected result) are similar (0.17 kg/day, child; 0.16 kg/day, lifetime), but the 90th percentile of the lifetime scenario (0.42 kg/day) is somewhat greater than the child (0.31 kg/day). These distributions are intended to represent the consumption of locally produced milk among a rural residential population and to represent the product of a parameter distribution for total milk consumption and a parameter distribution for the FI. The distribution for milk consumption is well defined, but few data are available to define FI. A normal distribution with a mean of 0.4 and standard deviation of 0.27

was used, reproducing the recommendation of RAGS that 0.4 is the average and 0.75 is an RME (assumed to mean 90th percentile). Experience suggests that the distribution may more likely be bimodal (either a person drinks home-produced milk or doesn't), but the recommendations in RAGS and the EFH were the only basis available to define FI. The RME values provided on these figures are time-weighted averages normalized to body weight that have been calculated using values presented in Table 2.4.3.2-1a.

Figures 2.4.5-2 and 2.4.5-3 illustrate the distributions of homegrown vegetable and meat, respectively, and consumption rates in the child chronic and lifetime scenarios. As shown, adults consume more of each than children. Alternatively, contrast the distributions for vegetables and meat. A significant portion of the population consumes little or no meat (locally produced or otherwise), but nearly everyone consumes vegetables. That portion of the population with low rates of homegrown vegetable consumption includes individuals with neither gardens nor access to gardens.

2.4.5.5.2 Example Results

As will be shown in Section 4.1.1 and Appendix F, dieldrin is estimated to impose greater carcinogenic risks at RME intake levels in zone 3 than any other chemical in any zone. Multiple pathways contribute significantly to dieldrin exposure in zone 3. For these reasons, the lifetime intake uncertainty analysis for dieldrin in zone 3 provides an instructive example of uncertainty analysis results. The RME oral intake of dieldrin was estimated to be 1.0×10^{-5} mg/kg/day in this zone. Figure 2.4.5.5.2-1 shows the predicted distribution of potential lifetime oral intakes for dieldrin in zone 3. The distribution exhibits the highly skewed shape of an exponential distribution. The expected or mean intake was calculated to be 1.2×10^{-6} mg/kg/day in this simulation. The 50th and 95th percentiles are 6.1×10^{-7} and 4.1×10^{-6} mg/kg/day, respectively. The RME value, which is beyond the scale at which this graph was produced, is nonetheless less than the maximum intake of 1.6×10^{-5} mg/kg/day calculated in this simulation (500 iterations). The RME value falls at the 99.3 percentile of the estimated distribution. Additional results presented in Appendix E demonstrate that ingestion of homegrown vegetables and shallow groundwater are the

most important pathways contributing to total oral intake. According to the uncertainty analysis, the mean intake by the vegetable pathway is 7.5 x 10^{-7} mg/kg/day (65 percent of total oral intake), and direct ingestion of shallow groundwater contributes an additional 32 percent. These results are similar to the RME analysis, where vegetables contributed 75 percent and groundwater 25 percent.

Distributions of the concentrations of dieldrin in groundwater, surface water, soil, meat, and vegetables are shown in Figures 2.4.5.5.2-2 through 2.4.5.5.2-5. Each of these media contribute significantly to exposure, although surface water and soil contribute primarily through indirect pathways involving food. The RME values for groundwater, surface water, and soil concentrations are well represented by the 95th percentile of the distributions shown in Figures 2.4.5.5.2-2 through 2.4.5.5.2-4 because the procedure for defining RME values is equivalent to the distributional input to @RISK®. Concentrations in vegetables, on the other hand, were estimated by an equilibrium partition model, and the uncertainty in the input parameters is explicitly addressed in the uncertainty analysis. The RME exposure concentrations, calculated using RME input parameters to the model equation, was 0.016 mg/kg for vegetables. The RME falls at the 96th percentile of the distribution shown in Figure 2.4.5.5.2-5. RAGS (EPA, 1989a) recommends use of a UL95 for defining exposure concentration using monitoring data. By analogy, it would be consistent to use the 95th percentile of the agricultural products concentration distributions (the inputs to these distributions are assumed to be intensive; thus the outputs represent uncertainty in the mean) to define exposure concentration in foods. The uncertainty analysis demonstrates that the combination of all RME inputs is marginally more conservative than the 95th percentile of the distribution (RME value of CF_v is approximately 34 percent greater than the 95th percentile of the distribution). This degree of conservatism is not excessive or significant to the overall findings of the risk assessment.

Dieldrin is unique among the five critical COCs selected for uncertainty analysis because of the diversity of pathways that contribute significantly to exposure. On the other extreme is DIMP, whose exposure is dominated by the direct ingestion of groundwater pathway. DIMP's

results are also unique because the distribution of observed concentrations of DIMP in zone 4 is extremely skewed and is not well fit by either a normal or lognormal distribution. The distribution is illustrated in Appendix E. The unusual shape of the DIMP groundwater concentration distribution in zone 4 resulted in a UCL95 greater than the maximum observed concentration, so the maximum observed value was selected as the exposure concentration. Of the 136 groundwater exposure concentrations estimated in this assessment, less than 3 percent had a UCL95 greater than the maximum observed value. Because this distribution is not well fit by either a normal or lognormal distribution, the uncertainty analysis used the observed cumulative distribution as input for groundwater concentrations.

The distribution of DIMP oral intakes illustrated in Figure 2.4.5.5.2-6 is extremely skewed, reflecting the characteristics of the groundwater concentrations. The RME intake of 0.25 mg/kg/day exceeds the maximum intake estimated in the 500 iteration uncertainty analysis (0.22 mg/kg/day). The RME is estimated to be greater than the 99.8th percentile of this distribution.

The uncertainty analysis of chloroform in zone 2 illustrates an additional pathway not considered for dieldrin and DIMP: release of volatiles from groundwater used for domestic purposes. The distribution of oral and inhalation intakes (Figures 2.4.5.5.2-7 and 2.4.5.5.2-8) are typical of other results for volatile contaminants. The RME oral intake for chloroform in zone 2 was estimated to be 9.3×10^{-4} mg/kg/day, which falls at the 98th percentile of the resultant distribution. The RME inhalation intake of 7.9×10^{-4} falls at the 97th percentile of the distribution shown in Figure 2.4.5.5.2-8.

2.4.5.5.3 Summary of Results

The uncertainty analysis results reported in Appendix E are summarized in Table 2.4.5.5.3-1, showing the 50th and 95th percentiles of the intake distributions evaluated, the mean (expected result), the RME intake, the percentile at which the RME falls, and the ratios of the RME intakes to the 50th and 95th percentiles and mean results.

The RMEs typically fall at the 99th percentile of the respective intake distributions. The RME is most conservative for dieldrin lifetime intakes, which consistently fall at the 99.4th percentile or higher. The RME intake is typically one order of magnitude greater than the mean or expected result. The mean would be a more appropriate basis for estimation of population-weighted average risks. The RME typically exceeds the 95th percentile by a factor of 3.

The ratio of mean to 50th percentile is an indication of the degree of skewness or nonnormality of the distribution. This ratio is highest for chloroform inhalation intake in zone 2 and DIMP oral in zone 4.

Additional results presented in Appendix E show that most of the spread illustrated in the distributions is due to the variability in the exposure factors among the potentially exposed population, not the uncertainty in the monitoring data or models used to estimate exposure concentrations. This was shown by substituting the expected result for all exposure concentrations in place of the distributions while maintaining the distributional inputs for the exposure factors. This test was conducted for dieldrin (lifetime) in zone 3 and chloroform in zone 2. The resultant distributions have nearly the same shape, apparent spread, and standard deviations of the full uncertainty analysis results when all sensitive parameters are varied. Therefore, it is appropriate to interpret these distributional results as primarily representing variability in exposure among the potentially exposed population, with a minor contribution from uncertainty in defining the exposure concentrations.

The uncertainty analysis results reveal that large variation in chronic and lifetime intakes are expected among the potentially exposed population. More than half the population is expected to experience intakes below the 50th percentiles, which are typically 18 times less than the RME intakes. The uncertainty analysis demonstrates that the RME intakes for the food chain pathways generally exceed the 95th percentile. However, the analysis shows that the RME result ranges from 1 to 4 times the targeted (95th percentile) RME exposure. The quantitative uncertainty analysis can help assess the conservativeness of the RME intake estimates. For the several

pathways studied, RME parameter estimates were in reasonable agreement with the 95th percentile values from the exposure distributions although the RME intake estimates were often higher. Differences ranged between factors of 1 and 4, and in general, the RME intake estimates exceeded the 95th percentile values by a factor of 3. Considering the uncertainty of potential exposures, these differences are relatively small. However, the fact that the RME intake estimates were consistently higher suggests that the results of the quantitative uncertainty analysis can be used to support the conclusion that the RME intake estimates are indeed conservative.

This uncertainty analysis is limited in a variety of ways, and these limitations should be recognized in interpretation and application to the decision-making process for the Offpost OU. Many of the limitations also apply to the RME analysis. Included among these limitations are:

1. The uncertainty analysis does not address the possibility that some of the pathways may be incomplete either now or in the future. On the other hand, the uncertainty analysis does not include those pathways that were determined to be incomplete or insignificant for the RME analysis (see Section 2.3). The uncertainty analysis assumes that each of the pathways quantified for the RME analysis is complete and that no other pathways contribute significantly to exposure/uncertainty.

2. The distributions of exposure factors, such as consumption of vegetables, duration of residence at one location, are derived from nationwide statistics, not local or regional data. This limitation also applies to the RME analysis.

3. Possible correlation between variables was not addressed explicitly. Implicit consideration of possible correlation was addressed in limited cases, for example body weight is not a variable in the simulation, a decision made to avoid unlikely combinations such as low body weight with high food or water consumption.

4. The quantitative uncertainty analysis addresses uncertainty in intakes only. Uncertainty in toxicity values was not addressed; thus the variability in intakes does not address all factors that affect the risk estimate. It may be inferred that the uncertainty in the risk estimate exceeds the variability calculated for the intake estimates. It may also be inferred that the toxicity values have been defined from conservative principles such that inclusion of the additional uncertainty in toxicity values would probably "spread" the distribution of possible risk estimates toward a lower estimate of risk (to the left).

2.5 SUMMARY OF EXPOSURE ASSESSMENT

Chemicals have migrated to the Offpost OU as a result of waste management practices on RMA. Existing contamination apparently crossed the RMA boundaries primarily by airborne and groundwater pathways. Contaminant transport by both pathways has been reduced, if not completely interdicted, by onpost remedial actions, but past releases have caused contamination of

groundwater, surface water, surficial soil, and biota. Offpost surface water has been contaminated by the offpost discharge of contaminated groundwater. Offpost surficial soil was contaminated by the deposition of airborne contaminants.

COCs include OCPs, halogenated aliphatics, aromatic hydrocarbons, DIMP, sulfur-containing organic chemicals, arsenic, and dissolved salts. These COCs exhibit great variability in their mobility and persistence in environmental media. The OCPs are relatively immobile and persistent, tending to associate with soil and sediment. Most of the remaining COCs are mobile in groundwater, and the aromatics and aliphatics are volatile in surface water. The fate properties of the COCs tend to determine distribution in the Offpost OU. All COCs were detected in groundwater, but the more mobile chemicals are more widely distributed. The OCPs are virtually the only COCs detected at concentrations above background levels in soil and sediment. The volatiles were not significantly elevated above background in surface water and in fact were rarely detected.

Groundwater containing levels of COCs significantly elevated above background travels north and northwest from north and northwest boundaries of RMA, forming three distinct plumes with characteristically different groundwater quality conditions. These are referred to as the northern paleochannel, due north of the RMA north boundary; the First Creek paleochannel, paralleling First Creek northwest of the north boundary of RMA; and the northwest boundary plume. Most of the contamination is transported by the alluvial flow system in paleochannels characterized by coarser sediment. Groundwater traveling along the First Creek paleochannel discharges to First Creek, probably seasonally, resulting in elevated levels of several COCs in First Creek. First Creek discharges to O'Brian Canal, an irrigation ditch, but concentrations of COCs are reduced substantially upon discharge to O'Brian Canal, and only two COCs (DIMP and fluoride) are significantly elevated above background in the irrigation channel.

2.5.1 Residential Scenario

Approximately 950 people resided in Land Use Areas I and II of the Offpost OU in 1985. The population is projected to increase to 4600 by the year 2010. The population is substantially

similar in age and sex distribution to the national average. Few institutions in the Offpost OU would attract or house potentially sensitive subpopulations. Potentially sensitive subpopulations residing in the Offpost OU include women of childbearing age and children. Land use is predominantly agricultural and rural residential, with significant commercial/industrial land uses and open space. The portion of the Offpost OU north of O'Brian Canal where irrigation water is available from the canal and Burlington Ditch contains vegetable and turf farms.

The predominant traditional agricultural land use of the area supports the evaluation of exposure pathways involving consumption of locally produced foods. It has been shown that the most important pathways under the RME scenario (RME includes potential future exposure pathways that may not be complete at this time) are direct ingestion of groundwater used as potable supply; inhalation of volatile COCs released from groundwater used for all domestic purposes; and consumption of locally produced vegetables, meat, and dairy products. Exposure concentrations in foods were estimated using equilibrium partition models. Predictions of the models were compared with limited site-specific sampling and analytical data (1 composite egg sample and 2 beef fat samples), and the models were shown to reproduce observed concentrations in meat and eggs approximately. Monitoring data for milk and vegetables are insufficient to verify the models.

The Offpost OU has been subdivided into 8 zones (one was subdivided into three subzones) having distinct exposure conditions. Variability in media-specific exposure concentrations and land and water use were considered in defining these zones. In effect, a separate exposure assessment has been performed for each zone. Potential future intakes under the RME scenario are greatest in zones 2, 3, and 4, directly north of the RMA northern boundary.

Intakes have been estimated for lifetime, chronic, and acute exposure durations. Intakes were estimated for children and adult women to address potentially sensitive subpopulations. The lifetime scenario begins at age one and extends for 30 years, considering age-dependent body-weight, consumption of milk, and direct ingestion of soil. The chronic child scenario assumes an exposure duration from age one to ten. Children are estimated to be exposed at greater rates

(mg/kg/day) than adults, so children represent the RME for chronic noncarcinogenic risk assessment.

DIMP has the highest estimated intake of any organic COC. DIMP intakes are much higher in zone 4 (First Creek paleochannel) than in any other zone. Chloroform intakes are estimated to be higher than those of any other volatile COC. Chloroform intakes are much higher in zone 2 (northern paleochannel) than in any other zone. Dieldrin has the highest intakes of any OCPs, and its estimated intakes are highest in zones 2, 3 (near 96th Avenue and Peoria Street) and 4.

The RME intake estimates include potential future exposure pathways that are not complete at this time. Currently no residents are in zones 3, 4, and 5. Residential intake estimates in these zones do not represent existing exposures. Residents in zones 1B and 2 do not use the alluvial aquifer, hence reducing actual intakes in those zones below the RME intake estimates presented.

A quantitative uncertainty analysis has been performed to evaluate the possible variation of exposure among the potentially exposed population. The uncertainty analysis shows that the RME intakes represent an intake that is unlikely to be exceeded by more than 1 percent of the population. Population mean intakes would probably be one order of magnitude less than the RME estimate, and more than half the population would experience exposures more than a factor of 18 less than the RME. The uncertainty analysis combines both uncertainty in defining exposure concentrations (from monitoring data and from equilibrium partition models) and variability in exposures among the potentially exposed population. Supplementary applications of the uncertainty analysis process demonstrate that most of the variance in intake estimates can be attributed to variability across the population rather than uncertainty in defining the exposure concentrations.

The uncertainty analysis provides a tool to assess the degree of conservatism in the EA. EPA guidance targets an RME estimate in the upper range of those possible. The uncertainty analysis suggests that RME intakes may approach the 99th percentile, certainly meeting the definition for an RME estimate.

2.5.2 Commercial/Industrial Scenario

Approximately 9 percent of Land Use Areas I and II are currently zoned commercial or industrial. By the year 2010, planning jurisdictions project 37 percent of Areas I and II will become commercial and industrial, and 31 percent will become open space/floodplain due to the changing land use in the offpost area. It is expected that development resulting from encroachment of the Denver suburban fringe from the southwest and the new regional airport to the east will tend to supplant agricultural land uses with residential and commercial/industrial land uses over the next 20 years. The area currently has no residences in zones 3, 4, and 5. Only zone 5 was evaluated for the commercial and industrial scenario due to the changing land uses in these areas.

Exposure pathways and exposure factors evaluated for the commercial/industrial scenario were taken from EPA guidance (EPA, 1991a). The exposure pathways for the commercial/industrial scenario included ingestion of and inhalation exposure to groundwater, dermal exposure to soil, and ingestion of soil.

Chronic intakes have been estimated for workers. Subchronic and acute intakes were evaluated but not reported because chronic hazard indices (Section 4.0) were very low. COCs contributing the largest intakes to commercial/ industrial receptors were very similar to those COCs contributing to residential receptors.

2.6 UNCERTAINTIES

In addition to the implications of the quantitative uncertainty analysis, other factors contribute to uncertainty in the exposure assessment that have not been quanitified. Several of these have been discussed in Sections 2.1.3 and 2.3.4. Some of the most important uncertainties in the exposure assessment are summarized here:

1. Chemical concentrations are expected to decline over time as a result of degradation processes and onpost remedial actions already in place. RME intake estimates are based on monitoring data from 1989 through 1991 and do not account for these expected declines. Alternatively, it is possible although highly unlikely, that the performance of the boundary containment systems (BCS) may deteriorate, thus increasing groundwater concentrations. Recent performance of the BCS has been improving since 1989.

2. Significant development of property in the Offpost OU will, in all likelihood, be accompanied by the development of community water supply systems, which will be required to treat delivered water to comply with the Safe Drinking Water Act. This assessment conservatively assumes that untreated shallow groundwater will be used for domestic supply.

3. Localized areas considerably smaller than the six zones selected for grouping and averaging data may exhibit somewhat higher concentrations than the zone averages, and these hot spots may reflect exposure conditions for one or more residents. It is shown in Appendix E Volume VIII, that isolated hot spots of contamination in zones 2 and 3 may exhibit intakes of relatively high risk chemicals up to twice as high as the zonewide average RME intakes.

4. On the basis of projected future contaminant concentrations in groundwater, the exposure point concentrations will decrease substantially (see Section 2.4.2.2). Conservative estimates of the carcinogenic risks attributable to aldrin and dieldrin in groundwater are expected to decrease in zones 3 and 4, during the next 15 years.

5. COCs other than dieldrin may be present in chicken eggs but were not quanitified because limitations in the technical basis for quantification indicate that such estimates would be highly uncertain. Nonetheless, eggs account for 10 to 20 percent of the total RME intake of dieldrin, so this pathway may be significant for other OCPs. The relative contribution of other OCPs to total carcinogenic risk is small, however, so a 20 percent increase in each of the other OCPs would not increase total risk by more than 1 percent, a negligible amount.

6. The plant uptake model used to predict COC concentrations in vegetables, milk, and beef, though consistent with limited available data, is not field-validated. Several of the assumptions used to develop the model are clearly not valid for volatile chemicals, for which it is probably unrealistically conservative. The latter problem, however, appears to have a negligible effect on RME intake estimates for these chemicals. Even with the conservative model, agricultural pathways contribute little to total intake of the volatile chemicals.

7. RME exposure concentrations are uncertain where the distribution of monitoring is highly skewed (not normal). Use of alternative procedures would not change exposure concentrations for specific carcinogenic chemicals by more than a factor of 2, and an average would not change exposure concentrations of the carcinogenic COCs by more than 20 percent. The greatest uncertainty attributable to this element of the assessment relates to the concentration of DIMP in zone 4 groundwater, where the procedures used (Land procedure) yield an exposure concentration more than 5 times higher than the alternative normal procedures.

8. The quantitative uncertainty analysis can help assess the conservativeness of the RME estimates. For the several pathways studied, RME estimates were in reasonable agreement with the 95th percentile values form the exposure distribution although the RME estimates were often higher. Differences ranged between factors of 1 and 4, and, in general, the RME estimates exceeded the 95th percentile values by a factor of 3. Considering the uncertainty in potential exposures, these differences are relatively small. However, the fact that the RME estimates were consistently higher suggests that the results of the quantitative uncertainty analysis can be used to support the conclusion that the RME estimates are indeed conservative.

3.0 TOXICITY ASSESSMENT

Toxicity assessment is an integral part of the EA process. The purpose of toxicity assessment is to (1) weigh evidence regarding the potential for contaminants to adversely affect exposed individuals and (2) estimate the relationship between the extent of exposure and the increased likelihood and/or severity of adverse effects (EPA, 1989a). As described by EPA (1989a), the first step in the toxicity assessment process is hazard identification, which involves characterizing the nature and strength of adverse effects. The second step is the dose-response evaluation, which involves characterizing and quantifying the relationship between dose and effect. From this quantitative dose-response relationship, toxicity values are derived that can be used to estimate the incidence or potential for adverse effects as a function of human exposure. The toxicity values are then used during risk characterization to estimate the likelihood of adverse effects occurring in humans or other receptors at the expected exposure levels (EPA, 1989a).

As described in Section 1.4, a total of 56 chemicals associated with RMA activities were identified in the offpost soil, groundwater, and surface water; of those, 34 were selected as COCs. This section describes the methodology used in this EA to derive the human RfDs and the associated use of the RfDs in assessing the potential noncarcinogenic risks associated with the COCs. A discussion of the approach used to assess the potential noncarcinogenic risks from COCs that have been identified as known, probable, or possible human carcinogens is also included. Finally, a comprehensive description of the approach used to address potential toxicity to nonhuman receptors is included. Toxicological profiles for each of the COCs are in Appendix F.

3.1 HUMAN REFERENCE DOSES

As defined by EPA, the chronic RfD is an estimate for the human population, including sensitive subpopulations, of a daily exposure level to a chemical that is likely to be without an appreciable risk of deleterious noncarcinogenic effects during a lifetime (Integrated Risk Information System [IRIS], 1991; EPA, 1989a). The uncertainty of the estimate may span an order of magnitude or greater. EPA has derived RfDs for both carcinogenic and noncarcinogenic

compounds. Where sufficient data are available, EPA derives RfDs for chronic and subchronic exposure by inhalation and oral routes. Chronic exposure for humans is generally regarded as more than seven years and subchronic exposure as three months to seven years. The RfD, which is generally expressed in units of mass of contaminant per mass of body weight per day (mg/kg/day), is useful as a reference point from which to gauge the potential toxic effects of the chemical. Doses less than the RfD are not likely to be associated with adverse health risks. However, as the frequency and/or magnitude of the exposures exceeding the RfD increase, the potential for adverse effects occurring in a human population also increases.

Two sources provide EPA-derived RfDs. The first source is an EPA database known as IRIS, which is updated monthly and is available online. Health risk assessment information, including RfDs, is included in IRIS only after a consensus is reached within EPA. Many contaminants identified at RMA have been reviewed by EPA work groups and are currently listed in IRIS. However, with few exceptions, IRIS provides only chronic oral RfDs.

Additional EPA-derived RfDs are listed in the Health Effects Assessment Summary Tables document (HEAST), which is updated quarterly. Chemicals considered in HEAST are those for which Health Effects Assessment (HEA) documents, Health and Environmental Effects Profiles (HEEPs), Health and Environmental Effects Documents (HEEDs), Health Assessment Documents (HADs), or Air Quality Criteria Documents (AQCDs) have been prepared. Many values listed in HEAST represent interim values because they are pending final approval before being listed in IRIS. HEAST often provides chronic and subchronic RfDs for both oral and inhalation exposure pathways, subject to the availability of data.

In addition to the RfD, EPA also provides cancer slope factors (SFs) for estimating the potential carcinogenicity of compounds. As defined by EPA (1989a), the SF is a plausible upper-bound estimate of the probability of a response (generally the induction of tumors) per unit intake of a chemical over a lifetime. It is used in risk assessments to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. The cancer SF is usually the UL95 of the slope of the dose-response curve

and is expressed as the reciprocal of milligrams of contaminant per kilogram of body weight per day ($[mg/kg/day]^{-1}$).

For this EA, if an RfD for a compound was unavailable from either IRIS or HEAST, other documents were considered. In the prescribed hierarchy of documents presented in Table 3.1-1, the first alternative was the Maximum Contaminant Level Goal (MCLG), primarily a health-based criterion developed by EPA. As described in the NCP, the MCLG for carcinogens is zero and is therefore not appropriate for deriving an RfD.

If no values regarding a compound were available in IRIS or HEAST and no MCLG exists, the toxicity values available in the Health Advisories were considered. A Health Advisory presents acceptable water concentrations for one-day, ten-day, and longer-term exposures for a 10-kg child and concentrations for longer-term and lifetime exposures for adults. Because children were identified as a sensitive subpopulation at RMA, priority was given to the Health Advisories for children. As presented in Table 3.1-1, the longer-term value Health Advisory for children was preferred to the ten-day or the one-day value. When none of these values was available, priority was given first to the adult lifetime value and then to the longer-term values derived to protect adults. If one of the shorter-term exposure Health Advisories was selected, a modifying factor was applied to adjust the value so that it was protective for a chronic exposure. For DIMP, the EPA Health Advisory indicates potential effects to the central nervous system (CNS) with acute, but not chronic, exposures in laboratory animals (EPA, 1989c). However, to be conservative, the EA assumed DIMP affects the CNS.

If no toxicity value was provided in any of these references, a group of reference databases was reviewed for available toxicological data with emphasis on the toxicological endpoints described in Table 3.1-1. These reference databases include the Hazardous Substances Data Bank (HSDB, 1991), Reprotext (1991), the Teratogen Information System (TERIS, 1991), and Shepard's Catalog of Teratogenic Agents (Shepard, 1991). When available, human data were preferred over animal data.

Regardless of the receptor, most studies are designed so that the lowest exposure dose is not expected to cause an effect, and higher doses are expected to cause varying degrees of toxicity. Based on the available literature values, the highest dose at which no statistically significant effect is observed is designated the no-observed-effect level or concentration (NOEL or NOEC); if a reported effect is observed but not considered adverse, then it is referred to as the NOAEL or NOAEC. The lowest concentration at which an effect is observed is designated the lowest-observed-effect level or concentration (LOEL or LOEC); if the effect is adverse, it is referred to as the LOAEL or LOAEC.

If either a NOEL/NOAEL or LOEL/LOAEL was used to derive an RfD, it was necessary to adjust the reported values to levels that are expected to be protective of the receptor of concern, whether human or nonhuman. In deriving human RfDs, EPA (1989a) addressed this point by developing uncertainty factors to be applied to the appropriate effect level value. Considerations that influence the selection of uncertainty factors include the test animal species used and available metabolic and pharmacokinetic data. One or more uncertainty factors may be applied as appropriate for the following reasons (EPA, 1989a):

1. A factor of 10 is used to protect sensitive members of the human population when extrapolating from valid human study results.
2. A factor of 10 is applied when extrapolating from long-term exposure studies involving experimental animals to human exposure.
3. A factor of 10 is used when extrapolating from less-than-chronic to chronic exposure.
4. A factor of 10 is used to account for the uncertainty associated with extrapolating from a reported concentration representing a LOEL/LOAEL to one that represents a NOEL/NOAEL.
5. A modifying factor of >0 to 10 is included to reflect a qualitative professional assessment of additional uncertainties in the critical study and in the entire database for the chemical not explicitly addressed by the preceding uncertainty factors. A value of >0 to 1 is applied to account for nutritional essentiality. Best professional judgment shall be used to determine the values to be applied as the modifying factor.

If the EPA sources or other literature identified no toxicity information, such as either a NOEL/NOAEL or a LOEL/LOAEL, the available literature was reviewed to identify a dose or concentration that was reported to be lethal to some percentage of an exposed population; the most

common nomenclature is the LD_{50} or the LC_{50}, which indicates that the level is lethal to 50 percent of the exposed population. In some instances, a value was described in the literature as an acute lethal dose. For the purpose of deriving RfDs in the toxicity profiles, a dose described as an acute lethal dose was considered equivalent to an LD_{50} or LC_{50} dose. Organoleptic (taste and odor) threshold information may have been used to develop RfDs if other data were insufficient. Table 3.1-2 presents the toxicity data available for each offpost COC.

Table 3.1-3 presents the noncarcinogenic RfD values and potential noncarcinogenic effects that are either available from EPA (IRIS, 1991; HEAST, 1991) or derived from a Health Assessment, NOEL/NOAEL, LOEL/LOAEL, LD_{50} or LC_{50}, or organoleptic data. The carcinogenic COCs are listed in Table 3.1-4 with the appropriate SFs for inhalation and oral exposure, as available. Additional regulatory criteria for offpost COCs, including MCLs, MCLGs, Health Advisory values for one-day, ten-day, longer-term, and lifetime exposures, and ambient water quality criteria (AWQC), are presented in Table 3.1-5.

3.2 POTENTIAL CARCINOGENICITY OF CHEMICALS OF CONCERN

The potential carcinogenicity of COCs was evaluated primarily by reference to peer-reviewed assessments by EPA, as summarized in IRIS (1991) and HEAST (1991). The two important elements of EPA's carcinogenicity assessment are (1) assigning chemicals to a weight of evidence category and (2) estimating a 95 percent confidence limit upper-bound of the cancer SF.

3.2.1 Weight of Evidence

Chemicals evaluated for potential carcinogenicity by EPA were assigned a categorical classification on the basis of the weight of the evidence reported in the technical literature regarding their potential carcinogenicity in humans. If there was sufficient evidence that the chemical causes cancer in humans, it was assigned to EPA group A. As shown in Table 3.1-4, two of the COCs (arsenic and benzene) are known to cause cancer in humans.

If a chemical has been shown to cause cancer in laboratory animals, but there is inadequate or no evidence that the chemical causes cancer in humans, the chemical was assigned to

EPA group B2, which indicated it is a probable human carcinogen. In other words, there is a presumption that carcinogenicity in laboratory animals (mammals) probably indicates carcinogenicity in humans. Eleven offpost COCs were designated probable human carcinogens (B2) on the basis of studies in laboratory animals. It is not known whether these COCs cause cancer in humans.

One COC (atrazine) was assigned to group C as a possible human carcinogen, which indicates that limited data exist that atrazine causes cancer in laboratory animals, but insufficient data exist to substantiate that atrazine causes cancer in humans.

3.2.2 Slope Factor

The cancer SF quantifies the relationship between dose and response from laboratory animal and/or human studies. The response used is generally the induction of tumors. As defined by EPA (1989a), the SF is a plausible upper-bound estimate of the probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. The SF is usually the UL95 of the slope and of the dose-response curve and is expressed as $mg/kg/day^{-1}$.

Intake rates of potential carcinogens in the Offpost OU are substantially less than intakes shown to generate cancer in controlled dose/response experiments, which is generally true in all environmental exposure scenarios. As a result, it is necessary to extrapolate data obtained at higher exposure levels to the lower intakes expected from environmental exposures. A mathematical model must be used to make this extrapolation and thus calculate the SF. EPA usually assumes that a chemical that induces tumors in animals at high exposure levels will cause cancer in humans at much lower intakes. It is assumed that there is a risk of cancer, perhaps low, no matter how small the dose. Possible differences between the physiology and metabolic processes of the laboratory animals and humans could result in a species-dependent response. Considering these factors, it is possible that some COCs identified as possible (group C) or probable (group B2) human carcinogens may not induce cancer in humans at environmental exposure levels.

Several models can be used to extrapolate from high to low dose. EPA usually uses the linear multistage model, which is consistent with several hypothesized mechanisms of cancer

induction. The linearized multistage model is usually more conservative than alternative models, which are also consistent with proposed cancer induction mechanisms. This EA used SFs listed in IRIS (1991) and HEAST (1991).

The extrapolation from high dose data to estimated low dose exposure scenarios results in substantial uncertainty in the estimated risk at low dose. This uncertainty is resolved conservatively by EPA by selecting the UL95 of the SF as the recommended basis for cancer risk assessment.

3.3 NONHUMAN RECEPTOR TOXICITY REFERENCE VALUES

The purpose of this section is to provide a usable and reliable method to derive nonhuman Toxicity Reference Values (TRVs) based on the derivation of a NOAEL through the consistent application of uncertainty factors that reflect various types of toxicity data sets (e.g., chronic/subchronic exposures, LD_{50} data) and similarly, consistent application of uncertainty factors related to phylogenetic differences. Where possible, toxicological effects were quantified to derive doses that are not expected to be harmful to nonhuman receptor populations or individuals of threatened or endangered species. The approach used in this section to estimate the effects of contaminants in the RMA offpost environment is intended to derive TRVs in a manner similar to that of the EPA RfD.

The approaches described in this section that were used to derive the reference media concentrations for vegetation and aquatic organisms and the TRVs for birds and mammals are based on the methodology described in the Biota RI report (ESE, 1989b). The uncertainty factors applied to some of the approaches described herein vary from those presented in the Biota RI report because the derivation of TRVs is considered an evolving process and subject to change as new information becomes available. Although a clear basis (i.e., explanation or definition) for the assignment of an uncertainty factor value may not be possible in all cases, the values selected were judged for reasonableness in relation to existing toxicological data.

3.3.1 Vegetation

The most commonly cited toxic effect to vegetation is growth retardation, which is usually reported as either a 25 or 50 percent growth reduction per treatment. Uncertainty factors of 5 and 10 were selected to be applied to describe the variability of the 25 and 50 percent growth reduction (Figure 3.3.1-1). Because the observed effects are usually associated with shorter test periods (typically days or weeks) during critical growth phases, there was no further need to differentiate between chronic or less-than-chronic exposure periods. The vegetation TRVs are presented as reference media concentrations for vegetation. These values are listed in Table 3.3.1-1.

3.3.2 Aquatic Organisms

For aquatic organisms, EPA determined acute and/or chronic AWQC for many chemicals to protect freshwater and/or marine organisms as well as humans. In many instances, although no criteria have been derived, EPA provides values considered to represent the LOEC for chronic and/or acute exposures to a COC (EPA, 1986c). Uncertainty factors are rarely provided in the AWQC documents.

As shown in Figure 3.3.1-1, no additional uncertainty factors were used with the AWQC values. If an AWQC was unavailable and a chronic LOEC (EPA, 1986c) was used, an uncertainty value of 10 was applied to derive a water concentration that is expected to protect aquatic organisms (ESE, 1989b). If only an acute LOEC was available (EPA, 1986c), an uncertainty factor of 100 was applied to derive a protective water concentration (ESE, 1989b). If no EPA data were available, the open literature was reviewed. If chronic values were available (identified), an uncertainty factor of 10 was applied. If only acute data were available, an uncertainty factor of 100 was applied to an acute value (usually 24-, 48-, or 96-hour LC_{50}) to derive a protective water concentration. If both chronic and acute data were available, the chronic value was preferred; however, the ratio of acute to chronic values was used as a modifying factor (Figure 3.3.1-1). If no information pertaining to the toxicity of a contaminant to aquatic organisms could be

identified, no protective water concentration was provided. The TRVs for aquatic organisms are presented as reference media concentrations in Table 3.3.1-1.

3.3.3 Terrestrial Organisms

A satisfactory system was not identified in the literature for deriving uncertainty factors to be applied to the available toxicity data for birds, livestock, and terrestrial wildlife. However, several references (described below) were identified that describe uncertainty associated with the extrapolation of aquatic toxicity data and offer guidance for possible mechanisms to arrive at uncertainty for terrestrial extrapolations.

The approach developed for this EA to derive TRVs for terrestrial nonhuman receptors is based on the method used by EPA (1986b) in deriving human RfDs. The RfDs represent values protective of human health against systemic toxicity effects. The basic premise is that homeostatic, compensating, and adaptive mechanisms exist that must be overcome before a toxic endpoint is manifested; thus, with systemic toxicity, there is a threshold effect. The RfD represents a benchmark dose operationally derived from a NOAEL by the consistent application of uncertainty factors that reflect various types of data sets used to estimate RfDs. That is, the critical toxicity value from the literature is divided by a value representing the product of all uncertainty factors and modifying factors determined to be appropriate on the basis of the quality of the data used to arrive at the NOAEL.

The methodology for deriving TRVs observed similar concepts presented by EPA in the RfD development. The resultant TRVs represent estimates of the daily dose in mg/kg/day to individual receptors within a population that are likely to be without an appreciable risk of deleterious effects to that population. If the receptor is an endangered species (e.g., bald eagle), an additional modifying factor is applied to the individual members of this animal population. This approach is similar to that used to derive a human RfD, where the RfD is routinely derived to protect the most sensitive subgroups of a population.

The derivation of a TRV for terrestrial organisms is a two-step process. First, a NOAEL is derived from an appropriate toxicity study through the application of an uncertainty factor, as

depicted in Figure 3.3.3-1. Second, the NOAEL is modified to reflect uncertainty associated with phylogenetic effects. These steps are described below. The TRVs presented in Table 3.3.3-1 were derived for each species of concern for the sediment, soil, and surface-water pathways, and the references used to derive these TRVs are listed in Table 3.3.3-2. The TRVs for cattle also include the groundwater pathway. The derived species-specific TRV for each contaminant was subsequently compared with the exposure intake developed in the exposure assessment to estimate a population hazard quotient (Volume III, Section 5.0, Ecological Assessment).

3.3.3.1 Derivation of a No-Observed-Adverse-Effect Level

The initial step in applying the TRV development process entails reviewing the available literature to ensure that all available data are considered during the development process. The resulting database is then searched to identify any data specific to RMA target species. If class-specific toxicity data for any of the target receptors are identified, the data are carried through the development of a NOAEL, as presented in Figure 3.3.3-1. The step-wise approach in Figure 3.3.3-1 indicates that the lowest uncertainty to derive a NOAEL is associated with a chronic NOEL or NOAEL, and the highest uncertainty is associated with an acute LD_{50} value. The primary variable considered was whether the study data represent a chronic, subchronic, or acute exposure. An uncertainty factor of 30 to 100 was applied to an acute value (including an LD_{50}) to equate it to a chronic exposure, and an uncertainty factor of 10 or 20 was applied to a subchronic exposure.

The greatest uncertainty in deriving a NOAEL from the available toxicity data is uncertainty associated with acute studies, particularly LD_{50} data. Layton and others (1981) state that neither the LD_{50} nor the chronic NOEL should be considered as biological constants because both are subject to variations caused by inter- and intraspecies differences, as well as differences in test protocols and conditions.

Frequently, LD_{50} data for specific chemicals are only specified by species, sex, and route of exposure, yet other intrinsic and extrinsic factors can influence an experimental animal's response to the test agent. These factors may include the animal's weight, age, and health status, as well as

environmental conditions, such as diet, housing conditions, and ambient temperature. However, studies indicate that the actual variation in LD_{50} values for a given species is low, considering the various sources of uncertainty associated with lethal toxicities (Layton and others, 1987). LD_{50} data are rarely, if ever, used to derive human RfDs.

Unfortunately, because of the shortage of chronic toxicity data for wildlife and livestock, ecological risk assessments must rely on acute studies to extrapolate to chronic effects in terrestrial biota. Therefore, an appropriate, but reasonable, level of uncertainty must be applied when deriving NOAELs from acute studies.

The uncertainty associated with extrapolation from acute LD_{50} studies to field conditions is further illustrated by comparing LC_{50} data to LD_{50} data. Wildlife are usually exposed to xenobiotics in food and drinking water, whereas laboratory animals used for oral LD_{50} studies are usually exposed to the chemical dissolved in a carrier substance and administered via gavage (stomach tube). Although both of these scenarios represent oral exposures, the LD_{50} studies are usually designed to promote maximum exposure (absorption) because less of the chemical is complexed with dietary material. Dietary (LC) studies may give a better indication of the real toxicity effects of the pesticides tested (i.e., in nature, the pesticide residues are likely to be associated with food items ingested) (Dobson, 1985; Peterle, 1991). However, there are inadequate numbers of these studies addressing the COCs and target receptors in the Offpost OU, and the derivation of useful LC_{50}s from LD_{50} data is questionable (McCann and others, 1981).

The use of LC_{50} and LD_{50} toxicity values to derive no-effect levels has precedent. The Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME) contains toxicological data for more than 400 substances. Using this model, hazard assessments for aquatic biota are conducted using LC_{50} and EC_{50} data. A hazard value for each species group is derived by dividing the acute toxicity value by 100 to estimate a no-effect level. The NRDAM/CME approach assumes that the same dose-response relationship holds for all hazardous substances, and sources of uncertainty surrounding the hazard values are not addressed

(EPA, 1988e). The application of an uncertainty factor of 100 to derive a NOAEL from an LD_{50} value as depicted in Figure 3.3.3-1 is supported by the NRDAM/CME approach.

Likewise, a Standard Evaluation Procedure (SEP) has been developed by the Office of Pesticide Programs, EPA, for conducting ecological risk assessments to evaluate environmental toxicology and affects data submitted in support of pesticide registration (EPA, 1986d and EPA, 1988e). The SEP approach is a modified quotient method (similar to the hazard quotient method used in this ecological assessment [Volume III, Section 5.0]) in which estimated environmental concentrations are compared to environmental toxicity endpoint values (regulatory risk criteria [RRCs]). Both aquatic and terrestrial receptors are addressed by this method. The assessments are focused at the population level; however, individual members of endangered species are considered by using a more stringent RRC.

For acute toxicity, the RRCs are equal to the LC_{50} or LD_{50} divided by a safety factor of either 5, 10, or 20. According to the SEP, mortality of 0.1 percent is regarded as sufficiently protective of a population. For the typical (average) dose-response curve, a value one-fifth of the LC_{50} or LD_{50} corresponds to mortality in 0.1 percent of a population. Therefore, a safety factor of 5 is applied to the acute toxicity value to derive an RRC. An additional safety factor of 2 (total of 10) is used for aquatic species. An additional safety factor of 2 is applied if an endangered species might be at risk (total of 10 for terrestrial and 20 for aquatic endangered species).

The total uncertainty associated with the SEP approach is intended to be applied to acute toxicity data (LC_{50} or LD_{50}) to extrapolate to acceptable concentrations for acute exposure scenarios. The SEP approach does not apply any safety (uncertainty) factors to chronic no-effect level toxicity values to account for uncertainty associated with laboratory-to-field extrapolations (EPA, 1986d and EPA, 1988e). Although the SEP approach may not be protective for chronic exposure scenarios, it does support the application of smaller uncertainty factors to derive NOAELs from toxicity studies other than LD_{50}s.

Menzie and others (1992), when evaluating the potential of DDT intake, and its metabolites (DDTR), for effects on bird survival, used the lowest NOAEL reported in the literature for

DDTR (10 mg/kg) with no additional modifications by uncertainty factors. The high end of their toxicity range was estimated as one-tenth of the highest LC_{50} value reported for birds. Menzie and others (1992) report that this is consistent with the application of uncertainty factors of 10 for deriving NOAEL values from LOAEL values.

The approach for this ecological assessment represents an uncertainty range of 1 to 100 to derive a chronic NOAEL from toxicity study values other than LD_{50} studies (Figure 3.3.3-1). The Biota RI had uncertainty ranging from 5 to 5000 (ESE, 1989b). Although, on the surface, the current approach may appear less conservative, the methodology for determining water criteria (not a TRV) for terrestrial biota in the Biota RI did not have additional uncertainty applied to the derived NOAEL. In the current approach, additional uncertainty based on phylogenetic effects was applied to the derived NOAEL. An inspection of the overall uncertainty, as listed in Table 3.3.3-1, shows that the total uncertainty is more conservative in many cases compared to that presented in the Biota RI (ESE, 1989b). A description of and the justification for the phylogenetic effect uncertainties are described below.

3.3.3.2 Phylogenetic Differences

Phylogenetic differences applied to the extrapolation process are used to establish a comparison related to the separation of species. The assumption is that taxonomic similarity results in toxicological similarity and that a particular species response will be similar to that of congeneric species. Consequently, as the taxonomic similarity decreases, extrapolation uncertainty increases (EPA, 1991d).

A simple pragmatic test was used to arrive at the size of the uncertainty factor for each phylogenetic decision point in the TRV process. For example, there are potentially five decision points in the process (Figure 3.3.3-1) to derive TRVs from a NOAEL; if an uncertainty factor of 10 is applied to each decision point, extremely conservative estimates of uncertainty (100,000) would result. However, when a value of 2 is applied as an uncertainty factor to each appropriate, equally-weighted step in the decision process for the derivation of TRVs from a NOAEL derived from toxicity data, the result is an adequately represented uncertainty associated with the

phylogenetic effects. In developing these uncertainty factors, it was imperative to remember that the values derived are not indicative of the potential toxicity of the contaminant being considered, but rather each value was a measure of the uncertainty associated with each of the variables involved in deriving a TRV for one species from toxicity data available for another species. The details of the development of specific TRVs and the scientific studies consulted for the justification of the uncertainty factors are described in greater detail in the following paragraphs.

The phylogenetic differences address the potential for dissimilarities as the taxonomic distance increases between the experimental animal and the target species. The concept of transphylogenetic similarities and differences was presented by Best (1983) in presenting the potential use of planarians for toxicological evaluations.

The question of how much uncertainty to apply to the extrapolation process based on phylogenetic differences between test animal species and the target organism is open to debate based on the limited amount of knowledge that is currently available. Because it is not possible to test all wildlife species, particularly endangered species, it is necessary to identify surrogate species that are useful for answering problems of both acute and chronic toxicity (Lamb and Kenaga, 1981). The open literature offers some guidance on the extrapolation of laboratory animal toxicity data to wildlife (Peakall and Tucker, 1985; Lamb and Kenaga, 1981; Calabrese, 1988; Cholakis and others, 1981; Barnthouse and others, 1990; Suter and Rosen, 1988; Hoffman and others, 1990; Williams, 1974; Gregus and others, 1983; Watkins and Klaassen, 1986; EPA, 1991d; EPA, 1988e).

Illustrating the phylogenetic differences in response to toxicants, a comparison of acute lethality values for the rat and bird (starling), starling and red-winged blackbird, and mallard and bull frog, showed that the differences increased as the phylogenetic differences increased (Peakall and Tucker, 1985). The starling was approximately five times more sensitive than the rats, the red-winged blackbird was more sensitive than the starling, and the bull frog-mallard comparison showed little predictive value. Toxicity effects can be found at all organizational levels: molecular, cellular, tissue, organ, and whole animal. Generally, the extent of phylogenetic

variation increases from the molecular to the whole animal (Peakall and Tucker, 1985; Calabrese, 1988).

Perhaps the best information on uncertainty related to taxonomic extrapolations is found in the aquatic literature. Suter and Rosen (1988) summarized the freshwater and marine taxonomic extrapolations for LC_{50}s. From their study, the total uncertainty, at each taxonomic level, based on the n-weighed means of the 95 percent prediction intervals, progressively increased for freshwater and marine fish from the species level to the order level. The total uncertainties at the order level were 19 for marine fish and 22 for freshwater fish. The total uncertainty reported for marine crustaceans and freshwater arthropods was an order of magnitude higher but fewer data were presented. The higher uncertainty for these organisms may be related to their more primitive evolutionary status.

Barnthouse and others (1990) also summarized the n-weighed mean of 95 percent prediction intervals for taxonomic extrapolations of selected aquatic organisms. The uncertainty ranged from a geometric mean of 6 at the species level to a geometric mean of 20 at the order level (25 if a high anomalous value is included). Barnthouse and others (1990) also determined the range of maximum amount of uncertainty required to permit extrapolation of different types of trifluralin toxicity data to obtain lifetime concentrations in water that would be protective of Gulf menhaden and Chesapeake striped bass. The different types of toxicity data used and the range of uncertainty included life cycle tests using species of interest (1.7-3), life cycle tests using nonspecies of interest (83-120), partial life cycle tests using species of interest (50-53), partial life cycle tests using nonspecies of interest (138-151), acute tests using species of interest (148-174), and acute tests using nonspecies of interest (282-417). These data are discussed further below.

The degree of extrapolation considered to be unacceptable for this ecological risk assessment is the extrapolation across animal classes, i.e., extrapolation from mammalian to avian and vice versa. However, the extrapolation within class is acceptable, and the total uncertainty associated with the process can be reasonably derived and justified although some scientific uncertainty is still associated with the process.

3.3.3.2.1 Intraspecies Differences

Toxicity data collected from studies including male and female members of the same genus and species often demonstrate differences between the sexes. Information contained in the Toxicological Profiles (Appendix F) illustrates some of these differences based on sex. Cholakis and others (1981) noted a twofold sex difference when evaluating data from pesticide subacute toxicity feeding studies involving voles. Female voles were twice as sensitive as the male voles to methyl parathion, and for pentachloronitrobenzene (PCNB), a fungicide, the male vole was twice as sensitive as the female vole. Cholakis and others (1981) also noted a twofold difference in sensitivity between two of the vole species tested.

It is generally accepted in the study of toxicology that difference in response can be influenced by the age of the animal (Klaassen and others, 1991; Hodgson and Levi, 1987; Osweiler and others, 1985). Generally, the very young and older animals tend to be more susceptible to the toxic effects of chemicals. Although these differences are probably the result of different metabolic transformation processes in the animals, the effects associated with these differences should be treated above those associated at the genus/species level. Hence, an uncertainty factor of 2 was selected to address differences occurring at the intraspecies level. This uncertainty factor represents the minimum value applied to the NOAEL to derive a TRV.

3.3.3.2.2 Genus and Species Differences

The genus and species phylogenetic characteristics appear as separate decision points on the derivation diagram (Figure 3.3.3-1); however, for this discussion, they are considered as one decision point.

Although there is concern about the use of toxicity data gathered from laboratory animal species to extrapolate to wildlife species (Lamb and Kenaga, 1981), studies have revealed that laboratory rodents, when compared to their native wild counterparts, are generally more sensitive to the test chemicals (Lamb and Kenaga, 1981; Cholakis and others, 1981; Hoffman and others, 1990).

Because some laboratory animals tend to be more sensitive than wild species, use of toxicity data generated from experimental studies is appropriate to use, and, when adjusted with appropriate uncertainty factors, reasonable toxicity reference values may be determined. Cholakis and others (1981) reported that laboratory rodents appeared to be more susceptible to 2,4-D, dieldrin, methyl parathion, parathion, propinal, and 2,4,5-T than voles. Cholakis and others (1981) noted that laboratory rats were approximately two to ten times more sensitive.

Perhaps one of the most important factors influencing interspecies/genus variation in susceptibility to toxicants is differential metabolism because of different enzyme systems and varying degrees of enzyme activity. For example, the mixed function oxidase (MFO) enzymes, which occur in several organ systems, especially the liver, transform lipid-soluble materials, like the OCPs, to more polar molecules. The activity of these MFOs and other metabolic enzymes can vary greatly between the various animal species. Generally, the activities are highest in mammals and birds and decrease in lower life forms (Peakall and Tucker, 1985; Hoffman and others, 1990).

Species variations in enzymes metabolizing xenobiotics have been reviewed and studied (Williams, 1974; Gregus and others, 1983; Dobson, 1985; Watkins and Klaassen, 1986). The relative concentrations of total cytochrome P-450 (an MFO) enzymes were determined for 11 animal species (Watkins and Klaassen, 1986). The study, reporting the results as a percentage of the value determined for rats, showed that of the livestock species tested, swine had the lowest concentration, 52 percent, and cattle had concentrations very similar to the rat, >90 percent. Rabbits had 41 percent more P-450 than rats, but cats, dogs, and rainbow trout had about 35 percent less. The lowest concentrations were measured in the livers of quail and swine. The maximal difference in total cytochrome P-450 content was a threefold variation between rabbits and quail. For 9 of the 11 species examined, the maximal difference was twofold or less.

Because differential metabolism appears to be species-dependent, the approximate two- to threefold difference in metabolic rates described above and the species sensitivity observations cited by Cholakis and others (1981) support the uncertainty factor of 2 applied at these phylogenetic levels. Also, the total phylogenetic uncertainty at this point (8) is very close to that

presented in the Suter and Rosen (1988) and Barnthouse and others (1990) papers, 6 to 7 and 6, respectively, for aquatic organisms.

3.3.3.2.3 Family/Order Differences

The next decision point (Figure 3.3.3-1) in the process to select uncertainty factors related to the phylogenetic effects is to determine whether the ecological receptor being considered is a member of the same family and/or order as the experimental test animal. A review of oral LD_{50} data depicted in Table 3.3.3.2.1-1 (Registry of Toxic Effects of Chemical Substances [RTECS], 1991) for Offpost OU COCs shows that the data for animals within the same family but of different orders (e.g., rat and mouse) differ by a factor of 1 to 4, thus supporting a reasonable uncertainty factor of 2 at this level of phylogenetic difference. The data are narrowly distributed between the rat and mouse for the OCPs, the COCs of primary importance because of their ability to bioaccumulate and biomagnify in the food chain. The volatile solvents, chloroform and carbon tetrachloride, differ the most between the rat and mouse; however, these chemicals are not likely to present long-term (chronic) concerns because they do not accumulate in tissues.

At the family/order level of phylogenetic effects, there may be some subtle influence from the trophic-level position coupled with the anatomical and physiological characteristics of the digestive systems of the animals. However, according to Stevens (1988), many of the digestive and absorptive processes are common to most species.

A comparison of LD_{50} data (Table 3.3.3.2.1-1) between rats (an omnivore) and rabbits (a herbivore), animals at slightly different trophic levels and having different digestive systems, shows that the data differ by a factor of 1 to 3. The rat and rabbit were chosen for comparison because more data are available on these species for comparison purposes. Dog (a carnivore) and rabbit data exist for a few of the OCPs (aldrin, dieldrin, and DDT) (Table 3.3.3.2.1-1), and again the difference between these two species is a factor of less than 2. These data also support the uncertainty factor of 2 applied at this level of phylogenetic difference. Although Table 3.3.3.2.1-1 also lists dog/rabbit data for 1,2-dichloroethane, the difference between the

values (approximately a factor of 7) may not be significant because this compound is not expected to biomagnify like the OCPs.

The total uncertainty possible at this level, 16, is within the range reported by Suter and Rosen (1988) and Barnthouse (1990). The antilog of the n-weighed mean of 95 percent prediction interval reported by Suter and Rosen (1988) results in an uncertainty value of approximately 9 at the family level and approximately 20 at the order level for freshwater and marine fish. The geometric mean of the uncertainty values for the family and order levels reported in Barnthouse and others (1990) results in similar values. Although these data were generated for aquatic extrapolations, they tend to support the selection of an uncertainty factor of 2 for each decision point in the phylogenetic algorithm.

3.3.3.2.4 Threatened or Endangered Species

Because the bald eagle is protected under the Endangered Species Act, it was considered desirable to apply an additional level of "uncertainty" to protect the bald eagle population. The factor of 2 applied at this decision point to derive a TRV for the bald eagle is not a degree of uncertainty based in science because there is no empirical toxicological evidence that the bald eagle is at a greater risk to the COCs than the other receptor organisms. Rather, this factor represents an adjustment based on policy (an issue of social and political importance) to ensure protection of the species. The use of a factor of 2 is identical to that applied in the ecological risk assessment SEPs as developed by the Office of Pesticide Programs in EPA to protect threatened and endangered species (EPA, 1988e).

This factor was not applied to the TRV derivation process for animals covered by the Migratory Bird Treaty Act because the TRVs derived for these species were considered to provide sufficient protection based on professional scientific judgement.

3.4 MAXIMUM ACCEPTABLE TISSUE CONCENTRATIONS

The significance of potential adverse effects resulting from COCs that are capable of bioaccumulating and biomagnifying in tissues of target receptor organisms is evaluated by

comparing the predicted tissue concentration of the COC (as determined by food web models) to the COC-specific maximum acceptable tissue concentration (MATC).

The MATCs (Volume IV, Appendix H) represent tissue concentrations that correspond to no effect, or minimal effects, in a few animals in a population. The Army, EPA, U.S Fish and Wildlife Service (USFWS), and Shell met jointly to derive the MATC values. The MATCs were derived from toxicity data reported in the open literature on the basis of a scientific consensus. In the development of the MATCs, all available data were consulted, and sublethal or NOEL studies were selected over lethality studies. The literature consulted in support of the MATC is referenced in Appendix H. MATC values have been derived with supporting toxicological basis for all species (trophic levels) for which data are available. The MATCs were derived to be protective of a population and healthy individuals within the population.

3.5 UNCERTAINTIES IN TOXICITY ASSESSMENT

This section summarizes the uncertainties associated with human toxicity and ecological TRVs.

3.5.1 Human Toxicity Assessment

The uncertainties in quantification of toxicity factors (whether human reference doses, carcinogenic SFs, or nonhuman TRVs), are integral to the process of defining those values, as discussed in depth throughout Section 3.0. Each of the tables presenting these values also includes relevant information regarding the uncertainties inherent in use of the values. For example, the magnitude and rationale for uncertainty factors used to calculate RFDs are in Table 3.1-3. Weight of evidence categories for potentially carcinogenic chemicals characterize uncertainty regarding their carcinogenicity to humans. The qualitative interpretation of these categories is in Section 3.2.1.

Uncertainty regarding human health effects of the COCs is profound and contributes to uncertainty in the baseline risk assessment. At the current state of scientific knowledge, quantification of the effect of this uncertainty on the risk characterization is not possible. Much

of the uncertainty results from extrapolation of experimental results from laboratory animals to predict health effect in humans, often at much lower dose levels than used in the experiments. Chronic reference doses typically recognize uncertainty of two to three orders of magnitude. For carcinogenic risks, the uncertainties include the possibility that some COCs may not induce cancer in humans (e.g., EPA group C carcinogens). In virtually all instances, such uncertainties are resolved conservatively by EPA's procedures. One possible expectation would be that some COCs that are not considered carcinogenic by EPA may, upon further research, be found to be carcinogenic. Potential synergistic or antagonistic effects of simultaneous exposure to multiple COCs other than additivity have not been evaluated but are assumed to be minor at environmental exposure levels.

3.5.2 Toxicity Reference Values

On initial inspection of the TRV derivation process, the use of an uncertainty factor of 2 to address uncertainty associated with each level of phylogenetic differences may appear to lack conservativeness. This is especially true when the traditional use of an uncertainty factor of 10 at each decision point in the derivation of human RfDs is considered. However, the reader is encouraged to focus on the overall (total) uncertainty associated with the NOAEL and phylogenetic differences calculated for each TRV. The individual and total uncertainty factors are depicted in Table 3.3.3-1 along with the final TRV.

The use of the number "10" to address safety (uncertainty) was initially proposed by Lehman and Fitzhugh when they introduced the concept of acceptable daily intake (ADI) in 1954 and presented a simple procedure to derive the ADI from toxicity data (Lewis and others, 1990). The ADI concept was intended to provide guidance for maximum allowable levels of contaminants in food items. To derive the ADI, Lehman and Fitzhugh proposed adjusting the selected toxicity data to a NOAEL through the application of safety factors, now referred to as uncertainty factors.

The first safety factor was selected to adjust for intraspecies variability. The downward adjustment of the NOAEL by an arbitrary factor of 10 was to account for the possibility that some members of the experimental animal population might be more sensitive to the toxic effect

of the test chemical than had been the members of the relatively small test population (Lewis and others, 1990).

The second safety factor, an arbitrary factor of 10, was applied to adjust for the possible greater sensitivity among humans than had been observed among the test animal population. The factor was essentially an adjustment for interspecies variability on the basis of the conservative assumption that humans may be 10 times more susceptible to chemical toxicity than are laboratory animals (Lewis and others, 1990).

In 1954, when Lehman and Fitzhugh proposed this approach, a limited amount of data was available on the toxicity of many chemicals, and the conservative approach using safety factors of 10 to extrapolate from laboratory animal data to humans was prudent.

Lewis and others (1990) present an argument for reducing the amount of uncertainty applied to a NOAEL to derive a reference dose (the replacement for ADI). Basically, the current uncertainty factors of 10 are retained as default adjustment factor values; however, depending on criteria set forth in the article, Lewis has allowed for greater flexibility in modifying the adjustment factors to values less than 10, typically 2 or 3, and in some cases, less than 1. Lewis has included a series of factors to adjust for data quality and a nonscientific, judgmental "safety" factor (i.e., social or political value) that may take a value from 1 to 10. Following this approach, an aggregate adjustment ("uncertainty") of about 250 is typical and, as the authors state, "approaching the practical maximum."

The total uncertainty applied to the derivation of the TRV associated with phylogenetic effects can be further supported by an examination of available nonprimate mammalian oral LD_{50} data (Table 3.3.3.2.1-1). When the highest LD_{50} value for a specific COC is divided by the lowest LD_{50} value for the same chemical, regardless of species, a chemical-specific "uncertainty" ratio can be obtained (Table 3.3.3.2.1-1). This chemical-specific "uncertainty" ratio encompasses the variations in toxicity responses resulting from the phylogenetic differences described above (i.e., family, order, genus, and species).

For the COCs that have sufficient data to evaluate, the "uncertainty" ratios range from 1 to 25. When these two extreme values are eliminated, the remaining data have a median value of 3 and a geometric mean of 3. These values are below the theoretical maximum of 16 (excluding the multiple of 2 for threatened and endangered species) for the total uncertainty associated with phylogenetic difference for the TRV approach. Also, the theoretical maximum uncertainty of 16 is near the values reported by Suter and Rosen (1988) and Barnthouse (1990) at the order taxonomic level for the extrapolation of acute toxicity data. These data indicate that the uncertainty applied to the phylogenetic differences is sufficient, and the resulting TRV is adequate to protect the ecological receptors.

The total TRV uncertainty (NOAEL uncertainty multiplied by phylogenetic uncertainty) ranges from 2 to 3200 (Table 3.3.3-1). Most TRVs have uncertainty factors of 1 to 3 orders of magnitude representing a 16- to 3200-uncertainty factor, even greater than that proposed by Lamb and Kenaga (1980) to be applied to acute toxicity data.

Although independent validation of the TRV process with actual field and receptor-specific data would be ideal, the reasonable conservativeness of the derived TRVs can be supported by the following example. A recent study on dieldrin toxicity to mallard ducklings reported a NOAEL of 0.08 mg/kg/day (Nebeker and others, 1992). Using this value as the initial dose in the TRV process, a final TRV of 0.04 mg/kg-bw/day is derived. However, using a dieldrin LOAEL (less desirable) dose of 0.40 mg/kg/day for the mallard (ESE, 1989b), the resulting TRV is 0.01 mg/kg-bw/day because of the greater uncertainty associated with the LOAEL. Although the range of these values differs by a factor of 8, the difference is less than an order of magnitude, and the difference is not likely to be toxicologically significant.

In summary, the TRVs represent dose values that are sufficiently conservative and thus are expected to be protective of ecological receptors.

Table 1.0-1: Data Needs in Each Medium

Media	Description of Need
Alluvium/groundwater	Additional data on contaminant distribution and hydrogeologic character in the area immediately downgradient of the RMA northern boundary and downgradient of the RMA northwest boundary.[1]
Surface water	Data on surface-water quality along First Creek and O'Brian Canal. Additional data on contaminant distribution in the area downgradient of the canals.
Surficial soil	Data on contaminant distribution in surficial soil, including assessment of background concentrations of selected compounds.
Sediment	Data on distribution of contaminated sediments along First Creek, O'Brian Canal, and Burlington Ditch.
Biota	Data on possible contamination of native and domestic biota in area immediately north of RMA northern boundary.
VOC vapor accumulation	Data on possible accumulation of chloroform vapors in basements resulting from volatilization from the groundwater table.

[1] These data needs will be addressed during ongoing interim response action (IRA) investigations.

RMA = Rocky Mountain Arsenal
VOC = volatile organic compound

Table 1.3.1-1: Statistical Comparison With Background - Groundwater
(Page 1 of 2)

Chemical	Detection Frequency: Designated Zone	Detection Frequency: Background	Method	Z	Significantly Elevated?	Comment
1,1-Dichloroethane	1/76	1/58	MOP	<0	No	n_d<5, %d<10
1,2-Dichloroethane	17/76	0/58	MOP	3.86	Yes	
1,3-Dichlorobenzene	1/13	NA	NA	NA	NA	%d<10
Aldrin	13/32	1/96	MOP	6.21	Yes	
Arsenic	21/56	1/45	MOP	4.25	Yes	
Atrazine	10/44	0/8	MOP	1.50	Yes	
bis(2-Ethylhexyl)phthalate	1/11	NA	NA	NA	NA	%d<10
Bicycloheptadiene	1/35	0/11	MOP	0.58	No	n_d<5, %d<10
Benzothiazole	1/7	2/6	MOP	<0	No	n_d<5
Benzene	7/82	1/71	MOP	1.98	Yes	%d<10
Calcium	45/45	52/52	WRS	5.31	Yes	
Carbon tetrachloride	12/81	1/112	MOP	3.81	Yes	
Cadmium	5/53	3/43	MOP	0.42	No	%d<10
Methylene chloride	1/76	4/58	MOP	<0	No	%d<10
Chloroform	45/81	0/112	NR	NR	Yes	
Chloride	64/64	53/56	WRS	9.04	Yes	
Hexachlorocyclopentadiene	5/32	14/14	MOP	<0	No	
Chlorobenzene	16/56	3/45	MOP	2.70	Yes	
Chlordane	9/37	0/18	MOP	2.28	Yes	
CPMS	14/95	3/89	MOP	3.45	Yes	
CPMSO	26/96	2/90	MOP	4.74	Yes	
$CPMSO_2$	10/96	2/90	MOP	2.27	Yes	
Chromium	6/47	7/43	MOP	<0	No	
Copper	5/54	13/43	MOP	<0	No	
Cyanide	1/27	0/6	MOP	0.48	No	n_d<5, %d<10
Dibromochloropropane	27/94	0/118	MOP	6.24	Yes	
1,4-Dichlorobenzene	6/11	NA	NA	NA	NA	
Dicyclopentadiene	30/96	0/99	MOP	6.05	Yes	
Vapona	1/24	0/8	MOP	0.59	No	n_d<5,%d<10
DIMP	80/81	0/119	NR	NR	Yes	
Dithiane	22/95	2/89	MOP	4.23	Yes	
Dieldrin	43/53	0/110	NR	NR	Yes	
Dimethyldisulfide	1/71	2/52	MOP	<0	No	n_d<5, %d<10
Dimethylmethyl phosphonate	2/91	1/88	MOP	0.57	No	n_d<5, %d<10
Endrin	25/65	0/110	MOP	7.00	Yes	
Ethylbenzene	1/12	0/50	MOP	2.06	Yes	n_d<5, %d<10
Fluoride	76/78	53/116	WRS	9.58	Yes	
Iron	4/4	NA	NA	NA	NA	n_d<5
Mercury	6/53	3/42	MOP	0.69	No	
Isodrin	10/65	0/110	MOP	4.25	Yes	
Potassium	51/52	53/55	WRS	3.01	Yes	
Toluene	4/82	1/87	MOP	1.46	Yes	%d<10
Magnesium	45/45	50/52	WRS	8.36	Yes	
Malathion	5/24	0/8	MOP	1.40	Yes	
Manganese	3/4	NA	NA	NA	NA	
Sodium	46/46	52/52	WRS	7.38	Yes	
Nitrate	51/53	54/57	WRS	<0	No	
1,4-Oxathiane	15/94	2/89	MOP	3.21	Yes	

Table 1.3.1-1: Statistical Comparison With Background - Groundwater
Table 1.3.1-1: (Page 2 of 2)

Chemical	Detection Frequency: Designated Zone	Detection Frequency: Background	Method	Z	Significantly Elevated?	Comment
Lead	4/50	1/43	MOP	1.21	No	
DDE	7/61	0/53	MOP	2.56	Yes	
DDT	8/58	14/14	MOP	<0	No	
Parathion	2/27	0/7	MOP	0.74	No	n_d<5, %d<10
Sulfate	64/64	56/61	WRS	9.11	Yes	
Supona	1/24	0/7	MOP	0.56	No	n_d<5, %d<10
Tetrachloroethene	39/80	7/112	MOP	6.80	Yes	
Trichloroethene	37/81	23/112	MOP	3.73	Yes	
Xylene	2/94	0/87	MOP	1.35	Yes	n_d<5
Zinc	29/53	26/43	WRS	<0	No	

%d<10 = The detection frequency in the impact data set is less than 10 percent; in this circumstance, the Method of Proportions may not be valid
MOP = Method of Proportions
NA = No site-specific background data are available for this contaminant
n_d<5 = The number of detected values above the certified reporting limit (CRL) is less than 5; in this circumstance, the Method of Proportions may not be valid
NR = Not required, the procedure for defining background and impact data sets is contingent on the assumption that DIMP, chloroform, and dieldrin are significantly elevated in groundwater
WRS = Wilcoxon rank sum test
Z = Z statistic

Table 1.3.1-2: Chemicals of Concern - Groundwater

Chemical	Comment
Aldrin	
Arsenic	
Atrazine	
Benzene	
Carbon tetrachloride	
Chloroform	
Chloride	
Chlorobenzene	
Chlordane	
CPMS	
CPMSO	
$CPMSO_2$	
Dibromochloropropane	
Dicyclopentadiene	
DDE	
DDT	Elevated with 89.4 percent confidence, detection frequency 14 percent
1,2-Dichloroethane	
Dichlorobenzene	Insufficient site-specific background data, high detection frequency
DIMP	
Dieldrin	
Dithiane	
Endrin	
Ethylbenzene	
Fluoride	
Hexachlorocyclopentadiene	Elevated with 89.9 percent confidence, detection frequency 16 percent
Isodrin	
Malathion	
Manganese	Insufficient site-specific background data, high detection frequency
Oxathiane	
Sulfate	
Tetrachloroethene	
Toluene	
Trichloroethene	
Xylene	

Table 1.3.1-3: Summary of Available Information on Toxicity and Essentiality of Calcium, Iron, Potassium, Magnesium, and Sodium

Chemical	Reference Dose (mg/kg/day)	Most Restrictive State Groundwater Standard (mg/l)	Maximum Exposure Concentration in Offpost Groundwater[a] (mg/l)	Corresponding Adult Intake[b] (mg/day)	Recommended Daily Intake/ Allowance (mg/day)
Calcium	NA	NS	291	582	800 - 1200[d]
Iron	NA	0.3[c]	0.276	0.552	10 - 18[d]
Potassium	NA	NS	5.74	11.5	1875 - 5600[e]
Magnesium	NA	NS	84.1	168	300 - 450[d]
Sodium	NA	NS	590	1180	1100 - 3300[e]

[a] Highest upper 95 percent confidence limit on the arithmetic mean (UL95) concentration for any of the six zones defined in Section 2.4.1. The maximum exposure concentrations exist in Zone 4 for each of the listed analytes except potassium (Zone 3) and magnesium (Zone 5).
[b] Assuming an ingestion rate of 2 l/day.
[c] Secondary Drinking Water Standard based on filtered sample.
[d] National Academy of Sciences (1974).
[e] National Academy of Sciences (1990).

mg/day = milligrams per day
mg/kg/day = milligrams per kilogram per day
mg/l = milligrams per liter
NA = no reference dose has been established by EPA
NS = no standard has been established by the State of Colorado

Table 1.3.2-1: Statistical Comparison with Background - Surface Water (First Creek)

Chemical	Detection Frequency		Method	Z	Significantly Elevated?	Comment
	First Creek	Background				
1,2-Dichloroethane	1/12	0/16	MOP	0.89	No	n_d<5, %d<10
Aldrin	1/16	1/15	MOP	<0	No	n_d<5, %d<10
Arsenic	6/14	2/13	MOP	1.56	Yes	
Atrazine	2/8	0/5	MOP(m)	1.25	No	n_d<5
Calcium	11/11	10/10	WRS	0.81	No	
Chloride	22/22	18/18	WRS	3.36	Yes	
Chlordane	2/5	0/3	MOP(m)	2.01	Yes	n_d<5
$CPMSO_2$	1/12	0/16	MOP	1.17	No	n_d<5, %d<10
Chromium	1/12	5/12	MOP	<0	No	%d<10
Dicyclopentadiene	8/27	0/19	MOP	2.60	Yes	
DIMP	13/23	1/17	WRS	2.93	Yes	
Dithiane	2/23	0/16	MOP	1.21	No	n_d<5, %d<10
Dieldrin	3/6	1/15	MOP	2.29	Yes	n_d<5
Endrin	1/15	0/16	MOP	1.05	No	n_d<5, %d<10
Fluoride	16/16	6/18	WRS	2.46	Yes	
Mercury	2/15	1/13	MOP(m)	0.32	No	n_d<5
Potassium	13/13	12/12	WRS	1.44	Yes	
Magnesium	11/11	10/10	WRS	3.06	Yes	
Sodium	11/11	10/10	WRS	3.07	Yes	
Nitrate	11/15	13/13	WRS	<0	No	
DDE	1/12	0/13	MOP	1.06	No	n_d<5, %d<10
DDT	2/5	0/13	MOP	2.42	Yes	n_d<5
Sulfate	18/18	14/14	ANOVA(ln)	5.07^f	Yes	
Tetrachloroethylene	1/23	0/18	MOP	0.90	No	n_d<5, %d<10
Trichloroethylene	1/23	0/18	MOP	0.90	No	n_d<5, %d<10
Zinc	4/16	6/13	MOP	<0	No	

%d<10 = The detection frequency in the impact data set is less than 10 percent; in this circumstance, the Method of Proportions may not be valid
ANOVA (ln) = Parametric analysis of variance, lognormal distribution
f = F value from ANOVA (analysis of variance)
MOP = Method of Proportions
MOP(m) = Modified Method of Proportions for small sample size and %d>10 (see text)
n_d<5 = The number of detected values above the certified reporting limit (CRL) is less than 5; in this circumstance, the Method of Proportions may not be valid
WRS = Wilcoxon rank sum test
Z = Z statistic

Table 1.3.2-2: Chemicals of Concern - Surface Water (First Creek)

Chemical	Comment
Arsenic	
Chlordane	
Chloride	
Dicyclopentadiene	
DDE	Elevated with 86 percent confidence plus degradation product of DDT
DDT	
Dieldrin	
DIMP	
Fluoride	
Sulfate	

Table 1.3.2-3: Statistical Comparison With Background - Surface Water (Canals)

Chemical	Detection Frequency		Method	Z	Significantly Elevated?	Comment
	Canals[1]	Background				
Arsenic	4/19	4/16	MOP	<0	No	
Chloride	22/22	17/17	WRS	<0	No	
Chlordane	0/15	0/4	MOP	0	No	No hits
Dicyclopentadiene	0/28	0/19	MOP	0	No	No hits
DIMP	7/29	1/19	MOP	1.71	Yes	
Dieldrin	0/27	0/17	MOP	0	No	No hits
Fluoride	9/21	3/17	MOP	1.66	Yes	
DDE	1/18	0/16	MOP	0.97	No	
DDT	1/18	0/16	MOP	0.97	No	
Sulfate	20/20	16/16	WRS	<0	No	

[1] O'Brian Canal and Burlington Ditch.

MOP = Method of Proportions
WRS = Wilcoxon rank sum test
Z = Z statistic

Table 1.3.2-4: Statistical Comparison With Background - Surface Water (Barr Lake)

Chemical	Detection Frequency		Method	Z	Significantly Elevated?	Comment
	Canals[1]	Background				
DIMP	1/19	1/19	MOP	0	No	n_d<5, %d<10
Fluoride	2/16	3/17	MOP	<0	No	

%d<10 = The frequency of detection in the impact data set is less than 10 percent; in this circumstance, the Method of Proportions may not be valid

MOP = Method of Proportions

n_d<5 = The total number of detects above the certified reporting limit (CRL) is less than 5; in this circumstance, the Method of Proportions may not be valid

Z = Z statistic

Table 1.3.2-5: Statistical Comparison With Background - Sediment (First Creek)

Chemical	Detection Frequency		Mean ($\bar{x} + \sigma\ \bar{x}$)[a]		Maximum[a]				
	Designated Zone	Background	Designated Zone	Background	Designated Zone	Background	Method	Z	Significantly Elevated?
Arsenic	4/12	1/2	2.8±0.4	5.6±3.3	7.27	8.92	MOP	<0	No
Cadmium	1/11	0/2	0.47±0.05	<0.9	0.926	<0.9	MOP	0.44	No[b]
Chromium	7/11	2/2	10.1±1.9	18.4±8.7	21.3	27.1	WRS	<0	No
Copper	9/11	1/2	9.5±1.7	13.3±10.9	18.4	24.2	WRS	<0	No
Lead	4/11	1/2	12.3±2.6	34.7±26.2	25.1	60.9	MOP	<0	No
Zinc	10/11	2/2	41.4±6.5	71.3±27.4	75.9	98.7	WRS	<0	No

[a] Units are in milligrams per kilogram (mg/kg).
[b] n_d<5 and %d<10; Method of Proportions may not be valid.

MOP = Method of Proportions
WRS = Wilcoxon rank sum test
Z = Z statistic

Table 1.3.2-6: Statistical Comparison With Background - Sediment (O'Brian Canal)

Chemical	Detection Frequency O'Brian Canal[a]	Detection Frequency Background	Method	Z	Significantly Elevated?	Comment
Aldrin	0/10	0/9	MOP	0	No	No hits
Dibromochloropropane	0/11	0/11	MOP	0	No	No hits
Dieldrin	3/5	2/4	WRS	0.12[b]	No	
Endrin	0/10	1/9	MOP	<0	No	No hits
DDE	0/10	2/9	MOP	<0	No	No hits
DDT	1/5	3/4	MOP	<0	No	

[a] O'Brian Canal downstream of First Creek.
[b] Z statistic provided for information only; significance based on small sample test (n_1, $n_2 \leq 10$), presented by McClave and Dietrich, 1985.

MOP = Method of Proportions
WRS = Wilcoxon rank sum test
Z = Z statistic

Table 1.3.2-7: Statistical Comparison With Background - Sediment (Barr Lake)

Chemical	Detection Frequency		Method	Z	Significantly Elevated?	Comment
	Barr Lake	Background				
Aldrin	0/9	0/9	MOP	0	No	No hits
Dibromochloropropane	1/5	0/4	MOP(m)	2.12	No	$n_d<5$
Dieldrin	2/5	2/4	MOP	<0	No	$n_d<5$
Endrin	1/5	1/4	MOP	<0	No	$n_d<5$
DDE	1/5	2/4	MOP	<0	No	$n_d<5$
DDT	2/5	3/4	MOP	<0	No	

MOP = Method of Proportions
MOP(m) = Modified Method of Proportions for small sample size and %d>10 (see text)
$n_d<5$ = The total number of detects above the certified reporting limit (CRL) is less than 5; in this circumstance, the Method of Proportions may not be valid
Z = Z statistic

Table 1.3.3-1: Statistical Comparison With Background - Surficial Soil

Chemical	Detection Frequency		Method	Z	Significantly Elevated?	Comment
	Designated Zone[a]	Background				
Aldrin	14/17	2/20	WRS	4.47	Yes	
Arsenic	1/18	3/20	MOP	<0	No	
Hexachlorocyclopentadiene	1/17	0/20	MOP	1.10	No	$n_d<5$, %d<10
Chlordane	7/33	0/28	MOP	2.59	Yes	
Chromium	5/5	8/8	WRS	<0		
Copper	5/5	8/8	ANOVA	3.652[b]	Yes	
Dieldrin	17/33	11/20	WRS	6.15	Yes	
Endrin	13/33	1/20	MOP	3.31	Yes	
Mercury	1/17	0/20	MOP	1.10	No	$n_d<5$, %d<10
Isodrin	2/17	1/20	MOP(m)	0.76	No	$n_d<5$
Lead	5/5	8/8	WRS	1.54[c]	Yes	
DDE	9/14	1/20	WRS	1.41	Yes	
DDT	16/33	3/28	MOP	3.18	Yes	
Zinc	5/5	8/8	WRS	1.68[c]	Yes	

[a] Designated locations where highest concentrations of RMA-related chemicals occur or are expected to occur.
[b] F value from ANOVA (Analysis of Variance).
[c] Z statistic provided for information only; significance based on small sample test (n_1, $n_2 \leq 10$), presented by McClave and Dietrich (1985).

MOP = Method of Proportions
MOP(m) = Modified Method of Proportions for small sample size and %d>10 (see text)
WRS = Wilcoxon rank sum test
Z = Z statistic

Table 2.1-1: Henry's Law Constant (Dimensionless) for Organic Groundwater Chemicals of Concern

Chemical	Henry's Law Constant MLE	Henry's Law Constant RME	Report Range	References
Aldrin/dieldrin	0.00098	NR	NR	Ebasco, 1990; EPA 1986a; Lyman and others, 1982; Merck Index, 1989; Park and Bruce, 1968; Rosenblatt and others, 1975
Atrazine	6.5×10^{-8}	NR	NR	Ebasco, 1990
Benzene	0.25	NR	NR	Ebasco, 1990; EPA, 1979a
Carbon tetrachloride	1.05	NR	NR	Ebasco, 1990; Verschueren, 1983
Chlordane	0.00033	NR	NR	Ebasco, 1990
Chlorobenzene	0.16	NR	NR	Ebasco, 1990; EPA, 1979a; Verschueren, 1983
Chloroform	0.14	0.17	0.12 - 0.18	ATSDR, 1989h; Banerjee and others, 1980; Ebasco, 1990; EPA, 1986a; Verschueren, 1983;
CPMS	0.045	NR	NR	Ebasco, 1990
$CPMSO_2$	0.00018	NR	NR	Ebasco, 1990
CPMSO	0.00050	NR	NR	Ebasco, 1990
Dibromochloropropane	0.013	0.0147	0.013 - 0.0147	Ebasco, 1990
1,3-Dichlorobenzene	0.12	NR	NR	EPA, 1979a
1,2-Dichloroethane	0.16	NR	NR	Ebasco, 1990
DDE/DDT	0.0087	NR	NR	Ebasco, 1990; EPA, 1979a
Dicyclopentadiene	0.76	NR	NR	Ebasco, 1990
DIMP	0.000082	NR	0.000055 - 0.00016	Bentley and others, 1976; Lyman and others, 1982; Rosenblatt and others, 1975
Dithiane	0.0019	NR	NR	Ebasco, 1990
Endrin/isodrin	0.000072	NR	NR	Ebasco, 1990
Ethylbenzene	0.33	NR	NR	Ebasco, 1990
Malathion	5×10^{-6}	NR	NR	Ebasco, 1990
Oxathiane	0.0014	NR	NR	Ebasco, 1990
Tetrachloroethane	0.98	NR	NR	Ebasco, 1990
Toluene	0.27	NR	NR	Ebasco, 1990; Verschueren, 1983
Trichloroethene	0.43	NR	NR	Ebasco, 1990
Xylene	0.19	NR	NR	Ebasco, 1990

MLE = most likely exposure
NR = not required
RME = reasonable maximum exposure

Table 2.1-2: Molecular Diffusivity in Air and Water (m^2/day)

Chemical	D_a MLE	D_a RME	D_w MLE	D_w RME	References
Chloroform	0.76	0.85	0.000076	0.000085	Lyman and others, 1982
Dibromochloropropane	0.59	0.68	0.000059	0.000066	Lyman and others, 1982

D_a = molecular diffusivity in air
D_w = molecular diffusivity in water

m^2/day = square meters per day
MLE = most likely exposure
RME = reasonable maximum exposure

Table 2.1-3: Solubility (mg/l) and Vapor Pressure (torr) for Organic Groundwater Chemicals of Concern
(Page 1 of 2)

Chemical	Solubility[a]	Reported Range	Reference	Vapor Pressure[a]	Reported Range	References
Aldrin/dieldrin	0.15	0.11 - 0.19	Park and Bruce, 1968	4.3×10^{-7}	2.8×10^{-8} - 7.78×10^{-6}	Ebasco, 1990; EPA, 1986a; Lyman and others, 1982; Merck Index, 1989; Rosenblatt and others, 1975
Atrazine	70	NA	Ebasco, 1990	4.2×10^{-7}	3×10^{-7} - 5.3×10^{-7}	Ebasco, 1990
Benzene	1590	870 - 1800	Ebasco, 1990; EPA, 1979a	79	45.5 - 100	Ebasco, 1990; EPA, 1979a
Carbon tetrachloride	891	780 - 1160	Ebasco, 1990; Verschueren, 1983	105	90 - 115.2	Ebasco, 1990; Verschueren, 1983
Chlordane	0.64	0.056 - 1.85	Ebasco, 1990	0.00001	NA	Ebasco, 1990
Chlorobenzene	472	448 - 500	Ebasco, 1990	11	8.8 - 11.8	Ebasco, 1990; Verschueren, 1983
Chloroform	7700	7200 - 9200	Ebasco, 1990	170	150.5 - 197	ATSDR, 1989h; Ebasco, 1990; Verschueren, 1983
CPMS	12[b]	NA	Ebasco, 1990	0.08	0.05 - 0.11	Ebasco, 1990
$CPMSO_2$	1100[b]	1050 - 1170	Ebasco, 1990	0.0018	0.0005 - 0.003	Ebasco, 1990
CPMSO	1100[b]	1050 - 1200	Ebasco, 1990	0.039	0.0008 - 0.078	Ebasco, 1990
Dibromochloropropane	1100[b]	1000 - 1230	Ebasco, 1990; Verschueren, 1983	1.0	0.8 - 1.1	Ebasco, 1990
1,3-Dichlorobenzene	123	NA	EPA, 1979a	2.3	NA	EPA, 1979a
1,2-Dichloroethane	7930	5500 - 8820	Ebasco, 1990	180	180 - 182	Ebasco, 1990
DDE/DDT	0.035	0.0012 - 0.14	EPA, 1979a	3.2×10^{-6}	1.5×10^{-7} - 6.5×10^{-6}	EPA, 1979a
Dicyclopentadiene	20[b]	NA	Ebasco, 1990	1.8	1.4 - 2.2	Ebasco, 1990
DIMP	22,000	511 - 32,000	Bentley and others, 1976; Lyman and others, 1982	0.18	NA	Rosenblatt and others, 1975
Dithiane	3000[b]	NA	Ebasco, 1990	0.80	NA	Ebasco, 1990
Endrin/isodrin	0.42[b]	0.02 - 1.4	Ebasco, 1990; EPA, 1979a	2.4×10^{-7}	2.0×10^{-7} - 2.7×10^{-7}	Ebasco, 1990
Ethylbenzene	151	140 - 161	Ebasco, 1990; EPA, 1979a; Verschueren, 1983	10	7 - 12	Ebasco, 1990; Verschueren, 1983
Hexachlorocyclopentadiene	1.6[b]	0.805 - 2.1	Ebasco, 1990	0.08	NA	Ebasco, 1990
Malathion	145	NA	Ebasco, 1990	0.000032	0.000024 - 0.00004	Ebasco, 1990
Oxathiane	20,000[b]	NA	Ebasco, 1990	4.5	3.9 - 5.1	Ebasco, 1990

Table 2.1-3: Solubility (mg/l) and Vapor Pressure (torr) for Organic Groundwater Chemicals of Concern
(Page 2 of 2)

Chemical	Solubility[a]	Reported Range	Reference	Vapor Pressure[a]	Reported Range	References
Tetrachloroethene	150	150 - 200	Ebasco, 1990	16	14 - 17.8	Ebasco, 1990
Toluene	521	470 - 566	Ebasco, 1990; Verschueren, 1983	25	22 - 28.7	Ebasco, 1990; Verschueren, 1983
Trichloroethene	963	825 - 1100	Ebasco, 1990	59	57.9 - 60	Ebasco, 1990
Xylene	185	130 - 198	Ebasco, 1990	6.9	5 - 10	Ebasco, 1990; Verschueren, 1983

[a] Mean value.
[b] Used to estimate cattle bioaccumulation.

mg/l = milligrams per liter
NA = not applicable (only one reported value)
torr = vapor pressure

Table 2.1-4: Octanol/Water Partition Coefficients (log K_{ow})

Chemical	Log K_{ow}[1]	Reported Range	References
Aldrin/dieldrin	5.02	3.01 - 7.40	Ebasco, 1990; Hansch and Leo, 1979
Atrazine	2.66	2.32 - 2.75	Ebasco, 1990; Lyman and others, 1982; Veith and others, 1979
Benzene	2.07	1.56 - 2.34	Ebasco, 1990; EPA, 1979a, Hansch and Leo, 1979; Sangster, 1989
Carbon tetrachloride	2.71	2.03 - 2.83	Ebasco, 1990; Hansch and Leo, 1979; Sangster, 1989
Chlordane	4.40	2.78 - 6.00	Ebasco, 1990; Lyman and others, 1982
Chlorobenzene	2.74	2.18 - 3.08	Ebasco, 1990; Hansch and Leo, 1979; Sangster, 1989; Veith and others, 1979
Chloroform	1.94	1.90 - 1.97	Ebasco, 1990; Hansch and Leo, 1979
CPMS	3.22	NA	Ebasco, 1990
$CPMSO_2$	1.20	NA	Ebasco, 1990
CPMSO	1.30	1.26 - 1.33	Ebasco, 1990
Dibromochloropropane	2.37	2.29 - 2.43	Ebasco, 1990
1,3-Dichlorobenzene	3.50	3.38 - 3.60	EPA, 1986a; Hansch and Leo, 1979
1,2-Dichloroethane	1.57	1.45 - 1.79	Ebasco, 1990; Hansch and Leo, 1979
DDE/DDT	5.84	3.98 - 7.48	Ebasco, 1990; EPA, 1979a; Hansch and Leo, 1979; Veith and others, 1979; Verschueren, 1983
Dicyclopentadiene	3.14	NA	Ebasco, 1990
DIMP	1.60	1.00 - 1.82	Ebasco, 1990
Dithiane	0.77	NA	Ebasco, 1990
Endrin/isodrin	4.94	3.21 - 6.51	Ebasco, 1990; Veith and others, 1979; Verschueren, 1983
Ethylbenzene	3.14	3.07 - 3.28	Ebasco, 1990; Hansch and Leo, 1979; Sangster, 1989
Hexachlorocyclopentadiene	4.52	3.52 - 5.51	Ebasco, 1990; Veith and others, 1979, Callahan and others, 1979
Malathion	2.70	2.36 - 2.89	Ebasco, 1990
Oxathiane	-0.16	NA	Ebasco, 1990
Tetrachloroethene	2.68	2.53 - 2.88	Ebasco, 1990; Veith and others, 1979
Toluene	2.62	2.11 - 2.94	Ebasco, 1990; Hansch and Leo, 1979; Sangster, 1989
Trichloroethene	2.74	2.29 - 3.30	Ebasco, 1990
Xylene	3.13	2.77 - 3.52	Ebasco, 1990; EPA, 1986a; Hansch and Leo, 1979; Sangster, 1989

[1] Mean value.

K_{ow} = octanol/water partition coefficient
NA = not applicable (only one reported value)

Table 2.1-5: Adsorption Coefficient (l/kg) for Chemicals Elevated in Soil or Sediment

Chemical	K_{oc}[a]	Rerported Range	References
Aldrin/dieldrin	35,000	3300 - 96,000	Briggs, 1981; Ebasco, 1990; Lyman and others, 1982; Saha and others, 1971
Arsenic	250[b]	20 - 3376	Elkhatib and others, 1984; Rosenblatt and others, 1975; Wauchope, 1975; Wauchope and McDowell, 1984
Chlordane	48,000	422 - 141,200	Ebasco, 1990
Dibromochloropropane	170	130 - 225	Ebasco, 1990
DDE/DDT	100,000	19,350 - 4,400,000	Ebasco, 1990
Endrin/isodrin	89,000	897 - 339,900	Ebasco, 1990
Manganese	65[b]	NA	Baes and others, 1984

[a] Mean value.
[b] The value provided for metals is K_d = adsorption coefficient.

K_{oc} = adsorption coefficient normalized to soil/sediment organic carbon content ($K_d = K_{oc}f_{oc}$)
l/kg = liters per kilogram
NA = not applicable

Table 2.1-6: Uptake to Roots, K_{wr} (l/kg), for Organic Groundwater Chemicals of Concern

Chemical	K_{wr} MLE	K_{wr} RME	References
Aldrin/dieldrin	103	144	Briggs and others, 1983; Harris and Sans, 1969; Lichtenstein and others, 1965; Lichtenstein and others, 1970; Lichtenstein and others, 1971; Onsager and others, 1970; Saha and others, 1971; Sheets and others, 1969; Talekar and others, 1983;
Arsenic	3.0[a]	37[a]	Baes and others, 1984; Isaac and others, 1976; Johnson and Hiltbold, 1969; Stevens and others, 1972
Atrazine	4.2	6.5	Briggs and others, 1982
Benzene	2.1	3.2	Briggs and others, 1982
Carbon tetrachloride	4.5	7.1	Briggs and others, 1982
Chlordane	55	118	Briggs and others, 1982; Onsager and others, 1970; Sand and others, 1972
Chlorobenzene	4.7	7.4	Briggs and others, 1982
Chloroform	1.8	2.8	Briggs and others, 1982
CPMS	9.9	19	Briggs and others, 1982
$CPMSO_2$	1.1	1.7	Briggs and others, 1982
CPMSO	1.1	1.8	Briggs and others, 1982
Dibromochloropropane	1.7	2.8	Briggs and others, 1982; Newsome and others, 1977
1,3-Dichlorobenzene	16	25	Briggs and others, 1982
1,2-Dichloroethane	1.3	2.0	Briggs and others, 1982
DDE/DDT	28	81	Briggs and others, 1982; Harris and Sans, 1967; Harris and Sans, 1969; Lichtenstein, 1959; Onsager and others, 1970; Sand and others, 1972; Talekar and others, 1983
Dicyclopentadiene	8.7	17	Briggs and others, 1982
DIMP	1.6	2.1	Briggs and others, 1982; O'Donovan and Woodward, 1977
Dithiane	0.94	1.5	Briggs and others, 1982
Endrin/isodrin	26	90	Briggs and others, 1982; Harris and Sans, 1967; Hermanson, 1970; Wheeler and others, 1969
Ethylbenzene	8.8	14	Briggs and others, 1982
Hexachlorocyclopentadiene	29[b]	67	Briggs and others, 1982
Malathion	4.4	7.6	Briggs and others, 1982
Manganese	2.2	12.4	Baes and others, 1984; Shacklette and Boerngen, 1984
Oxathiane	0.84	1.3	Briggs and others, 1982
Tetrachloroethene	4.3	6.7	Briggs and others, 1982
Toluene	3.9	6.2	Briggs and others, 1982
Trichloroethene	4.7	8.4	Briggs and others, 1982
Xylene	8.6	13	Briggs and others, 1982

[a] K_{wr} for arsenic was treated as an extensive parameter because of uncertainty regarding its speciation in offpost water.

[b] Briggs and others (1982) predicts K_{wr} when log K_{ow} >4; consequently, the Briggs estimate was multiplied by 0.31, consistent with comparison of observed: predicted value for aldrin/dieldrin, chlordane, DDE/DDT, and endrin/isodrin.

K_{wr} = equilibrium partition coefficient relating concentration in soil water to concentration in roots and tubers
l/kg = liters per kilogram
MLE = most likely exposure
RME = reasonable maximum exposure

Table 2.1-7: Uptake to Plants, K_{wp} (l/kg), for Organic Groundwater Chemicals of Concern

Chemical	K_{wp} MLE	K_{wp} RME	References
Aldrin/dieldrin	22	32	Briggs and others, 1983; Harris and Sans, 1969; Lichtenstein and others, 1965; Lichtenstein and others, 1970; Lichtenstein and others, 1971; Lichtenstein and others, 1965; Saha and others, 1971; Sheets and others, 1969; Talekar, 1983
Arsenic	3.0[a]	37[a]	Baes and others, 1984; Isaac and others, 1976; Johnson and Hiltbold, 1969; Stevens and others, 1972
Atrazine	2.2	4.3	Briggs and others, 1983
Benzene	1.2	2.5	Briggs and others, 1983
Carbon tetrachloride	2.3	4.6	Briggs and others, 1983
Chlordane	7.6	16	Briggs and others, 1983; Dorough and others, 1972; Tafuri and others, 1977
Chlorobenzene	2.4	4.7	Briggs and others, 1983
Chloroform	1.1	2.1	Briggs and others, 1983
CPMS	3.7	8.1	Briggs and others, 1983
$CPMSO_2$	0.64	1.3	Briggs and others, 1983
CPMSO	0.69	1.4	Briggs and others, 1983
Dibromochloropropane	0.89	1.6	Briggs and others, 1983; Newsome and others, 1977
1,3-Dichlorobenzene	4.6	9.2	Briggs and others, 1983
1,2-Dichloroethane	0.84	1.7	Briggs and others, 1983
DDE/DDT	45	79	Barrentine and Cain, 1969; Briggs and others, 1983; Dorough and Randolph, 1969; Harris and Sans, 1969; Nash, 1968; Sheets and others, 1969; Voerman and Besemer, 1975; Wheeler and others, 1969; Young, 1969
Dicyclopentadiene	3.4	7.3	Briggs and others, 1983
DIMP	3.3	4.5	Briggs and others, 1983; O'Donovan and Woodward, 1977
Dithiane	0.45	0.96	Briggs and others, 1983
Endrin/isodrin	9.8	28	Barrentine and Cain, 1969; Briggs and others, 1983; Dorough and Randolph, 1969; Nash, 1968; Wheeler and others, 1969
Ethylbenzene	3.5	6.9	Briggs and others, 1983
Hexachlorocyclopentadiene	6.4	13	Briggs and others, 1983
Malathion	2.3	4.6	Briggs and others, 1983
Manganese	2.2	12.4	Baes and others, 1984; Shacklette and Boerngen, 1984
Oxathiane	0.14	0.31	Briggs and others, 1983
Tetrachloroethene	2.2	4.4	Briggs and others, 1983
Toluene	2.1	4.2	Briggs and others, 1983
Trichloroethene	2.4	4.9	Briggs and others, 1983
Xylene	3.4	6.8	Briggs and others, 1983

[a] K_{wp} for arsenic was treated as an extensive parameter because of uncertainty regarding its speciation in offpost water.

K_{wp} = equilibrium partition coefficient relating concentrations in soil water to concentrations in plants
l/kg = liters per kilogram
MLE = most likely exposure
RME = reasonable maximum exposure

Table 2.1-8: Plant Uptake Coefficients, K_{sr} (Dimensionless), for Chemicals of Concern in Offpost Surfical Soil

Chemical	K_{sr} MLE	K_{sr} RME	Reported Range[1]	References
Aldrin/dieldrin	0.34	0.65	0.06 - 1.8	Briggs and others, 1983; Harris and Sans, 1969; Saha and others, 1971; Sheets and others, 1969; Lichtenstein and Schultz, 1965; Lichtenstein and others, 1971; Lichtenstein and others, 1970; Lichtenstein and others, 1965; Onsager and others, 1970; Talekar and others, 1983
Chlordane	0.13	0.21	0.004 - 0.21	Briggs and others, 1982; Onsager and others, 1970; Sand and others, 1972
DDE/DDT	0.04	0.12	0.010 - 0.208	Briggs and others, 1982; Harris and Sans, 1969; Harris and Sans, 1967; Lichtenstein, 1959; Onsager and others, 1970; Sand and others, 1972; Talekar and others, 1983
Endrin/isodrin	0.35	0.66	0.02 - 0.66	Briggs and others, 1982; Harris and Sans, 1967; Hermanson and others, 1970; Wheeler and others, 1969

K_{sr} is treated as an extensive parameter because it depends on soil organic carbon content, which varies in offpost soil.

[1] Range after normalization to 0.9 percent organic carbon content.

K_{sr} = equilibrium partition coefficient relating concentration in bulk soil to concentration in roots and tubers
MLE = most likely exposure
RME = reasonable maximum exposure

Table 2.1-9: Plant Uptake Coefficients, K_{sp}, for Chemicals of Concern in Offpost Surficial Soil

Chemical	K_{sp} MLE	K_{sp} RME	Reported Range[1]	References
Aldrin/dieldrin	0.07	0.14	0.013 - 1.23	Briggs and others, 1983; Harris and and others, 1956; Lichtenstein and Shultz, 1965; Lichtenstein and others, 1971; Lichtenstein and others, 1970; Saha and others, 1971; Sand, 1969; Sheets and others, 1969; Talekar, 1983
Chlordane	0.02	0.035	0.005 - 0.035	Briggs and others, 1983; Dorough and Pass, 1972; Talekar, 1983
DDE/DDT	0.05	0.10	0.0006 - 0.22	Barrentine and Cain, 1969; Dorough and Randolph 1969; Sheets and others, 1969; Wheeler and others, 1969; Young, 1969
Endrin/isodrin	0.16	0.33	0.01-0.48	Barrentine and Cain, 1969; Briggs and others, 1983; Dorough and Randolph, 1969; Nash, 1968; Wheeler and others, 1969

K_{sp} is treated as an extensive parameter because it depends on soil organic carbon content, which varies in offpost soil.

[1] Range after normalization to 0.9 percent organic carbon content.

K_{sp} = equilibrium partition coefficient relating concentration in bulk soil to concentration in plants
MLE = most likely exposure
RME = reasonable maximum exposure

Table 2.1-10: Beef Bioaccumulation Coefficients, K_{pm}, for All Chemicals of Concern

Chemical	K_{pm} MLE	K_{pm} RME	Reported Range	References
Aldrin/dieldrin	0.63	0.75	0.15 - 1.5	Baxter, 1983; Braund and others, 1969; Bruce and others, 1965; Gannon and others, 1959; Harris and others, 1956; Kenaga, 1980; Link and others, 1964; Potter and others, 1974; Wilson and others, 1970
Arsenic	0.10	0.14	0.03 - 0.25	Baxter, 1983; Baes and others, 1984; Peoples, 1964
Atrazine	0.0012	0.021	NA	Kenaga, 1980
Benzene	0.00063	0.011	NA	Kenaga, 1980
Carbon tetrachloride	0.0013	0.022	NA	Kenaga, 1980
Chlordane	0.023	0.038	0.007 - 0.060	Baxter, 1983; Dorough and Hemkin, 1973; Kenaga, 1980
Chlorobenzene	0.0014	0.023	NA	Kenaga, 1980
Chloroform	0.00018	0.0026	NA	Kenaga, 1980
CPMS	0.0016	0.023	NA	Kenaga, 1980
$CPMSO_2$	0.00017	0.0025	NA	Kenaga, 1980
CPMSO	0.00017	0.0025	NA	Kenaga, 1980
Dibromochloropropane	0.00022	0.0032	NA	Kenaga, 1980
1,3-Dichlorobenzene	0.0032	0.055	NA	Kenaga, 1980
1,2-Dichloroethane	0.00036	0.0062	NA	Kenaga, 1980
DDE/DDT	0.40	0.60	0.16 - 1.6	Baxter, 1983; Bruce and others, 1965; Fries and others, 1969; Kenaga, 1980; Link and others, 1964; Rumsey and others, 1977; Wilson and others, 1970
Dicyclopentadiene	0.0013	0.018	NA	Kenaga, 1980
DIMP	0.00012	0.0003	<0.0003	Kenaga, 1980; Ivie, 1980
Dithiane	0.00011	0.0016	NA	Kenaga, 1980
Endrin/isodrin	0.080	0.10	0.01 - 0.10	Baldwin and others, 1976; Kenaga, 1980; Kiigemagi and others, 1958; Baldwin and others, 1976
Ethylbenzene	0.0021	0.036	NA	Kenaga, 1980
Hexachlorocyclopentadiene	0.0045	0.062	NA	Kenaga, 1980
Malathion	0.0013	0.022	NA	Kenaga, 1980
Manganese	0.02	0.02	NA	Baxter, 1983
Oxathiane	0.000041	0.00065	NA	Kenaga, 1980
Tetrachloroethene	0.0013	0.021	NA	Kenaga, 1980
Toluene	0.0012	0.020	NA	Kenaga, 1980
Trichloroethene	0.0014	0.024	NA	Kenaga, 1980
Xylene	0.0021	0.036	NA	Kenaga, 1980

K_{pm} = equilibrium partition coefficient relating concentration in feed to concentration in beef

MLE = most likely exposure
NA = not applicable
RME = reasonable maximum exposure

Table 2.1-11: Milk Bioaccumulation Coefficients, K_{pd}, for All Chemicals of Concern

Chemical	K_{pd} MLE	K_{pd} RME	Reported Range	References
Aldrin/dieldrin	0.13	0.15	0.11 - 0.34	Baes and others, 1984; Braund and others, 1969; Bruce and others, 1965; Gannon and others, 1959; Harris and others, 1956; Peoples, 1964; Potter and others, 1974; Vreman and others, 1976; Wiese and others, 1970
Arsenic	0.0047	0.006	0.004 - 0.006	Baes and others, 1984; Peoples, 1964
Atrazine	0.00028	0.0048	NA	Kenaga, 1980
Benzene	0.00015	0.0025	NA	Kenaga, 1980
Carbon tetrachloride	0.00030	0.0051	NA	Kenaga, 1980
Chlordane	0.0050	0.0080	NA	Dorough and Hemkin, 1973; Kenaga, 1980
Chlorobenzene	0.00031	0.0052	NA	Kenaga, 1980
Chloroform	0.000042	0.00060	NA	Kenaga, 1980
CPMS	0.00037	0.0053	NA	Kenaga, 1980
$CPMSO_2$	0.000040	0.00058	NA	Kenaga, 1980
CPMSO	0.000039	0.00057	NA	Kenaga, 1980
Dibromochloropropane	0.000050	0.00073	NA	Kenaga, 1980
1,3-Dichlorobenzene	0.00074	0.013	NA	Kenaga, 1980
1,2-Dichloroethane	0.000081	0.0014	NA	Kenaga, 1980
DDE/DDT	0.08	0.12	NA	Baxter and others, 1983; Kenaga, 1980; Link and others, 1964; Rumsey and others, 1977; Wilson and others, 1970
Dicyclopentadiene	0.00029	0.0041	NA	Kenaga, 1980
DIMP	0.000028	0.00006	<0.00006	Ivie, 1980; Kenaga, 1980
Dithiane	0.000024	0.00036	NA	Kenaga, 1980
Endrin/isodrin	0.02	0.028	0.028 - 0.033	Baldwin and others, 1976; Kenaga, 1980; Kiigemagi and others, 1958; Baldwin and others, 1976
Ethylbenzene	0.00049	0.0083	NA	Kenaga, 1980
Hexachlorocyclopentadiene	0.001	0.014	NA	Kenaga, 1980
Malathion	0.00030	0.0051	NA	Kenaga, 1980
Manganese	0.018	0.018	NA	Baes and others, 1984
Oxathiane	0.000009	0.00015	NA	Kenaga, 1980
Tetrachloroethene	0.00029	0.0049	NA	Kenaga, 1980
Toluene	0.00027	0.0046	NA	Kenaga, 1980
Trichloroethene	0.00031	0.0054	NA	Kenaga, 1980
Xylene	0.00049	0.0083	NA	Kenaga, 1980

K_{pd} = equilibrium partition coefficient relating concentration in feed to concentration in milk

MLE = most likely exposure
NA = not applicable
RME = reasonable maximum exposure

Table 2.1-12: Fish Bioaccumulation Coefficients, K_{wf} (l/kg), for Surface-Water Chemicals of Concern

Chemical	K_{wf} MLE	K_{wf} RME	Reported Range	References
Aldrin/dieldrin	7700	11,000	2740 - 13,000	Davies and Dobbs, 1984; Kenaga, 1980; Lyman and others, 1982; Waller and Lee, 1979
Arsenic	0.8	5.1	0 - 5.5	Banarjee and others, 1980; Schuth and others, 1974; Spehar and others, 1980; Woolsen and others, 1976
Chlordane	11,000	14,000	162 - 37,800	ATSDR, 1988a; EPA, 1979a; Lyman and others, 1982; Verschueren, 1983
Dibromochloropropane	38	47	11.2 - 67.5	Ebasco, 1990
DDE/DDT	47,000	60,000	200 - 180,000	Ebasco, 1990; EPA, 1979a; Lyman and others, 1982; Verschueren, 1983
Dicyclopentadiene	80	143	53 - 143	Ebasco, 1990
DIMP	5.1	19	<0.6 - 6.1	Ebasco, 1990; Lyman and others, 1982; Davies and Dobbs, 1984

K_{wf} = equilibrium partition coefficient relating concentration in water to concentration in edible fish tissue
l/kg = liters per kilogram
MLE = most likely exposure
RME = reasonable maximum exposure

Table 2.2.2.1.2-1: Population by Land-Use Area

Study Area	Year 1985	Mean Density per Acre	Year 1995	Mean Density per Acre	Annual Growth 1985 to 1995	Year 2010	Mean Density per Acre	Annual Growth 1995 to 2010	Percent Total
I	121	0.05	512	0.21	15.5	1725	0.72	8.4	37
II	825	0.18	1333	0.30	4.9	2915	0.65	5.4	63
Total	946	0.14	1845	0.27	6.9	4640	0.67	6.3	100

Source: Denver Regional Council of Governments.

Table 2.2.2.1.2-2: Land Use by Land-Use Area (in acres)

Land Use	I	II	Total	Percentage
1985 Study Areas				
Agricultural	2000	3750	5750	84
Industrial/Commercial	300	350	650	9
Residential	100	300	400	6
Open Space/Floodplain	0	75	75	1
Total	2400	4475	6875	100
2010 Study Areas				
Agricultural	0	0	0	0
Industrial/Commercial	1160	1360	2520	37
Residential	1000	1240	2240	32
Open Space/Floodplain	240	1875	2115	31
Total	2400	4475	6875	100

Sources: Adams County Future Land Use Plan, 1984; Adams County, 1990; 2010 Airport Environs Plan, 1989.

Residential land use not shown in plans; population is expected to increase from more than 2400 to nearly 3900 in 25 years.

Table 2.2.2.1.2-3: Potentially Sensitive Subpopulations

Population Subgroup	Study Area Percentage[1]	State Percentage	National Percentage
Children (under 15)	25.8	21.7	22.0
Women (age 15-44)	24.0	25.3	23.3
Elderly (65 and over)	7.3	8.7	11.7

Source: U.S. Census, 1980.

[1] Based on Census Tracts 85.14, 85.12, 88.01, and 88.02.

Table 2.2.2.4.1-1: Well-Use Data From Colorado State Master Extract Register

Study Area	Numbers of Wells by Use Code[1]										Total
	0	1	2	3	4	5	6	7	8	9	
I	1	30	2	4	2	0	0	0	0	0	39
II	1	71	4	13	5	1	84	2	2	1	184
Total Number of Wells	2	101	6	17	7	1	84	2	2	1	223

Source: Colorado Division of Water Resources, 1985.

[1] Use Codes:
0 = in-house domestic use only
1 = in-house and outside domestic use
2 = livestock use
3 = livestock and domestic use
4 = commercial use
5 = industrial use
6 = irrigation use
7 = irrigation and in-house domestic use
8 = municipal supply well
9 = all other uses

Table 2.2.2.4.1-2: Well-Use Data From Consumptive Use Phase I, II, and III Studies

Study Area[1]	All Purpose	Domestic Sanitary Only[2]	Well Use Unknown[3]	Irrigation[4]	Livestock[5]	Total[6]
I	9	0	4	5	3	18
II	20	4	11	8	33	68
Total Number of Wells	29	4	15	13	36	86

[1] When assigning the wells to study areas, wells on the boundary of two study areas were assigned to the study area with higher concentrations.
[2] The separation of domestic wells by specific use is sometimes subjective; however, wells were listed as all-purpose only if the well report gave an indication that the water may be used for drinking.
[3] Wells that had no apparent receptors were not included in the analysis.
[4] If the permitted use listed was irrigation, the well was counted even if not currently in use.
[5] Wells were listed as livestock wells only if the well reports specifically mentioned such use.
[6] Total number of wells represents the actual number of wells in each study area. Because some wells have multiple uses and each use is counted as a separate well, the rows do not total across.

Table 2.2.2.4.1-3: Preliminary Estimate of the Number of Wells by Well Use in the Offpost Operable Unit

Study Area	Well Use[1]			Total Number of Wells
	Potable	Irrigation	Livestock	
I	30 - 45	0 - 10	5 - 15	40 - 60
II	75 - 85	75 - 85	15 - 20	200 - 280
Total Number of Wells	105 - 130	75 - 95	20 - 35	240 - 340

Source: Colorado Department of Water Resources, 1985 and ESE, 1988a.

Because of the uncertainty in the estimates, the upper and lower bound estimates are rounded up and down, respectively, to the nearest 5.

[1] The separation of domestic wells by specific use is sometimes subjective; however, wells were listed as all-purpose only if the well report gave an indication that the water may be used for drinking.

Table 2.2.2.4.1-4 Well Use Data From the Tri-County Health Department Survey

Formation Tapped	Number of Wells Surveyed	Percentage of Wells Surveyed	Well Use[1]							
			Potable[2]	Cooking[3]	Sanitary Only[4]	Irrigation[5]	Livestock[6]	Pets[7]	Not Used[8]	Use Unknown[9]
Alluvial	301	53.8	24%	1%	8%	48%	7%	2%	22%	3%
Arapahoe	235	42.0	80%	2%	7%	13%	9%	2%	7%	1%
Denver	14	2.5	71%	0%	7%	21%	0%	7%	7%	0%
Fox Hills	2	0.4	0%	0%	100%	0%	0%	0%	0%	0%
Unknown[10]	8	1.4								
Total Number of Wells[11]	560		40%	1%	8%	32%	7%	2%	15%	4%

Source: Tri-County Health Department Survey (TCHD), 1990.

1 Percentage of wells in the designated aquifer used for the specific purpose. Some wells have multiple uses; therefore, the percentage of wells in the well use columns may not add across to equal 100 percent.
2 All wells specified as a potable source are also assumed to be used for various domestic purposes.
3 These wells are not used as a potable water supply; however, they are used for cooking and other domestic uses.
4 Domestic uses include bathing and washing hands, dishes, clothes, cars, equipment.
5 Includes those irrigation wells specified as closed or closed for winter/season; also, specific well use listed as vegetable garden, trees, yard, lawn, etc.
6 Includes those livestock wells specified as closed or closed for winter/season; also, specific well use listed as cattle, hogs, fowl, pasture, etc.
7 Includes only those wells specified for pets, dogs, horses, etc. Some wells listed as "all domestic" may also be used as pet drinking water supplies.
8 Includes wells that are not in use, capped, deteriorated, dry, and those listed as not having electricity or a pump (even if a use is specified).
9 Includes wells for which no specific use information was given or owner would not discuss details.
10 Wells for which there were no hardness or conductivity measurements made and for which insufficient information was available to classify the well with respect to the aquifer tapped.
11 Total number of wells includes domestic, municipal, commercial, and industrial wells.

% = percent

Table 2.2.2.4.1-5: Combined Estimate of the Number of Wells by Well Use in the Offpost Operable Unit

Study Area	Data Source[1]	Well Use			Total Number of Wells[2]
		Potable	Irrigation	Livestock	
I	*	28	6	7	45
II	**	104	97	13	260
Total Number of Wells		132	103	20	305

Source: Tri-County Health Department (TCHD), 1990.

[1] Sources and rationale used to determine the number of wells in each study area.
[2] Total number of wells represents the actual number of wells in each study area. Because some wells have multiple uses and each use is counted as a separate well, the rows do not total across.

* The number of wells in Study Area I was estimated by adding 10 percent of the median number of wells in each well use category from Table 2.2.2.4.1-3 to the number of wells determined from the TCHD Well Survey because the TCHD survey area only covered approximately 90 percent of Study Area I.

** The number of wells in Land Use Area II was determined using data from the TCHD Well Survey (1990) because the study areas were entirely within the area surveyed by TCHD.

Table 2.3.3.1-1: Exposure Pathways: Inhalation Route

Potentially Exposed Population	Current/ Future	Pathway	Selected?	Reason for Selection or Exclusion
R	C, F	Vapors in residences following volatilization from groundwater	No	Exposure much less than other quantified groundwater pathways
R, I/C	F[1]	Vapors in residences that volatilized from groundwater during domestic use	Yes	Groundwater COCs include volatiles and groundwater is preferred source of domestic water
R, I/C	C, F	Chemicals in surficial soils may be reentrained by wind, erosion, or mechanical disturbance	No	Exposure much less than other quantified soil pathways
R, I/C	C, F	Chemicals released to the air by onpost sources may be transported offpost	No	No COCs are elevated above background at RMA boundary

[1] Current exposures are substantially reduced by provision of alternative water supply at most heavily contaminated locations.

C = current
COC = chemical of potential concern
F = future
I/C = industrial/commercial workers
R = residential
RMA = Rocky Mountain Arsenal

Table 2.3.3.2-1: Exposure Pathways: Dermal Route

Potentially Exposed Population	Status	Pathway	Selected?	Reason for Selection or Exclusion
R, I/C	C, F	Direct contact with surficial soil	Yes	Surficial soils are contaminated at potential exposure points
R	C, F	Direct contact with sediments of First Creek	Yes	First Creek sediments are contaminated and access is unrestricted
R	C, F	Direct contact with First Creek water	Yes	First Creek is contaminated, and access is unrestricted
R	F[1]	Direct contact with groundwater used in the home	No	Exposure much less than other quantified groundwater pathways

[1] Current exposures are substantially reduced by provision of alternative water supply at most heavily contaminated locations.

C = current
F = future
I/C = industrial/commercial workers
R = residential

Table 2.3.3.3-1: Exposure Pathways: Ingestion Route
(Page 1 of 2)

Potentially Exposed Population	Status	Pathway	Selected?	Reason for Selection or Exclusion
R, I/C	C, F	Incidental ingestion of surficial soil	Yes	Surficial soil contains COCs at potential exposure points
R	C, F	Incidental ingestion of First Creek sediments	Yes	First Creek sediments contain COCs and access is unrestricted
R	C, F	Meat is consumed from livestock (e.g., cattle) that are exposed to contaminated forage, soil, groundwater, or surface water	Yes	Rural residential land use; documented to be complete pathway
R	C, F	Milk consumed from cattle exposed to contaminated forage, soil, groundwater, or surface water	Yes	Rural residential land use; documented homegrown dairy consumption
R	C, F	Eggs are consumed from chickens exposed to contaminated surficial soil	Yes	Rural residential land use; documented to be complete pathway
R	C, F	Vegetables grown in contaminated soil or irrigated by contaminated groundwater or surface water	Yes	Rural residential land use; homegrown vegetable consumption and use of irrigation water are documented
R	C, F	Fruits grown in contaminated soil or irrigated with groundwater or surface water containing COCs	No	Exposure expected to be much less than other quantified pathways involving same media; low fruit production in area
R	C, F	Consumption of fish caught recreationally that bioaccumulate COCs from surface water or sediments	No	No fish in First Creek; no OCPs in canals; no COCs in Barr Lake
R	C, F	Consumption of game that bioaccumulate COCs from soil or surface water	No	Offpost pheasant not contaminated above background
R, I/C	F[1]	Groundwater used for potable supply	Yes	Groundwater contaminated at potential exposure points

Table 2.3.3.3-1: Exposure Pathways: Ingestion Route
(Page 2 of 2)

Potentially Exposed Population	Status	Pathway	Selected?	Reason for Selection or Exclusion
R	C, F	Incidental ingestion of surface water during wading	No	Exposure much less than other quantified surface-water pathways

[1] Current exposures are substantially reduced by provision of alternative water supply at potentially contaminated locations.

C = current
COCs = chemicals of concern
F = future
I/C = industrial/commercial workers
OCPs = organochlorine pesticides
R = residential

Table 2.4.2.4-1: Nonchemical-specific Parameters Used in Bioaccumulation Models

Parameter	Potential Range[1]	MLE	RME	References	Comments
f_e	0 to 1.0	0.62	1.0	EPA, USDA85	Corn is not exposed; ratio of homegrown aboveground vegetable consumption excluding corn to consumption of homegrown aboveground vegetables; RME is 90th percentile
K_{dep} (l/kg)	0.4 to 33	2.4	3.5	DD78, KN80	RME is upper 90 percent confidence limit on the arithmetic mean
I_{pwm} (l/kg)	0.2 to 2.9	0.9	1.2	HE68, OS85, SH82, BA83, WI70, CH77	RME is upper 90 percent confidence limit on the arithmetic mean
I_{pwd} (l/kg)	0.5 to 8.6	1.7	2.4	HE68, KO77, OS85, BA83, NAS71, SH82, SF80, SF79, AL54, FR73, LI64	RME is upper 90 percent confidence level on the arithmetic mean
I_{ps}	0.003 to 0.040	0.010	0.014	TA83, FR82, MA77, KS80, HE68	RME is upper 90 percent confidence limit on the arithmetic mean

Sources: Albritton, 1954 (AL54); Baxter and others, 1983 (BA83); Donigan and Davis, 1978 (DD78); EPA, 1989d; Fries and others, 1973 (FR73); Fries and others, 1982 (FR82); Healy, 1968 (HE68); Kirby and Stuth, 1980 (KS80); Knisel, ed., 1980 (KN80); Konikow, 1977 (KO77); Link and others, 1964 (LI64); Mayland and others, 1977 (MA77); National Academy of Sciences, 1971 (NAS71); Osweiler and others, 1985 (OS85); Shor and Fields, 1979 (SF79); Shor and Fields, 1980 (SF80); Shor and others, 1982 (SH82); Taleker and others, 1983 (TA83); U.S. Department of Agriculture, 1985 (USDA85); Wilson and others, 1970 (WI70).

[1] Can be range in reported values, upper and lower bounds based on known constraints, or range in calculated values.

l/kg = liters per kilogram
MLE = most likely exposure
RME = reasonable maximum exposure

Table 2.4.2.5-1: Concentration of Aldrin Plus Dieldrin in Zone 3

Media	MLE	RME
Groundwater (μg/l)	0.14	0.26
Surface water (μg/l)	0.67	2.6
Surficial soil (mg/kg)	0.093	0.126

μg/l = micrograms per liter
mg/kg = milligrams per kilogram
MLE = most likely exposure
RME = reasonable maximum exposure

Table 2.4.2.5-2: Chemical-specific Properties of Aldrin and Dieldrin

Parameter	MLE	RME
K_{se}	0.049	0.087
K_{pm}	0.63	0.75
K_{pd}	0.13	0.15
K_{wp} (l/kg)	22	32
K_{wr} (l/kg)	103	144
K_{sp}	0.07	0.14
K_{sr}	0.34	0.65

l/kg = liters per kilogram
MLE = most likely exposure
RME = reasonable maximum exposure

Table 2.4.2.6-1: Exposure Concentrations, Groundwater, Zone 1

Chemical of Concern	Exposure Concentration[1] (µg/l)	Frequency of Occurrence (%)
Aldrin	0.029	3
Arsenic	2.15	31
Atrazine	2.87	2
Benzene	0.61	2
Chloride	120,000	100
Chlorobenzene	1.02	21
Chloroform	0.68	18
DDE	0.029	2
DDT	0.037	8
Dieldrin	0.034	3
DIMP	63.3	80
Endrin	0.033	3
Fluoride	1830	94
Hexachlorocyclopentadiene	0.029	4
Isodrin	0.028	2
Nitrate	7320	100
Sulfate	340,000	100
Tetrachloroethene	0.70	5
Xylene	0.75	2

[1] All exposure concentrations represent the upper 95 percent confidence limit on the arithmetic mean of measured concentrations in monitoring and private wells.

µg/l = micrograms per liter
% = percent

Table 2.4.2.6-2: Exposure Concentrations, Groundwater, Zone 2
(Northern Paleochannel)

Chemical of Concern	Exposure Concentration[1] (µg/l)	Frequency of Occurrence (%)
Aldrin	0.045	11
Arsenic	1.63	10
Atrazine	5.31	17
Benzene	0.64	2
Carbon tetrachloride	0.76	2
Chlordane	0.18	16
Chloride	205,000	100
Chlorobenzene	1.78	22
Chloroform	67.5	47
CPMSO	14.5	19
$CPMSO_2$	4.35	3
Dibromochloropropane	0.44	29
DDE	0.029	4
DDT	0.033	4
Dichlorobenzene	5.1	20
1,2-Dichloroethane	0.77	3
Dicyclopentadiene	3.64	3
Dieldrin	0.035	14
DIMP	713	78
Endrin	0.037	9
Fluoride	2210	93
Hexachlorocyclopentadiene	0.033	7
Isodrin	0.035	4
Malathion	0.26	8
Manganese	1580	33
Nitrate	11,600	100
Sulfate	636,000	100
Tetrachloroethene	10.1	34
Trichloroethene	0.64	19

[1] All exposure concentrations represent the upper 95 percent confidence limit on the arithmetic mean of measured concentrations in monitoring and private wells.

µg/l = micrograms per liter
% = percent

Table 2.4.2.6-3: Exposure Concentrations, Groundwater, Zone 3
(96th Avenue and Peoria Street)

Chemical of Concern	Exposure Concentration[1] (µg/l)	Frequency of Occurrence (%)
Aldrin	0.050	11
Atrazine	12.9	38
Benzene	0.75	7
Chlordane	0.19	23
Chloride	487,000	100
Chlorobenzene	1.77	25
Chloroform	5.01	50
CPMSO	10.4	20
$CPMSO_2$	6.63	20
Dibromochloropropane	0.14	13
DDE	0.22	14
DDT	0.11	18
1,2-Dichloroethane	0.92	11
Dicyclopentadiene	163	30
Dieldrin	0.21	32
DIMP	590	87
1,4-Dithiane	1.97	10
Endrin	0.73	38
Fluoride	3510	96
Hexachlorocyclopentadiene	0.044	9
Isodrin	0.047	5
Malathion	0.38	13
Nitrate	7950	100
1,4-Oxathiane	1.32	3
Sulfate	909,000	100
Tetrachloroethene	20.7	39
Toluene	1.28	3
Trichloroethene	0.51	7

[1] All exposure concentrations represent the upper 95 percent confidence limit on the arithmetic mean of measured concentrations in monitoring and private wells.

µg/l = micrograms per liter
% = percent

Table 2.4.2.6-4: Exposure Concentrations, Groundwater, Zone 4
(First Creek Paleochannel)

Chemical of Concern	Exposure Concentration[1] (µg/l)	Frequency of Occurrence (%)
Aldrin	0.12	33
Arsenic	2.78	30
Atrazine	7.36	37
Benzene	0.93	3
Chlordane	0.54	35
Chloride	660,000	100
Chlorobenzene	4.51	40
Chloroform	1.51	28
CPMSO	7.68	5
$CPMSO_2$	5.09	15
Dibromochloropropane	0.15	15
DDE	0.085	17
DDT	0.10	29
Dichlorobenzene	2.9	13
1,2-Dichloroethane	7.32	20
Dicyclopentadiene	66.6	29
Dieldrin	0.055	23
DIMP	4950	80
1,4-Dithiane	4.22	22
Endrin	0.058	25
Ethylbenzene	0.57	2
Fluoride	3290	98
Hexachlorocyclopentadiene	0.043	3
Isodrin	0.057	19
Malathion	0.32	8
Manganese	1250	50
Nitrate	8730	100
1,4-Oxathiane	2.21	16
Sulfate	1,118,000	100
Tetrachloroethene	6.09	25
Toluene	1.18	3
Trichloroethene	2.70	24
Xylene	1.11	2

[1] All exposure concentrations represent the upper 95 percent confidence limit on the arithmetic mean of measured concentrations in monitoring and private wells.

µg/l = micrograms per liter
% = percent

Table 2.4.2.6-5: Exposure Concentrations, Groundwater, Zone 5
(Northwest Boundary)

Chemical of Concern	Exposure Concentration[1] (µg/l)	Frequency of Occurrence (%)
Aldrin	0.039	11
Arsenic	2.68	25
Chloride	262,000	100
Chlorobenzene	1.09	21
Chloroform	12.0	75
Dibromochloropropane	0.10	3
Dieldrin	0.071	42
DIMP	7.68	52
Fluoride	1810	88
Hexachlorocyclopentadiene	0.035	4
Manganese	670	100
Nitrate	4610	100
Sulfate	148,000	100
Tetrachloroethene	0.75	5

[1] All exposure concentrations represent the upper 95 percent confidence limit on the arithmetic mean of measured concentrations in monitoring and private wells.

µg/l = micrograms per liter
% = percent

Table 2.4.2.6-6: Exposure Concentrations, Groundwater, Zone 6

Chemical of Concern	Exposure Concentration[1] (µg/l)	Frequency of Occurrence (%)
Aldrin	0.030	5
Atrazine	4.48	10
Chloride	191,000	100
Chlorobenzene	1.27	25
Chloroform	3.33	81
Dieldrin	0.039	29
DIMP	4.67	82
Fluoride	2230	100
Isodrin	0.040	5
Nitrate	6420	100
Sulfate	213,000	100
Tetrachloroethene	1.67	14
Trichloroethene	4.04	19

[1] All exposure concentrations represent the upper 95 percent confidence limit on the arithmetic mean of measured concentrations in monitoring and private wells.

µg/l = micrograms per liter
% = percent

Table 2.4.2.6-7: Estimated Future Exposure Concentrations for Aldrin and Dieldrin, Groundwater, Zones 3 and 4

Time (years)	Dieldrin[1] Zone 3 (µg/l)	Dieldrin[1] Zone 4 (µg/l)	Aldrin[1] Zone 3 (µg/l)	Aldrin[1] Zone 4 (µg/l)
0	0.210	0.060	0.050	0.120
1	0.155	0.041	0.037	0.088
2	0.128	0.034	0.031	0.073
3	0.114	0.030	0.027	0.065
4	0.102	0.027	0.025	0.058
5	0.090	0.025	0.025	0.051
10	0.055	0.025	0.025	0.031
15	0.039	0.025	0.025	0.025
20	0.034	0.025	0.025	0.025
25	0.025	0.025	0.025	0.025
30	0.025	0.025	0.025	0.025
Average[2]	0.057	0.027	0.027	0.036

[1] All exposure concentrations represent the upper 95 percent confidence limit on the arithmetic means of modeled groundwater concentrations.
[2] Average values are based on all data points modeled over the 30-year period.

µg/l = micrograms per liter

Table 2.4.2.6-8: Exposure Concentrations in Surface Water

Chemical of Concern	First Creek[1] (µg/l)	Irrigation Canals[1] (µg/l)
Arsenic	18	NE
Chlordane	0.18	NE
Chloride	206,000	NE
DDE	0.089	NE
DDT	0.046	NE
Dicyclopentadiene	10	NE
Dieldrin	2.6	NE
DIMP	230	20
Fluoride	2550	970
Nitrate	5000	NE
Sulfate	438,000	NE

[1] All exposure concentrations represent the upper 95 percent confidence limit on the arithmetic mean of measured concentrations in unfiltered surface-water samples.

µg/l = micrograms per liter
NE = chemical not significantly elevated above background in the irrigation canals

Table 2.4.2.6-9: Exposure Concentrations in Surficial Soil and Sediments (mg/kg)

Chemical of Concern	Soil, Zone 3[1] (96th Avenue and Peoria Street)	Soil[1,2] (Outside Zone 3)	Sediments[1] (First Creek)
Aldrin	0.014	0.0021	0.011
Chlordane	0.049	ND	ND
Dibromochloropropane	NE	NE	0.099
DDE	0.024	0.015	0.0005
DDT	0.063	0.030	0.0084
Dieldrin	0.112	0.018	0.134
Endrin	0.032	0.0042	0.0038

[1] All exposure concentrations represent the upper 95 percent confidence limit on the arithmetic mean of measured concentrations in soil and sediments.
[2] Only surficial soil samples representing the upper 0.1-foot interval were used to estimate exposure concentrations in surficial soil.

mg/kg = milligrams per kilogram
ND = chlordane not detected in soil outside subarea 3 nor in sediments of First Creek
NE = dibromochloropropane not significantly elevated above background in surficial soil

Table 2.4.2.6-10: Reasonable Maximum Exposure Concentrations in Vegetables: Maximum Concentration Estimated in Any Zone

Chemical of Concern	C_p[1] (µg/kg)	Zone in Which Maximum Occurs
Arsenic	15	4
Atrazine	83	3
Benzene	3.8	4
Carbon tetrachloride	5.7	2
Chlordane	2.5	4
Chlorobenzene	32	4
Chloroform	280	2
CPMSO	48	2
$CPMSO_2$	19	3
Dibromochloropropane	1.7	2
DDE	3.3	3
Dichlorobenzene	98	2
1,2-Dichloroethane	24	4
Dicyclopentadiene	2100	3
Dieldrin	16	3
DIMP	22,000	4
Dithiane	11	4
Endrin	14	3
Ethylbenzene	6.2	4
Hexachlorocyclopentadiene	1.7	3
Malathion	2.7	3
Manganese	10,000	2
Oxathiane	5.0	4
Tetrachloroethene	140	3
Toluene	8.0	3
Trichloroethene	20	4
Xylene	12	4

[1] All exposure concentrations are estimated values based on (1) reasonable maximum exposure concentrations in soil, groundwater, and surface water and (2) reasonable maximum equilibrium partition coefficient.

µg/kg = micrograms per kilogram
C_p = concentration in plants

Table 2.4.2.6-11: Reasonable Maximum Exposure Concentrations in Dairy and Meat Products: Maximum Concentration Estimated in Any Zone

Chemical of Concern	C_d[1] (µg/kg)	C_m[1] (µg/kg)	Zone in Which Maximum Occurs
Arsenic	0.053	0.89	1B
Atrazine	0.17	0.62	2
Benzene	0.0077	0.026	2
Carbon tetrachloride	0.027	0.098	2
Chlordane	0.0047	0.014	2
Chlorobenzene	0.066	0.24	2
Chloroform	0.18	0.59	2
CPMSO	0.031	0.093	2
$CPMSO_2$	0.0094	0.028	2
Dibromochloropropane	0.0013	0.0039	2
DDE	0.22	1.1	1B
Dichlorobenzene	0.75	2.9	2
1,2-Dichloroethane	0.0044	0.014	2
DCPD	0.14	0.55	2
Dieldrin	0.19	0.91	2
DIMP	0.29	1.2	2
Endrin	0.032	0.10	2
Hexachlorocyclopentadiene	0.0070	0.028	2
Malathion	0.0091	0.033	2
Manganese	190	180	2
Tetrachloroethene	0.34	1.2	2
Trichloroethene	0.025	0.094	2
Xylene	0.058	0.22	1B

[1] Exposure concentrations were not calculated for zones 3, 4, and 5 because the pathways are incomplete under the operative land use scenario.

µg/kg = micrograms per kilogram
C_d = concentration in dairy products
C_m = concentration in meats

Table 2.4.2.6-12: Reasonable Maximum Exposure Concentrations in Eggs
(Zones 1, 2, and 6)

Chemical of Concern	C_e (µg/kg)
DDE	3.9
Dieldrin	1.7
Endrin	0.36

µg/kg = micrograms per kilogram
C_e = concentration in eggs

Table 2.4.3-1: Summary of Land Use Scenarios Used to Estimate Reasonable Maximum Exposure Intakes by Zone

Scenario	Zone[1]	Pathways Quantified
Rural residential	1, 2, 6	Dermal, soil Inhalation, groundwater Oral, dairy Oral, eggs Oral, groundwater Oral, meat Oral, soil Oral, vegetables
Urban residential	3, 4	Dermal, soil Dermal, sediment Dermal, surface water Inhalation, groundwater Oral, groundwater Oral, sediment Oral, soil Oral, vegetables
Commercial/industrial	5	Dermal, soil Inhalation, groundwater Oral, groundwater Oral, soil

[1] Zone in which the scenario is assumed to represent RME scenario.

RME = reasonable maximum exposure

Table 2.4.3.1-1: Dermal Absorption from Soil/Sediment

Chemical of Concern	ABS
Aldrin	0.0195
Chlordane, total	0.0195
DDE	0.0156
DDT	0.0156
Dibromochloropropane	0.0150
Dieldrin	0.0195
Endrin	0.0195
Isodrin	0.0195

ABS = absorption factor for dermal contact with soil and sediment

Table 2.4.3.2-1: Exposure Factors: Ingestion Rates

Ingestion Rates	Lifetime[1]	Adult Chronic[2]	Adult Acute (Female)[3]	Child Chronic[4]	Child Acute[5]	References
IR_w (l/day)	2	2	2	0.78	0.78	EPA, 1989c
IR_s (mg/day)	TWA	100	100	TWA	200	Anderson and others, 1985
IR_v (kg/day)	0.08	0.08	0.265	0.0334	0.194	Pao and others, 1982; EPA, 1991a
IR_m (kg/day)	0.075	0.075	0.212	0.059	0.108	EPA, 1991a; Pao and others, 1982
IR_e (kg/day)	0.061	0.061	0.113	0.0435	0.0934	EPA, 1991a
IR_d (kg/day)	TWA	0.300	0.382	TWA	0.716	Anderson and others, 1985; EPA, 1991a

[1] Lifetime same as adult chronic except for soil and dairy products, where childhood ingestion per body weight is much greater than adults; then a time-weighted average intake was calculated using age-specific ingestion and body weight.

[2] Adult chronic is 90th percentile consumption of foods times homegrown fraction. For IR_v, IR_m, and IR_d, see (EPA, 1989c). Homegrown fraction assumed to be 1 for eggs in lieu of data and guidance.

[3] 90th percentile per eating occasion, including nonconsumers; homegrown fraction - 1; adult females age 19 to 34 typically consume dairy products 1.3 times per day; therefore, IR_d = 90th percentile per occasion times 1.3.

[4] Same procedure as adult chronic using data for age 3 to 5.

[5] Same procedure as adult acute using data for age 3 to 5.

kg/day = kilograms per day
l/day = liters per day
mg/day = milligrams per day
TWA = time-weighted average, see Table 2.4.3.2-1(a)

Table 2.4.3.2-1a: Parameters Used in Time-weighted Average Intakes Calculation (Milk and Soil Ingestion)

	IR_d (kg/day)	IR_s (mg/day)	ED (yr)	BW (kg)
Lifetime				
	0.533	200	6	15
	0.593	100	6	29
	0.608	100	6	54
	0.300	100	6	64
	0.300	100	6	68
Child Chronic				
	0.533	200	6	15
	0.591	100	3	26

Sources: EPA, 1989a; EPA, 1991a; Pao and others, 1982.

kg/day = kilograms per day
mg/day = milligrams per day
yr = year

Table 2.4.3.2-2: Exposure Factors: Exposure Frequency and Duration

Exposure Factors	Exposure Frequency and Duration	References
EF (days/year), lifetime/chronic	350 days/year	EPA, 1991a
EF for direct exposure to surface water/sediments	62 days/year	NOAA, 1989 (days when climatological normal maximum temperature exceeds 80°F at Stapleton Airport)
EF (day/year), acute scenarios	365 days/year	RME 1-day exposure (EPA, 1991a)
ED (year), adult chronic and lifetime	30 years	EPA, 1989c (90th percentile in single residence)
ED (year), child chronic	9 years	Shortest duration considered chronic (EPA, 1989c), short duration is conservative if targeted on portion of life cycle with maximum exposure
ED (year) acute scenarios	0.00274 (1 day)	
ET (hours/day) dermal contact with surface water	2.6 hours/day	National average for swimming (EPA, 1989a) assumed to be conservative for First Creek where only wading is possible
AT (day) noncarcinogenic effect	AT = ED x 365 days/year	EPA, 1989a
AT (day) carcinogenic effects (lifetime)	25,550 day	EPA, 1989a
AT (day) acute scenarios	0.00274 (1 day)	

AT = averaging time
ED = exposure duration
EF = exposure frequency
ET = exposure time
RME = reasonable maximum exposure
NOAA = National Oceanic and Atmospheric Administration

Table 2.4.3.2-3: Exposure Factors: Physiology

Ingestion Rates	Lifetime	Adult Chronic	Adult Acute (Female)	Child Chronic	Child Acute	References
BW[a] (kg)	70[b]	70	62	18[b]	18[b]	Anderson and others, 1985; EPA, 1989a
SA[c] (cm^2/event)	3000	3000	3000	1575	1575	

[a] 50th percentiles.
[b] For dairy and soil ingestion pathways, age-specific values were used in time-weighted average intake calculations; childhood body weight is at five years, the midpoint of the nine-year exposure duration; food consumption values were also selected to represent age five for consistency.
[c] 50th percentile surface area of hands and arms.

BW = body weight
cm^2/event = square centimeters per event
kg = kilogram
SA = skin surface area

Table 2.4.4-1: Exposure Factors: Commercial/Industrial
(Reasonable Maximum Exposure)

Parameter	Unit	Description	Worker	Source
BW	kg	Body weight	70	EPA, 1989a
AT	days	Averaging time	25,550 (carcinogens)	EPA, 1989a
			9125 (noncarcinogens)	EPA, 1990
EF	days/year	Exposure frequency	250	EPA, 1991a
ED	years	Exposure duration	25	EPA, 1991a
IR_s	mg/day	Ingestion rate (soil)	50	EPA, 1991a
SA_s	cm^2	Dermal surface area (soil)	3200	EPA, 1990
AF	mg/cm^2	Adherence factor (soil)	0.90	EPA, 1990
FIs	dimensionless	Ingestion fraction (soil)	1.0	EPA, 1989a
BA	dimensionless	Bioavailability factor	0.9	ATSDR, 1987a
MF	dimensionless	Matrix factor	0.15	Hawley, 1985
VW	l/day	Ingestion rate of water	1.0	EPA, 1989a

ATSDR = Agency for Toxic Substances and Disease Registry
cm^2 = square centimeters
kg = kilogram
l/day = liters per day
mg/day = milligrams per day
mg/cm^2 = milligrams per square centimeter

Table 2.4.4-2: Exposure Factors: Commercial/Industrial
(Most Likely Exposure)

Parameter	Unit	Description	Worker	Source
BW	kg	Body weight	70	EPA, 1989a
AT	days	Averaging time	25,550 (carcinogens) 3650 (noncarcinogens)	EPA, 1989a EPA, 1990
EF	days/year	Exposure frequency	243	EPA, 1991a
ED	years	Exposure duration	10	EPA, 1991a
IR_s	mg/day	Ingestion rate (soil)	25	EPA, 1991a
SA_s	cm^2	Dermal surface area (soil)	3200	EPA, 1990
AF	mg/cm^2	Adherence factor (soil)	0.51	EPA, 1990
FIs	dimensionless	Ingestion fraction (soil)	1.0	EPA, 1989a
BA	dimensionless	Bioavailability factor	0.9	ATSDR, 1987a
MF	dimensionless	Matrix factor	0.15	Hawley, 1985
VW	l/day	Ingestion rate of water	0.7	EPA, 1989a

ATSDR = Agency for Toxic Substances and Disease Registry
cm^2 = square centimeter
hrs/day = hours per day
kg = kilogram
l/day = liters per day
mg/day = milligrams per day
mg/cm^2 = milligrams per square centimeter

Table 2.4.5.1-1: Sensitivity Analysis Summary

Parameter	Sensitivity (Percent)
Contact rate (CR)	74
Exposure duration (ED)	70
Concentration, water (Cgw)	59
Concentration, soil (Cs)	46
Ingestion rate, water (IRw)	26
Groundwater fraction (GWF1)	24
Ingestion rate, eggs (IRe)	20
Coefficient, soil-root (Ksr)	16
Coefficient, soil-egg (Kse)	13
Coefficient, soil-plant (Ksp)	12
Ingestion rate, meat (IRm)	10
Ingestion rate, dairy (IRd)	9
Root fraction (RF)	9
Ingestion rate, vegetables (IRv)	6
Concentration, surface water (Csw)	5

Table 2.4.5.5.3-1: Uncertainty Analysis Results

Zone	Chemical of Concern	Scenario	Route	Intakes (mg/kg/day) 50th Percentile	Mean	95th Percentile	RME	RME Percentile	RME: 50th	RME: Mean	RME: 95th
1B	Dieldrin	Lifetime	Oral	2.0×10^{-7}	3.1×10^{-7}	1.0×10^{-6}	3.6×10^{-6}	>99.8[a]	18	12	4
2	Chloroform	Lifetime	Inhalation	1.0×10^{-5}	4.8×10^{-5}	1.9×10^{-4}	7.9×10^{-4}	99	79	16	4
	Chloroform	Lifetime	Oral	3.2×10^{-5}	7.9×10^{-5}	3.1×10^{-4}	9.3×10^{-4}	99.4	29	12	3
3	Dieldrin	Child chronic	Oral	1.9×10^{-5}	2.2×10^{-5}	4.6×10^{-5}	3.9×10^{-5}	91	2	2	0.9
	Dieldrin	Lifetime	Oral	6.1×10^{-7}	1.2×10^{-6}	4.1×10^{-6}	1.0×10^{-5}	99.4	16	8	2
4	Arsenic	Lifetime	Oral	5.4×10^{-6}	8.7×10^{-6}	2.9×10^{-5}	4.0×10^{-5}	98	6	5	1.4
	DIMP	Child chronic	Oral	1.3×10^{-3}	2.1×10^{-2}	1.1×10^{-1}	2.5×10^{-1}	>99.8	190	12	2
6	Dieldrin	Lifetime	Oral	1.7×10^{-7}	2.8×10^{-7}	1.0×10^{-6}	3.0×10^{-6}	>99.8[a]	18	11	3

[a] Unable to define >99.8th percentile with 500 iterations; estimated by lognormal fit to be 99.95 percentile.

mg/kg/day = milligrams per kilogram per day
RME = reasonable maximum exposure

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Table 3.1-1: Hierarchy of Documents Referenced Regarding Toxicity Data

1. EPA IRIS database (online, updated monthly)
2. EPA HEAST database (updated and printed quarterly)
3. EPA MCLG, for use with noncarcinogens only
4. Health Advisories (updated periodically)
   - Longer-term, child
   - 10-day, child
   - 1-day, child
   - Lifetime, adult
   - Longer-term, adult
5. NOEL/NOAEL, human
6. LOEL/LOAEL, human
7. NOEL/NOAEL, nonhuman
8. LOEL/LOAEL, nonhuman
9. LD_{50}
10. Organoleptic effects

EPA = U.S. Environmental Protection Agency
HEAST = Health Effects Assessment Summary Table
IRIS = Integrated Risk Information System
LD_{50} = dose that is lethal to 50 percent of exposed population
LOAEL = lowest-observed-adverse-effect level
LOEL = lowest-observed-effect level
MCLG = Maximum Contaminant Level Goal
NOAEL = no-observed-adverse-effect level
NOEL = no-observed-effect level

Table 3.1-2: Toxicity Data for Rocky Mountain Arsenal Offpost Chemicals of Concern
(Page 1 of 2)

Compound	Noncarcinogenic Reference Dose[1]		Cancer Slope Factor[2]								
	Oral	Inhalation	Oral	Inhalation	MCL[3]	MCLG[3]	HA[3]	AWQC[3]	Vegetation[4]	Avian and Aquatic Organisms	Terrestrial Wildlife[5]
Aldrin	x	-	x	x	-	-	-	x	-	x	x
Arsenic	x	-	x	x	x	x	x	x	x	x	x
Atrazine	x	-	x	-	x	x	x	-	x	x	x
Benzene	x	-	x	x	x	x	x	x	-	x	x
Carbon tetrachloride	x	-	x	x	x	x	x	x	-	x	x
Chlordane	x	-	x	x	x	x	x	x	-	x	x
Chloride	-	-	-	-	x[6]	-	-	-	-	x	x
Chlorobenzene	x	x	-	-	x	x	x	x	-	x	x
Chloroform	x	x	x	x	x	-	-	x	-	x	x
CPMS	-	-	-	-	-	-	-	-	x	-	x
CPMSO	-	-	-	-	-	-	-	-	x	-	x
$CPMSO_2$	-	-	-	-	-	-	-	-	x	-	x
Dibromochloropropane	-	x	x	x	x	x	x	-	-	-	x
Dichlorobenzene	x	x	x	-	x	x	x	x	-	x	x
DDE	-	-	x	x	-	-	-	-	-	x	x
DDT	x	-	x	x	-	-	-	x	-	x	x
1,2-Dichloroethane	-	-	x	x	x	x	x	x	-	x	-
Dicyclopentadiene	x	x	-	-	-	-	-	-	x	x	x
Dieldrin	x	x	x	x	-	-	x	x	x	x	x
DIMP	x	-	-	-	-	-	x	-	x	x	x
1,4-Dithiane	-	-	-	-	-	-	-	-	-	-	-
Endrin	x	-	-	-	x	x	x	x	-	x	x
Ethylbenzene	x	-	-	-	x	x	x	x	-	x	-
Fluoride	x	-	-	-	x	x	-	-	-	x	x
Isodrin	-	-	-	-	-	-	-	-	-	x	x
Malathion	x	-	-	-	-	-	-	-	x	x	x
Manganese	x	x	-	-	x[6]	-	-	-	x	x	x
1,4-Oxathiane	-	-	-	-	-	-	-	-	-	-	-
Sulfate	-	-	-	-	x	x	-	-	-	-	x
Tetrachloroethene	x	x	x	x	x	x	x	x	-	x	x
Toluene	x	x	-	-	x	x	-	x	-	x	-

Table 3.1-2: Toxicity Data for Rocky Mountain Arsenal Offpost Chemicals of Concern
(Page 2 of 2)

Compound	Noncarcinogenic Reference Dose[1]		Cancer Slope Factor[2]		MCL[3]	MCLG[3]	HA[3]	AWQC[3]	Vegetation[4]	Avian and Aquatic Organisms	Terrestrial Wildlife[5]
	Oral	Inhalation	Oral	Inhalation							
Trichloroethene	-	x	x	x	x	x	-	x	-	x	-
Xylenes	x	x	-	-	x	x	x	-	-	x	-

[1] Refer to Table 3.1-3.
[2] Refer to Table 3.1-4.
[3] Refer to Table 3.1-5.
[4] Refer to Table 3.3.1-1.
[5] Refer to Tables 3.3.3-1 and 3.3.3-2.
[6] The chloride and manganese MCLs are secondary MCLs.

- = no information available
AWQC = Ambient Water Quality Criteria
HA = Health Advisory
MCL = Maximum Contaminant Level
MCLG = Maximum Contaminant Level Goal
RMA = Rocky Mountain Arsenal
x = information available

Table 3.1-3: Noncarcinogenic Reference Doses and Potential Noncarcinogenic Effects
(Page 1 of 4)

Chemical	Chronic RfD (mg/kg/day)	Confidence Level	Critical Effect	RfD Basis/ RfD Source	Uncertainty[1] and Modifying Factors[2]	RfD_s (mg/kg/day)	Basis/ Source
Aldrin, oral	3E-5	Medium	Liver	Feeding study/IRIS	1000 H,A,L	3E-5	Oral/HEAST
Arsenic, oral	3E-4	Medium	Skin cancer	Human exposure/IRIS	3	1E-3	Human exposure/HEAST
Atrazine, oral	5E-3	High	Cardiac	Diet/IRIS	100 H,A	5E-3	Oral/HEAST
Benzene, oral	2E-2	-	Liver	10-day Health Advisory/EPA, Office of Drinking Water	100 H,A	-	-
Carbon tetrachloride, oral	7E-4	Medium	Liver lesions	Gavage/IRIS	1000 H,A,S	7E-3	Oral/HEAST
Chlordane, oral	6E-5	Low	Liver	Diet/IRIS	1000 H,A,L	6E-5	Oral/HEAST
Chloride, oral	7.1	-	Organoleptic	Secondary MCL	-	-	Oral/HEAST
Chlorobenzene							
oral	2E-2	Medium	Liver and kidney	Oral/IRIS	1000 H,A,S	2E-1	Oral/HEAST
inhalation	5E-3	-	Liver and kidney	Inhalation/HEAST	10,000 H,A,L,S	5E-2	Inhalation/HEAST
Chloroform, oral	1E-2	Medium	Liver cysts	Oral/IRIS	1000 H,A,L	1E-2	Oral/IRIS
CPMS, oral	2E-2	-	No effect	Mouse and rat studies/ Ebaasco	1000 H,A,S	-	-
CPMSO, oral	2E-2	-	No effect	Mouse and rat studies/ Ebasco	1000 H,A,S	-	-
$CPMSO_2$, oral	2E-2	-	No effect	Mouse and rat studies/ Ebasco	1000 H,A,S	-	-
Dibromochloropropane							
oral	5E-3	-	Liver and kidney	10-day health advisory	100 H,A	-	EPA, Office of Drinking Water
inhalation	5.7E-5	Medium	Lung and testicles	Rabbit studies/IRIS	1000	-	

Table 3.1-3: Noncarcinogenic Reference Doses and Potential Noncarcinogenic Effects
(Page 2 of 4)

Chemical	Chronic RfD (mg/kg/day)	Confidence Level	Critical Effect	RfD Basis/ RfD Source	Uncertainty[1] and Modifying Factors[2]	RfD_s (mg/kg/day)	Basis/ Source
Dichlorobenzenes[3]							
oral	9E-2	Low	None	Oral/IRIS	100 H,A (MF = 10)	9E-1	Oral/HESAT
inhalation	4E-2	-	Body weight effects	Inhalation/IRIS	1000 H,A,S	4E-1	Inhalation/IRIS
DDE, oral	5E-4	-	-	DDT RfD	-	5E-4	DDT RfD_s/HEAST
DDT, oral	5E-4	Medium	Liver lesions	Diet/IRIS	100 H,A	5E-4	Oral/HESAT
1,2-Dichloroethane, oral	7E-2	-	Lung and heart	Longer-term Health Advisory/EPA, Office of Drinking Water	100 H,A	-	-
Dicyclopentadiene							
oral	3E-2	-	General	Oral/HEAST	1000 H,A,S	3E-1	Oral/HEAST
inhalation	6E-5	-	Kidney dysfunction	Inhalation/HEAST	10,000 H,A,L,S	6E-4	Inhalation/HEAST
Dieldrin, oral	5E-5	Medium	Liver lesions	Diet/IRIS	100 H,A	5E-5	Oral/HEAST
DIMP, oral	8E-2	Low	CNS[4]	Diet/IRIS	1000 H,A	8E-1	Oral
1,4-Dithiane, oral	3E-1	-	Liver and kidney	Rat LOEL/Ebasco	10,000 H,A,S,L	-	-
Endrin, oral	3E-4	Medium	Liver lesions	Oral/IRIS	100 H,A	5E-4	Oral/IRIS
Ethylbenzene							
oral	1E-1	Low	Liver and kidney	Oral/IRIS	1000 H,A,S	1	Oral/IRIS
inhalation	3E-1	-	Developmental	Inhalation/IRIS	300 H,A,S(3)	3E-1	Inhalation/HEAST
Fluoride, oral	6E-2	High	Dental fluorosis	Epidemiology/IRIS	1	6E-2	Epidemiology/ HEAST
Hexachlorocyclopentadiene	7E-3	Low	Stomach lesions	Oral/IRIS	1000 H,A,S	7E-2	Oral/IRIS

Table 3.1-3: Noncarcinogenic Reference Doses and Potential Noncarcinogenic Effects
(Page 3 of 4)

Chemical	Chronic RfD (mg/kg/day)	Confidence Level	Critical Effect	RfD Basis/ RfD Source	Uncertainty[1] and Modifying Factors[2]	RfD_s (mg/kg/day)	Basis/ Source
Isodrin, oral	7E-5	-	Death	Rat acute LD_{50}/ Literature	100,000	-	-
Malathion, oral	2E-2	Medium	Cholines-terase inhibition	Diet/IRIS	10 H	2E-2	Oral/HEAST
Manganese							
oral	1E-1	Medium	CNS	Oral/IRIS	1	1E-1	Oral/HEAST
inhalation	1.1E-4	Medium	Respiratory, CNS	Inhalation/IRIS	300 H,L,S(MF=3)	4E-4	Inhalation/HEAST
1,4-Oxathiane, oral	3E-1	-	CNS	Rat acute LD_{50}/ Ebasco	100,000	-	-
Sulfate, oral	11	-	Gastro-enteritis	Proposed MCLG/EPA, Office of Drinking Water	1	-	-
Tetrachloroethene							
oral	1E-2	Medium	Liver toxicity	Gavage/IRIS	1000 H,A,S	1E-1	Oral/HEAST
inhalation	1E-2			Oral RfD		-	IRIS
Toluene							
oral	2E-1	Medium	Organ weight change	Gavage/IRIS	1000 H,A,S	2	Oral/HEAST
inhalation	1.1E-1	-	CNS, eyes, nose	Inhalation/HEAST	100 H,A	5.7E-1	Inhalation/HEAST
Trichloroethene							
oral	4E-1	-	Lethal	Acute human inhalation/ATSDR	1000 H,A,L (MF=10)	-	ATSDR
inhalation	4E-1			Oral RfD/Ebasco		-	Ebasco
Xylene							
oral	2	Medium	Body weight effects, mortality	Gavage/IRIS	100 H,A	4	Oral/HEAST

Table 3.1-3: Noncarcinogenic Reference Doses and Potential Noncarcinogenic Effects
(Page 4 of 4)

Chemical	Chronic RfD (mg/kg/day)	Confidence Level	Critical Effect	RfD Basis/ RfD Source	Uncertainty[1] and Modifying Factors[2]	RfD_s (mg/kg/day)	Basis/ Source
inhalation[5]	8.6E-2	Medium	CNS, nose, throat	Oral Rfd	100 H,S	8.6E-2	Based on Oral Rfd

Sources: EPA, 1988d; Ebasco, 1990; U.S. Environmental Protection Agency (EPA), 1988b; HEAST, 1991, 1992; IRIS, 1992; Shell, 1990.

[1] Uncertainty factors are multiples of 10 and are provided using the following code:
A = to extrapolate from animal study to human
H = to protect sensitive humans
L = to convert from lowest-observed-effect level (LOAEL) to no-observed-effect level (NOEL)
MF = modifying factor
S = to convert from subchronic to chronic

[2] Modifying factors allow for additional protection and may be assigned a value of 0 to 10, depending on severity of effects with values of 0 to 1 used for nutritional essentiality; value is assumed to be 1 unless otherwise indicated.

[3] Value presented is for 1,2-dichlorobenzene.

[4] Based on acute effects (EPA, 1986b).

[5] Chronic RfC is considered nonverifiable by RfD/RfC work groups (HEAST, 1992); value is from HEAST, 1991.

- = no EPA review
ATSDR = Agency for Toxic Substances and Disease Registry
CNS = central nervous system
HEAST = Health Effects Assessment Summary Table document
IRIS = Integrated Risk Information System
LD_{50} = dose that is lethal to 50 percent of exposed population
MCL = Maximum Contaminant Level
MCLG = Maximum Contaminant Level Goal
mg/kg/day = milligrams per kilogram per day
RfD = reference dose
RfD_s = subchronic reference dose

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Table 3.1-4: Cancer Slope Factors and Potential Carcinogenic Effects of Carcinogenic Operable Unit Offpost Chemicals of Concern
(Page 1 of 3)

Chemical	Slope Factor $(mg/kg/day)^{-1}$	Weight-of-Evidence Classification[a]	Type or Site of Cancer	Source Factor Basis/ Source Factor Source
Aldrin				
oral	1.7E+1	B2	Liver	Oral/IRIS
inhalation	1.7E+1	B2	Liver	Oral/HEAST
Arsenic				
oral	1.75[b]	A	Skin	Oral/IRIS
inhalation	5.0E+1	A	Lung	Occupational/HEAST
Atrazine				
oral	2.2E-1	C	Mammary	Oral/HEAST
inhalation	Not available	C	Not available	Not available
Benzene				
oral	2.9E-2	A	Leukemia	Oral/IRIS
inhalation	2.9E-2	A	Leukemia	Occupational/HEAST
Carbon tetrachloride				
oral	1.3E-1	B2	Liver	Oral/IRIS
inhalation	5.3E-2	B2	Liver	Oral/HEAST
Chlordane				
oral	1.3	B2	Liver	Oral/IRIS
inhalation	1.3	B2	Liver	Oral/HEAST
Chloroform				
oral	6.1E-3	B2	Kidney	Oral/IRIS
inhalation	8.1E-2	B2	Liver	Oral/HEAST

Table 3.1-4: Cancer Slope Factors and Potential Carcinogenic Effects of Carcinogenic Operable Unit Offpost Chemicals of Concern
(Page 2 of 3)

Chemical	Slope Factor $(mg/kg/day)^{-1}$	Weight-of-Evidence Classification[a]	Type or Site of Cancer	Source Factor Basis/ Source Factor Source
Dibromochloropropane				
oral	1.4	B2	Mouse forestomach nodules	Oral/HEAST
inhalation	2.4E-3	B2	Respiratory	Inhalation/HEAST
Dichlorobenzenes				
oral	2.4E-2	C	Liver	Oral/HEAST
inhalation	Not available	C	Not available	Not available
DDE				
oral	3.4E-1	B2	Liver	Oral/IRIS
inhalation	3.4E-1	B2	Liver	DDT/HEAST
DDT				
oral	3.4E-1	B2	Liver	Oral/IRIS
inhalation	3.4E-1	B2	Liver	Oral/HEAST
1,2-Dichloroethane				
oral	9.1E-2	B2	Circulatory system	Oral/IRIS
inhalation	9.1E-2	B2	Circulatory system	Oral/HEAST
Dieldrin				
oral	1.6E+1	B2	Liver	Oral/IRIS
inhalation	1.6E+1	B2	Liver	Oral/IRIS
Tetrachloroethene				
oral	5.1E-2[+]	B2	Liver	Oral/HEAST[c]
inhalation	1.8E-3[+]	B2	Leukemia, liver	Inhalation/HEAST[c]

Table 3.1-4: Cancer Slope Factors and Potential Carcinogenic Effects of Carcinogenic Operable Unit Offpost Chemicals of Concern
(Page 3 of 3)

Chemical	Slope Factor $(mg/kg/day)^{-1}$	Weight-of-Evidence Classification[a]	Type or Site of Cancer	Source Factor Basis/ Source Factor Source
Trichloroethene				
oral	1.1E-2+	B2	Liver	Oral/HEAST[c]
inhalation	1.7E-2+	B2	Lung	Inhalation/HEAST[c]

Sources: Integrated Risk Information System (IRIS), 1992; Health Effects Assessment Summary Table (HEAST), 1992.

[a] A = known human carcinogen (adequate human data)
B1 = probable human carcinogen (limited human, adequate animal data)
B2 = probable human carcinogen (inadequate human data, adequate animal data)
C = possible human carcinogen (inadequate human data, limited animal data)
[b] Arsenic slope factor has been withdrawn by EPA, pending review; slope factor value is based on interim unit risk of 5×10^{-5} $(\mu g/l)^{-1}$.
[c] HEAST, Annual, 1991.

+ = removed from IRIS
mg/kg/day = milligrams per kilogram per day
$\mu g/l$ = micrograms per liter

Table 3.1-5: Regulatory Criteria for Rocky Mountain Arsenal Offpost Operable Unit, Chemicals of Concern
(Page 1 of 2)

Compound	Safe Drinking Water Act			Drinking Water Health Advisories				Ambient Water Quality Criteria		
	Primary MCL (µg/l)	Secondary MCL (µg/l)	MCLG (µg/l)	1-Day[a] (µg/l)	10-Day[a] (µg/l)	Longer Term[a] (µg/l)	Life-Time (µg/l)	Fish and Water (µg/l)	Fish Only (µg/l)	Water Only (µg/l)
Aldrin	-	-	-	-	-	-	-	7.4E-5[b]	7.9E-3[b]	1.2E-3[b]
Arsenic	50/30(P)[c]	-	50/0(P)[c]	50	50	50	50	2.2E-3[b]	1.75E-2[b]	2.5E-2[b]
Atrazine	3	-	3	100	100	50	3	-	-	-
Benzene	5	-	0	235	235	ND	1[b]	0.66[b]	40[b]	0.67[b]
Carbon tetrachloride	5	-	0	4000	160	71	-	0.40[b]	6.94[b]	0.42[b]
Chlordane	2	-	0	60	60	-	-	4.6E-4[b]	4.8E-4[b]	0.022
Chloride	-	250,000	-	-	-	-	-	-	-	-
Chlorobenzene	100	100	100	1800	1800	1800	100	488	None	488
Chloroform	100[++]	-	-	-	-	-	0.19[b]	15.7[b]	0.19[b]	
CPMS	-	-	-	-	-	-	-	-	-	-
CPMSO	-	-	-	-	-	-	-	-	-	-
$CPMSO_2$	-	-	-	-	-	-	-	-	-	-
Dibromochloro-propane	0.2	-	0	200	50	ND	ND	-	-	-
1,3-Dichlorobenzene	600	-	600	8900	8900	8900	620	400	2,600	-
DDE	-	-	-	-	-	-	-	-	-	-
DDT	-	-	-	-	-	-	-	2.4E-5[b]	2.44-5[b]	>1.2E-3[b]
1,2-Dichloroethane	5	-	0	740	740	740	ND	0.94	243	0.94
Dicyclopentadiene	-	-	-	-	-	-	-	-	-	-
Dieldrin	-	-	-	0.5	0.5	0.5	0.002[b]	7.1E-5[b]	7.6E-5[b]	1.1E-3[b]
DIMP	-	-	-	-	-	8000	600	-	-	-
1,4-Dithiane	-	-	-	-	-	-	-	-	-	-
Endrin	2	-	2	20	20	3	2	1[d]	None	1[d]
Ethylbenzene	700	-	700	32,000	3200	970	680	1400	3280	2400
Fluoride	4000	2000	4000	-	-	-	-	-	-	-
Isodrin	-	-	-	-	-	-	-	-	-	-
Malathion	-	-	-	-	-	-	-	-	-	-
Manganese	-	50	-	-	-	-	-	50	100	-

Table 3.1-5: Regulatory Criteria for Rocky Mountain Arsenal Offpost Operable Unit, Chemicals of Concern
(Page 2 of 2)

Compound	Safe Drinking Water Act			Drinking Water Health Advisories				Ambient Water Quality Criteria		
	Primary MCL (µg/l)	Secondary MCL (µg/l)	MCLG (µg/l)	1-Day[a] (µg/l)	10-Day[a] (µg/l)	Longer Term[a] (µg/l)	Life-Time (µg/l)	Fish and Water (µg/l)	Fish Only (µg/l)	Water Only (µg/l)
1,4-Oxathiane	-	-	-	-	-	-	-	-	-	-
Sulfate	400,000/ 500,000	250,000	400,000/ 500,000	-	-	-	-	-	-	-
Tetrachloroethene	5	-	0	2000	2000	1400	0.7[b]	0.80	8.85	0.88
Toluene	1000	-	1000	20,000	2000	2000	1000	14,300	424,000	15,000
Trichloroethene	5	-	0	-	-	-	3[b]	2.7[b]	80.7[b]	2.8[b]
Xylene	10,000	-	10,000	40,000	40,000	40,000	10,000	-	-	-

[a] Value is for a 10-kg child.
[b] Carcinogenic; value represents 10^{-6} cancer risk.
[c] Draft value, pending release.
[d] Organoleptic (taste and odor) considerations.
[++] Value represents trihalomethanes.

- = no value available
µg/l = micrograms per liter
MCL = Maximum Contaminant Level
MCLG = Maximum Contaminant Level Goal
NA = not applicable
ND = not determined
P = proposed value

20000,317 - OEA
0908111992

Table 3.3.1-1: Reference Media Concentrations for Vegetation and Aquatic Organisms

Compound	Vegetation Soil Concentration (mg/kg)	Aquatic Organisms Water Concentration	
		Acute (µg/l)	Chronic (µg/l)
Aldrin	-	3.0	NA
Arsenic (b_{III})	1.9	360	190
Arsenic (b_V)	ND	ND	30
Atrazine	0.022 mg/l[a]	ND	41[b]
Benzene	-	53[c]	NA
Carbon tetrachloride	-	16[c]	NA
Chlordane	-	2.4	0.0043
Chloride	183 mg/l[a]	860,000	230,000
Chlorobenzene	-	2.5[b,c]	NA
Chloroform	-	2.7	2.7
CPMS	0.7	-	-
CPMSO	0.7	-	-
$CPMSO_2$	0.7	-	-
Dibromochloropropane	64 mg/l[a]	-	-
1,3-Dichlorobenzene	-	ND	965[2]
DDE	-	11[c]	NA
DDT	-	1.1	0.001
1,2-Dichloroethane	-	ND	2000[c]
Dicyclopentadiene	100 mg/l[a]	105[b]	NA
Dieldrin	20	2.5	0.0019
DIMP	20 mg/l[a]	2600[b]	NA
1,4-Dithiane	-	-	-
Endrin	100	0.18	0.0023
Ethylbenzene	-	320[c]	NA
Fluoride	-	22[b]	NA
Isodrin	-	0.025[b]	NA
Malathion	0.1	ND	0.1
Manganese	0.12	1500	NA
1.4-Oxathiane	-	-	-
Sulfate	NA	-	-
Tetrachloroethene	NA	ND	84[c]
Toluene	-	175[c]	NA
Trichloroethene	-	ND	2200
Xylene	-	82[b]	NA

[a] Value is in mg/l and represents a nutrient solution.
[b] Value derived from the open literature.
[c] No U. S. Environmental Protection Agency (EPA) criterion available; values derived from EPA-reported lowest-observed-effect concentration (LOEC).

µg/l = micrograms per liter
- = no data available for this compound
mg/kg = milligrams per kilogram
mg/l = milligrams per liter
NA = not available; insufficient data for estimating a concentration protective of aquatic organisms for this exposure; i.e., acute or chronic
ND = not determined, some data available

Table 3.3.3-1: Toxicity Reference Values for Avian and Terrestrial Vertebrate Species of Concern Identified at Rocky Mountain Arsenal
(Page 1 of 4)

Chemical of Concern	Species of Concern	Study Type	Dose (mg/kg-bw/day)	Test Species	NOAEL UF	Family/Order UF	Genus UF	Species UF	Intraspecies UF	T or E Species	Total UF	TRV (mg/kg-bw/day)
Arsenic	Mallard duck	LOAEL	18.9	Duck	20	1	1	1	2	1	40	4.7E-01
Arsenic	Great blue heron	LOAEL	18.9	Duck	20	2	2	2	2	1	320	5.9E-02
Arsenic	Bald eagle	LOAEL	18.9	Duck	20	2	2	2	2	2	640	3.0E-02
Arsenic	American kestrel	LD50	39	Duck	100	2	2	2	2	1	1600	2.4E-02
Arsenic	Great horned owl	LD50	39	Duck	100	2	2	2	2	1	1600	2.4E-02
Arsenic	Chicken	LOAEL	18.9	Duck	20	2	2	2	2	1	320	5.9E-02
Arsenic	Mouse	LD50	145	Mouse	100	2	2	2	2	1	1600	9.1E-02
Arsenic	Prairie dog	LD50	145	Mouse	100	2	2	2	2	1	1600	9.1E-02
Arsenic	Cattle	LD	1.3	Cow	100	1	1	1	2	1	200	6.5E-03
Aldrin/dieldrin	Mallard duck	NOAEL	0.08	Duck	1	1	1	1	2	1	2	4.0E-02
Aldrin/dieldrin	Great blue heron	NOAEL	1.10	Quail	1	2	2	2	2	1	16	6.0E-02
Aldrin/dieldrin	Bald eagle	LD50	9	Partridge	100	2	2	2	2	2	3200	2.8E-03
Aldrin/dieldrin	American kestrel	NOAEL	0.05	Owl	1	2	2	2	2	1	16	3.1E-03
Aldrin/dieldrin	Great horned owl	NOAEL	0.05	Owl	1	1	1	1	2	1	2	2.5E-02
Aldrin/dieldrin	Chicken	LD	0.52	Chicken	100	1	1	1	2	1	200	2.6E-03
Aldrin/dieldrin	Mouse	LD50	43	Vole	100	2	2	2	2	1	1600	2.7E-02
Aldrin/dieldrin	Prairie dog	LD50	43	Vole	100	2	2	2	2	1	1600	2.7E-02
Aldrin/dieldrin	Cattle	NOAEL	5	Cow	1	1	1	1	2	1	2	2.5E+00
Atrazine	Cattle	NOEL	10	Cow	1	1	1	1	2	1	2	5.0E+00
Benzene	Cattle	LOAEL	10	Rat	20	2	2	2	2	1	320	3.1E-02
Carbon tetrachloride	Cattle	LOAEL	20	Cow	20	1	1	1	2	1	40	5.0E-01
Chloroform	Cattle	NOEL	30	Rat	1	2	2	2	2	1	16	1.9E+00
Chlordane	Mallard duck	LD50	1250	Duck	100	1	1	1	2	1	200	6.3E+00
Chlordane	Great blue heron	LD50	14.1	Quail	100	2	2	2	2	1	1600	8.8E-03
Chlordane	Bald eagle	LD50	14.1	Quail	100	2	2	2	2	2	3200	4.4E-03
Chlordane	American kestrel	LD50	14.1	Quail	100	2	2	2	2	1	1600	8.8E-03
Chlordane	Great horned owl	LD50	14.1	Quail	100	2	2	2	2	1	1600	8.8E-03
Chlordane	Chicken	LD50	14.1	Quail	100	2	2	2	2	1	1600	8.8E-03
Chlordane	Mouse	NOEL	1.2	Rat	1	2	2	2	2	1	16	7.5E-02
Chlordane	Prairie dog	NOEL	1.2	Rat	1	2	2	2	2	1	16	7.5E-02
Chlordane	Cattle	NOEL	10	Cow	1	1	1	1	2	1	2	5.0E+00
Chlorobenzene	Cattle	NOEL	54.5	Dog	1	2	2	2	2	1	16	3.4E+00
CPMS	Cattle	LOAEL	14.1	Rat	20	2	2	2	2	1	320	4.4E-02
CPMSO	Cattle	LOAEL	14.1	Rat	20	2	2	2	2	1	320	4.4E-02
CPMSO2	Cattle	LOAEL	16.3	Rat	20	2	2	2	2	1	320	5.1E-02
1,2-Dichloroethene	Cattle	LD50	670	Rat	100	2	2	2	2	1	1600	4.2E-01
DDE/DDT	Mallard duck	LOAEL	4	Duck	20	1	1	1	2	1	40	1.0E-01

Table 3.3.3-1: Toxicity Reference Values for Avian and Terrestrial Vertebrate Species of Concern Identified at Rocky Mountain Arsenal
(Page 2 of 4)

Chemical of Concern	Species of Concern	Study Type	Dose (mg/kg-bw/day)	Test Species	NOAEL UF	Family/Order UF	Genus UF	Species UF	Intraspecies UF	T or E Species	Total UF	TRV (mg/kg-bw/day)
DDE/DDT	Great blue heron	NOEL	0.88	Quail	1	2	2	2	2	1	16	5.5E-02
DDE/DDT	Bald eagle	NOEL	0.88	Quail	1	2	2	2	2	2	32	2.7E-02
DDE/DDT	American kestrel	LOAEL	0.31	Kestrel	5	1	1	1	2	1	10	3.1E-02
DDE/DDT	Great horned owl	LOAEL	0.30	Owl	5	1	1	1	2	1	10	3.0E-02
DDE/DDT	Chicken	NOEL	0.88	Quail	1	2	2	2	2	1	16	5.5E-02
DDE/DDT	Mouse	LOAEL	35.7	Mouse	20	2	2	2	2	1	320	1.1E-01
DDE/DDT	Prairie dog	LOAEL	12.1	Rat	20	2	2	2	2	1	320	3.8E-02
DDE/DDT	Cattle	LOAEL	12.1	Rat	20	2	2	2	2	1	320	3.8E-02
DIMP	Mallard duck	LOAEL	410	Duck	20	1	1	1	2	1	40	1.0E+01
DIMP	Great blue heron	LOAEL	60	Quail	5	2	2	2	2	1	80	7.5E-01
DIMP	Bald eagle	LOAEL	60	Quail	5	2	2	2	2	2	160	3.8E-01
DIMP	American kestrel	LOAEL	60	Quail	5	2	2	2	2	1	80	7.5E-01
DIMP	Great horned owl	LOAEL	60	Quail	5	2	2	2	2	1	80	7.5E-01
DIMP	Chicken	LOAEL	60	Quail	5	2	2	2	2	1	80	7.5E-01
DIMP	Mouse	NOAEL	300	Mouse	1	2	2	2	2	1	16	1.9E+01
DIMP	Prairie dog	NOEL	150	Rat	1	2	2	2	2	1	16	9.4E+00
DIMP	Cattle	NOEL	500	Cow	30	1	1	1	2	1	60	8.3E+00
Dibromochloropropane	Mallard duck	LD50	66.8	Duck	100	1	1	1	2	1	200	3.3E-01
Dibromochloropropane	Great blue heron	LD50	66.8	Duck	100	2	2	2	2	1	1600	4.2E-02
Dibromochloropropane	Bald eagle	LD50	66.8	Duck	100	2	2	2	2	2	3200	2.1E-02
Dibromochloropropane	American kestrel	LD50	66.8	Duck	100	2	2	2	2	1	1600	4.2E-02
Dibromochloropropane	Great horned owl	LD50	66.8	Duck	100	2	2	2	2	1	1600	4.2E-02
Dibromochloropropane	Chicken	LD50	60	Chicken	100	1	1	1	2	1	200	3.0E-01
Dibromochloropropane	Mouse	NOEL	0.50	Rat	1	2	2	2	2	1	16	3.1E-02
Dibromochloropropane	Prairie dog	NOEL	0.50	Rat	1	2	2	2	2	1	16	3.1E-02
Dibromochloropropane	Cattle	NOEL	0.50	Rat	1	2	2	2	2	1	16	3.1E-02
1,3-Dichlorobenzene	Cattle	LOEL	250	Rat	5	2	2	2	2	1	80	3.1E+00
Dicyclopentadiene	Mallard duck	LD50	40,000	Duck	100	1	1	1	2	1	200	2.0E+02
Dicyclopentadiene	Great blue heron	LD50	1010	Bobwhite quail	100	2	2	2	2	1	1600	6.3E-01
Dicyclopentadiene	Bald eagle	LD50	1010	Bobwhite quail	100	2	2	2	2	2	3200	3.2E-01
Dicyclopentadiene	American kestrel	LD50	1010	Bobwhite quail	100	2	2	2	2	1	1600	6.3E-01
Dicyclopentadiene	Great horned owl	LD50	1010	Bobwhite quail	100	2	2	2	2	1	1600	6.3E-01

Table 3.3.3-1: Toxicity Reference Values for Avian and Terrestrial Vertebrate Species of Concern Identified at Rocky Mountain Arsenal
(Page 3 of 4)

Chemical of Concern	Species of Concern	Study Type	Dose (mg/kg-bw/day)	Test Species	NOAEL UF	Family/Order UF	Genus UF	Species UF	Intraspecies UF	T or E Species	Total UF	TRV (mg/kg-bw/day)
Dicyclopentadiene	Chicken	LD50	1010	Bobwhite quail	100	2	2	2	2	1	1600	6.3E-01
Dicyclopentadiene	Mouse	NOEL	32	Rat	1	2	2	2	2	1	16	2.0E+00
Dicyclopentadiene	,4-Prairie dog	NOEL	32	Rat	1	2	2	2	2	1	16	2.0E+00
Dicyclopentadiene	Cattle	LD50	1200	Cow	100	1	1	1	2	1	200	6.0E+00
1,4-Dithiane	Cattle	LOEL	105	Rat	20	2	2	2	2	1	320	3.3E-01
Endrin/isodrin	Mallard duck	NOAEL	0.30	Duck	1	1	1	1	2	1	2	1.5E-01
Endrin/isodrin	Great blue heron	NOAEL	0.30	Duck	1	2	2	2	2	1	16	1.9E-02
Endrin/isodrin	Bald eagle	NOAEL	0.30	Duck	1	2	2	2	2	2	32	9.4E-03
Endrin/isodrin	American kestrel	LOAEL	0.12	Owl	20	2	2	2	2	1	320	3.8E-04
Endrin/isodrin	Great horned owl	LOAEL	0.12	Owl	20	1	1	1	2	1	40	3.0E-03
Endrin/isodrin	Chicken	LD	1.04	Chicken	100	1	1	1	2	1	200	5.2E-03
Endrin/isodrin	Mouse	LOAEL	0.58	Mouse	20	2	2	2	2	1	320	1.8E-03
Endrin/isodrin	Prairie dog	LOAEL	0.58	Mouse	20	2	2	2	2	1	320	1.8E-03
Endrin/isodrin	Cattle	LOAEL	0.05	Dog	20	2	2	2	2	1	320	1.6E-04
Ethylbenzene	Cattle	NOEL	97.1	Rat	1	2	2	2	2	1	16	6.1E+00
Fluoride	Mallard duck	LOAEL	420	Duck	20	1	1	1	2	1	40	1.1E+01
Fluoride	Great blue heron	LOAEL	420	Duck	20	2	2	2	2	1	320	1.3E+00
Fluoride	Bald eagle	LOAEL	420	Duck	20	2	2	2	2	2	640	6.6E-01
Fluoride	American kestrel	NOEL	28	Chicken	1	2	2	2	2	1	16	1.8E+00
Fluoride	Great horned owl	NOEL	28	Chicken	1	2	2	2	2	1	16	1.8E+00
Fluoride	Chicken	NOEL	28	Chicken	1	1	1	1	2	1	2	1.4E+01
Fluoride	Mouse	LOAEL	50	Rat	20	2	2	2	2	1	320	1.6E-01
Fluoride	Prairie dog	LOAEL	50	Rat	20	2	2	2	2	1	320	1.6E-01
Fluoride	Cattle	NOAEL	0.60	Sheep	1	1	2	2	2	1	8	7.5E-02
Hexachlorocyclo-pentadiene	Cattle	LD50	113	Rat	100	2	2	2	2	1	1600	7.1E-02
Malathion	Cattle	NOEL	10	Cow	1	1	1	1	2	1	2	5.0E+00
Manganese	Cattle	NOEL	10	Cow	1	1	1	1	2	1	2	5.0E+00
1,4-Oxathiane	Cattle	LD50	3323	Rat	100	2	2	2	2	1	1600	2.1E+00
Sulfate	Mallard duck	LOAEL	750	Fowl	5	2	2	2	2	1	80	9.4E+00
Sulfate	Great blue heron	LOAEL	750	Fowl	5	2	2	2	2	1	80	9.4E+00
Sulfate	Bald eagle	LOAEL	750	Fowl	5	2	2	2	2	2	160	4.7E+00
Sulfate	American kestrel	LOAEL	750	Fowl	5	2	2	2	2	1	80	9.4E+00
Sulfate	Great horned owl	LOAEL	750	Fowl	5	2	2	2	2	1	80	9.4E+00
Sulfate	Chicken	LOAEL	750	Fowl	5	2	2	2	2	1	80	9.4E+00

Table 3.3.3-1: Toxicity Reference Values for Avian and Terrestrial Vertebrate Species of Concern Identified at Rocky Mountain Arsenal
(Page 4 of 4)

Chemical of Concern	Species of Concern	Study Type	Dose (mg/kg-bw/day)	Test Species	NOAEL UF	Family/Order UF	Genus UF	Species UF	Intraspecies UF	T or E Species	Total UF	TRV (mg/kg-bw/day)
Sulfate	Mouse	LOAEL	750	Rat/Mice	5	2	2	2	2	1	80	9.4E+00
Sulfate	Prairie dog	LOAEL	750	Rat/Mice	5	2	2	2	2	1	80	9.4E+00
Sulfate	Cattle	NOEL	130	Cow	1	1	1	1	2	1	2	6.5E+01
Trichloroethene	Cattle	LD50	5680	Dog	100	2	2	2	2	1	1600	3.6E+00
Tetrachloroethene	Cattle	LD50	8100	Mouse	100	2	2	2	2	1	1600	5.1E+00
Toluene	Cattle	NOAEL	422	Rat	1	2	2	2	2	1	16	2.6E+01
Xylene	Cattle	NOAEL	250	Rat	1	2	2	2	2	1	16	1.6E+01

LD = lethal dose
LD_{50} = lethal dose to 50 percent of test animal population
LOAEL = lowest-observed-adverse-effect level
LOEL = lowest-observed-effect level
NOAEL = no-observed-adverse-effect level
NOEL = no-observed-effect level
T or E = threatened or endangered
TRV = toxicity reference value
UF = uncertainty factor
mg/kg-bw/day = milligrams per kilogram-bodyweight per day

Table 3.3.3-2: References for Critical Toxicity Studies Used to Derive Terrestrial Toxicity Reference Values Listed in Table 3.3.3-1
(Page 1 of 2)

Chemical Of Concern	Test Species	Source[1]
Arsenic	Duck	VanVleet (1982)[2]
	Chicken	Hatch (1977)
	Mouse	Gough and others (1979)
	Cow	Hatch (1977)
Aldrin/dieldrin	Duck	Nebeker and others (1992)
	Partridge	Negherbon (1959)
	Chicken	Davison and others (1971)[2]
	Vole	Cholakis and others (1981)[2]
	Cow	Radeleff (1970)
	Owl	Mendenhall (1983)
Atrazine	Cow	Palmer and Radeleff (1964)[2]
Benzene	Rat	Wolf and others (1956)
Chloroform	Rat	Palmer and others (1979)
Carbon tetrachloride	Cow	Roberson (1977)
Chlordane	Duck	Hudson and others (1984)
	Quail	Hudson and others (1984)
	Mouse	Epstein, (1976)[2]
	Rat	HEAST (1991)
	Cow	Osweiler and others (1985)
Chlorobenzene	Dog	IRIS (1991)
CPMS	Rat	Thake and others (1979)
CPMSO	Rat	Thake and others (1979)
$CPMSO_2$	Rat	Thake and others (1979)
Chloride	Invertebrates	EPA (1988)
1,2-Dichloroethane	Rat	RTECS (1991)
DDE/DDT	Duck	Haegele and Hudson (1974)[2]
	Quail	Ludke (1977)[2]
	Mouse	USAF (1989)
	Rat	USAF (1989)
	Owl	Mendenhall (1983)
	Kestrel	Wiemeyer and others (1980)
DIMP	Duck	Aulerich and others (1979)[2]
	Quail	Aulerich and others (1979)
	Mouse	Hart (1976)
	Rat	Hart (1976)
	Cow	Cysewski (1981)
Dibromochloropropane	Duck	Hudson and others (1984)
	Chicken	Berkowitz and others (1978)
	Rat	EPA (1987a)

Table 3.3.3-2: References for Critical Toxicity Studies Used to Derive Terrestrial Terrestrial Toxicity Reference Values
(Page 2 of 2)

Chemical Of Concern	Test Species	Source[1]
1,3-Dichlorobenzene	Rat	HSDB (1991)
Dicyclopentadiene	Duck	Hart (1980)
	Quail	Aulerich and others (1979)
	Rat	Ebasco (1990)
	Cow	NIOSH (1982)
Dithiane	Rat	Ebasco (1990)
Endrin/Isodrin	Duck	Roylance and others (1985)[2]
	Chicken	ESE (1989b)
	Mouse	Repotext (1991)
	Dog	HEAST (1991)
	Owl	Fleming and others (1982)
Ethylbenzene	Rat	IRIS (1991)
Fluoride	Duck	Allcroft (1954)
	Chicken	Allcroft (1954)
	Mouse	Reprotext (1991)
	Sheep	Peirce (1959)
Malathion	Cow	Osweiller and others (1985)
Manganese	Cow	Gough and others (1979)
Oxathiane	Rat	Mayhew and Muni (1986)
Sulfate	Fowl	EPA (1985b)
	Monogastric mammals	EPA (1985b)
	Cow	Digesti and Weeth (1973)
Trichloroethene	Dog	Christensen and others (1974)
Tetrachloroethene	Mouse	RTECS (1991)
Toluene	Rat	IRIS (1991)
Xylene	Rat	IRIS (1991)

[1] Refer to the Toxicological Profiles (Appendix F) for more information.
[2] Refer to ESE (1989b) for additional information.

EPA = U.S. Environmental Protection Agency
ESE = Environmental Science and Engineering, Inc.
HEAST = Health Effects Assessment Summary Table
HSDB = Hazardous Substance Data Bank
IRIS = Integrated Risk Information System
NIOSH = National Institute for Occupational Safety and Health
RTECS = Registry of Toxic Efffects of Chemical Substances
TRV = toxicity reference value
USAF = U.S. Air Force

Table 3.3.3.2.1-1: Nonprimate Mammalian Oral LD_{50} Data
(Page 1 of 3)

Chemical Of Concern	Test Species	LD_{50}[1]	Chemical Specific Uncertainty[2]
Aldrin	Rat	30	3
	Mouse	44	
	Rabbit	50	
	Hamster	100	
	Dog	65	
Arsenic	Rat	763	5
	Mouse	145	
Atrazine	Rat	672	2
	Mouse	850	
	Rabbit	750	
	Hamster	1000	
	Mammal	1400	
Benzene	Rat	930	5
	Mouse	4700	
Carbon tetrachloride	Rat	2350	4
	Mouse	8263	
	Rabbit	5760	
	Guinea pig	5760	
Chlordane	Rat	283	
Chlorobenzene	Rat	2290	1
	Mouse	2300	
	Rabbit	2250	
	Guinea pig	2250	
Chloroform	Rat	908	25
	Mouse	36	
	Guinea pig	820	
CPMS	Rat	400	2
	Mouse	672	
CPMSO	Rat	463	1
	Mouse	400	
$CPMSO_2$	Rat	400	2
	Mouse	606	
Dibromochloropropane	Rat	170	2
	Mouse	257	
	Rabbit	180	
	Guinea pig	150	
1,3-Dichlorobenzene	NA	NA	NA

Table 3.3.3.2.1-1: Nonprimate Mammalian Oral LD_{50} Data
(Page 2 of 3)

Chemical Of Concern	Test Species	LD_{50}[1]	Chemical Specific Uncertainty[2]
DDE	Rat	880	1
	Mouse	700	
DDT	Rat	87	3
	Mouse	135	
	Rabbit	250	
	Guinea pig	150	
	Dog	150	
	Mammal	200	
1,2-Dichloroethane	Rat	670	12
	Mouse	489	
	Rabbit	860	
	Dog	5700	
Dichlorocyclopentadiene	Rat	353	6
	Mouse	190	
	Cattle	1200	
Dieldrin	Rat	38	3
	Mouse	38	
	Rabbit	45	
	Guinea pig	49	
	Hamster	60	
	Dog	65	
	Pig	38	
	Mammal	25	
DIMP	Rat	826	2
	Mouse	1041	
	Cow	750	
	Mammal	503	
1,4-Dithiane	Rat	2768	
Endrin	Rat	3	5
	Mouse	1.4	
	Rabbit	7	
	Guinea pig	16	
	Hamster	10	
Ethylbenzene	Rat	3500	
Isodrin	Rat	7	1
	Mouse	8.8	
	Mammal	7	

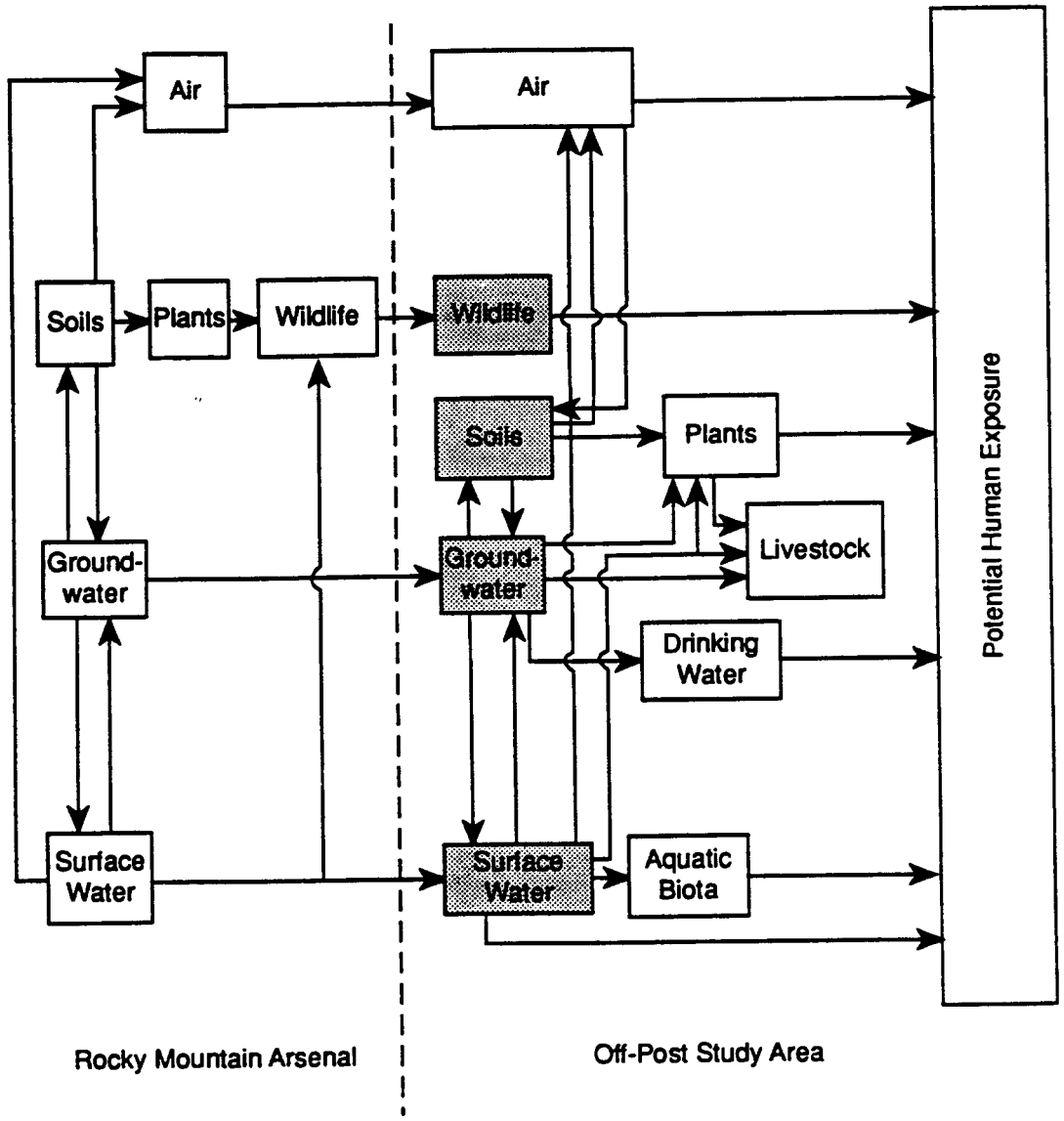
Table 3.3.3.2.1-1: Nonprimate Mammalian Oral LD_{50} Data
(Page 3 of 3)

Chemical Of Concern	Test Species	LD_{50}[1]	Chemical Specific Uncertainty[2]
Malathion	Rat	290	11
	Mouse	190	
	Rabbit	250	
	Guinea pig	570	
	Cow	53	
	Goat/sheep	500	
	Mammal	500	
Manganese	Rat	9000	
1,4-Oxathiane	Rat	2830	
Tetrachloroethene	Mouse	8100	
Toluene	Rat	5000	
Trichloroethene	Mouse	2402	
Xylene	Rat	4300	

Source: RTECS, 1991

[1] Values shown in milligrams per kilogram (mg/kg).
[2] Ratio of highest LD_{50} divided by lowest LD_{50} for each chemical of concern (COC).

LD_{50} = chemical dose that is lethal to 50 percent of the exposed population
NA = not applicable



EXPLANATION

Data Gaps

Adapted from: ESE, 1984

Prepared for:
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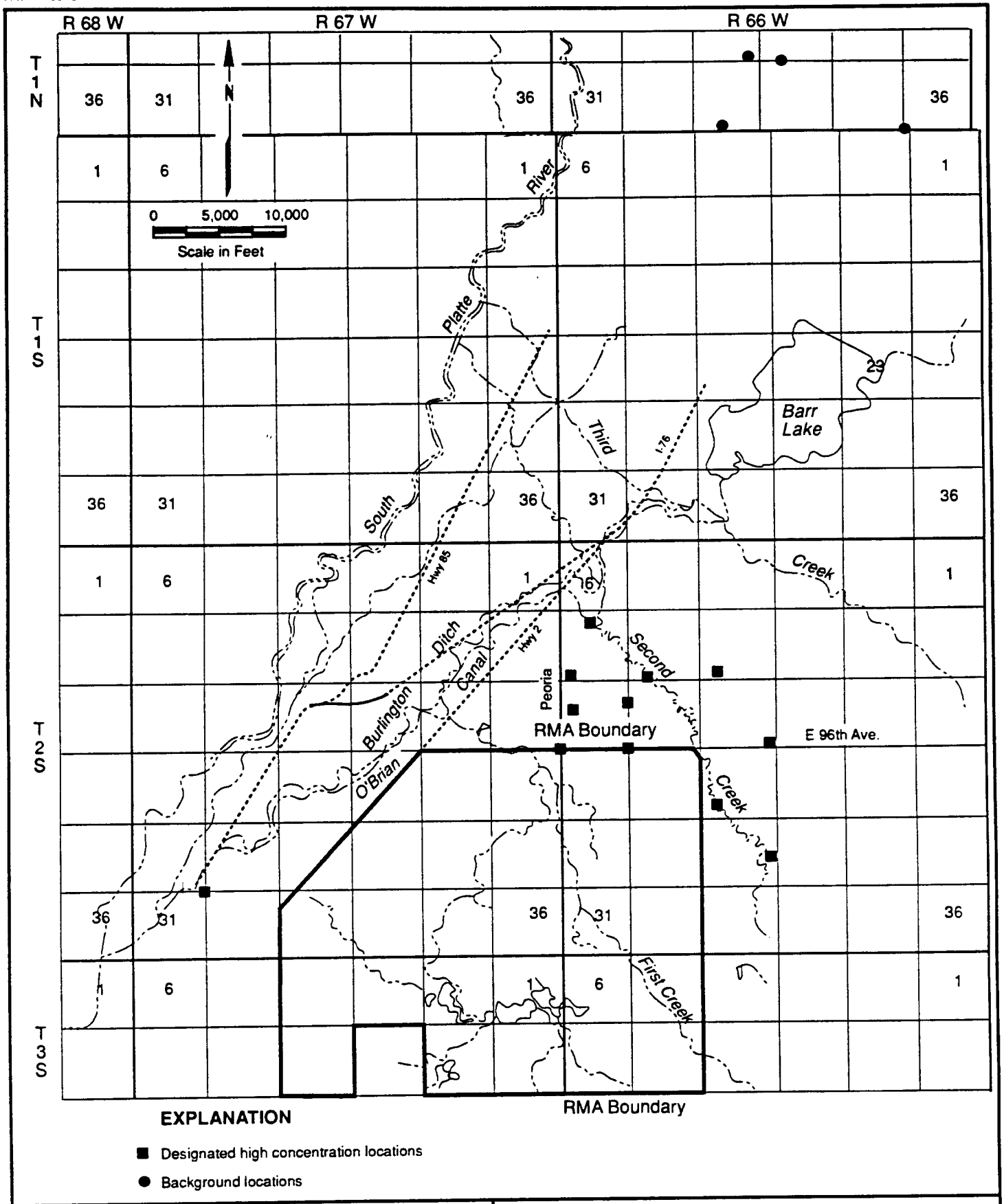
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 1.0-1

PRELIMINARY SITE CONCEPTUAL MODEL
PRE-REMEDIAL INVESTIGATION OFFPOST
OPERABLE UNIT

RMA1 1094c



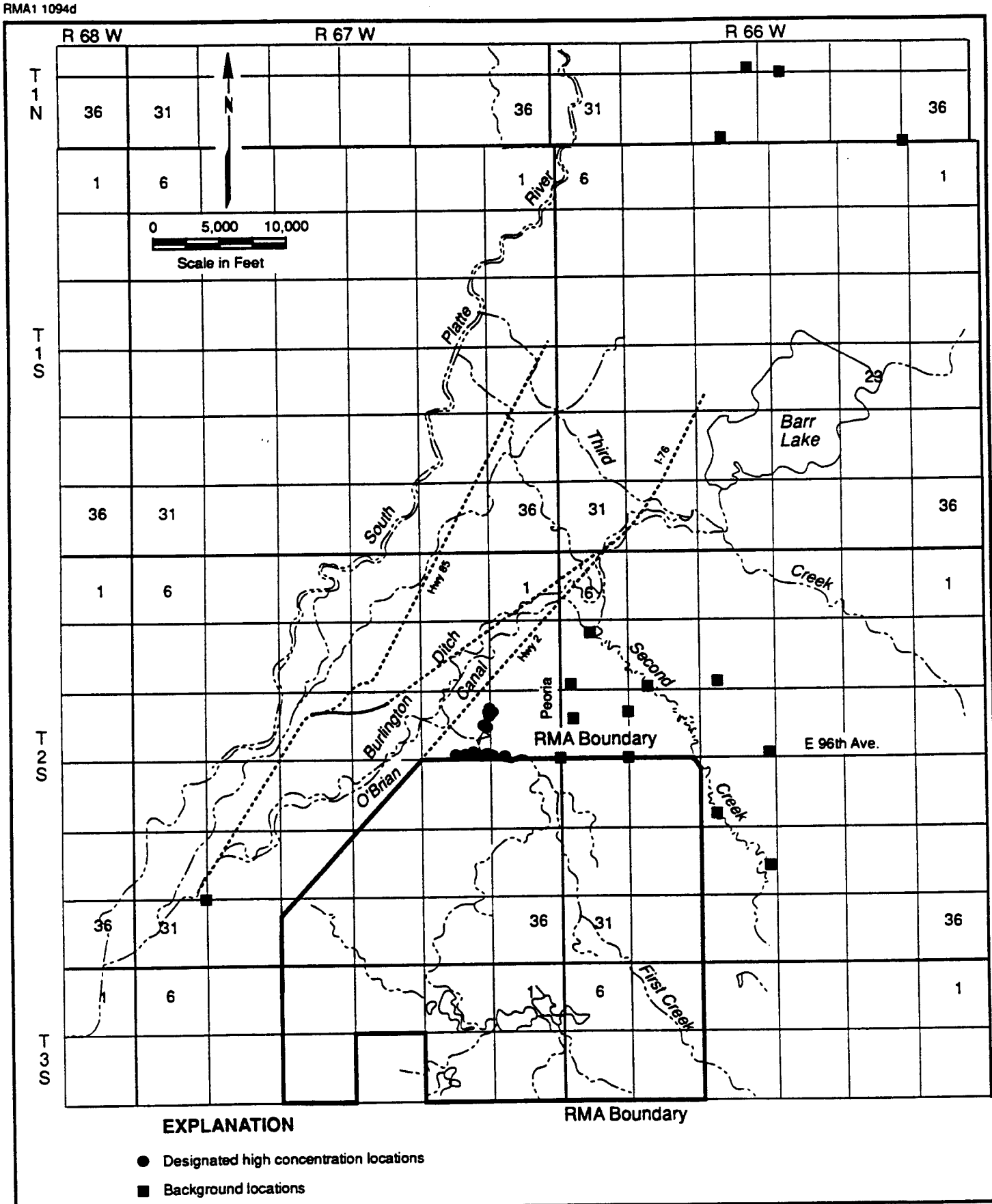
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 1.2-1

OFFPOST OPERABLE UNIT
BACKGROUND SURFICIAL SOIL
SAMPLING LOCATIONS

RMA1 1094d



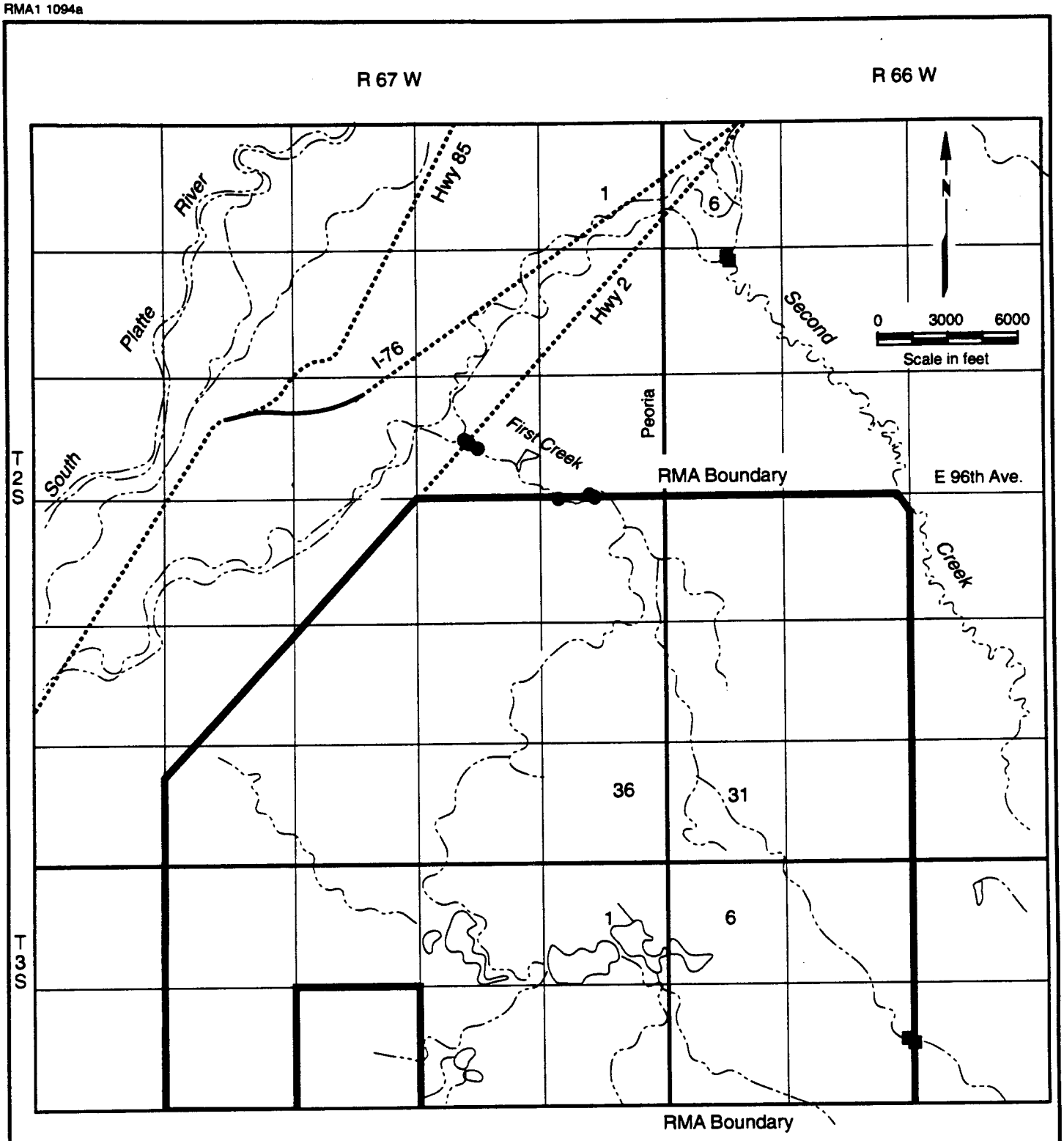
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 1.2-2

OFFPOST OPERABLE UNIT DESIGNATED SURFICIAL SOIL DATA SETS FOR COMPARISON WITH BACKGROUND

RMA1 1094a



EXPLANATION

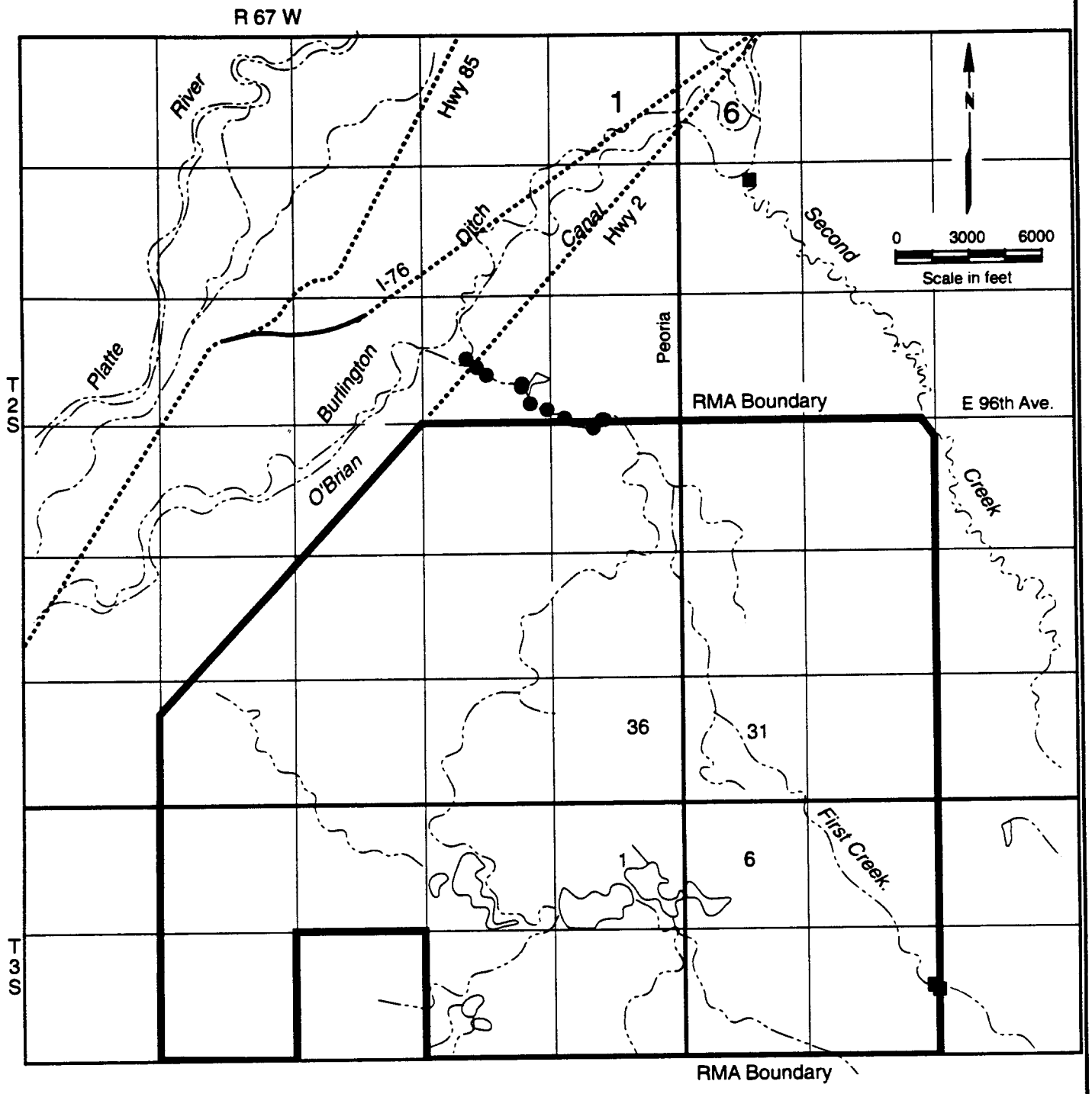
- ● Designated high concentration locations
- ■ Background locations

Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 1.2-3

OFFPOST OPERABLE UNIT FIRST CREEK
SURFACE-WATER SAMPLING LOCATIONS



EXPLANATION

- ● Designated high concentration locations
- ■ Background locations

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Rocky Mountain Arsenal

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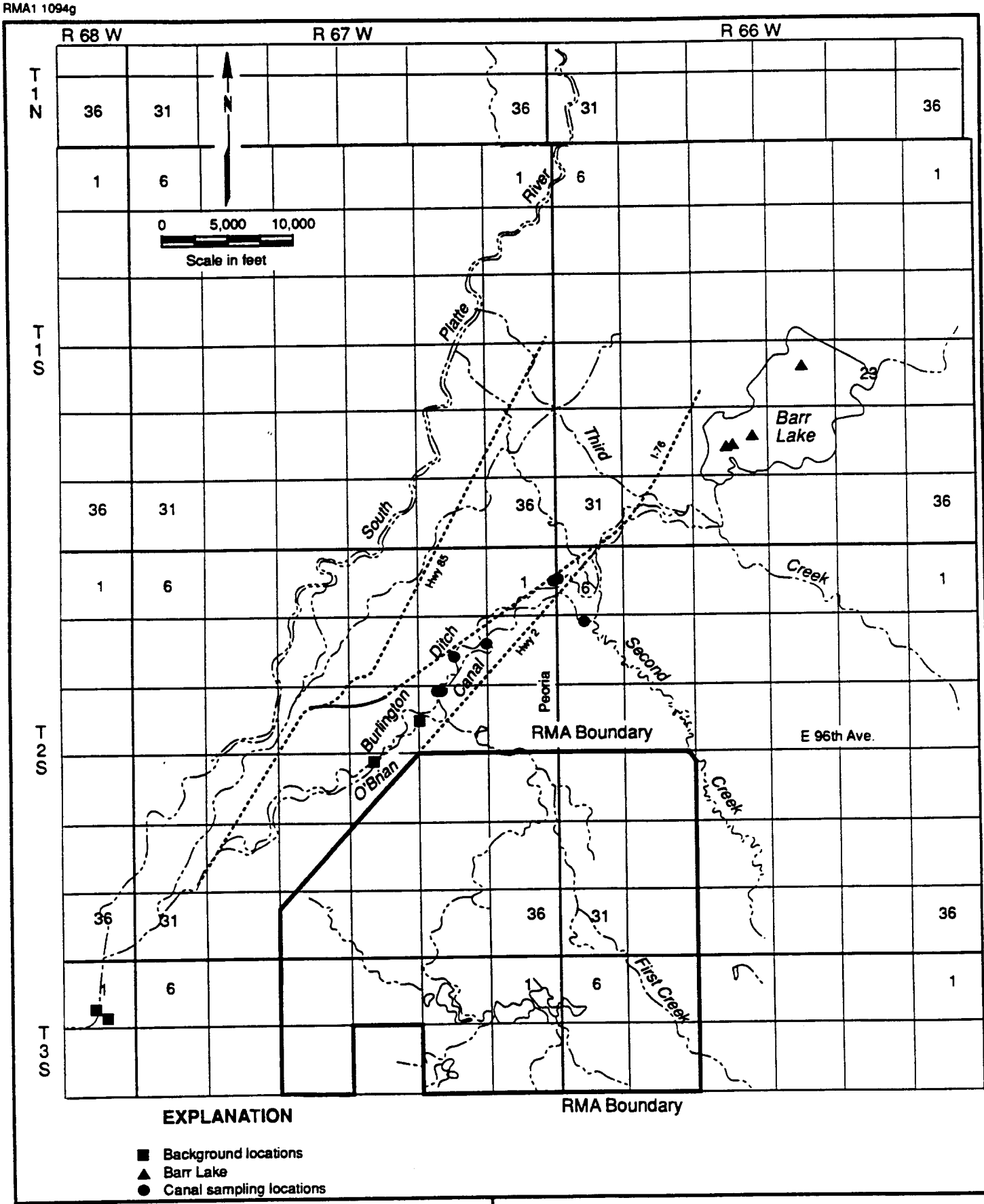
Figure 1.2-4

OFFPOST OPERABLE UNIT FIRST CREEK
SEDIMENT SAMPLING LOCATIONS

RMA1 1094g



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Rocky Mountain Arsenal

Commerce City, Colorado

Figure 1.2-5

OFFPOST OPERABLE UNIT
SURFACE-WATER SAMPLING LOCATIONS

RMA1 1094h

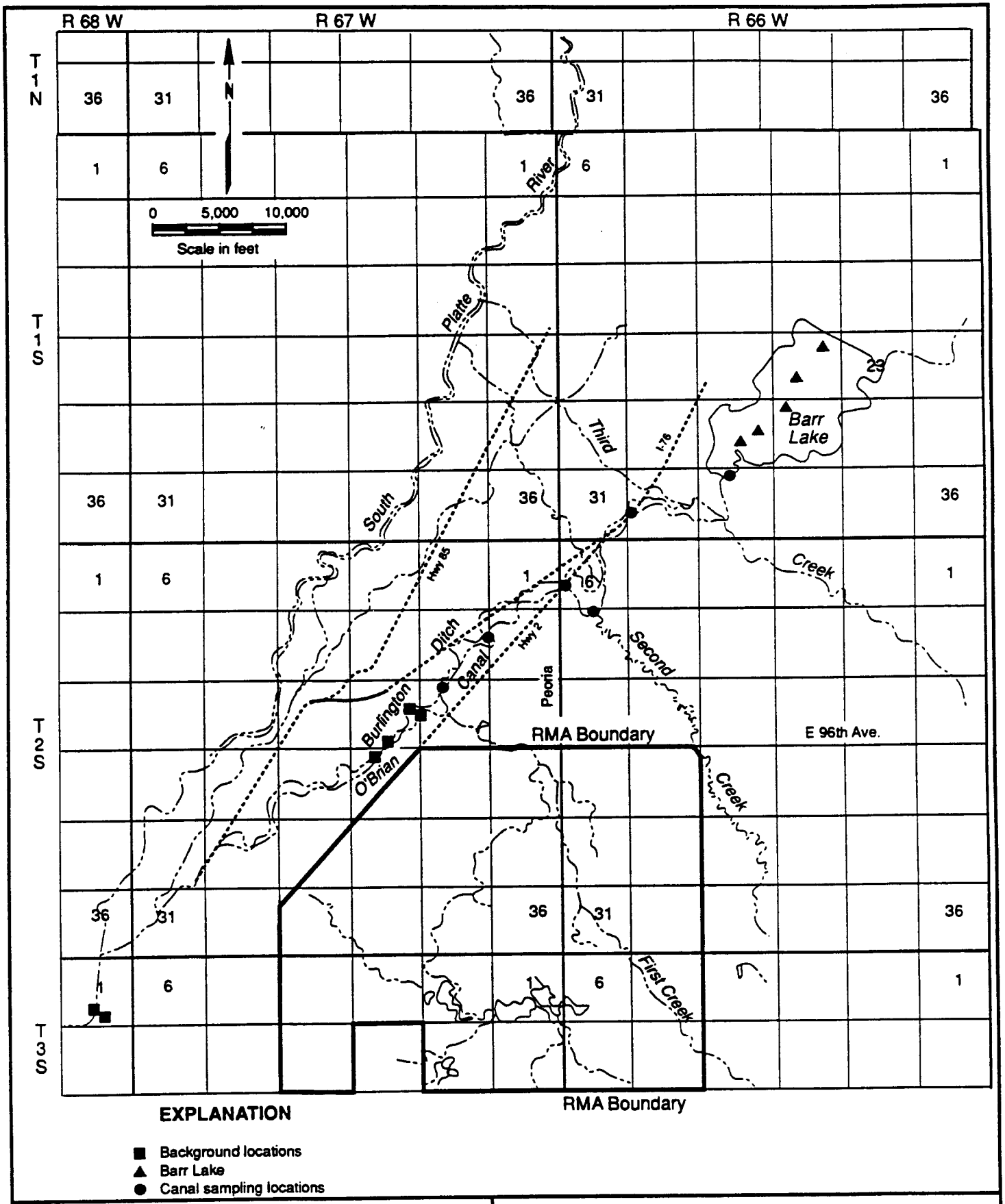

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Figure 1.2-6

OFFPOST OPERABLE UNIT
SEDIMENT SAMPLING LOCATIONS

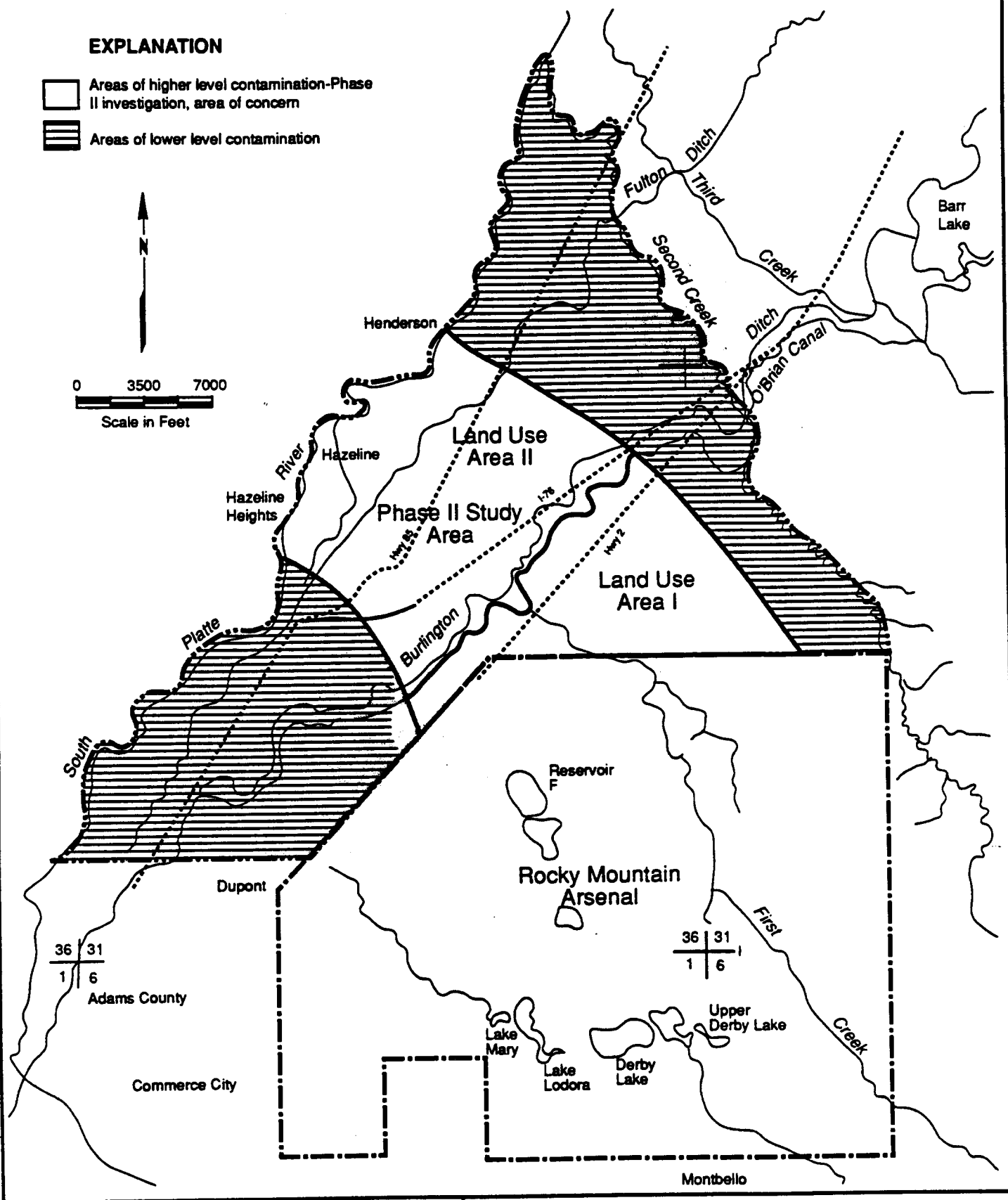

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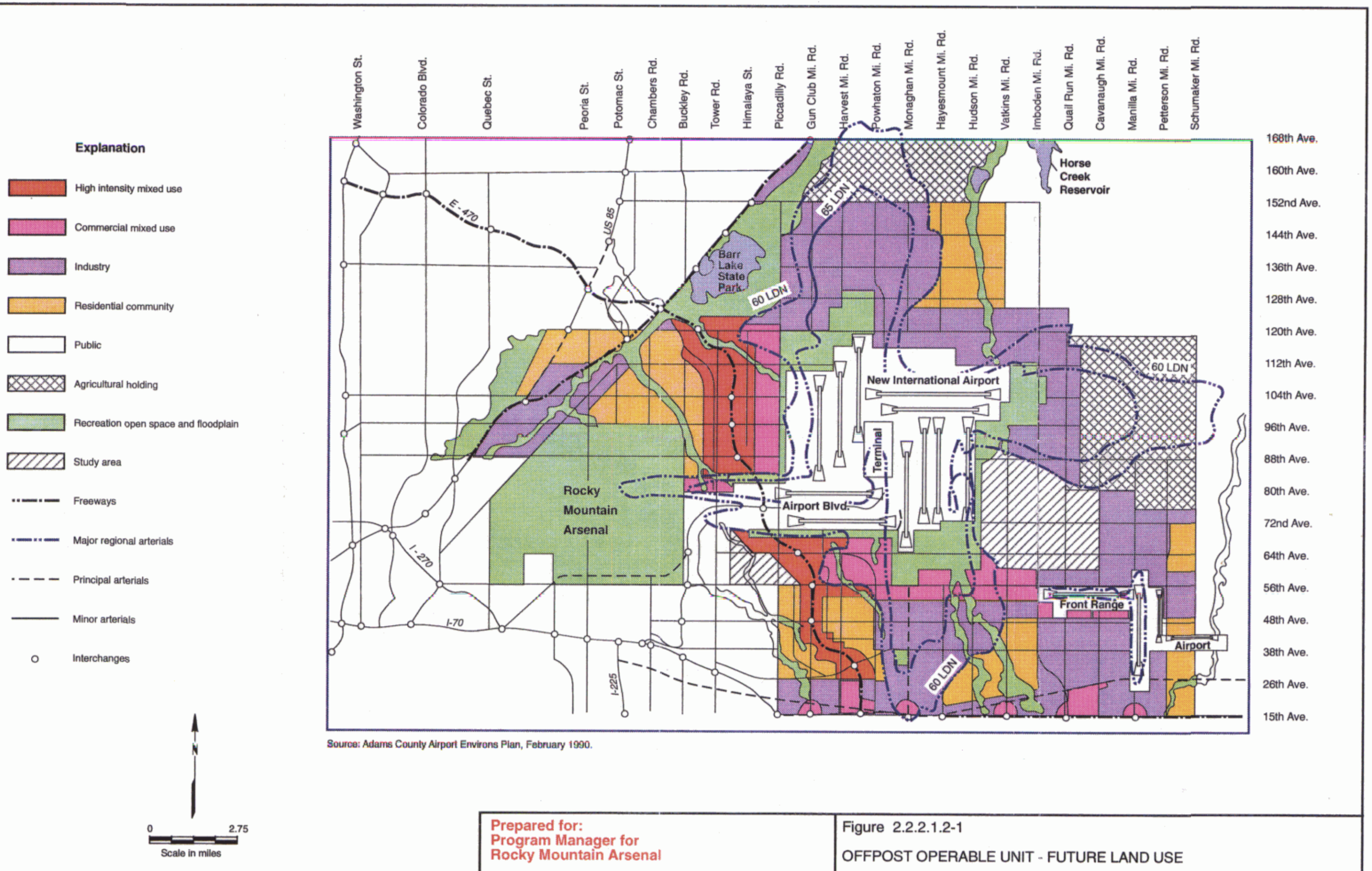
Figure 2.2.2.1.1-1

OFFPOST OPERABLE UNIT LAND USE AREAS AND CONSUMPTIVE USE PHASE II STUDY AREA
SOURCE: ESE., 1986



Source: Adams County Airport Environs Plan, February 1990.

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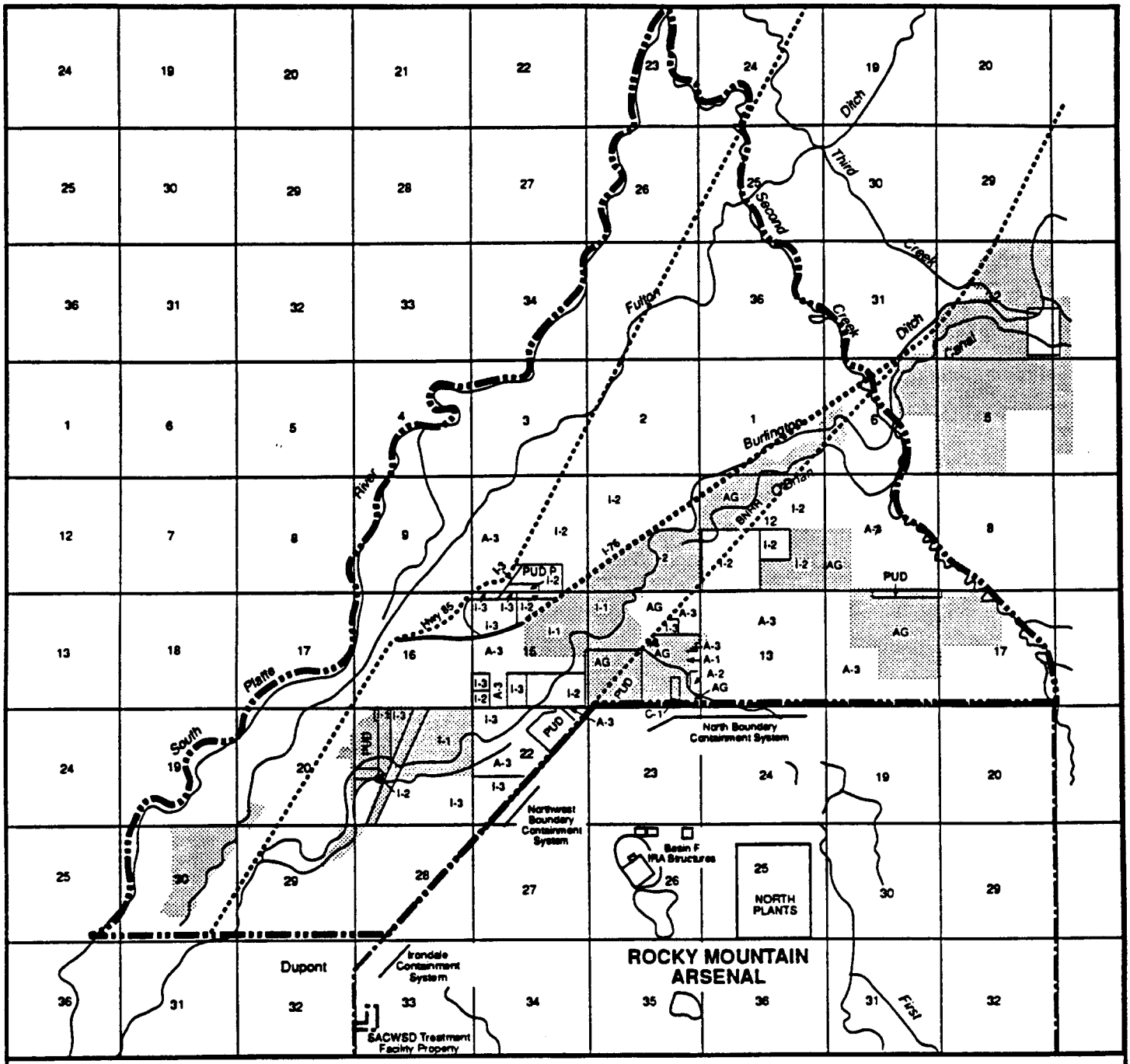
Figure 2.2.2.1.2-1

OFFPOST OPERABLE UNIT - FUTURE LAND USE



EXPLANATION

- Commerce City
- Adams County

0 2350 4700

Scale in feet

Zoning Designation	Commerce City	Adams County
AG	General Agriculture	–
A-1	–	Exclusive Rural Family
A-2	–	Rural Subdivision (10 Acres Minimum)
A-3	–	Irrigated Farming
C-1	Local Retail District	Local Retail District
C-4	–	General Retail District (Limited)
C-5	–	General Retail District (Broad)
I-0	Office/Warehouse	–
I-1	Light Industrial Park (Non-Hazardous Materials, No Outdoor Storage)	General Commercial and Restricted Industrial
I-2	Light Industrial Park (Non-Hazardous Materials, Outdoor Storage)	Light Industrial (Non-Hazardous Materials)
I-3	Heavy Industry	Heavy Industry
PUD	Planned Unit Development	Planned Unit Development
RIC	–	Single Family & Duplex
R-3	–	Moderate Density Residential

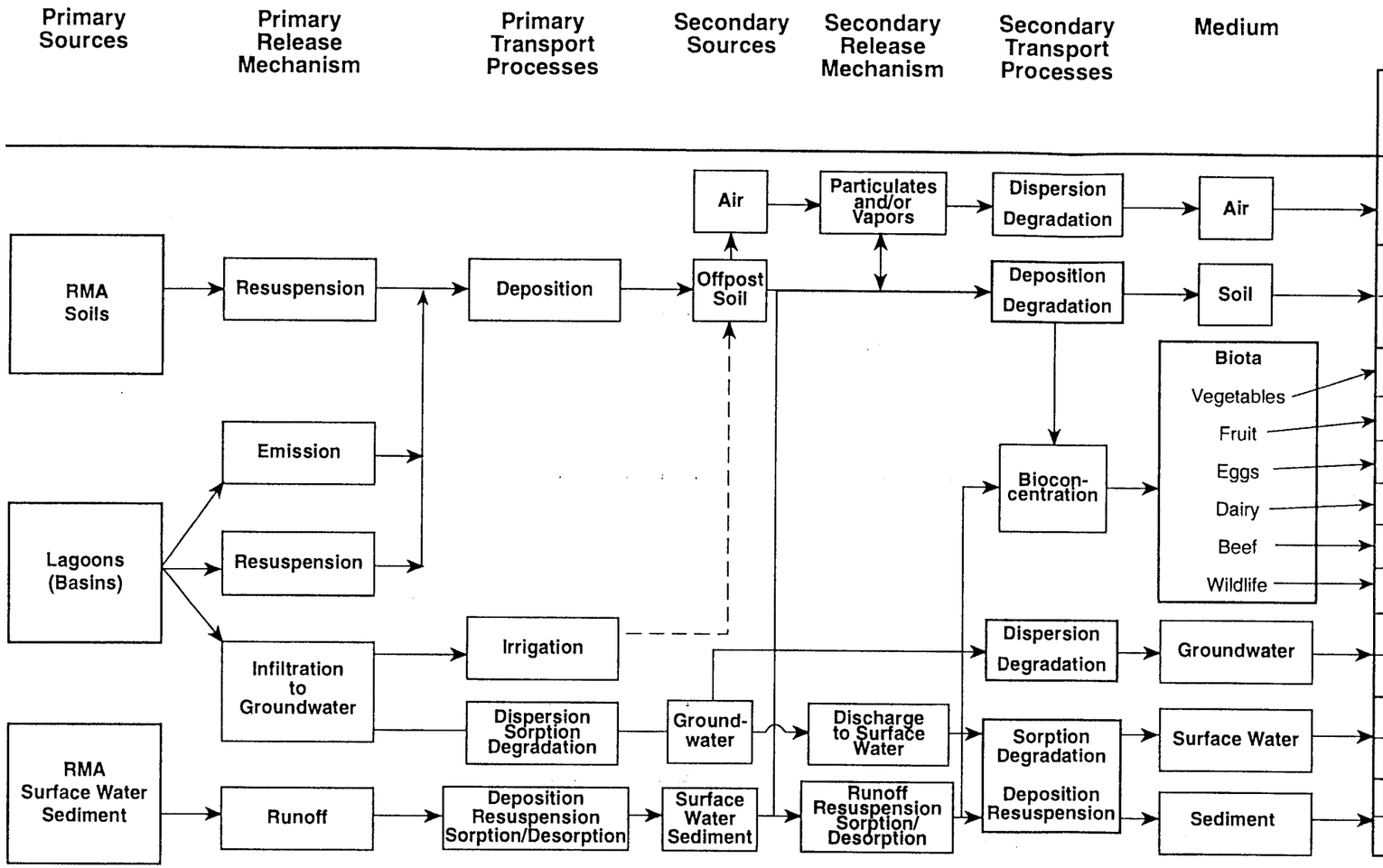
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.2.2.1.2-2

OFFPOST OPERABLE UNIT STUDY AREA
SELECTED CURRENT ZONING MAP, 1991

Source: Commerce City and Adams County Planning Departments.



Exposure Route	Residents		Commercial-Industrial	Recreational
	Child	Adult		
Inhalation	NQ	NQ	NQ	NQ
Ingestion	Q	Q	Q	Q
Dermal	Q	Q	Q	Q
Ingestion	Q	Q	NQ	NQ
Ingestion	NQ	NQ	NQ	NQ
Ingestion	Q	Q	NQ	NQ
Ingestion	Q	Q	NQ	NQ
Ingestion	Q	Q	NQ	NQ
Ingestion	NQ	NQ	NQ	NQ
Ingestion	Q	Q	Q	NQ
Inhalation	Q	Q	Q	NQ
Ingestion	NQ	NQ	NQ	NQ
Dermal	Q	Q	NQ	Q
Ingestion	Q	Q	NQ	Q
Dermal	Q	Q	NQ	Q

EXPLANATION

Q Quanitified

NQ Not Quantified

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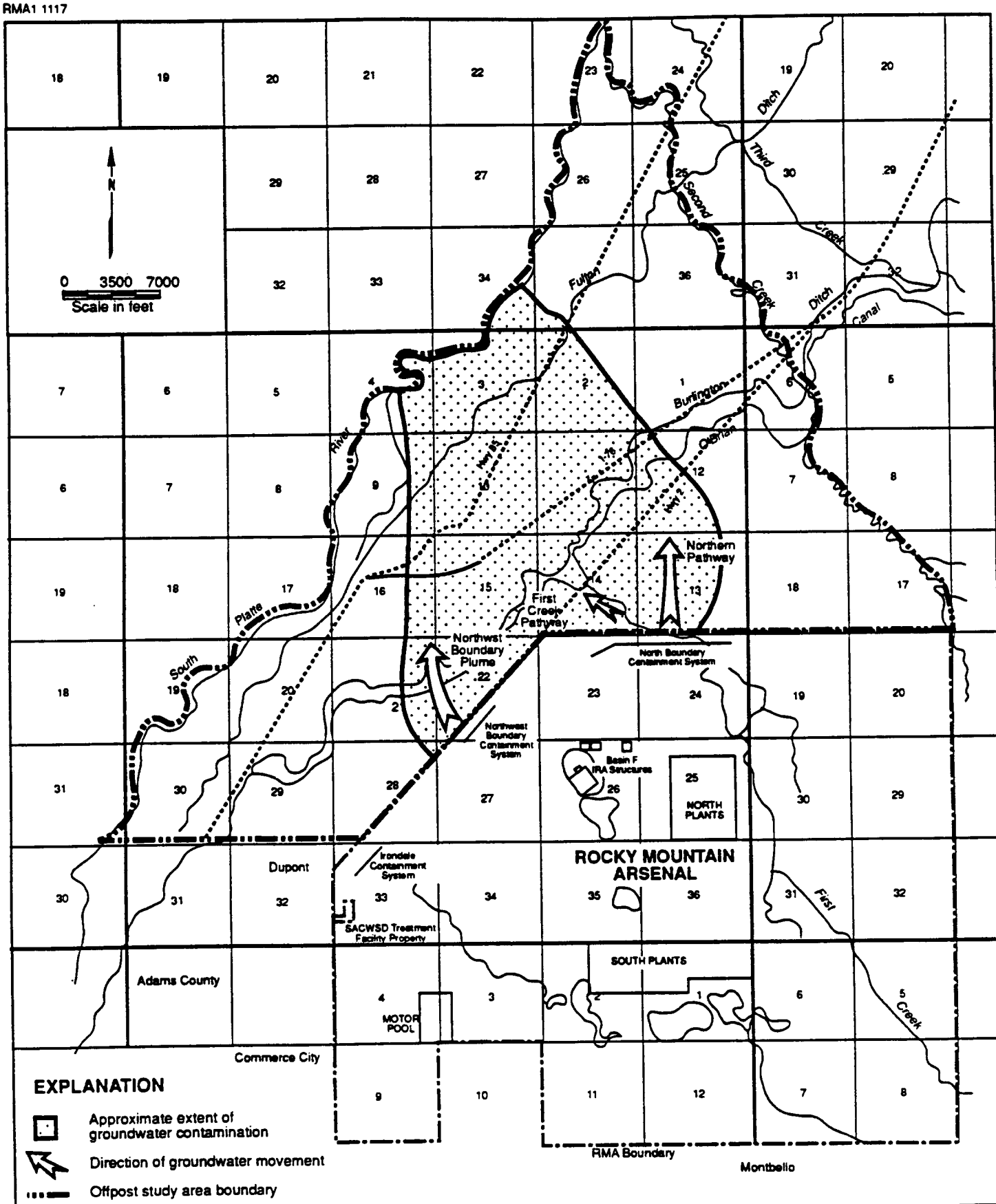
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.3.1-1

SITE CONCEPTUAL MODEL OFFPOST OPERABLE UNIT

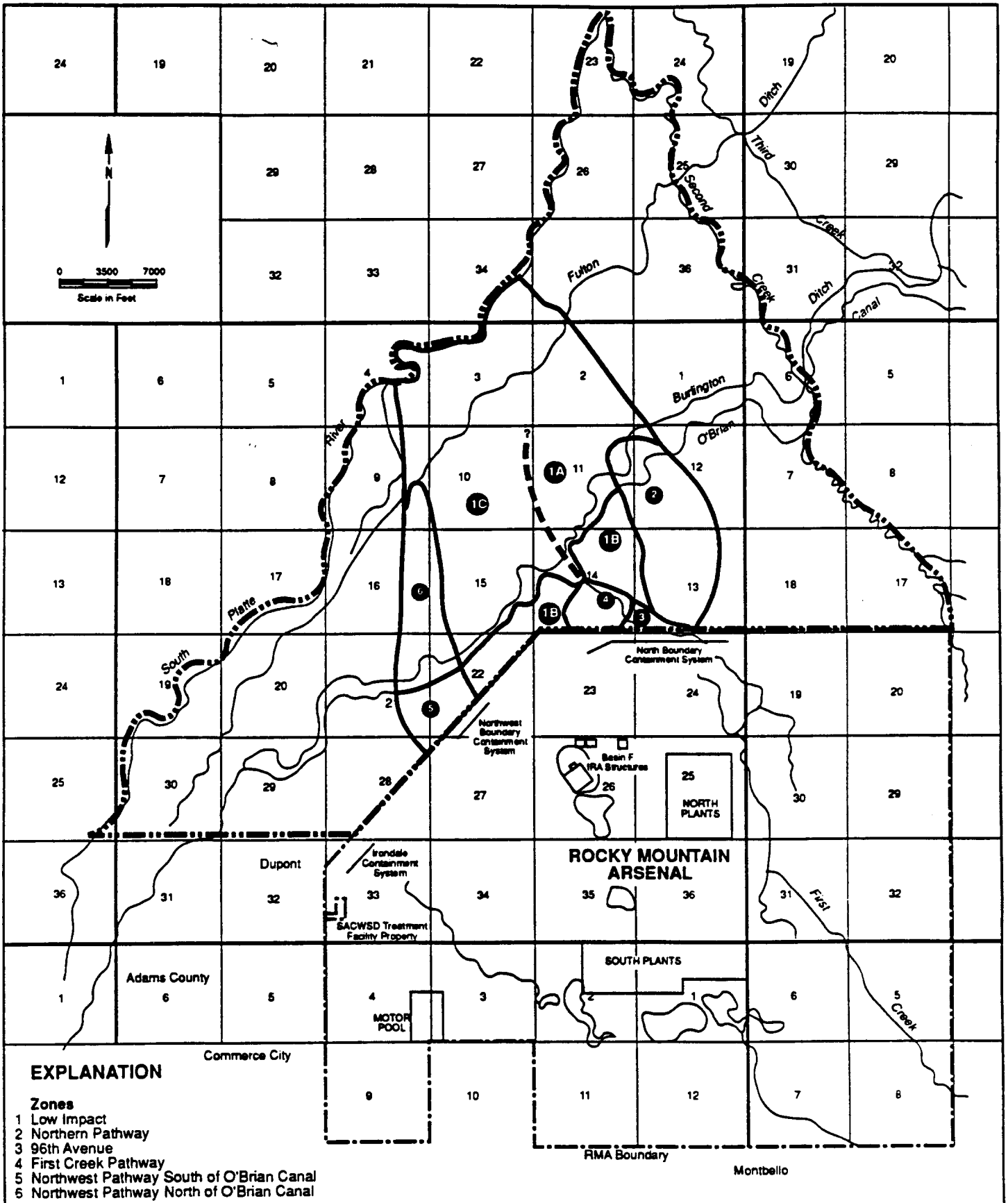


Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.4.1-1

OFFPOST OPERABLE UNIT ZONES
MAJOR PATHWAYS OF GROUNDWATER
CONTAMINANT TRANSPORT



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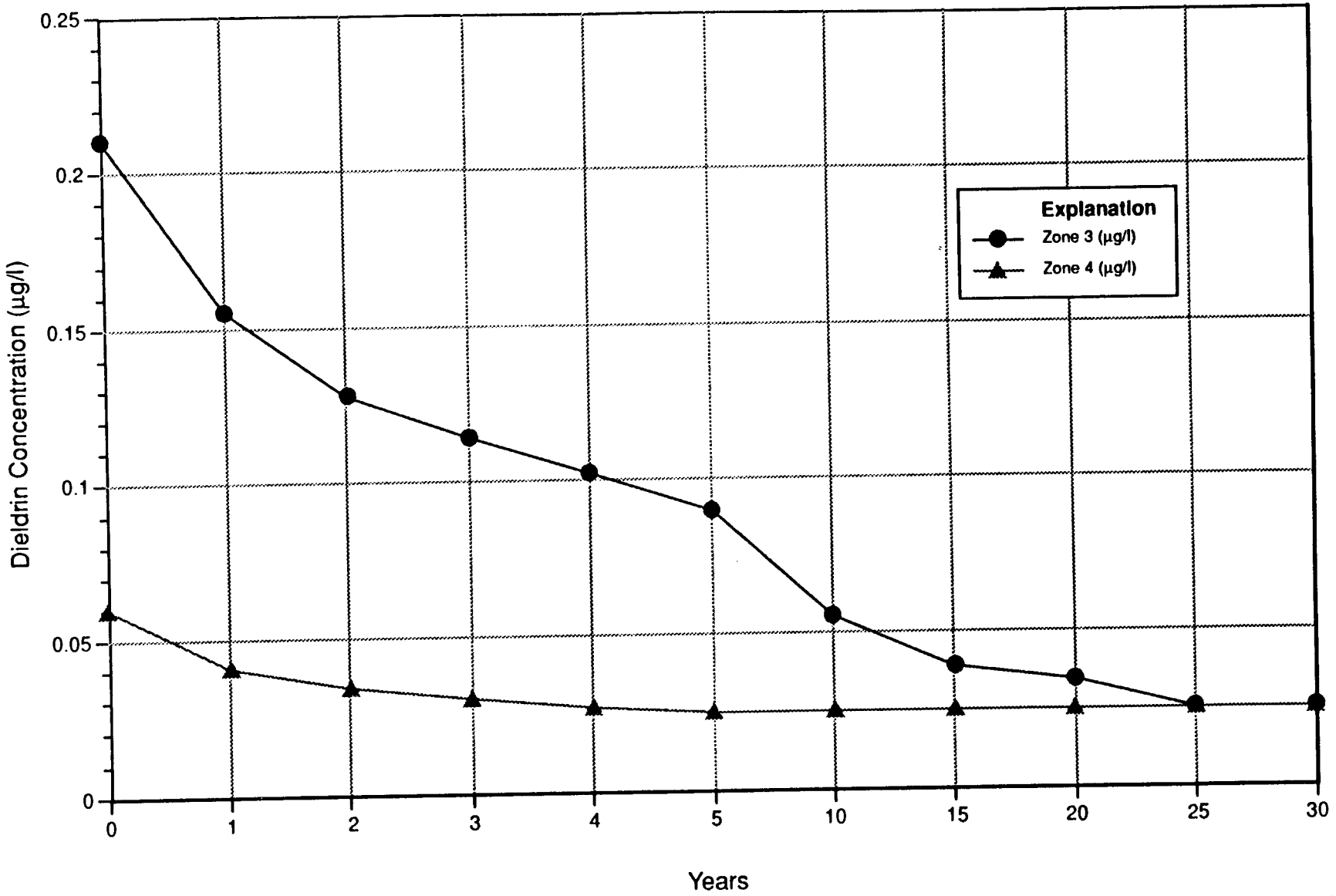
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.4.1-2

OFFPOST OPERABLE UNIT
ENDANGERMENT ASSESSMENT ZONES



Prepared for:
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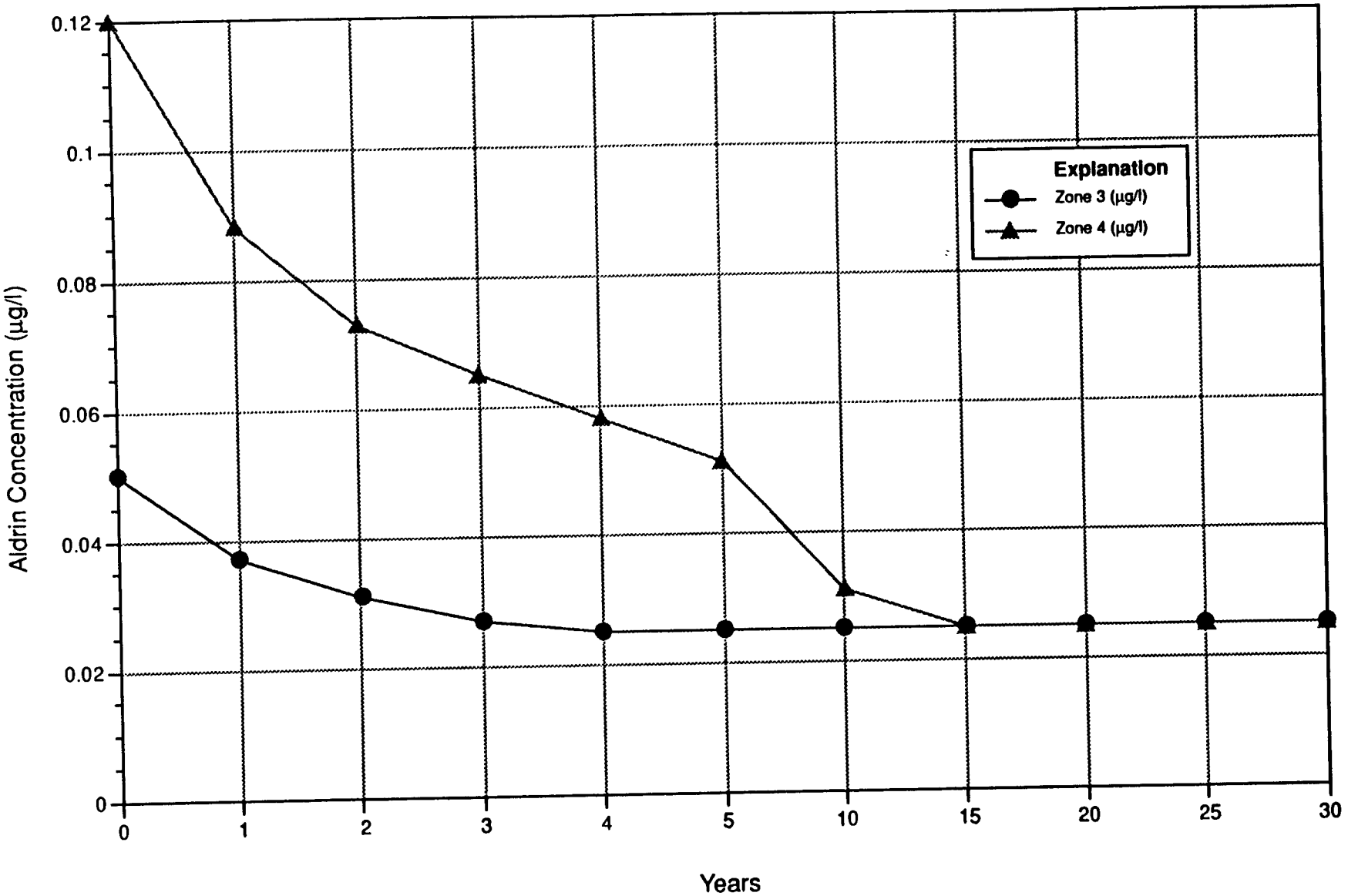
Commerce City, Colorado

Figure 2.4.2.6-1

ESTIMATED FUTURE EXPOSURE CONCENTRATIONS FOR DIELDRIN, GROUNDWATER, ZONES 3 AND 4



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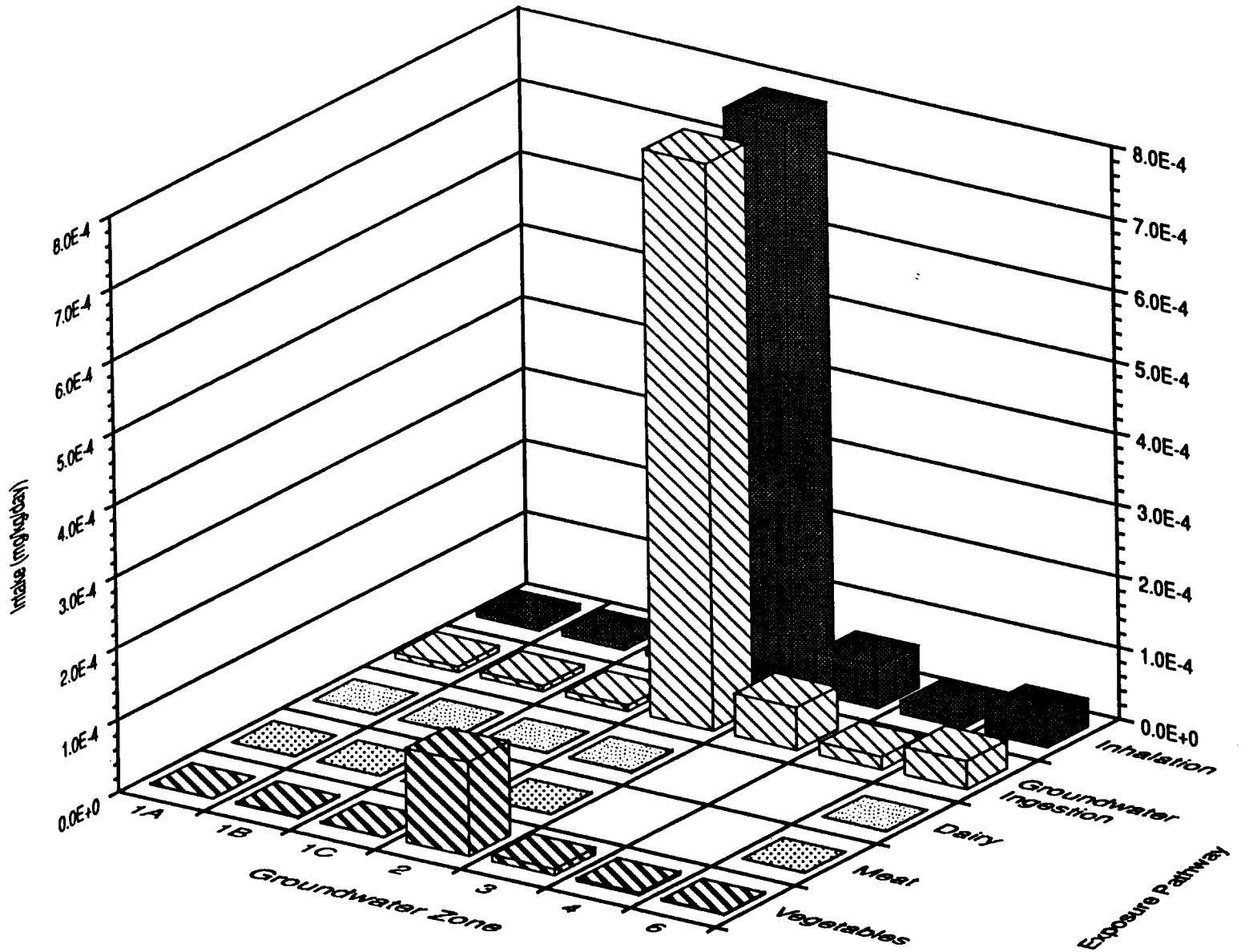
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.4.2.6-2

ESTIMATED FUTURE EXPOSURE CONCENTRATIONS FOR ALDRIN, GROUNDWATER, ZONES 3 AND 4



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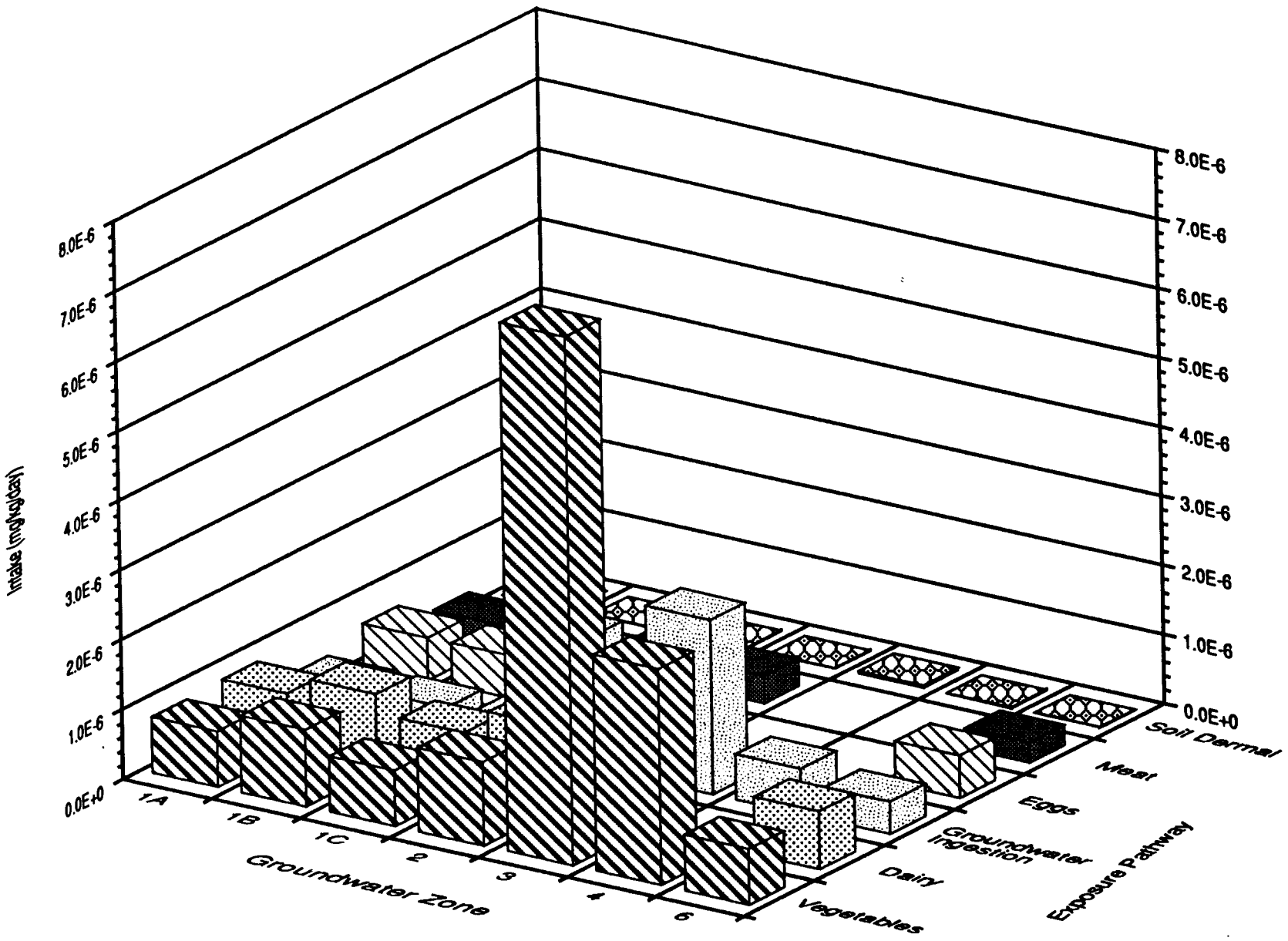
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.4.3.3-1

OFFPOST OPERABLE UNIT CHRONIC INTAKE OF CHLOROFORM BY PATHWAY AND GROUNDWATER ZONE - RESIDENTIAL SCENARIOS



Prepared for:
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Rocky Mountain Arsenal

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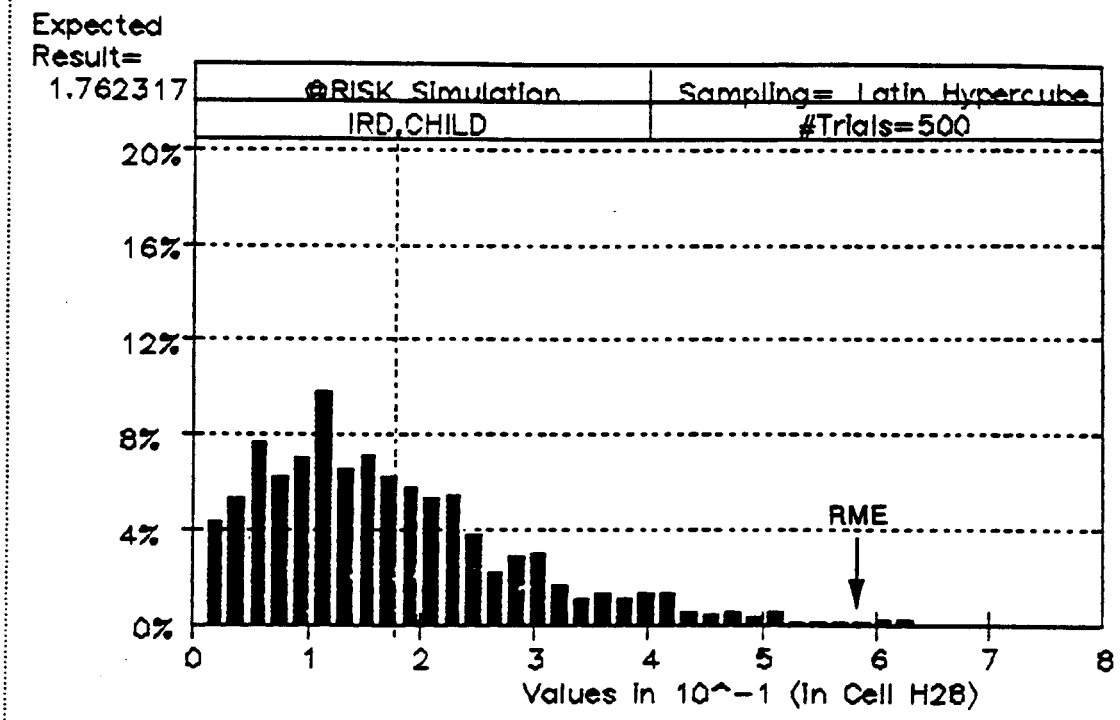
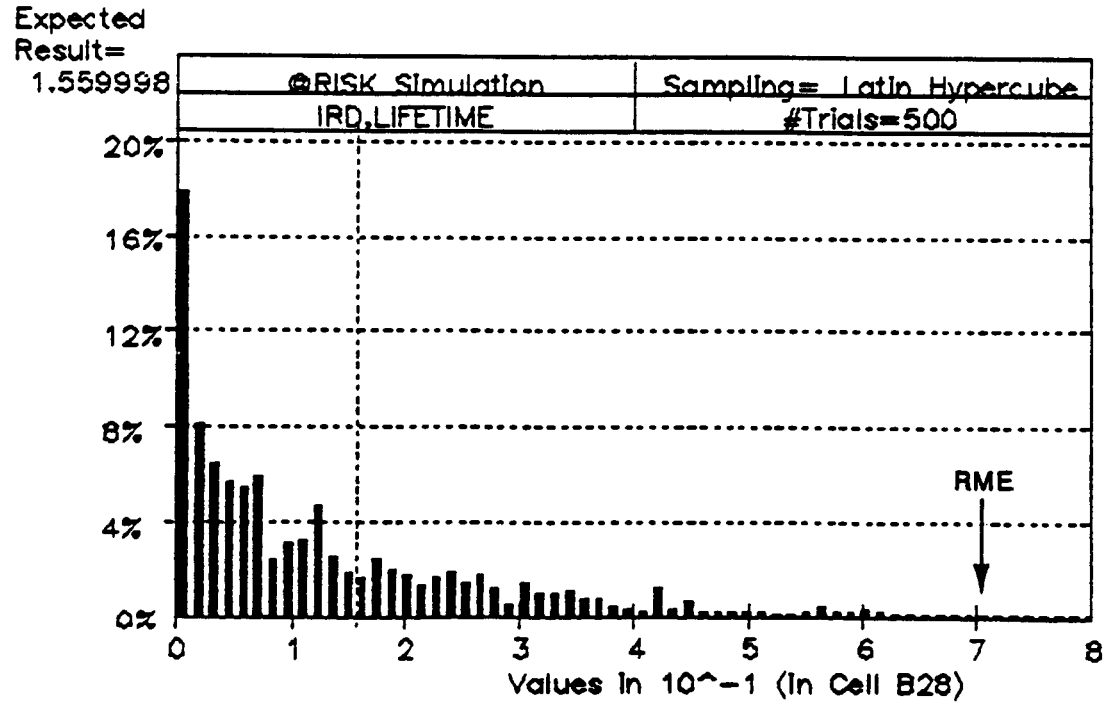
Figure 2.4.3.3-2

OFFPOST OPERABLE UNIT INTAKE OF DIELDRIN BY ZONE AND PATHWAY - RESIDENTIAL SCENARIO

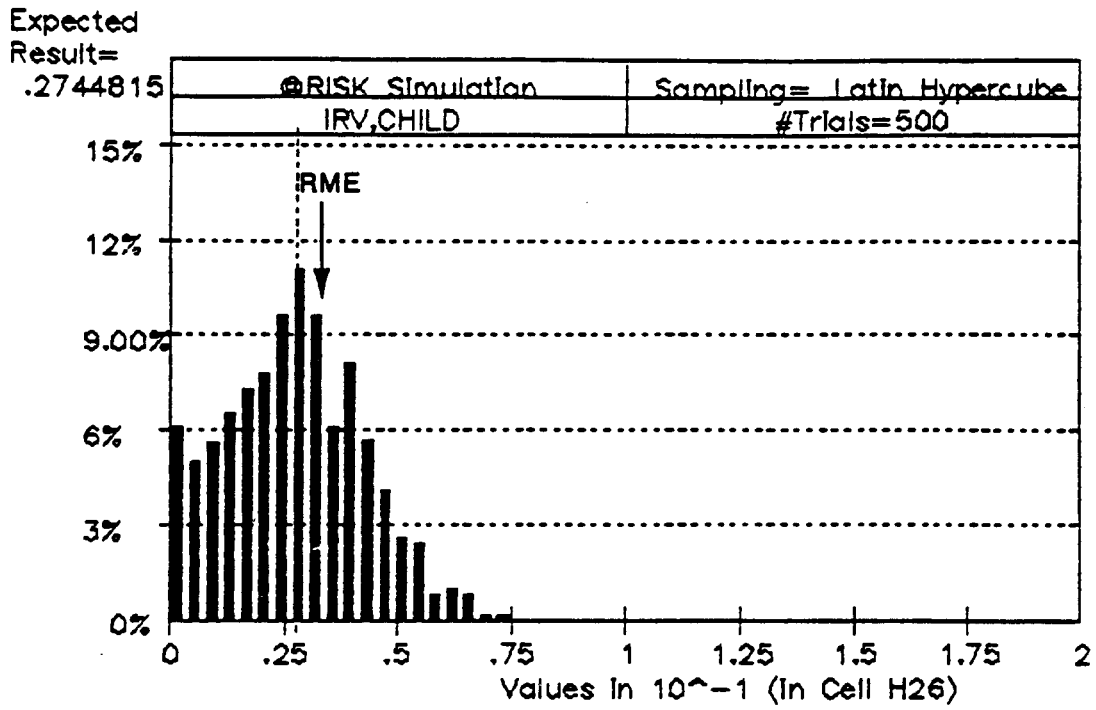


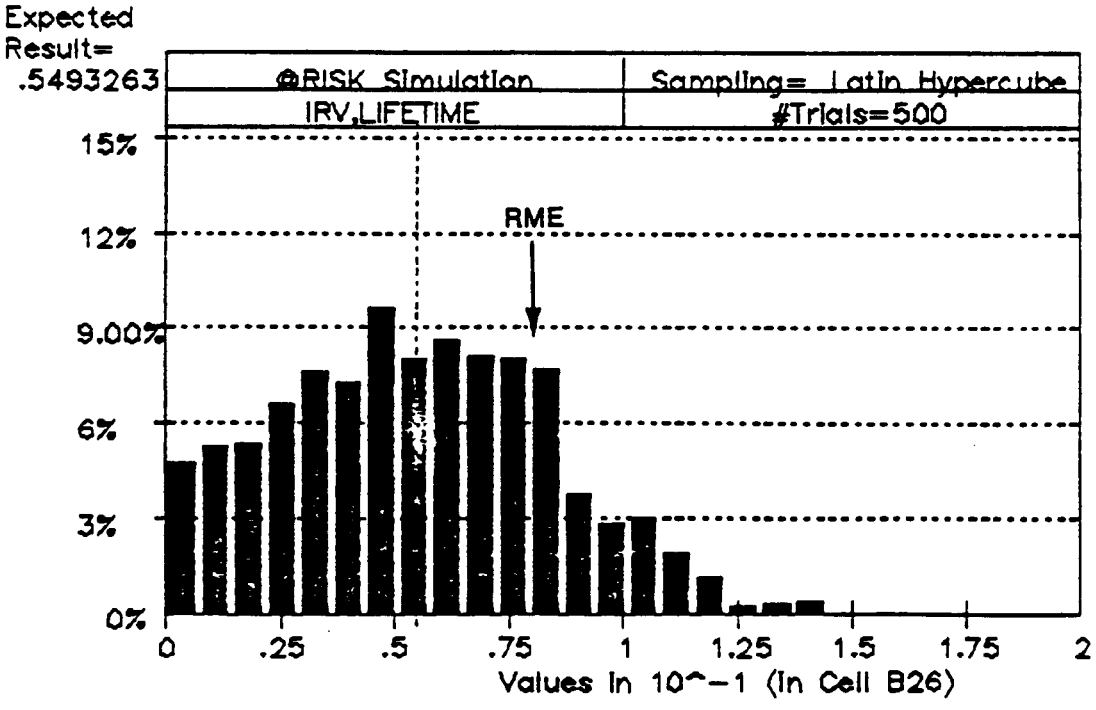


Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.4.5-1
OFFPOST OPERABLE UNIT HISTOGRAMS DESCRIBING THE DISTRIBUTION OF INGESTION RATE OF LOCALLY PRODUCED MILK (IRd, kg/day) FOR THE CHILD CHRONIC AND LIFETIME SCENARIOS-RESIDENTIAL





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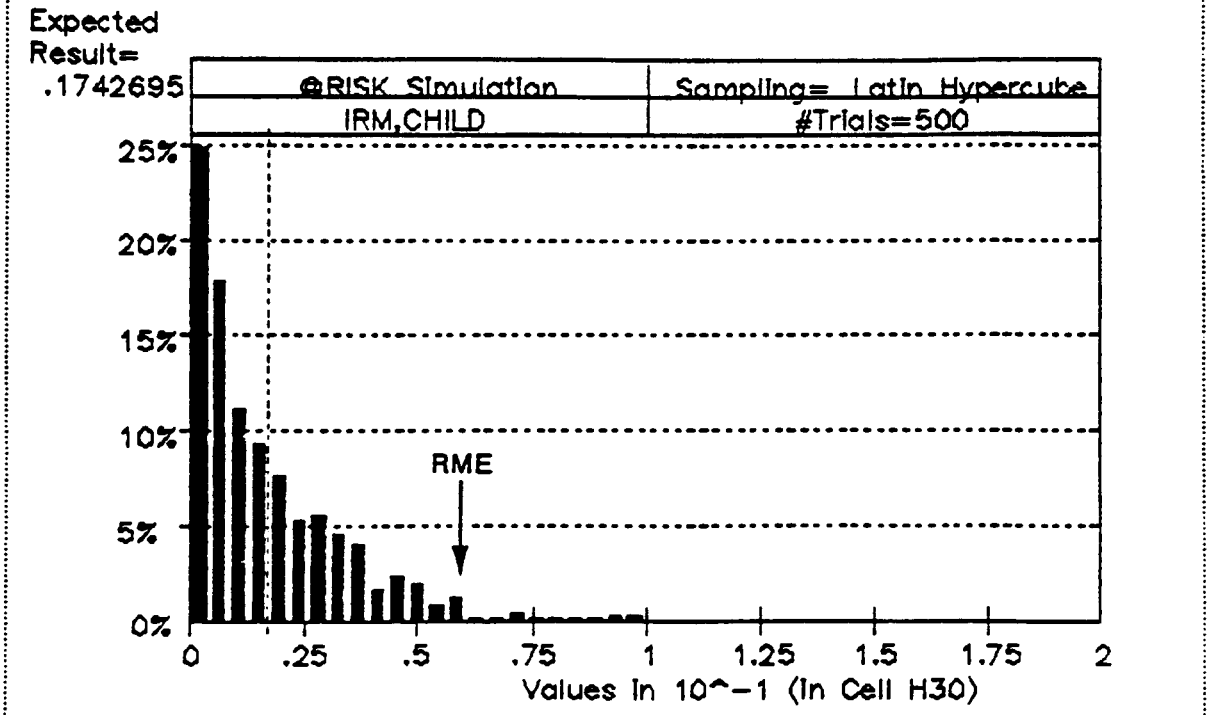
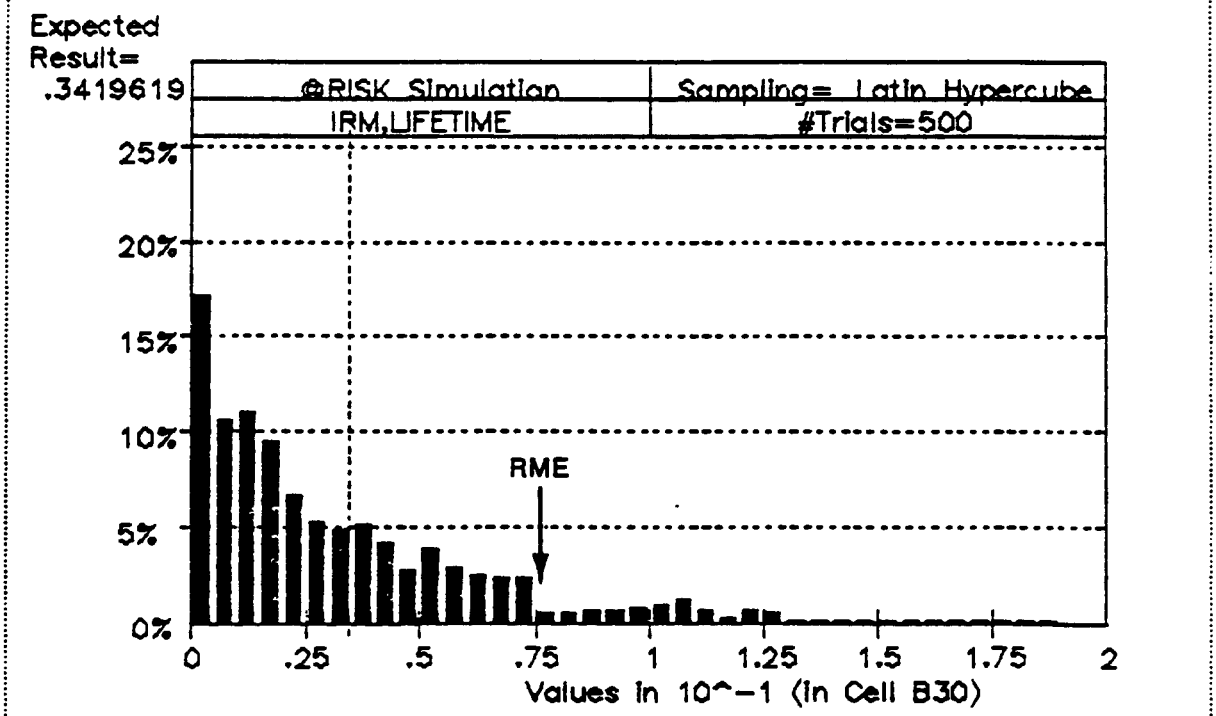
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.4.5-2
OFFPOST OPERABLE UNIT HISTOGRAMS DESCRIBING THE DISTRIBUTION OF INGESTION RATE OF LOCALLY PRODUCED VEGETABLES (IRv, kg/day) FOR THE CHILD CHRONIC AND LIFETIME SCENARIOS-RESIDENTIAL





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Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.4.5-3
OFFPOST OPERABLE UNIT HISTOGRAMS DESCRIBING THE DISTRIBUTION OF INGESTION RATE OF LOCALLY PRODUCED MEAT (IRm, kg/day FRESH WEIGHT) FOR THE CHILD CHRONIC AND LIFETIME SCENARIOS-RESIDENTIAL

FILE ####

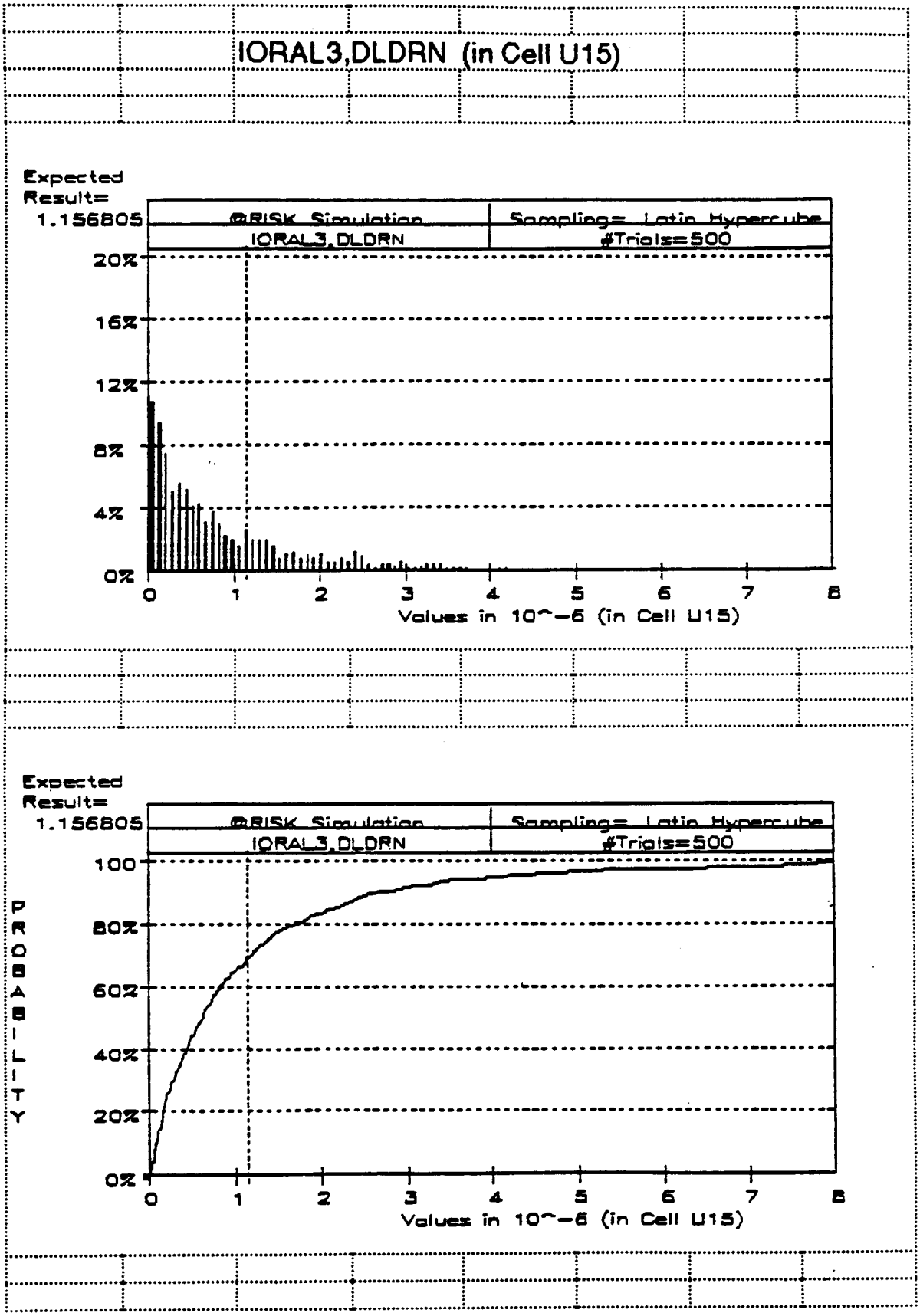

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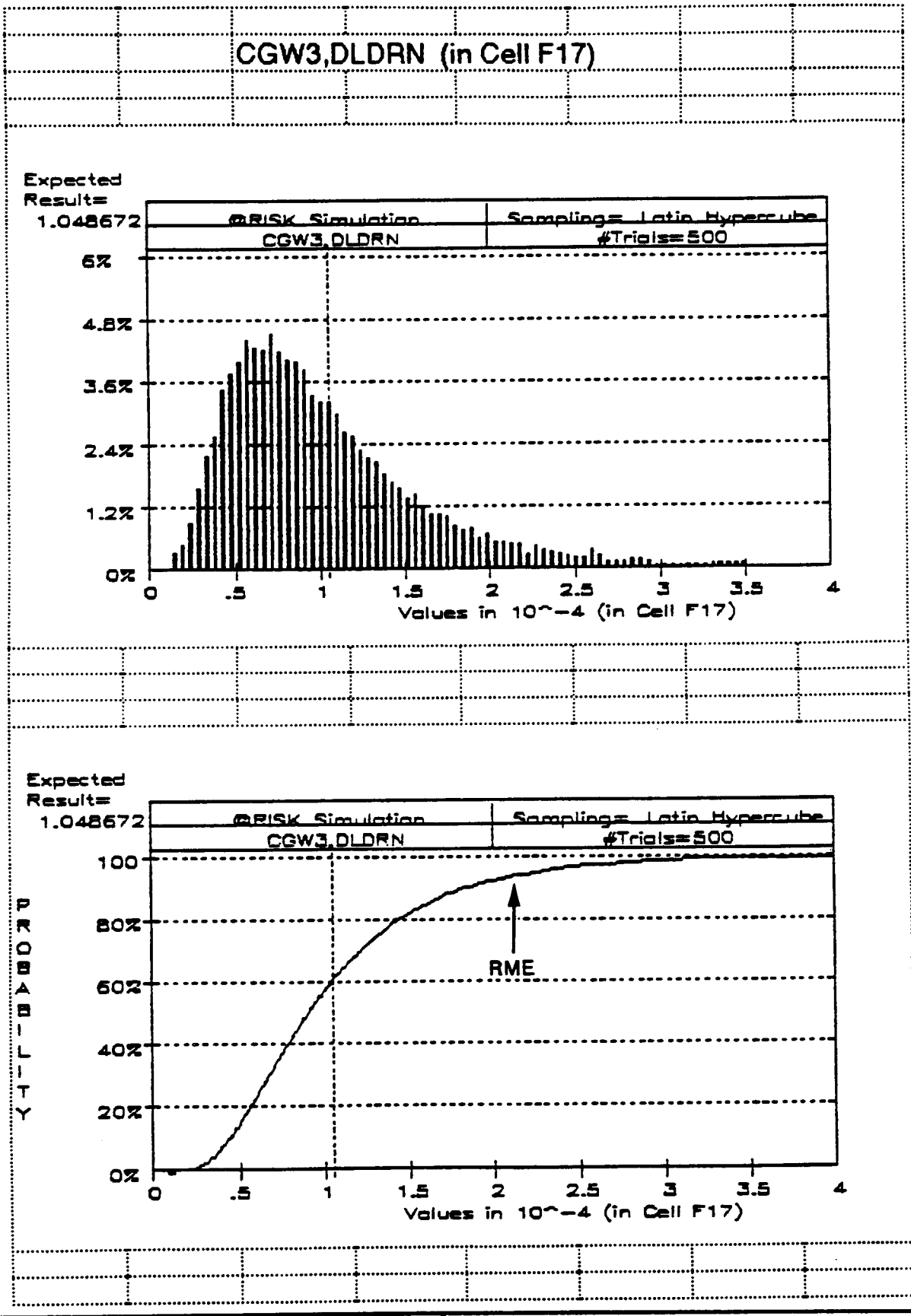
Figure 2.4.5.5.2-1

OFFPOST OPERABLE UNIT DISTRIBUTION OF LIFETIME ORAL INTAKE OF DIELDRIN IN ZONE 3 (mg/kg/day)-RESIDENTIAL

FILE ####



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Rocky Mountain Arsenal

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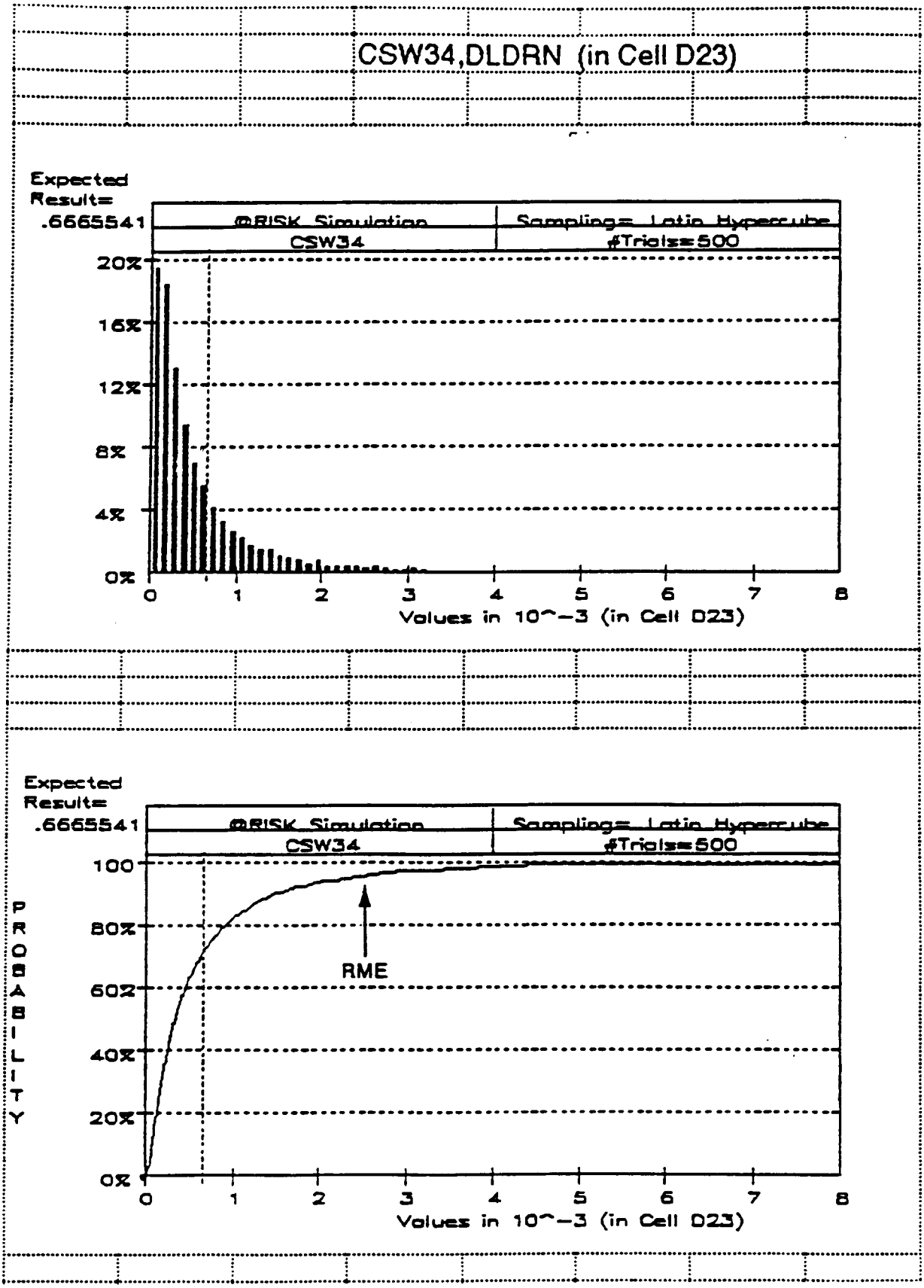
Figure 2.4.5.5.2-2

OFFPOST OPERABLE UNIT UNCERTAINTY IN THE MEAN CONCENTRATION OF DIELDRIN IN GROUNDWATER (mg/l) IN ZONE 3



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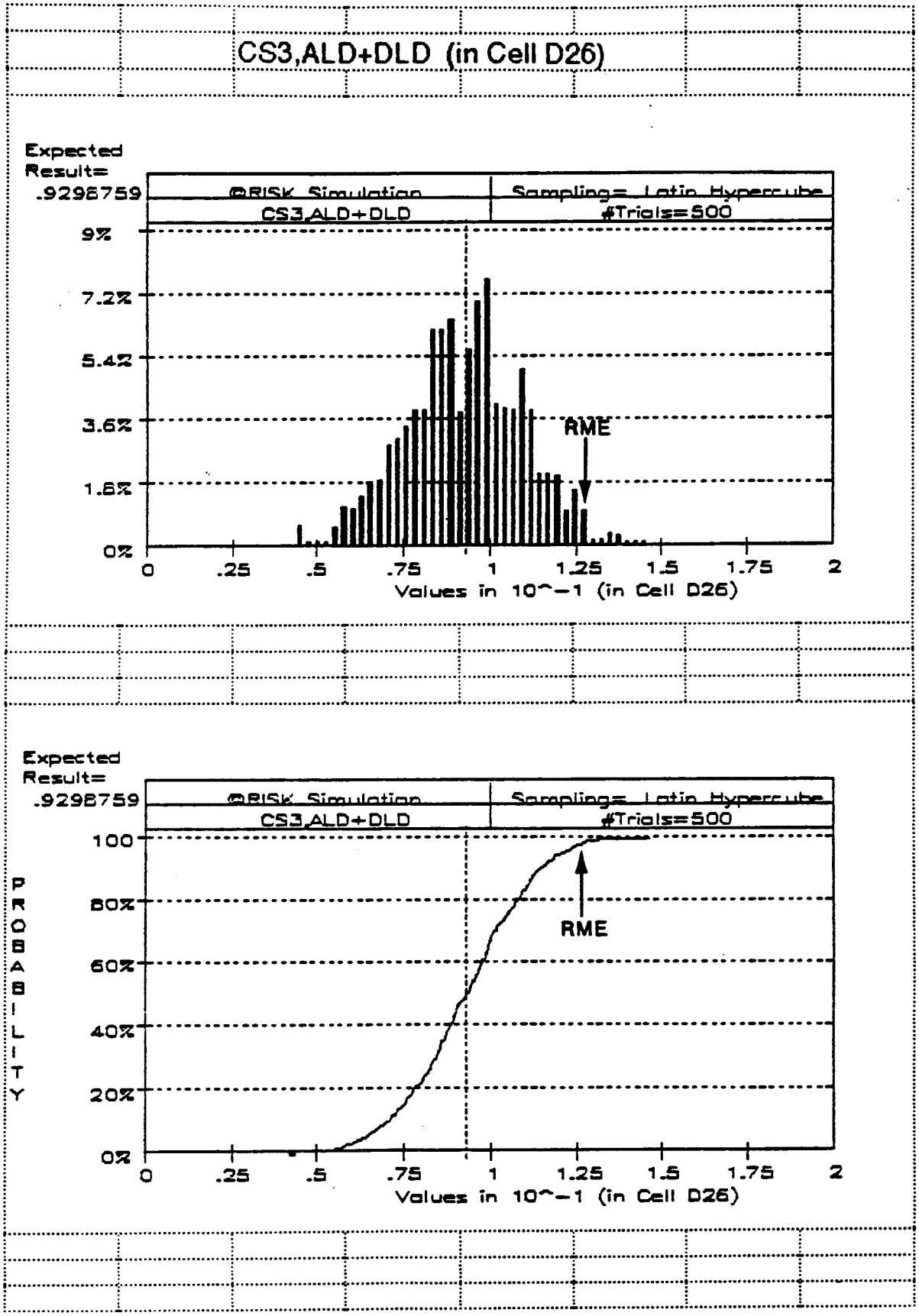
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.4.5.5.2-3

OFFPOST OPERABLE UNIT UNCERTAINTY IN THE MEAN CONCENTRATION OF DIELDRIN IN FIRST CREEK SURFACE WATER (mg/l)



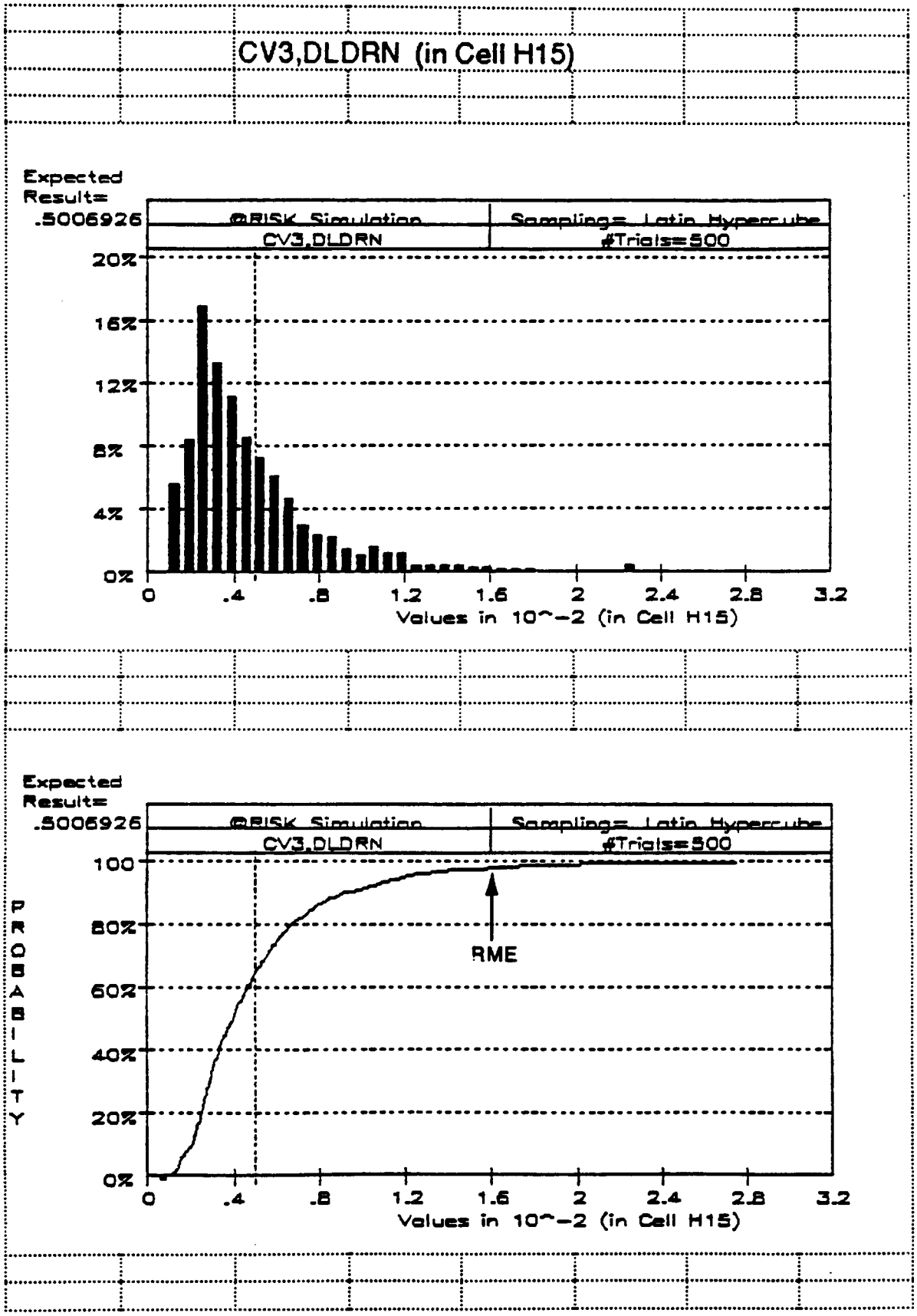
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.4.5.5.2-4

OFFPOST OPERABLE UNIT UNCERTAINTY IN THE MEAN CONCENTRATION OF ALDRIN AND DIELDRIN IN SURFACE SOIL OF ZONE 3 (mg/l)

FILE ####

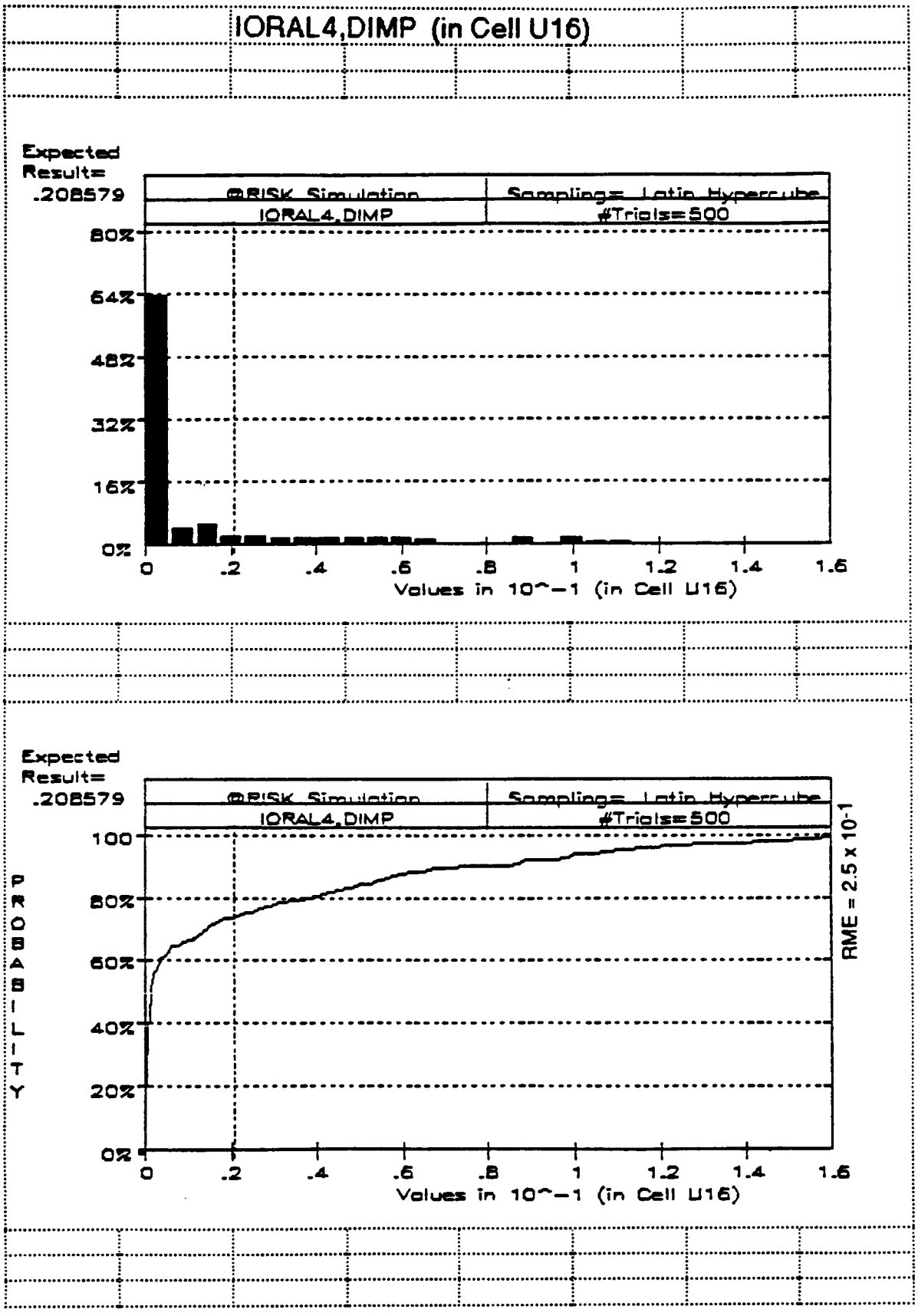


Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.4.5.5.2-5

OFFPOST OPERABLE UNIT UNCERTAINTY IN THE MEAN CONCENTRATION OF DIELDRIN IN VEGETABLES (CFv, mg/kg, FRESH WEIGHT) IN ZONE 3



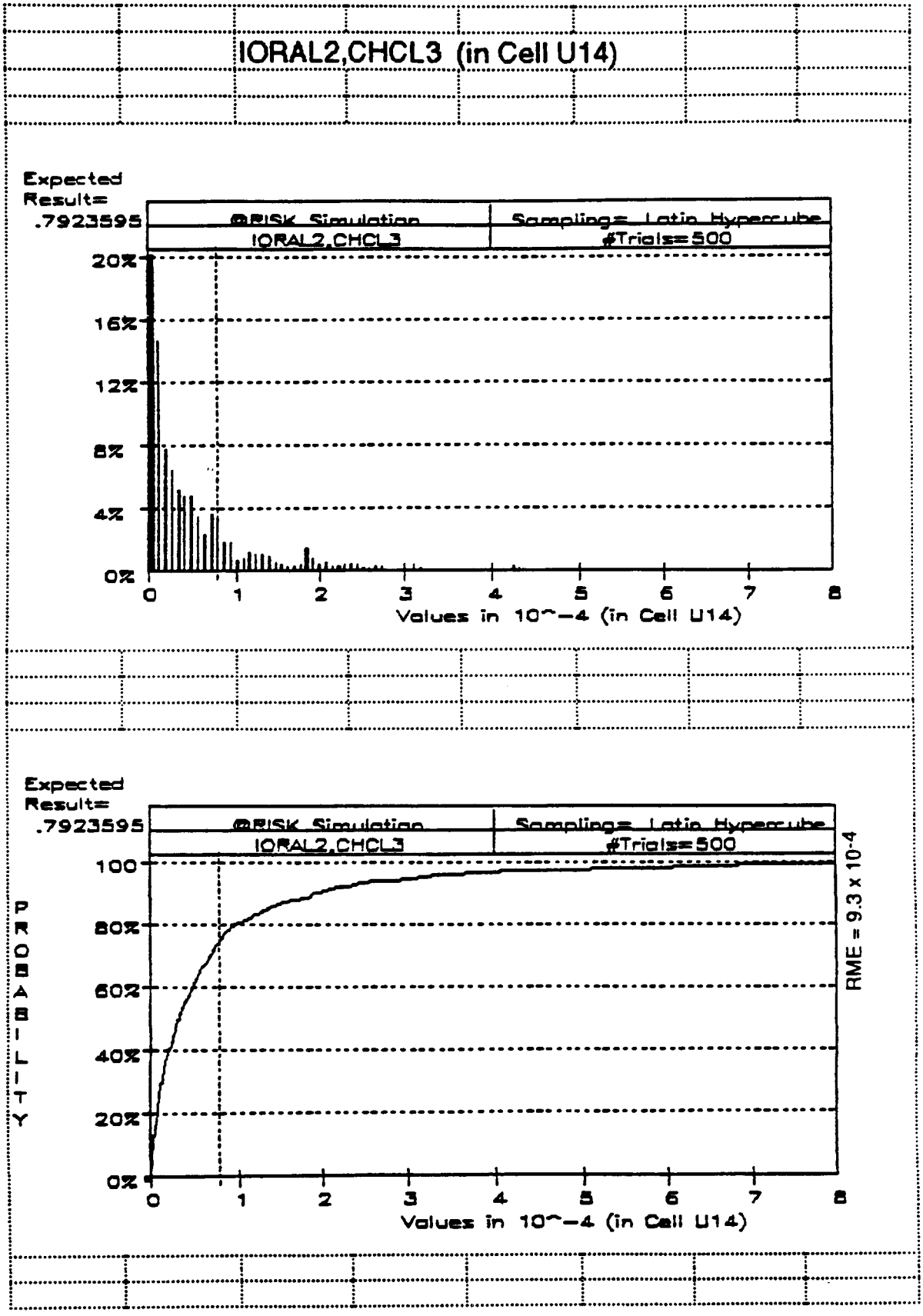
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.4.5.5.2-6

OFFPOST OPERABLE UNIT DISTRIBUTION OF CHILD CHRONIC ORAL INTAKE OF DIMP IN ZONE 4 (mg/kg/day)-RESIDENTIAL

FILE ####

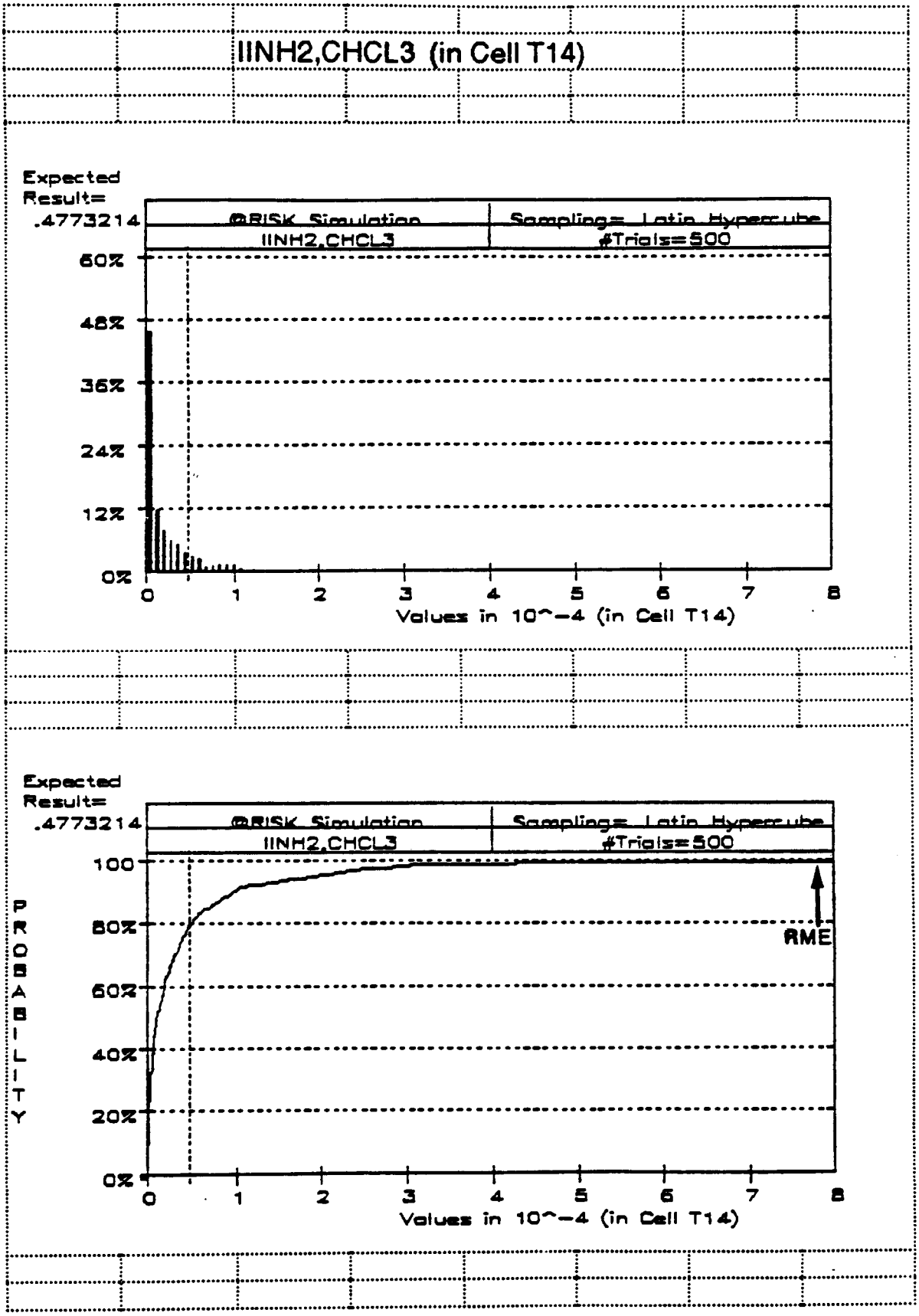


Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.4.5.5.2-7

OFFPOST OPERABLE UNIT DISTRIBUTION OF LIFETIME ORAL INTAKE OF CHLOROFORM IN ZONE 2 (mg/kg/day)-RESIDENTIAL

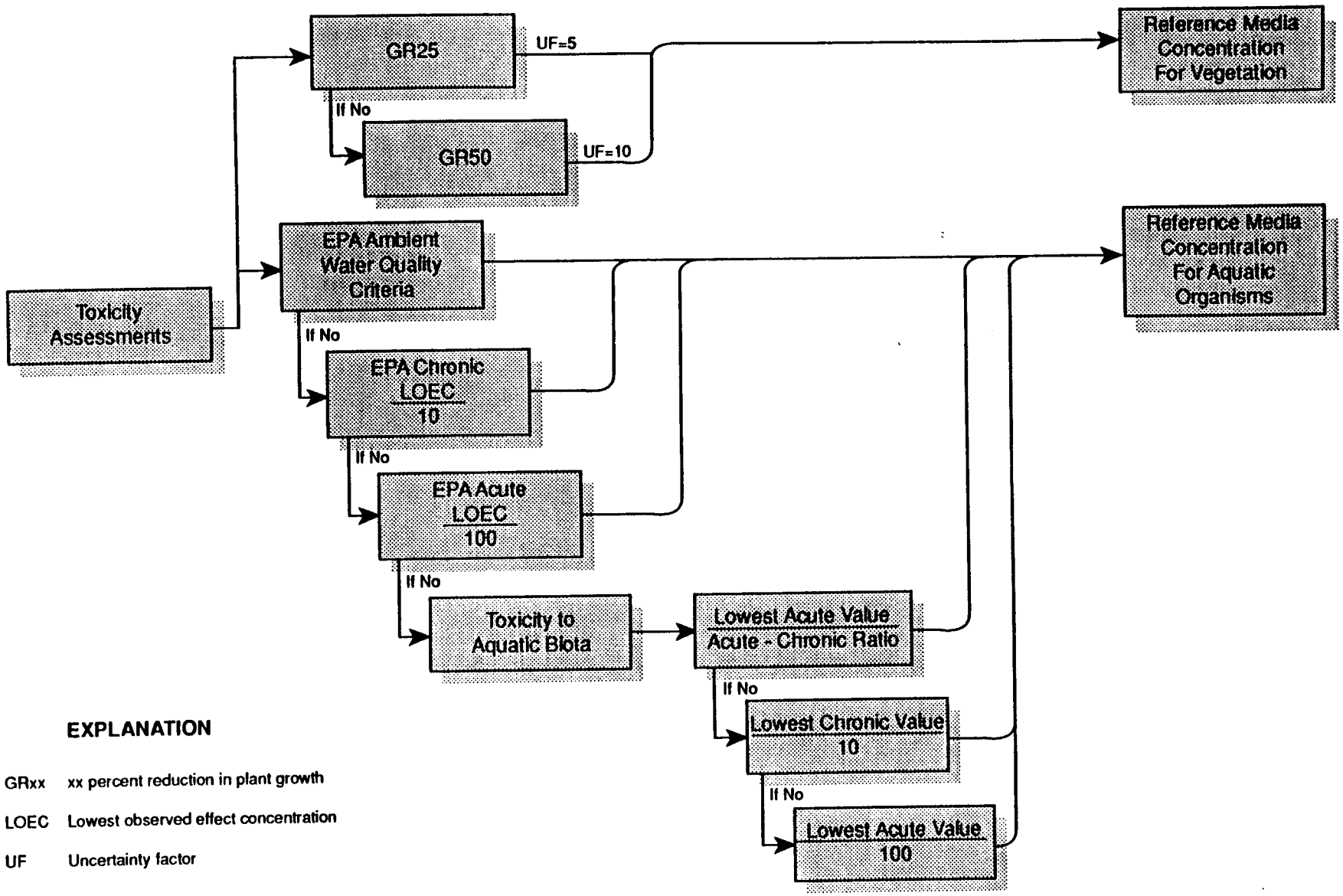


Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2.4.5.5.2-8

OFFPOST OPERABLE UNIT DISTRIBUTION OF LIFETIME INHALATION OF CHLOROFORM IN ZONE 2 (mg/kg/day)-RESIDENTIAL

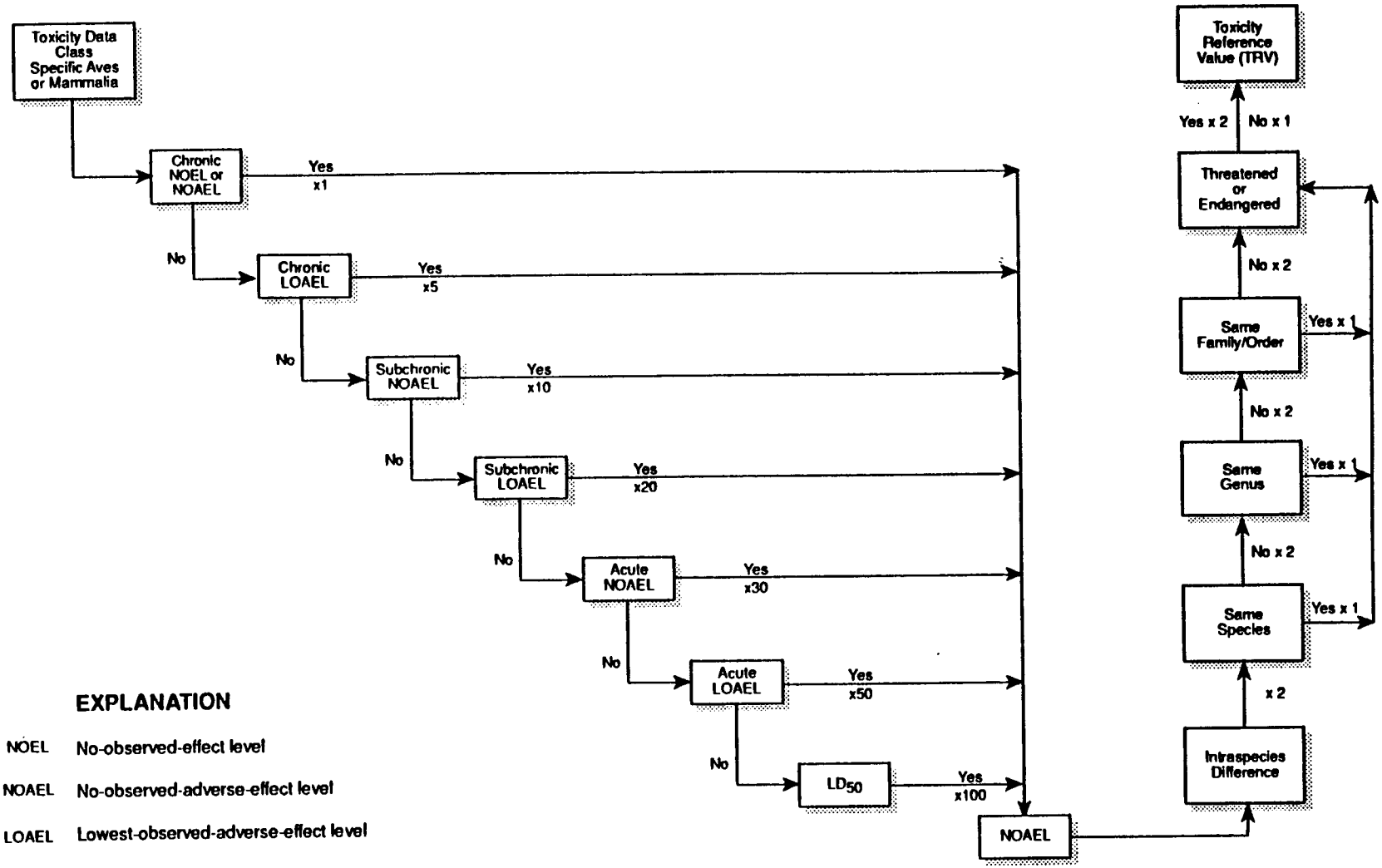


Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 3.3.1-1

METHODOLOGY FOR DETERMINING WATER AND SOIL REFERENCE MEDIA CONCENTRATIONS FOR VEGETATION AND AQUATIC ORGANISMS



Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 3.3.3-1

METHODOLOGY TO DERIVE TOXICITY REFERENCE VALUES (TRVs) FROM CLASS-SPECIFIC TOXICITY DATA

TECHNICAL SUPPORT FOR ROCKY MOUNTAIN ARSENAL

Offpost Operable Unit
Endangerment Assessment/Feasibility Study

Final Report

Volume III of VIII
(EA Sections 4.0, 5.0, 6.0, 7.0)

November 24, 1992
Contract Number DAAA15-88-0021
Task RIFS1 (Delivery Order 0001)

PREPARED BY

Harding Lawson Associates
Environmental Science and Engineering, Inc.

PREPARED FOR

PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL

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4.0 HUMAN RISK CHARACTERIZATION

This section integrates, summarizes, and interprets information from the exposure and toxicity assessments for the (1) rural residential and (2) commercial/industrial and recreational scenarios. The procedures used are presented in RAGS (EPA, 1989a) and include the following:

1. Determine Hazard Indices (HI) by comparing chronic and acute/subchronic intake estimates to RfDs to evaluate the potential for noncarcinogenic effects. An HI greater than 1.0 may warrant further evaluation.
2. Multiply estimated lifetime intakes by cancer SFs to estimate the UL95 of individual lifetime cancer risk under the RME assumptions.
3. Add HIs and cancer risks of multiple contaminants that are expected to cause similar effects.
4. Interpret the results by identifying chemical pathways and media contributing substantially to the overall risks and characterizing the uncertainties associated with the assessment.

Based on information presented in the toxicity assessment, COCs were categorized with respect to the target organ/system that was affected in the critical study, or studies, used to define the RfD. Some chemicals affect more than one organ or system at similar doses and may be placed in multiple categories. HIs are summed within categories. The target organ-specific COCs are presented in Table 4.0-1. The majority of chemicals presenting noncarcinogenic effects (i.e., HI >1) affect the liver, so additivity of chemical-specific HIs is most significant to the liver. Individual lifetime cancer risks are summed for all carcinogens regardless of target organ and weight-of-evidence classification (EPA, 1989a) to estimate the additive individual lifetime cancer risk. It is appropriate, however, to distinguish between carcinogens on the basis of target organ and weight of evidence as part of the risk management process, as presented and described in Section 4.3.

Uncertainties in the risk characterization represent the combined uncertainties of the exposure and toxicity assessments. Overall, these uncertainties were resolved by conservative assumptions. The quantitative uncertainty analysis of the estimated intakes indicates that the RME intake estimate is at the 98th to 99.8th percentile of the expected range of hypothetical

intakes among the exposed population. Hypothetically, most individuals would experience much lower intakes. For the Offpost OU, the 50th percentile of the uncertainty analysis resultant distribution is 10 to 100 times lower than the RME, and the 95th percentile is a factor of 3 lower than the calculated RME. This is an important finding to consider in the evaluation of the hypothetical risks described in subsequent sections since it suggests that exposures may be at or above the 99th percentile and therefore meets the definition of an RME (EPA, 1989a).

The quantitative uncertainty analysis did not address the uncertainty associated with infrequently detected chemicals. The uncertainty is resolved conservatively by the replacement method, which assumes nondetections are equal to one-half the CRL (Haas and Scheff, 1990).

A substantial portion of the estimated carcinogenic risk is attributable to EPA category B2 (probable human) carcinogens, particularly chloroform, and dieldrin. Category B2 designates chemicals for which there is sufficient evidence that the chemicals cause cancer in laboratory animals, but insufficient data that they are carcinogenic in humans. Because much of the total carcinogenic risk is based on the extrapolation of animal data to an assessment of human health effects, it is possible that these chemicals are not carcinogenic to humans at the estimated exposure levels.

A major fraction of the estimated noncarcinogenic HIs also rests on RfDs derived from extrapolation of laboratory animal data to an assessment of human health effects. Considering uncertainties associated with such extrapolation, as well as other factors (Section 3.1), the RfDs that critically determine the higher HIs reported here (e.g., liver toxicants and DIMP) incorporate uncertainty factors ranging from 100 to 1000.

4.1 RESIDENTIAL SCENARIO

As required by the NCP and RAGS (EPA, 1990a; EPA, 1989a), this section focuses on the estimation of an RME for the residential scenario, including the potential for future exposures that are not occurring currently. The alluvial aquifer is used for domestic supply only in zones 1A, 1C, and 6. Local agencies plan to develop a community water system, and the water supplied would come from uncontaminated sources or would be treated in compliance with the Safe

Drinking Water Act (SACWSD, 1991). Consequently, it is unlikely that residents of the Offpost OU are being or would be exposed to chemicals in groundwater at the RME intake rates. Groundwater is the ultimate source of approximately 80 to 90 percent of chemical intakes estimated under the RME scenario. Nonetheless, it was assumed conservatively that use of the alluvial aquifer as the primary domestic water supply could occur; therefore, the EA evaluated the use of the alluvial aquifer.

Parts of the offpost operable unit are expected to remain rural for the foreseeable future. In these areas, specifically zones 1, 2, and 6, a rural residential scenario in which residents keep chickens and/or cattle and consume their eggs, milk, and meat, is the land use likely to result in RME exposures. In other areas (zones 3 and 4), an urban residential land use, excluding farm animals, is possible and represents the RME. Finally, zone 5 is not expected to develop residentially, and commercial/industrial scenarios represent the RME.

Chemical intakes will vary widely among a potentially exposed residential population. The degree of variability is shown by the quantitative uncertainty analysis results presented in Section 2.4.5.5 (Volume II). Hypothetically, 91 to 99.8 percent of the population would experience intakes less than the calculated RME. According to the results of the quantitative uncertainty analysis (Section 2.4.5), the calculated RMEs for the Offpost OU have been found to be in the range of the 99th percentile and to exceed the 95th percentile by approximately 3-fold.

Recognizing the conservative aspects of this assessment, consistent with relevant guidance, most of this section is devoted to characterization of the risks at RME intake levels.

4.1.1 Hypothetical Future Exposures

Hypothetical future HIs and carcinogenic risks were calculated by zone, chemical, and pathway. Consistent with guidance (EPA, 1989a), zone carcinogenic risks have been rounded to one significant figure in the text and tables. The term "hypothetical future" is intended to address the conditions that exposure is only assumed (hypothetical) for the future scenario, that additional remediation is absent, and that the risks and HIs are derived from risk assessment methodologies, including low-dose and interspecies extrapolation, that are difficult to verify for humans.

Additive risks for each chemical (all pathways) and each pathway (all chemicals) were determined for each zone, leading to grand totals by zone for each target organ (noncarcinogenic) and total individual lifetime cancer risk. Results of these calculations are presented in a series of matrices in Appendix G. With respect to cancer risk, the cancer SFs used in these calculations are established at the UL95. Based on the uncertainty analyses, hypothetical risks cited in this section are likely overstated by 3-fold compared to the 95th percentile. Results of the assessment for carcinogens are summarized in Figure 4.1.1-1, which illustrates the data presented in Table 4.1.1-1.

Hypothetical future RME cancer risks may exceed 1×10^{-4} in zones 2, 3, and 4 with maximum risks of approximately 3×10^{-4} in zone 3. The hypothetical future combined risks from exposure to aldrin, arsenic, atrazine chloroform, and dieldrin account for more than 82 percent of the additive risk in each zone.

The results of the assessment of noncarcinogenic hypothetical future HIs are summarized in Table 4.1.1-2, which lists all child chronic combined HIs that exceed 1. Child chronic HIs are shown because HIs are greater for children than adults based on intake rates. Acute/subchronic results will be described separately.

Chlordane, chloroform, dicyclopentadiene, dieldrin, DIMP, and manganese are the only chemicals that contribute significantly to hypothetical future HIs greater than 1.

Reviewing these results, it is apparent that only a few COCs contribute substantially to hypothetical future cancer risks and HIs. The majority of the discussion will emphasize the COCs, arsenic, chloroform, DIMP, and dieldrin.

4.1.1.1 Hypothetical Carcinogenic Risks Related to Background

As indicated in Section 2.4.2.5, dieldrin concentrations in surficial soil outside zones 3 and 4 do not appear to be attributable to RMA but instead to agricultural practices. However, the risk associated with the dieldrin soil data was quantified. The hypothetical risk associated with dieldrin in soil in zones 1A, 1B, 1C, 2, 5, and 6 may be as great as 4×10^{-5}. This risk may not be attributable to RMA sources.

Naturally occurring arsenic also contributes to carcinogenic risk in several zones. The UL95 concentration of arsenic in the Offpost OU comparison data set was 1.86 μg/l; an additional comparison group located in the onpost southeastern tier had an UL95 arsenic concentration of 3.13 μg/l. The additive carcinogenic risk associated with these concentrations ranges from 4.4×10^{-5} to 7.4×10^{-5} for the offpost and onpost comparison data sets.

Combining the hypothetical risks from dieldrin in soil outside of zones 3 and 4 (4×10^{-5}) and from arsenic in groundwater (4.4×10^{-5}) yields a risk of 8×10^{-5} from sources that are either non-RMA related or naturally occurring background risks.

4.1.1.2 Child Chronic Hypothetical Future Hazard Indices

The hypothetical future HI for liver toxicants exceeds 1 in zones 2, 3, and 4, with a maximum HI of 2 in zone 3. Therefore, particularly in zones 2, 3, and 4, there is a hypothetical hazard of liver toxicity from future chronic exposure at RME intake levels. The hypothetical hazard of liver toxicity is predominantly attributable to exposure to chloroform, chlordane, dicyclopentadine, and dieldrin. The OCPs and the chlorinated aliphatics are included in the list of liver toxicants. Figure 4.1.1-2 shows the chemicals and pathways that pose the greatest hypothetical occurrence of liver toxicity. No single chemical or single pathway yields a hazard quotient greater than 1. Exposure by inhalation and ingestion routes to chloroform in shallow groundwater assumed to be used for domestic supply contributes significantly to the combined liver hazard index of 2 estimated for zone 2. Exposure to dieldrin in vegetables is the largest contribution to the combined liver hazard index of 2 in zone 3, and exposure to chlordane in groundwater is the largest contributor in zone 4.

Two chemicals have the potential to affect the CNS for which the hypothetical future RME HI exceeds 1 in zones 2 and 4 (Table 4.1.1-2). DIMP attains a maximum hypothetical future HI of 3.1 in zone 4 (Appendix G) and, in combination with manganese, produces an RME HI of 3.7 in zone 4. These chemicals are elevated in groundwater, and all exposure is oral. Uptake by vegetable crops when groundwater is used for irrigation contributes to exposure and HIs for these chemicals.

4.1.1.3 Adult Chronic Hypothetical Future Hazard Indices

As presented in Section 2.4.3, adult chronic intakes are consistently less than child chronic intakes, and HIs are also lower in direct proportion. The greatest hypothetical future HI for the adult chronic scenario is 1.3 for liver toxicants in zone 3, with dieldrin the largest contributor, and is approximately one-half the value of 2 estimated for children in the same zone. Hypothetical future adult chronic HIs greater than 1 occur for liver toxicants in zones 3 and 4. DIMP is the major contributor to a hypothetical future HI of 2.4 in zone 4.

4.1.1.4 Hypothetical Future Carcinogenic Risk

The hypothetical future risk associated with each carcinogenic chemical by zone is shown in Figure 4.1.1-3. These risks may be overstated by a factor of 3, according to the results of the uncertainty analysis. These results are based on the RME assumptions and an UL95 for the cancer SF. Clearly, hypothetical future carcinogenic risks are greater in zones 2, 3, and 4 than in other zones. Chloroform, arsenic, and dieldrin present the highest incremental risks. Chloroform risks are limited primarily to zone 2, and risk attributable to dieldrin is distributed more uniformly. Figure 4.1.1-3 further supports the identification of arsenic, chloroform, and dieldrin as the carcinogenic COCs of greatest concern.

4.1.1.5 Zone-specific Risks

In this subsection, the contribution of the most important exposure pathways to carcinogenic risk by COC is described for each zone. Several exposure pathways contribute to total carcinogenic risk, depending on chemical and zone. The hypothetical future carcinogenic risk in each zone is attributable to the following pathways: ingestion of shallow groundwater (47 percent), consumption of homegrown vegetables (average contribution to total carcinogenic risk - 26 percent), ingestion of locally produced milk (9 percent), consumption of locally produced eggs (6 percent), inhalation of volatiles via domestic use of groundwater (7 percent), and consumption of locally produced meat (3 percent). Dermal exposure does not contribute significantly to carcinogenic risk, nor does incidental ingestion of soil and sediment. The oral route accounts for

more than 90 percent of total hypothetical future carcinogenic risk, with the remainder predominantly by inhalation. As indicated previously, risks presented in this section may be overstated by a factor of 3 as indicated by the uncertainty analysis.

Zone 1A, north of O'Brian Canal, is an area of relatively low groundwater and soil contamination (Figure 2.4.1-2). Atrazine and arsenic in groundwater and dieldrin in soil are the largest contributors to hypothetical future carcinogenic risk in zone 1A. Dieldrin hypothetical future risks result from several exposure pathways because aldrin and dieldrin are bioaccumulated effectively by root vegetables, milk, meat, and eggs. The method for estimating exposure concentrations in foods assumes that agricultural products can bioaccumulate chemicals from soil and surface water and that aldrin is converted to dieldrin upon uptake. Groundwater and surface water in zone 1A do not contain large concentrations of dieldrin; thus, the dieldrin residues estimated in foods are attributable predominantly to uptake from soil.

An alternative way of characterizing the sources of the estimated risk is to disaggregate risk associated with the abiotic media (groundwater, surface water, and soil) from which each of the agricultural products may accumulate chemicals (Section 2.4.2). In zone 1A, surface water is uncontaminated, groundwater contributes approximately 60 percent of total potential risk, and soil contributes approximately 40 percent.

Zone 1B, south of O'Brian Canal, between the northwest boundary plume and the First Creek paleochannel (Figure 2.4.1-2), is an area of relatively low groundwater and soil contamination. No permanent surface-water features are in zone 1B, and agricultural water supply is assumed to be exclusively by alluvial groundwater. Otherwise, exposure conditions are identical in zones 1A and 1B. Results in these two zones differ (Figures 4.1.1-4 and 4.1.1-5) because agricultural water supplies were assumed to have higher concentrations of COCs because they are not diluted by uncontaminated surface water. As a result, future hypothetical risks are slightly higher in zone 1B.

Zone 1C is identical to 1A except that irrigation water is drawn from O'Brian Canal and the Burlington Ditch upstream of the outfall of First Creek and is not affected by RMA

(Figure 2.4.1-2). In fact, no carcinogenic COCs were detected at elevated concentrations in the canals downstream of First Creek, resulting in identical results for carcinogenic risks in zones 1A and 1C (compare Figures 4.1.1-4 and 4.1.1-6).

As described in Section 4.1.1.1, background concentrations of arsenic in groundwater and dieldrin in surficial soil may contribute as much as 8×10^{-5} carcinogenic risk to the totals shown in Table 4.1.1-1. The contribution of background risk to Zones 1A, 1B, 1C, 2, 5, and 6 should be considered when evaluating total risks in the Offpost OU.

Zone 2 is located directly north of the RMA northern boundary (northern paleochannel, Figure 2.4.1-2) and south of O'Brian Canal. No permanent surface-water features are in zone 2, an area with relatively high concentrations of COCs in groundwater but relatively low concentrations in surficial soil. Approximately 30 percent of the hypothetical future carcinogenic risk in zone 2 is attributable to the domestic use of groundwater containing chloroform and (Figure 4.1.1-7). Consistent with EPA guidance, inhalation intakes of volatile chemicals such as chloroform were assumed to equal intakes from ingestion of groundwater. Chloroform has a much higher slope factor by the inhalation route than the ingestion route, so hypothetical future risks by the groundwater inhalation pathway were estimated to be much greater than the groundwater ingestion pathway. More than 80 percent of the hypothetical future carcinogenic risk estimated for zone 2 is ultimately attributable to the use of groundwater. The inhalation route of exposure contributes approximately 30 percent of total hypothetical future carcinogenic risk in zone 2 (the highest relative contribution of the inhalation route for any zone, related to the dominance of volatile COCs in zone 2 groundwater).

Zone 3 is the area within approximately 0.5 mile of the intersection of Peoria Street and 96th Avenue (Figure 2.4.1-2). First Creek traverses zone 3, which is an area with relatively high concentrations of COCs in surficial soil, groundwater, and surface water. No human receptors currently reside in zone 3. Figure 4.1.1-8 presents RME estimates of hypothetical future risk under the hypothetical urban residential land use scenario for zone 3. Hypothetical future carcinogenic risk would be dominated by exposure to dieldrin by vegetable and groundwater

ingestion pathways. The oral route would account for approximately 97 percent of the total risk. Total hypothetical future carcinogenic risk for zone 3 under the hypothetical urban residential scenario would be attributable primarily to chemical concentrations in shallow groundwater (60 percent), with significant contributions from surface water (150 percent) and soil (30 percent).

Arsenic and dieldrin are the predominant contributors to hypothetical future carcinogenic risk in zone 4 (Figure 4.1.1-9). Zone 4 (First Creek paleochannel) is northwest of zone 3 and traversed by First Creek (Figure 2.4.1-2) and is an area of relatively high surface-water and groundwater contamination and relatively low surficial soil contamination. No human receptors reside in zone 4 at this time. COCs in groundwater ultimately are the source of approximately 80 percent of the total hypothetical future carcinogenic risk. Surface water contributes approximately 10 percent of total risk, and 10 percent of the hypothetical future carcinogenic risk is ultimately attributable to OCPs in surficial soil.

As shown in Figure 4.1.1-10, dieldrin and arsenic have the greatest contribution to total hypothetical future carcinogenic risk in zone 5, an area downgradient of the NWBCS and south of the canals (Figure 2.4.1-2). No surface-water features are in zone 5, soil concentrations are relatively low, and groundwater concentrations are moderate. Groundwater ingestion is the most important pathway, accounting for 89 percent of hypothetical risk. In zone 5, 99 percent of the hypothetical future RME risk is attributable to groundwater and less than 1 percent to soil concentrations.

Zone 6 is the extension of the northwest boundary plume north of the canals (Figure 2.4.1-2). Hypothetical future carcinogenic risks are predominantly attributable to dieldrin (Figure 4.1.1-11). Soil and groundwater each contribute approximately 50 percent of the hypothetical future risk.

A summary of the contributions to hypothetical future carcinogenic risk by chemical, exposure pathway, exposure route, and source media follows:

1. The contribution of dieldrin to total carcinogenic risk is greater than that of any other chemical in zones 1, 3, and 6. Chloroform poses the greatest risk in zone 2 and arsenic in zone 4.

2. Groundwater ingestion is the exposure pathway with the greatest contribution to total risk in all zones except zone 3. Ingestion of homegrown vegetables is the largest pathway in zone 3. Domestic use of groundwater (ingestion and inhalation) accounts for approximately 50 percent of hypothetical future carcinogenic risk outside zone 2 and 67 percent in zone 2.

3. Consumption of vegetables produced in the Offpost OU is also an important pathway contributing approximately 25 percent of the hypothetical future risk.

4. The oral exposure route contributes more than 90 percent of the total risk in each zone except zone 2, where inhalation contributes approximately 30 percent of total risk.

5. Background concentrations of dieldrin in soil attributable to agricultural practices appear to contribute 20 to 50 percent of the total hypothetical future carcinogenic risk in zones 1A, 1B, 1C, 2, and 6. Groundwater is the dominant source medium contributing to total hypothetical future carcinogenic risk. Naturally occurring arsenic in groundwater contributes a risk of approximately 4×10^{-5}. Surface water contributes less than 15 percent of total risk in zones 3 and 4.

4.1.1.6 Acute/Subchronic Effects

Hypothetical future acute effects were evaluated by comparison of acute intake estimates with Minimal Risk Levels (MRLs) developed by the ATSDR and summarized by EPA (1991b). Reference doses were also estimated from EPA's short-term health advisories (HAs) (shorter than 14 days). Acute intakes were estimated for two potentially sensitive subpopulations: women of childbearing age and children. MRLs were not exceeded for any chemical in any zone. Dieldrin is the only chemical estimated hypothetically to exceed HAs. EPA's one-day HA for dieldrin is exceeded hypothetically in zones 2, 3, and 4. An acute HI has been estimated by dividing acute intakes by acute reference doses. Results from children are illustrated in Figure 4.1.1-12 indicating that dieldrin is the predominant contributor to acute HIs and that the HI exceeds 1 in zones 2, 3, and 4, with a maximum acute HI of 4 in zone 3. Table 4.1.1-3 presents these results numerically. Adult female acute HIs are consistently about 60 percent less than children and less than 1 in all zones except 3. These results indicate that the potential for adverse health effects exists as the result of hypothetical future short-term exposure to dieldrin at the RME acute intake level in zones 2, 3, and 4.

Available data sources used to define exposure factors (Section 2.4.3.2) do not readily support the estimation of exposure factors averaged over subchronic exposure durations. Acute

and chronic intakes have been estimated. RME intakes over subchronic exposure durations are expected to be less than RME acute intakes and greater than or approximately equal to RME chronic intakes. Exposure assumptions adopted in the residential scenario assume continuous residency over periods encompassing a chronic exposure, and the most important exposure pathways are not expected to result in extreme seasonal variability in exposure. Vegetable consumption may vary seasonally with the availability of homegrown produce. Thus, although the RME subchronic intake is clearly less than the RME acute intake and greater than the RME chronic intake, it is probably in the low end of that range (i.e., slightly greater than the RME chronic intake).

The method used to estimate subchronic HIs is as follows: for the lower range, the RME chronic intake was divided by the subchronic reference dose; for the upper range, the RME acute intake was divided by the subchronic reference dose. Tables 4.1.1-4 and 4.1.1-5 summarize the zone/chemical combinations that have the potential for adverse effects as a result of exposures over subchronic duration for children and adult females, respectively (all chemicals whose RME acute intake exceeds the subchronic reference dose). Figure 4.1.1-13 illustrates the range of hepatic HIs for children by zone.

Dieldrin and manganese are the only chemicals with the potential for noncarcinogenic effects as a result of exposure of subchronic duration. When the upper end of the range reported exceeds 1, the potential for adverse effects exists; also, if the lower end of the range is greater than 1, the RME chronic intake exceeds the subchronic reference dose.

Subchronic reference doses have not been published by EPA for all offpost COCs. For those COCs, RME acute intakes were compared to chronic reference doses and subchronic MRLs (developed by ATSDR and summarized by EPA, 1991b). This final comparison revealed that no chemicals without subchronic reference doses have significant hypothetical future potential for adverse effects as the result of exposures over subchronic durations (i.e., RME acute intakes exceeded neither chronic reference doses nor subchronic MRLs for chemicals without subchronic reference doses).

4.1.2 Hypothetic Current Risks Versus Hypothetical Future Risks

As used in this subsection, the term "hypothetical" refers to the application of risk assessment methodologies that extrapolate from high doses to low doses and from laboratory animals to humans.

No residents are in zones 3 or 4 at this time; hence, exposure pathways are not complete, and there are no hypothetical current health risks in these zones for the residential scenario. Residents in zones 1B and 2 do not use the alluvial aquifer for domestic use; hence, these pathways are not complete. Based on the consumptive use surveys, alluvial groundwater may still be used as an agricultural water supply in zones 1B and 2, and RME intake levels associated with agriculture would result in hypothetical risks of less than 8×10^{-5}. These risks were determined by subtracting the hypothetical risks associated with the groundwater oral and inhalation exposure pathways (Volume IV, Appendix G). Background risks due to zone 1, 2, and 6 contaminants in soil alone, regardless of the source or use of water, are approximately 4×10^{-5} for residents who consume agricultural products produced in the Offpost OU at RME intake levels. All cited risks may be overstated by a factor of 3 as indicated by the uncertainty analysis.

By a similar process of eliminating currently incomplete pathways, the maximum hazard index under existing exposures is less than 1 in all zones.

4.1.3 Health Risk at Most Likely Exposure Intakes

The principal focus of the human risk characterization was to estimate health risks at RME intake levels. An uncertainty analysis was performed to characterize the distribution of chemical intakes among the potentially exposed population, the uncertainty associated with intake estimates, and the degree of conservatism incorporated in the RME risk estimate. To provide additional perspective on this topic, the MLE intakes as well as chronic HIs and cancer risks at the MLE intakes have been estimated. In calculating MLE risks, the same conservative RFDs and SFs used in the RME risk calculations were used, so the appropriate interpretation of the MLE risk estimates would be that they are conservative estimates of risk for individuals experiencing MLE intakes.

MLE intakes were estimated for all COCs and completed pathways for the hypothetical future exposure scenario. The chronic MLE intakes were estimated using the same equations used for the RME intakes. The input parameters selected for this analysis, however, were mean or median values. Mean values were used for exposure concentrations and parameters used to estimate exposure concentrations in food. Median values were used for exposure factors such as ingestion rates and exposure frequency and duration. As a result, the MLE intakes represent the best estimate of the median intake for the potentially exposed population. Because the toxicity factors were the same in both the MLE and RME analyses, the ratio of RME intakes to MLE intakes is the same as the ratio of RME risks to MLE risks. Table 4.1.1-6 summarizes the additive hypothetical carcinogenic risks at the MLE intake levels and compares these estimates to the RME risks. At MLE intake levels, hypothetical carcinogenic risks would not exceed 3×10^{-5} (zone 4). Risks at RME intake levels typically exceed MLE risks by a factor of 10. It is estimated that approximately half of a potentially exposed rural residential population would experience intakes less than the MLE and half would experience higher intakes. Less than 2 percent of the population would experience intakes as high as the RME (see Section 2.4.5).

With respect to potential noncarcinogenic effects, child-chronic HIs for hepatic effects at MLE intakes do not exceed 1 in any zone. Hepatic HIs at MLE intake levels are approximately one-third of the RME HIs. At MLE intake levels, the CNS HI was estimated to be 4 in zone 4. This result is affected by the unique features of the distribution of observed concentrations of DIMP in groundwater (see Section 2.4.5.5.2). Selection of the sample mean as the best estimate of the population mean, instead of the lognormal estimator (Gilbert, 1987) would have resulted in an MLE central nervous system HI <1 for zone 4.

An important implication of the MLE analysis, which is also supported by the uncertainty analysis, is that risks presented at RME intake levels are not representative of the risks faced by the majority of the hypothetically exposed population. Although a few individuals might be exposed at RME levels, the MLE intakes are more representative of the typical exposure levels. The RME exposure rates and corresponding risks overstate the carcinogenic risk to the typical

resident by factors ranging from 8 to 12 times. Similarly, the typical child's noncarcinogenic hepatic HI would be three times less than RME HIs reported (MLE hepatic HI ≤1).

4.1.4 Alternative Risk Estimate Based on Predicted Decline in Groundwater Concentrations

As presented in Section 2.4.2.2, groundwater concentrations are declining in zones 3 and 4, and may be expected to decline further over chronic 9- and 30-year average concentrations for aldrin and dieldrin. All other organic contaminants may be expected to decline at least as fast as these relatively immobile groundwater COCs. Over the 9-year exposure duration used for the noncarcinogenic assessment, concentrations were predicted to decline to 42 to 48 percent less than the RME concentrations based on 1989 to 1991 monitoring data. Over the 30-year exposure duration, average concentrations were predicted to decline by 48 to 74 percent.

The effect of using these predicted aldrin and dieldrin concentrations while holding other COC concentrations constant is not substantial. Cancer risk in zone 3 would be reduced from 3×10^{-4} to 2×10^{-4}, and the child chronic hepatic hazard index would remain at 2. In zone 4 the carcinogenic risk is unaffected when rounded off to one significant figure at 2×10^{-4}, and the child chronic hepatic hazard index would decline from 1.4 to 1.2. If, on the other hand, one assumes that all organic groundwater COCs would be reduced by similar percentages, the effect would be more significant. Carcinogenic risk would decline from 3×10^{-4} to 2×10^{-4} in zone 3 and from 2×10^{-4} to 1×10^{-4} in zone 4. The child chronic hepatic hazard index would decline from 2 to 1.4 in zone 3, and from 1.4 to 0.7 in zone 4. As noted in Section 2.4.2.2, these are conservative assumptions used in the aldrin/dieldrin decline prediction. Actual declines may be greater.

4.2 COMMERCIAL/INDUSTRIAL SCENARIO

The C/I scenario differs from the rural residential scenario in that no agricultural pathways are present (e.g., dairy, meat, vegetables). For this scenario, exposure pathways relating to groundwater and soil were evaluated. RME-estimated intake scenarios for carcinogenic risks and

noncarcinogenic HIs were quantified for zone 5 because of the likelihood of future land uses in this zone (Section 2.2.2.2).

The exposure pathways that were evaluated for the adult C/I worker included ingestion of groundwater and inhalation of volatiles from groundwater (including showering) and dermal exposure to and ingestion of soil. The sediment and surface-water exposure pathways were not evaluated because the ingestion and dermal exposure routes were not expected to occur in zone 5.

4.2.1 Adult Chronic Hypothetical Future Hazard Indices

The additive hypothetical future HI for liver toxicants was <0.1 in zone 5 (Figure 4.2.1-1). The OCPs account for the highest HIs through the soil and groundwater pathways via the ingestion route of exposure. Because the chronic liver HIs were less than 1, acute HIs are not presented.

4.2.2 Hypothetical Future Carcinogenic Risks

The hypothetical future carcinogenic risks for the C/I scenario range from 1.8×10^{-9} to 1.6×10^{-5} in zone 5. Arsenic is the major contributor to the hypothetical future carcinogenic risks in zone 5. Arsenic accounts for approximately 60 percent of the estimated risk in zone 5. Exposure to arsenic by the ingestion of groundwater is the single largest pathway component to the overall hypothetical future risk.

4.2.3 Carcinogenic Risk at Most Likely Exposure Intakes

For the C/I scenario, MLE HIs are approximately 67 percent less than the RME HIs. The MLE liver HI is 0.07 for zone 5. The MLE hypothetical future carcinogenic risks are approximately 30 percent less than the RME risks, with risks of 7×10^{-6} zone 5.

4.3 RISK CHARACTERIZATION SUMMARY

Additive carcinogenic risks for potential future residential exposures at RME intake levels by zone are summarized in Table 4.1.1-1, which shows that cancer risk is highest in zones 2, 3, and 4. These zones are south of O'Brian Canal and within approximately 1 mile of the north

RMA boundary. Hypothetical future cancer risks in each of these zones are estimated to be less than 3×10^{-4}. These risks may be overstated by a factor of 3 as indicated by the uncertainty analysis. More than 60 percent of the risk in each of these zones is attributable to category B2 and C carcinogens. Thus, the carcinogenic risk estimate is critically dependent on the extrapolation of toxicological data from animal to human. Discussions on the potential carcinogenicity of each COC are in the toxicological profiles, including Shell Oil Company's toxicological profile for aldrin and dieldrin, located in Appendix F of the EA. Dieldrin is the dominant contributor to total cancer risk in zones 3 and 6 and is significant in all other zones with an average contribution of approximately 50 percent. Chloroform contributes 30 percent in zone 2 and arsenic 30 percent in zone 4.

Several exposure pathways contribute to total hypothetical carcinogenic risk, depending on chemical and zone. More than 95 percent of the carcinogenic risk in each zone, however, is attributable to the following pathways, listed in order of their contribution to risk (highest to lowest):

1. Ingestion of shallow groundwater
2. Consumption of homegrown vegetables
3. Ingestion of locally produced milk
4. Inhalation of volatiles via domestic use of shallow groundwater
5. Ingestion of locally produced eggs
6. Ingestion of locally produced meat

Dermal exposures do not contribute significantly to carcinogenic risk, nor does incidental ingestion of soil and sediment. The oral exposure route accounts for more than 90 percent of total carcinogenic risk, with the remainder predominantly by inhalation.

Shallow groundwater is the dominant source medium contributing to total hypothetical carcinogenic risk in all zones accounting for 45 to 80 percent of total risk, depending on the zone. Soil contributes 20 to 60 percent of the risk in zones 1A, 1B, 1C and 6. Groundwater, surface water, and soil contribute to estimated risks via multiple pathways, specifically those involving

local food production. Groundwater and surface water were assumed to be used for irrigating vegetable crops and watering livestock. Each of the food pathways may also accumulate COCs from soil, and these relationships are quantified via the equilibrium partition models presented in Section 2.4.2.

Hypothetical risks from all carcinogens were added to determine total carcinogenic risk, regardless of target organ/system or weight-of-evidence category. The dominant contribution to total carcinogenic risk in all zones is from category B2 and C carcinogens, as previously described.

Hypothetical future noncarcinogenic effects were evaluated for all COCs. Children are a potentially sensitive subpopulation with the largest potential for adverse noncarcinogenic effects due to higher chemical intakes (mg/kg/day). Considering the target organ/system potentially affected by each of the COCs, the most probable noncarcinogenic effect would be on the CNS as a result of hypothetical future exposure to DIMP in zone 4, where the HI is 4. The hypothetical additive child chronic HI for liver toxicants has a maximum of 2 in zone 3.

The probability of adverse effects to women and fetuses is less than the risk to children because the adult female intake is less than the child intake based on intake rates and body weight. None of the chemicals with HIs approximately equal to or greater than 1 (indicating potential for adverse noncarcinogenic effects) demonstrate developmental toxicity effects at doses lower than those that adversely affect the mother. Consequently, the chronic and subchronic RfDs are protective for developmental effects.

RMEs of existing exposures and resultant health risks are substantially less than hypothetical future exposures. No human receptors reside in zones 3 and 4 at this time; hence, there is no current risk in these zones. Residences with RME concentrations in shallow groundwater wells in zones 1B, 2, 3, and 4 (before relocation) use water supplies other than shallow groundwater. Consequently, groundwater pathways are not complete in these zones. Residential risks due to existing exposure to soil, regardless of water use, range from as little as 1×10^{-5} (zone 4), to as much as 8×10^{-5} (in zone 3) for residents who might consume foodstuffs produced in the

Offpost OU at RME intake levels. However, the 4×10^{-5} risk associated with soil in zones other than zone 3 and 4 may not be attributable to RMA sources but to agricultural practices.

MLE HIs and carcinogenic risks were estimated for the residential scenario. The carcinogenic risks were from 8 to 12 times less than corresponding RME risks, depending on the zone.

Hypothetical future carcinogenic risks and noncarcinogenic HIs were estimated for RME intake levels for the C/I scenario. Dieldrin, aldrin, and arsenic account for the largest portion of risk, approximately 80 percent, through the groundwater ingestion exposure pathway. The chronic HIs for liver toxicants were all <0.1 for zone 5; the OCPs (chlordane, dieldrin, and aldrin) are the major HI chemical contributors through the groundwater ingestion pathway.

MLE HIs and carcinogenic risks for the C/I scenario are approximately 67 and 33 percent of the RME risks, respectively.

4.4 UNCERTAINTIES IN THE HUMAN HEALTH ASSESSMENT

Uncertainties in the risk characterization represent the combined uncertainties of the exposure and toxicity assessments. Overall, these uncertainties were resolved by conservative assumptions. Consideration of the risk characterization results permits identification of the most important contributors to overall uncertainty.

1. Identification of COCs

   Potential uncertainties in identification of COCs have a minor or insignificant effect on RME risk estimates. COCs contributing significantly to risk are clearly attributable to migration from RMA, and it is extremely unlikely that excluded chemicals could contribute significantly to the total RME risk.

2. Chemical Fate

   The quantitative uncertainty analysis documents that identified uncertainties in equilibrium partition coefficients used to estimate exposure concentration in foods do not contribute significantly to uncertainty in RME risk estimates. Bioaccumulation of pesticides in agricultural products was estimated from experiments using freshly applied chemicals. Site conditions differ; pesticides have aged in soil for many years. This source of uncertainty cannot be evaluated because of lack of pertinent research information. Numerous COCs have been shown to biodegrade over time in soil, surface water, sediment, and groundwater. Biodegradation processes were not quantified due to lack of pertinent site-specific information. This limitation of the assessment may cause chronic and lifetime risks to be overestimated.

3. Exposure pathways

   Exposure pathways contributing most of the residential RME risk in zones 2, 3, and 4 are not complete at this time. In zone 2, alluvial groundwater is not used for domestic supply, but this pathway contributes 74 percent of RME total carcinogenic risk and 56 percent of the child chronic hepatic HI. Pathways excluded from the quantification, through potentially complete, have the potential to add less than 15 percent to total carcinogenic risk.

4. Intake Estimation

   Chemical concentrations are expected to decline over time. Intake estimates are based on monitoring data from 1989 to 1991 and may overestimate current and future exposure concentrations. Exposure and risks may be greater than zonewide average risk estimates in localized (e.g., one to five acres) hot spots (up to twice as high in identified hot spots in zones 2 and 3). On the other hand, the risk throughout most of each zone is probably lower than the zonewide RME.

   RME exposure concentrations calculated from monitoring data may differ from actual exposure concentrations due solely to the selection of the statistical calculation procedure. The effect of these differences on carcinogenic risk estimates in any zone is estimated to be less than 40 percent. However, the CNS hazard index in zone 4 may be overstated by a factor of 5 for this reason.

   The results of the quantitative uncertainty analysis indicate that RME intakes achieve the goal of the RME in estimating an exposure in the upper range of those possible. In fact, RME estimates could significantly exceed the 95th percentile exposure, the lower boundary suggested by EPA for an upper range exposure estimate. The RME intakes consistently fall at or above the 98th percentile of the distribution of intakes and typically exceed the 95th percentile by a factor of 3. Most people in the Offpost OU will experience intakes substantially less than the RME.

5. Toxicity Assessment

   Reference doses typically are set 100 to 1000 times lower than the lowest doses found to produce an adverse effect in animal studies. These uncertainty factors are reflective of the uncertainties in risk caused by uncertainties in the toxicity assessment. These uncertainties are resolved conservatively by the EPA-recommended procedures adopted in the assessment.

   An overwhelming portion (59 to 100 percent, depending on zone) of total carcinogenic risk estimated for humans is attributable to category B2 and C carcinogens. There is insufficient evidence that these chemicals cause cancer in humans. Thus, it is possible that these chemicals are not carcinogenic to humans.

In summary, the RME risk estimates presented here are sufficiently conservative for use in risk management decisions for the offpost operable unit.

5.0 ECOLOGICAL ASSESSMENT

The objective of the Offpost OU ecological risk assessment was to evaluate potential adverse effects to the environment and nonhuman receptors as a result of potential exposure to chemicals migrating from onpost sources. This section of the EA reviews the site characterization with emphasis on ecological receptors. An ecological exposure assessment is provided that describes two ecological assessment endpoints: (1) residue concentration in tissue that could adversely affect function or health and (2) contaminant concentrations in abiotic media at levels that could have an impact on ecological receptors through direct toxicity. Procedures for evaluating each are described. The final section characterizes the risk to ecosystems, with particular reference to zones 3 and 4 in the Offpost OU.

Although the EPA has recently published several documents on ecological risk assessment (EPA, 1992a, 1992b, 1992c), guidance similar to that for human health risk assessments (EPA, 1989a) is not available. Therefore, the procedures the Army used to evaluate the potential effects of offpost chemicals of concern in ecological receptors for this ecological assessment have been developed from several sources, including the open literature, EPA documents, and professional judgement. Because of the evolving nature of ecological risk assessment methodology, the assumptions and approaches adopted for the Offpost OU Ecological Assessment may not be applicable for use at sites or locations outside the Offpost OU boundaries. Also, the acceptance of the Offpost OU procedures and values as they appear in this document does not imply that the Offpost procedures and values set precedent for use at other sites and locations.

5.1 SITE CHARACTERIZATION

5.1.1 Study Area Definition

The offpost area is defined as the triangular region north of RMA that is bounded by the South Platte River on the west and Second Creek on the east, including the waters of Barr Lake (Figure 2.4.1-2). Sampling areas for biota in the offpost area are in Figure 5.1.1-1 (HLA, 1992). Two major natural ecosystems occur in the Offpost OU: terrestrial and aquatic. The area is also

extensively used for agricultural purposes. Regional topography is represented by stream-valley lowlands and gently rolling uplands. A result of the topographic relief is apparent in well-defined surface-water drainage areas, wetland features, and large expanses of temperate grasslands. The Offpost OU supports many of the same wildlife species found on RMA; however, because biotic resources differ and because of the occurrence of intense agricultural land management practices in the Offpost OU, biota samples were primarily restricted to zones 3 and 4. The major ecological habitats are presented in Figure 5.1.1-2 (HLA, 1992).

5.1.1.1 Terrestrial Systems

A detailed analysis of aerial photography of the Offpost OU was conducted to identify site usage patterns and to delineate accurate boundaries of land use from aerial photographs taken in 1950, 1969, and 1983 (Bionetics Corporation, 1984). Since 1950, the majority of the Offpost OU has been dominated by agricultural lands, primarily supporting grain crops and pasture, with some fallow or idle fields.

During 1990, a visual characterization of the Offpost OU was conducted by ESE. The primary field crops grown in the Offpost OU include Winter wheat, hay, barley, corn for grain, corn for silage, sugar beets, and oats. Other crops in this area include a variety of vegetables, sorghum, dry beans, and Spring wheat. Of the field crops listed, Winter and Spring wheat, barley, sugar beets, and dry beans are produced for human consumption, and corn, hay crops, sorghum, and oats are produced for animal feed.

In general, areas of the Offpost OU located north of O'Brian Canal are irrigated, whereas areas south of the canal rely on dryland farming. Pasture is a significant resource within the Offpost OU but accounts for much less acreage than croplands. Intense grazing was observed along the First Creek corridor and in the First Creek Impoundment vicinity (HLA, 1992). Other land uses include confined livestock feeding operations, residential, industrial, transportation, and mineral extraction.

5.1.1.2 Aquatic Systems

Because of the degree of natural surface-water drainage and water resource management (waterways, lakes, ponds, reservoirs), limited, but important, wetland resources occur in the Offpost OU. Aquatic systems include Barr Lake, O'Brian Canal, Burlington Ditch, South Platte River, First Creek, Second Creek, and several ponds and reservoirs, as shown in Figure 1.2-5. First Creek Impoundment and First Creek were studied during the Offpost RI for habitat characterization, contamination, and species occurrence because these aquatic ecosystems contain the highest concentration and/or frequency of detection of chemical residues attributed to COCs originating from RMA sources. In addition to First Creek and First Creek Impoundment, surface-water and sediment samples were also collected from O'Brian Canal, Burlington Ditch, and Barr Lake (HLA, 1992).

As intermittent streams, First Creek and Second Creek do not support economically or environmentally important fish populations. O'Brian Canal is a manmade channel principally used for irrigation that can be expected to support fish species characteristic of the South Platte River. Fathead minnows, white suckers, and green sunfish are the most frequently observed species in these water bodies (Environmental Research and Technology [ERT], 1985).

Barr Lake is the largest lentic aquatic habitat of the Offpost OU. The Colorado Division of Wildlife stocks Barr Lake with channel catfish, smallmouth and largemouth bass, Sacramento and yellow perch, rainbow trout, crappie, and bluegill. Barr Lake provides important nesting and foraging habitat for a variety of birds, including white pelicans, great blue herons, cormorants, mallard ducks, grebes, gulls, and bald eagles. In addition to hosting a large heron rookery, Barr Lake has been the site where a pair of bald eagles has nested since 1986. Recreational fishing and waterfowl hunting are permitted at Barr Lake State Park. Angler effort and fish catch statistics for Barr Lake indicate that in 1980, 5000 fish were harvested, including carp, bass, and catfish, representing 24,000 angler hours. Barr Lake has received industrial and sewage effluent and runoff from urban and agricultural land since the lake was constructed more than 80 years ago (DRCOG, 1989).

5.1.2 Ecological Characterization of the Offpost Operable Unit

Habitat mapping of the First Creek portion of the Offpost OU (HLA, 1992) identified intensive human land use, including dryland farming, cattle grazing, private dumps, and residences (Figure 5.1.1-2). Small vacant lots, fallow fields, wetlands along First Creek, and prairie dog colonies comprise the balance of habitat types in the immediate offpost study area. Undisturbed habitats were not identified in the Offpost OU. Wildlife species found in habitats in the offpost area (Table 5.1.2-1) were also common on RMA. However, wildlife species diversity in the Offpost OU is limited by the lack of variety in habitats and degree of human disturbance. There are no federally designated critical habitats in or near the Offpost OU (USFWS, 1990).

The weedy forbs (WF) and grasses and weedy forbs (GWF) habitats were described in the Biota RI (ESE, 1989b). The predominant species in the WF habitat type include summer cypress *(Kochia iranica)*, prickly lettuce (*Lactuca serriola*), thistle (*Cirsium arvensis* and *Carduus nutans*), Russian thistle (*Salsola iberica*), field bindweed (*Convolvulus arvense*), various sunflowers (*Helianthus* spp.), and tumble mustard (*Sisymbrium altissimum*). The GWF habitat type is similar to the WF habitat type but with an increased abundance of cheatgrass (*Bromus tectorum*), western wheatgrass (*Agropyron smithii*), and bluegrass (*Poa* spp.) in addition to the forb species. WF and GWF habitat types support cattle and horse grazing in the offpost area, particularly along the channelized portion of First Creek below the First Creek Impoundment.

The offpost prairie dog (PD) colony habitat resembled the onpost RMA prairie dog habitat, with slightly less vegetative cover (field bindweed and bunchgrasses). The horse and cattle range appeared overgrazed, with only a few interspersed forbs and grasses (HLA, 1992). Plowed and unplowed fallow fields (PFF and FF) were lightly vegetated with remnant crops and grasses. The unplowed corners of the fallow fields were covered with WF-type vegetation, including the common Russian thistle. Shelter belt cottonwood trees and ornamental plants surround the residences and buildings in the mapped area, as shown in Figure 5.1.1-2.

Approximately 250 acres of wetlands occur along First Creek from the northern RMA boundary (North Bog) to the First Creek Impoundment. These wetlands have been delineated by

the U.S. Fish and Wildlife Service (Feasibility Study, Appendix B). These tall grass wetlands (TG-W) contain quackgrass (*Agropyron repens*), intermediate wheatgrass (*Agropyron intermediatum*), and cheatgrass. Many forbs found in the WF and GWF habitat types were also found in or adjacent to the wetlands. Cattail (*Typha angustifolia*) marshes (CTM) and areas dominated by sedges (*Carex* spp.) and rushes (*Scirpus* spp.) are interspersed in the First Creek drainage. Below the First Creek Impoundment, the wetland vegetation was limited to the banks of the river course, which has been channelized and grazed back to a GWF habitat type. No immersed wetlands occur below the First Creek Impoundment until the creek empties into O'Brian Canal. The wetlands habitat, along with WF and GWF habitat, support most of the wildlife species observed in the offpost area.

5.1.3 Contamination Pertaining to Offpost Biota

Data from the chemical analyses of cow milk and body fat; chicken tissues and a composite egg sample, and aquatic and terrestrial wildlife species are presented in the RI Addendum (HLA, 1992). Volume II, Section 1.0 of this EA summarizes the contamination in the various media.

Biota sampling locations are shown in Figure 5.1.1-1. Although dieldrin was the contaminant most often detected among offpost biota (bovine fat, chicken tissues [fat and skin, liver, and eggs], fish, earthworms, deer mice, prairie dogs, and pheasant liver samples), the concentrations detected were low and/or infrequent (HLA, 1992). Arsenic concentrations were detected in algal mats and a composite sample of crayfish from the First Creek Impoundment, earthworms, and one of four prairie dog samples (HLA, 1992). Mercury was detected in fathead minnows and carp collected from the First Creek Impoundment and in three of five earthworm samples. The mercury levels were determined to be within the expected range for background, as determined by data from McKay Lake in western Adams County and reported in the Biota RI (ESE, 1989b). DDE was detected in the fat and skin portion of a chicken collected from a farm north of RMA (site HA 1042BP). Aldrin and DDT were not detected in any biological sample collected in the Offpost OU.

The impact of groundwater on offpost ecological receptors was limited to areas where livestock and crops may be exposed to contaminated groundwater via agricultural wells. Exposure to these receptors may occur if contaminated wells are still in use; therefore, chemical concentrations in groundwater were evaluated for potential toxicity to agricultural receptors.

5.1.4 Selection of Chemicals of Concern for Biota

COCs for the ecological assessment were selected in a manner consistent with the approach used in the human health risk assessment (Section 1.0). COCs were considered to be those chemicals in abiotic media with concentrations significantly elevated with respect to background. In addition, for the ecological assessment, the selection of COCs was refined further by considering appropriate exposure media by food web (e.g., terrestrial or aquatic). For example, target analytes elevated in groundwater would be considered as groundwater COCs, but only livestock with access to agricultural wells would be exposed.

All biota could be exposed to COCs directly from abiotic media, and biota at higher trophic levels could receive additional exposure via bioaccumulation in food chains. Potential COCs for terrestrial and aquatic wildlife receptors were limited to site-related chemicals found in surface soil, surface water, and sediment. Groundwater COCs were used in the evaluation of agricultural receptors only. Tissue analytical data for ecological receptors were also evaluated with respect to the COCs in abiotic media. COCs in tissue (TCOCs) were selected by evaluating the biota data for the seven target analytes (aldrin, dieldrin, endrin, DDT, DDE, arsenic, and mercury) in tissue from the Offpost RI Addendum (HLA, 1992). Six of these seven analytes in tissue (aldrin, dieldrin, endrin, DDT, DDE, and arsenic) were also COCs in abiotic media and are thus considered TCOCs. Mercury was not elevated in offpost abiotic media (Volume II, Section 1.0). In addition, arsenic concentrations in earthworms from the Offpost OU were similar to the RMA onpost control samples (ESE, 1989b). Because arsenic in soil is considered to be within the range of background, arsenic was not evaluated further as a COC in a terrestrial ecosystems in the Offpost OU.

TCOCs were evaluated using a food web approach (dietary ingestion); other COCs were evaluated for direct toxicity (surface water, soil, and prey ingestion). The list of COCs to be evaluated for the ecological assessment is presented in Table 5.1.4-1.

5.2 EXPOSURE ASSESSMENT

This section describes the potential biological receptors and exposure pathways in the offpost area. It also describes how exposure point concentrations were used in the exposure assessment. Ecological assessment endpoints, residue concentrations, and associated procedures used to quantify exposure for the endpoints are also described.

5.2.1 Potential Biological Receptors and Sensitive Subpopulations

EPA guidance indicates that biological receptors (ecosystem components expected to reflect adverse effects of pollutant stress) be selected to represent any potential adverse effects to all ecosystem components (EPA, 1989f). Several site-related criteria were considered in screening for potential biological receptors. Initial screening was performed to identify receptors as potentially present and important in the Offpost OU. The numbers representing the following criteria correspond to numbers on the matrix presented in Table 5.2.1-1.

1. Species observed or collected offpost during RI activities, which confirms their presence offpost
2. Species presence at RMA, which implies their presence offpost
3. Species observed offpost or potentially within the study area, as noted by other studies or agencies
4. Species presence confirmed and an important component of offpost food chains (this may result in a source of exposure to higher trophic levels if species is an important forage component; ecosystem stability may alter if population is adversely affected)

EPA guidance states that special consideration be given to rare, threatened, and endangered species; birds listed in the Migratory Bird Treaty Act; and to species of commercial or sport value (EPA, 1989f). Representative receptor species and sensitive subpopulations for the Offpost OU were selected from the list of potential biological receptors using suggested EPA criteria and additional information:

5. Rare, threatened, or endangered species known to occur onpost and inferred also to occur offpost, and birds protected under the Migratory Bird Treaty Act
6. Potentially affected commercial or sport species
7. Species of high public interest
8. Behavior, life history, or physiological aspects of organism that may increase exposure or uptake or decrease threshold for toxic effects
9. Availability of ecotoxicity data for receptor species or related taxa

The representative biological receptors include major trophic levels (e.g., primary producer, predators) of the offpost ecosystem. In most cases, one or two organisms were used to represent adverse effects to other related taxa; for example, the bald eagle and great horned owl represent other large raptors.

Focusing the ecological risk assessment on the selected receptors served two purposes. First, the receptors were arranged into food webs to model bioaccumulation of contaminants. Food web modeling was used to predict contaminant exposure to trophic levels for which samples were unavailable from the RI (HLA, 1992). Second, selecting the most important and sensitive organisms helped ensure that if these species are protected in the risk assessment, other less sensitive or important organisms will be also protected.

5.2.1.1 Terrestrial Receptors

Wildlife species that can be considered potential receptors (Table 5.2.1-1) include several species that also occur on RMA as described in the Biota RI (ESE, 1989b), or which are listed as being observed offpost in Table 5.1.2-1 (HLA, 1992). Receptors of concern include rodents, especially mice (*Peromyscus* spp.) and prairie dogs (*Cynomys ludovicianus*), which fit site-related criteria 1, 2, and 4. Additional small mammals that are inferred to occur in the Offpost OU, but were not collected during the RI, include shrews, voles, and ground squirrels. Mice and prairie dogs are both burrowing animals, and thus potentially contact contaminated soil during burrowing activities, as well as during feeding and grooming. Mice have varied feeding habits that could

increase the overall contaminant exposure rate as compared to prairie dogs, which are primarily vegetarian.

Lagomorphs (rabbits) and deer also occur in the Offpost OU but were not collected for the Offpost RI. Neither species observed onpost contained elevated tissue residues on a regular basis (ESE, 1989b); therefore, they were determined to be less highly exposed than some other species.

Skunks, raccoons, bobcats, fox, and coyotes are other mammals that were inferred to occur or were observed in the offpost area (Table 5.1.2-1). However, because of inherent sampling problems, these animals were not collected for sample analyses during the Offpost RI.

Species selected as representative biological receptors are highlighted in bold type on Tables 5.2.1-1 and 5.2.1-2. It was assumed that the selection criteria ensured that these species would be representative of all ecological disturbance.

Avian species that are inferred to occur or were observed in the Offpost OU include a variety of upland species. Pheasants (*Phasianus colchicus*) fit site-specific criteria 1, 2, and 4. Bald eagles, golden eagles, hawks, falcons, and owls are inferred to occur or have been observed in the Offpost OU (Table 5.1.2-1). Bald eagles have nested at nearby Barr Lake since 1986. In addition, bald eagles fit the criterion for sensitive subpopulations because they are endangered and are potentially more highly exposed because of their feeding behavior. In addition, other raptors also fit the criteria of high public interest, migratory birds, and/or potential high exposure because of their feeding behavior. Avian predators are also sensitive to the effects of organochlorine pesticides (ESE, 1989b) and are thus represented more heavily as receptors than other predators. Raptors have large home ranges and may feed extensively outside the immediate First Creek drainage (U.S. Fish and Wildlife Service [USFWS], 1989a).

All soil invertebrates observed on RMA were presumed also to inhabit the Offpost OU. Earthworms were collected for the RI Addendum (HLA, 1992). These species are important prey items in terrestrial food chains for both mammalian and avian wildlife. Other invertebrates collected included grasshoppers, which also serve as important food items for both mammalian and avian species.

Upland vegetation, reptiles, and amphibians were inferred or were observed in the offpost area but were not collected as part of the RI Addendum (HLA, 1992).

The terrestrial species selected as representative indicators of COC effects included earthworms, grasshoppers, mice, prairie dogs, pheasants, great horned owls, American kestrels, and bald eagles. These species fit many of the selection criteria shown in Table 5.2.1-1. Adverse effects in bald eagles and great horned owls were considered representative of effects in other large raptors.

Terrestrial agricultural receptors selected include crops, chicken, and cattle because of their role in the human food chain. Crops represent all terrestrial plants because of a lack of specific data for most noncultivated plant species.

5.2.1.2 Aquatic Receptors

Potential freshwater aquatic receptors (Table 5.2.1-2) have been observed or are believed to be present in a variety of aquatic habitats, as described in the RI Addendum (HLA, 1992). Wetland resources were limited in the offpost area to riparian/floodplain areas adjacent to the creeks, rivers, and impoundments. First Creek and Second Creek are intermittent streams that do not support economically important fish populations.

Specimens collected from the First Creek Impoundment included macrophytes and algae, aquatic insects, crayfish, and fathead minnows (HLA, 1992). Fathead minnows are expected to provide food items for omnivorous wading birds. Fathead minnow tissue body burden data from the offpost area are reported in the RI Addendum (HLA, 1992).

Carp and bullhead catfish are expected to occur in the O'Brian Canal and other water bodies linked to the South Platte River. Despite seining of the entire First Creek Impoundment from bank to bank, only fathead minnows were collected (HLA, 1992). The pond is shallow, and Winter kill due to ice is expected to occur; thus, permanent populations of large fish are not anticipated. Previous reports of carp in this waterbody may be attributable to stocking the impoundment with fish collected from other areas. The freshwater aquatic species selected as representative for evaluation of contaminant effects and the predominant criteria for their

inclusion are summarized in Table 5.2.1-2. Larger fish (carp and bullhead) were not included in the food web because they were not found during the ecological characterization prepared for the RI Addendum (HLA, 1992).

Fathead minnows (*Pimephales promelas*) were observed in the First Creek Impoundment. This organism may have contact with sediments, thus increasing chemical exposure. This species may be an important prey item for higher trophic level biota such as great blue herons.

Crayfish (*Orconectes* sp.), a scavenging invertebrate, were also found in the First Creek Impoundment. Ecotoxicity data specific to this taxa are more limited, but invertebrate data for other species present at the site may be substituted with consideration of the resultant uncertainty inherent with extrapolation among taxa. Other aquatic invertebrates are expected to occur in the Offpost OU but were not collected during the RI Addendum (HLA, 1992).

Green algae were present in aquatic habitats of the Offpost OU and were collected as algal mats for analysis in the RI Addendum (HLA, 1992). Algae represent primary producers in the aquatic ecosystem.

Various waterfowl and shorebird species are common to the aquatic habitats in the offpost area. These birds have a variety of different feeding habits and are potential pathways to higher trophic level species, including humans. Toxicity data are available for different waterfowl species, but most data pertain to the mallard duck (*Anas platyrhynchos*). The bald eagle, mallard duck, and great blue heron were selected as representative avian species associated with aquatic or wetland systems to evaluate the potential adverse effects of the COCs.

5.2.2 Potential Exposure Pathways

The ecological conceptual site model, as shown in Figure 5.2.2-1, depicts the sources and pathways of exposure to the potential receptors. Essentially, the conceptual site model summarizes the exposure scenarios that were considered for each major receptor component of the ecological risk assessment. The model also indicates whether a specific pathway considered for evaluation was quantified.

Potential exposure pathways in relation to each media source are summarized in Table 5.2.2-1. It was difficult to evaluate some exposure scenarios with respect to biological receptors because of the lack of applicable exposure factors. For example, evaluating dermal contact toxicity data for mammals and wildlife species is not similar to the types of dermal exposure studied under experimental conditions. Under experimental (laboratory) conditions, the animal's hair is usually shaved, and the test compound applied directly to the skin. Under field conditions, only the foot pads or nose directly contact contaminated media. The dermal exposure pathway is expected to be minor compared to soil, water, or contaminated prey ingestion.

Inhalation of vapors or fugitive dusts is also expected to be a minor exposure pathway for wildlife species and agricultural receptors compared to ingestion. Most of the COCs in surface water, sediment, and surface soil are not volatile. Although the offpost area is expected to be dusty, especially during agricultural activities, the relatively low levels of COCs in surface soil (μg/kg or ppb) were expected to minimize risk via inhalation because of low exposure point concentrations.

Ingestion exposure pathways were evaluated because wildlife may ingest surface water or soil as part of burrowing, feeding, or grooming activities. Wildlife may also be exposed by ingestion of contaminated food items. Direct contact and ingestion of contaminated food items were considered for aquatic life. Exposure pathways are listed in Table 5.2.2-1 and are described below for each of the receptor species.

For earthworms, direct (i.e., dermal) contact is the most important exposure pathway. As with aquatic organisms, separating ingestion from dermal absorption from the surrounding media is difficult. Therefore, toxicity and bioaccumulation were evaluated in relation to direct contact with soil.

Grasshoppers may be exposed by direct contact with soil and ingestion of contaminated plants and soil. Quantifying the exposure by direct contact through soil ingestion is difficult because of limited information regarding this exposure route. Therefore, toxicity and bioaccumulation were considered in relation to ingestion of plants.

Mice and prairie dogs may be exposed by ingestion of contaminated soil with dietary items. Exposure by dermal contact is difficult to quantify because of limited information regarding this exposure route for wildlife. Because these species are very effective in conserving body water and receive most of their hydration via dietary intake, they consume little or no surface water . Contact with groundwater by these species is unlikely. Toxicity and bioaccumulation were considered in relation to ingestion of surface water, soil, invertebrates, and plants.

Pheasants may be exposed by direct or dermal contact with soil or surface water, dietary ingestion, and soil ingestion. Quantifying exposure by dermal contact is difficult because of limited information regarding this exposure route in avian species, but it is unlikely to be a major exposure pathway compared to ingestion. Surface water is consumed by pheasants; however, contact with groundwater is unlikely. Soil is ingested during feeding activities, but the actual exposure rates are uncertain. Toxicity and residue bioaccumulation were considered in relation to ingestion of soil, surface water, invertebrates, and plants.

Great horned owls, American kestrels, and bald eagles may be exposed by dermal contact, dietary ingestion, and soil and surface-water ingestion. As stated above, dermal contact is not likely to be a significant pathway compared to ingestion. Surface water is consumed by these species, but contact with groundwater is unlikely to occur. Limited quantities of soil may be ingested during feeding activities, but the actual exposure rate to soil is likely to be much less than for ground-feeding birds such as the pheasant. Ecological receptor soil ingestion rates determined for the Onpost EA (Ebasco, 1992 [Appendix H]) were used in this ecological risk assessment for consistency with the onpost ecological risk characterization. Toxicity and bioaccumulation were also considered in relation to surface-water, soil, and dietary (prey species) ingestion.

The lower trophic level freshwater aquatic receptors (green algae, crayfish, and fathead minnows) may be exposed by direct contact with their environment and, for some, via dietary ingestion. The higher trophic level organisms in the aquatic food web (mallard, bald eagle, and great blue heron) may be exposed by dermal contact, surface-water and sediment ingestion, and dietary ingestion of contaminated prey. Quantifying the exposure to higher trophic level

receptors by dermal contact is difficult because of limited information regarding this exposure route for wildlife. These species consume surface water; however, contact with groundwater is unlikely to occur. Limited quantities of sediment may be ingested during feeding activities. Toxicity and bioaccumulation were considered in relation to ingestion of surface water, sediment, and prey species.

Species in the agricultural food web may be exposed by dietary intake, surface-water intake, soil intake, and intake of contaminated groundwater via ingestion from agricultural wells. Toxicity and bioaccumulation for these species were considered in relation to each of these potential exposure pathways.

5.2.3 Exposure Point Concentrations

The groundwater exposure point concentrations developed for the human health assessment and presented in Section 2.4 (Table 2.4.2.5) were applied for agricultural biota. However, for wildlife receptors, the soil exposure point concentration for zone 3 was based on the geometric mean of the soil concentration rather than the UCL95 of the arithmetic mean used for the human health assessment. Additionally, a re-evaluation of the sediment and surface-water data indicated that the most reasonable exposure point concentration would be a geometric mean of useable data points because the data are not normally distributed. The data were evaluated in a manner similar to that used for the selection of appropriate data points for the groundwater exposure point calculations for the human health assessment described in Volume II, Section 2.0 of the EA. Geometric means were calculated for COCs, using all single value data points. In cases where duplicate samples were analyzed by two different methods, data for the method with the higher detection limit were eliminated if the following conditions occurred: (1) the eliminated value was a nondetection, (2) a duplicate sample was analyzed using a method with a lower detection limit, and (3) one-half the detection limit of the removed value is greater than the highest detected concentration for that analyte in zones 3 or 4. The exposure point concentrations for surface water, soil, and sediment are listed in Table 5.2.3-1. Terrestrial species are exposed to soil; some species may also contact surface water via ingestion. Lower trophic level aquatic species are

exposed to surface water continually by immersion in their environment. Toxicity to aquatic life resulting from contact with sediments was evaluated with the surface-water assessment. Livestock and crops may contact soil, surface water, or groundwater from agricultural wells.

5.2.4 Ecological Assessment Endpoints

Ecological assessment endpoints are expressions of values or characteristics that are to be protected. If these endpoints are determined to be significantly or adversely affected, remedial action is indicated (EPA, 1989f). The assessment endpoints for the Offpost EA were direct toxicity and bioaccumulation, which are indicated as potentially useful by EPA (1989f), and ones that can be addressed with the Offpost RI data and the food web models. EPA indicates that its list is not all inclusive and that other assessments endpoints are possible.

A measurement endpoint corresponds to or is predictive of assessment endpoints and can include data or models. The assessment endpoints were evaluated with the measurement endpoints of observed tissue concentrations and observed abiotic media concentrations, both of which can be correlated with mortality or sublethal toxic effects by use of data found in the toxicity assessments.

5.2.4.1 Terrestrial

Differences in species composition and/or distribution between RMA and the Offpost OU are influenced by land use and management, and thus comparison of population stability or diversity (as measured by species diversity, abundance, and productivity) or ecosystems productive capability (as measured by biomass or productivity) in relation to RMA is difficult, if not impossible. One assessment endpoint considered applicable for the ecological risk assessment was the link between TCOC residues and adverse effects. This assessment endpoint was evaluated by predicting TCOC levels, using food web modeling and comparing these levels to MATCs. The MATCs (described in Section 3.4 of Volume II) are tissue concentrations that correspond to no effect or minimal adverse effect in a few members of a population. Tissue residues may be indicative of impacts to sensitive individuals and populations.

Another ecological endpoint evaluated in this assessment was direct toxicity. Soil, water, and food intakes were evaluated for contaminant levels that could be correlated with direct toxicity. These intakes were compared with the TRVs contained in Section 3.3 of Volume II. This approach was relied upon, in part, because some COCs do not bioaccumulate in food webs and also to address exposure directly to abiotic media. TRVs are equivalent in concept to RfDs developed for human health. TRVs are a daily intake level that should not result in an adverse health effect to a population or an endangered species. The ratio of chemical intakes to TRVs is defined as a hazard quotient (HQ) for the purposes of this EA.

Although other environmental assessment endpoints may exist (EPA, 1988; EPA, 1989f), these endpoints may be subject to confounding exposures not associated with RMA. The use of registered insecticides and herbicides in the Offpost OU, the discharge of sewage effluent to Barr Lake (DRCOG, 1989), and the possible presence of contaminants in the South Platte River makes assessing the ecological risk attributable to chemicals from RMA sources difficult to separate from the risk from other sources.

5.2.4.2 Aquatic

Wetlands and habitats critical for survival of endangered species are generally considered sensitive habitats (EPA, 1989f). Barr Lake is an important migratory bird habitat and recreational area, but intense management activities, historical input of effluents and runoff (DRCOG, 1989), and human use make quantitative evaluation of RMA contaminant effects uncertain. Because of the level of habitat disturbance caused by land use practices in the Offpost OU, the assessment endpoints considered most applicable for the aquatic assessment were measured using the following criteria: (1) TCOC concentrations in biota using food web modeling and MATCs and (2) direct toxicity using TRVs. Other criteria include the AWQC that were used to determine risk to aquatic life. These measurement endpoints provide the best indication of potential adverse impacts in wetlands and aquatic systems resulting from site-related contamination.

5.2.5 Bioaccumulation Exposure

This section describes the procedures used for modeling the bioaccumulation of TCOCs in terrestrial and aquatic food webs. Predicted tissue concentrations are compared to MATCs in Sections 5.3.1 and 5.3.2.

5.2.5.1 Terrestrial Food Web Ingestion Pathways

Dietary and soil ingestion exposure pathways were evaluated for TCOCs, using food web modeling (ESE, 1989b; Fordham and Reagan, 1991) and analytical data. The food webs were made site-specific by including the offpost terrestrial and aquatic receptors. The food webs also outlined critical exposure pathways for each of the receptor species.

The terrestrial food web is presented in Figure 5.2.5.1-1. The indicator species that were sampled for chemical analysis consisted of all lower trophic animals. Bioaccumulation factors (BAFs) for each species were developed from the open literature on the basis of a scientific consensus and are presented in Appendix H (Table H2-1). A BAF is the ratio of a chemical concentration between tissue and intake, e.g., C_{biota}/C_{diet}. By definition, BAF includes uptake from both water and dietary intake. Because soil is frequently ingested along with diet, residues resulting from soil ingestion are considered as well. For the terrestrial species in the Offpost OU, many of which do not consume surface water as a drinking water source, the bulk of the chemical body burden is expected to be derived from soil and food ingestion. Residues resulting from surface-water ingestion are considered in Section 5.2.6.1.

The BAFs were developed through literature research and are contained in Appendix H. The BAFs for the species are intended to represent bioaccumulation by all members of the specific trophic compartment. A medium-sized bird BAF was not provided in the Onpost EA data; therefore, the BAF for the small birds was used to represent the pheasant (Table H2-1 of Appendix H). Prairie dogs were considered as medium-sized mammals.

The food chains in the terrestrial food web (Figure 5.2.5.1-1) are presented in Table H2-1 of Appendix H, using producer/consumer notation as indicated by arrow symbols (e.g., earthworm -> mouse). The total BAF (product of all BAFs in the food chain) for each food chain pathway for

each COC is also reported in Table H2-1 of Appendix H. The total BAF values for each food chain pathway were obtained by multiplying each of the individual BAFs in each pathway (Table H2-1). For example, the calculation of the total BAF for aldrin for a soil pathway is illustrated below.

BAFs								Total BAF
	6		x 3		x 19			= 342
Soil	->	Earthworm	->	Deer Mouse	->	Owl		

Dietary fractions for each food chain pathway, as shown in Table 5.2.5.1-1, were multiplied to obtain an overall dietary importance value for the food chain for the target organism. The results are shown in the column labeled percent organism in Table H2-1 of Appendix H. For example, food habits data indicate the owl feeds primarily (66.5 percent of diet) on deer mice, a small mammal (Table 5.2.5.1-1), and that deer mice eat a mixed diet, of which 48 percent is grasshoppers, an insect; therefore, this food chain contributes 32 percent of the owl's dietary intake:

Soil	->	Plants	->	Grasshoppers	->	Deer Mouse	->	Owl
	1.0	x	1.0	x	0.48	x	0.665	= 0.32

In general, dietary fractions were estimated from data used for the Onpost EA (Ebasco, 1992 [Appendix H]). Because the bald eagle's diet in the offpost area also includes a small fraction (0.031) derived from the aquatic food web, the bald eagle dietary fraction does not add up to 1.0 in the terrestrial food web.

By definition, a biomagnification factor (BMF) is a more general term that implies food chain transfer of residues. BMF is used to define the uptake by higher trophic level organisms caused by feeding in an entire food web.

The total BMF for a higher trophic level target organism is the sum of the products of the total BAF multiplied by fraction of pathway in the diet of the higher trophic level target species

(Table H2-1 of Appendix H). This adjusts the total BMF to reflect the contribution of the respective pathways (n) for the target organism (Table 5.2.5.1-1).

$$\sum_{n=1} (\text{total BAF}_1 \times \text{dietary fraction}_1) = \text{total BMF} \qquad (5\text{-}1)$$

To summarize, the dietary fraction of the pathway was multiplied by the total BAF for the pathway, and these values were summed for each species (Table H2-1 of Appendix H). The sum of the food chain pathways as depicted in Table H2-1 in Appendix H, for each target organism (i.e., bald eagle or owl) was labeled the total BMF. The total BMF represents the overall biomagnification predicted from soil and all the food chains leading to the target organism. The major species group (Table H2-1 of Appendix H) is presented to provide consistency with the onpost ecological risk characterization.

Soil was considered part of the dietary intake because soil intake data are frequently expressed as a percent in relation to diet. Contaminant uptake caused by surface-water ingestion was considered separately because surface-water intake rates for birds may exceed feed intake on a weight or volume basis (Sax, 1984) and are not usually expressed as a percent of the dietary intake. Absorption factors for uptake from water or soil were conservatively assumed to be equivalent to those for diet.

5.2.5.2 Terrestrial Food Web Predicted Tissue Concentrations

The predicted tissue concentrations of the five OCPs for the terrestrial food web species are depicted in Table 5.2.5.2-1. The predicted tissue concentrations were calculated by multiplying the geometric mean soil concentration of each OCP for zone 3 by the species- and chemical-specific total BMF developed from literature BAF values (Appendix H); also, a spatial adjustment factor was applied for the bald eagle, American kestrel, and great horned owl. For example, to determine the predicted tissue concentration of dieldrin for the American kestrel, the following equation was applied:

$$(0.043 \text{ mg/kg} \times 13) \times 0.2 = 0.11 \text{ mg/kg}$$

where:

0.043 mg/kg = soil dieldrin concentration

13 = total BMF for dieldrin for the American Kestrel

0.2 = spatial adjustment factor

Literature BAF values were used because offpost data were insufficient to determine site-specific values, and onpost data and values, which may have been appropriate for use, were unavailable. For those species occupying the upper trophic boxes and having a known home range (i.e., bald eagles, American kestrels, and great horned owls), the predicted tissue concentrations were spatially adjusted based on the home range for that particular species (Appendix H). The home range adjustment was deemed appropriate because these animals are mobile and will only obtain a fraction of their prey items within zone 3. The spatial adjustment factor is based on a ratio of the known home ranges of the species and the area of zone 3.

5.2.5.3 Aquatic Food Web Ingestion Pathways

The aquatic food web is presented in Figure 5.2.5.3-1. The shaded boxes indicate samples collected as part of the RI sampling program. Large fish (carp, bullhead) do not appear on the food web (reflecting current conditions). Thus, large fish were not evaluated as part of the food web model. Herons are assumed to feed primarily in the aquatic food web.

Dieldrin and arsenic were the only TCOCs observed in the species collected in the aquatic food web (HLA, 1992). Aquatic biota samples were collected from the First Creek Impoundment only because First Creek, an intermittent stream, was not found to support fish during the ecological characterization. For small aquatic species such as invertebrates, it is assumed that the surface area to volume ratio as well as the exchange of water across the gills causes sufficient absorption of chemical from water to outweigh uptake from diet. Species higher up the aquatic food chains obtain chemicals through dietary intake as well as from direct uptake from water.

Bioconcentration factors (BCFs), the ratio of chemical concentration in tissue to chemical concentration in water, were obtained from the open literature (Table H2-2 of Appendix H).

5.2.5.4 Aquatic Food Web Predicted Tissue Concentrations

The predicted tissue concentrations of the five OCPs and arsenic for the aquatic food web species are depicted in Table 5.2.5.4-1. The predicted tissue concentrations were calculated by multiplying the exposure point concentration of each chemical in surface water by the species- and chemical-specific total BMF developed from literature BCF values (Appendix H) for the major receptor species in only the BCF values for algae and invertebrates. Literature BCF values were used because offpost data were insufficient to determine site-specific values. A spatial adjustment was applied in a similar manner to that described previously for the terrestrial food web for bald eagles and the great blue heron. The spatial adjustment factor included feeding in zones 3 and 4. A spatial adjustment factor was not derived for the mallard duck because home range data were not available for consideration; therefore, the predicted tissue concentrations for the mallard duck are likely overestimated based on dietary intake from a single area. The predicted tissue concentrations based on the direct ingestion of sediment were also calculated in a similar manner (Table 5.2.5.4-2).

5.2.6 Direct Exposure to Chemicals of Concern

Procedures used to calculate the species' intake from surface-water ingestion, soil ingestion, dietary ingestion, and direct contact are discussed in this section. However, the intake values are presented in Tables 5.3.1-1 through 5.3.1-5 where these intakes are evaluated with respect to TRVs in Section 5.3.

5.2.6.1 Surface-Water Ingestion Pathway

Species that do not rely on surface water as a primary drinking water source (e.g., prairie dogs) are less likely to be exposed to potentially contaminated surface water. Birds, however, often drink surface water. Birds with limited home ranges that overlap a contaminated water source may conceivably obtain all their drinking water from the contaminated source. Large mammals and raptors with a relatively larger home range may not have as high an exposure rate

because of the opportunities to obtain water from uncontaminated sources. Surface-water ingestion was evaluated for the following species:

Species	Water Intake (l/kg-bw/day)
Ring-necked pheasant	0.25
Great horned owl	0.25
American kestrel	0.25
Bald eagle	0.25
Mallard duck	0.25
Great blue heron	0.25

Water intake rates for terrestrial avian species were estimated from chicken data (Sax, 1984), because similar data were not available for offpost area species. Water intake is expected to vary among species, locations, and seasons, when different dietary components may supply more water or when different energy expenditures require more water intake. Although mallards were reported to consume 0.2 l/kg-bw/day, in exposure intakes, they were conservatively modeled as ingesting 0.25 l/kg-bw/day to account for water intake during feeding and bathing activities. Great blue herons were also assumed to ingest 0.25 l/kg-bw/day.

The other components of the terrestrial food web (earthworms, grasshoppers, mice, and prairie dogs) either do not consume surface water as a drinking water source, or they are fairly immobile and cannot access surface water. However, all surface-water intakes were based on avian water intake rates, and these intake rates were assumed to be protective of other species (e.g., small mammals) in the terrestrial food web. In general, water intake per unit body weight for various mammalian species varies between approximately 0.05 to 0.2 l/kg-bw/day (Sax, 1984). Therefore, the use of avian intake rates would provide conservative (high) exposure estimates for mammals because deer mice and prairie dogs in the terrestrial food web do not ingest surface water as a drinking water source.

Direct ingestion is considered to be exposure to surface water caused by consumption, and direct toxicity is the adverse effect resulting from such exposure. The exposure point COC concentrations in surface water are presented in Table H3-1 of Appendix H with the estimated chemical intakes by avian species (raptors, heron, mallard, or pheasant). Chemical intake was

calculated by multiplying the exposure point concentration in surface water (μg/l) by the daily water intake for birds (0.25 l/kg bw/day). Total chemical intakes via all appropriate routes of exposure were compared to the TRVs presented in Section 3.0 to calculate an HQ to estimate potential hazards (Section 5.3).

5.2.6.2 Direct Contact with Surface Water or Sediment

Aquatic life (fish and macroinvertebrates) has direct contact with surface water and sediment in the environment; however, toxicity data with respect to contact with or ingestion of contaminated sediments are lacking for many of the COCs for the species of interest. Toxicity to aquatic life was estimated from direct contact with surface water and ingestion of sediment. TRVs for aquatic life were compared to the surface water, sediment, and dietary intakes and are addressed in Section 5.3, Risk Characterization.

5.2.6.3 Soil Ingestion

Soil ingestion by terrestrial biota for residue calculations was addressed previously via the terrestrial food web model. Soil ingestion rates are often presented as a fraction of the diet; however, as with surface water, direct toxicity as well as residue accumulation should be considered. Direct toxicity as a result of soil ingestion was predicted using the exposure point concentrations presented in Section 2.4. Up to 2 to 3 percent of the daily food intake may be composed of soil (Palmer and Fowler, 1975) (Table 5.2.5.1-1). Total daily food intake was determined to be a percentage of total body weight (Ebasco, 1992). Intakes were calculated on these values. In addition, aquatic birds (e.g., mallard or heron) may also ingest soil during nesting or feeding activities. The chemical intakes from sediment are assumed to represent soil intake by these species. The species-specific soil and sediment dietary fractions are listed in Appendix H.

Potential exposure to the terrestrial plant species (crops) in the Offpost OU could result from direct uptake of chemicals in soil, groundwater, and surface water in the affected areas. Exposure point concentrations of the COCs identified are presented in Section 2.4.2. Hazard to plants is addressed in Section 5.3.

5.2.6.4 Dietary Ingestion for Wildlife

Dietary intakes were derived by multiplying the estimated tissue concentrations in prey items (next lower trophic level) for both terrestrial or aquatic life (Tables 5.2.5.2-1 and 5.2.5.4-1) by the dietary fraction (Table 5.2.5.1-1) to obtain mg chemical/kg diet. Estimated concentrations in prey were obtained by use of the food web model. Assuming daily dietary ingestion rates listed in Appendix H (Ebasco, 1992), the following equation was derived.

$$\sum_{n=1} \left(\left(\begin{array}{c} \text{Prey residue} \\ \text{(mg/kg diet)} \end{array} \times f \right) \times r \right) \times SAF = \begin{array}{c} \text{Chemical intake} \\ \text{(mg/kg-bw/day)} \end{array} \qquad (5\text{-}2)$$

where:

f = dietary fraction of prey item (unitless)

r = daily dietary ingestion (feed) rate (kg prey/kg-bw)

SAF = spatial adjustment fraction (unitless)

The chemical intake from each component of the food chain is additive (due to the dietary fraction term); thus the total dietary intake is the sum of the amount of chemical in relation to each of n prey items. For example, in the terrestrial food web, the bald eagle consumes prairie dogs (91.5 percent), deer mice (0.5 percent), and pheasants (1.9 percent); therefore, the dietary DDE intake for the eagle is [[(0.03 x 0.915) + (0.54 x 0.005) + (0.27 x 0.019)] x 0.09] x 0.0009 or 2.8 x 10-6 mg/kg-bw/day. The value 0.09 represents the feeding rate, and the value 0.0009 is the spatial adjustment factor for the bald eagle.

5.2.6.5 Dietary and Soil Ingestion Pathways for Livestock

The dietary and soil ingestion pathways were evaluated for chickens and cattle. Only zones 1, 2, and 6, classified as the rural residential scenario, were evaluated for potential COC effects on chickens and cattle. The agricultural food web (Figure 5.2.6.5-1) indicates the potential exposure pathways.

Chickens may be exposed to COCs through direct soil consumption. The chicken intake for soil ingestion was calculated as follows:

$$\text{Chicken soil intake} = \frac{C_s \times I_s}{BW} \qquad (5\text{-}3)$$

where:

C_s = concentration in soil (mg/kg)

I_s = soil ingestion rate = 200 mg/day

BW = body weight of chicken = 2.5 kg

Cattle may be exposed to COCs from the soil through incidental soil ingestion while feeding. Exposure to the COCs in the groundwater and surface water could occur from direct water consumption. Cattle forage may bioaccumulate COCs from soil or irrigation water. Explanation of the classification of the groundwater and surface-water use patterns is in Section 2.2.2.4.

The intake from contaminated media was calculated by a procedure designed to be consistent with the estimates of concentrations in meat used in the human health assessment (Section 2.4.2). The procedure was as follows:

$$\text{Cattle plant intake (mg/kg/day)} = \frac{CF_m \times I_p}{K_{pm} \times BW_m} \qquad (5\text{-}4)$$

where:

CF_m = concentration of the chemical in beef (mg/kg, fresh weight)

I_p = ingestion rate of feed (kg/day, fresh weight)

BW_m = body weight of the cattle (kg)

K_{pm} = equilibrium partition coefficient relating chemical concentration in aboveground plant part to concentration in the soil aqueous phase (l/kg)

By substituting equation 2.4.2-4 for CF_m into equation 5-4 and rearranging terms, it can be shown that equation 5-4 is equivalent to the following:

$$\text{Intake} = \frac{C_p I_p + C_w I_w + C_s I_s}{BW_m} \qquad (5\text{-}5)$$

where:

I_w = ingestion rate of water by cattle

I_s = ingestion rate of soil by cattle

C_p = concentration of chemical in plant

I_p = ingestion rate of feed

C_w = concentration of chemical in water

C_s = concentration of chemical in soil

BW_m = body weight of cattle (kg)

Equation 5-4 was applied using a zone-specific estimated concentration in meat and I_p = 37.7 kg/day, BW_m = 450 kg. The CF_m values are provided in Table H4-1 of Appendix H. The K_{pm} values are included in Table 2.1-10.

5.3 RISK CHARACTERIZATION

Potential hazards to the different ecological components of the Offpost OU were addressed by considering the risk to terrestrial, aquatic, and agricultural life separately. Bioaccumulation and direct toxicity endpoints were evaluated for terrestrial and aquatic life; only direct toxicity was evaluated for underwater aquatic life and agricultural life.

5.3.1 Terrestrial Food Web Ecological Risk

The toxicity of TCOC residues was evaluated when data were available. This type of toxicity is applicable only to those contaminants that bioaccumulate; therefore, residue toxicity was addressed only for the terrestrial food web for higher trophic level organisms. Residue toxicity was estimated by using MATC values that were developed during extensive literature searches (Volume IV, Appendix H). The MATC is based on soil and dietary intake and is also a function of the residue assimilated by the top predator species, whereas the TRV considers intake from all media, particularly for nonbioaccumulative COCs. The MATC is specific for toxicity relative to an organism's residue body burden, whereas the TRV accounts for any toxicologic response to dose. The MATC's strength is that it allows comparison of observed biota data to

tissue concentrations that, if exceeded, predict possible effects for species not included in the sampling program (such as endangered species). The MATCs are in Appendix H.

MATCs were developed after reviewing literature describing tissue concentrations for avian and mammalian species dosed in toxicity studies. In the food web models, multiple food chains lead to a target organism, or sink species. Chemicals that bioaccumulate tend to concentrate within each level of the food chain such that the sink species are exposed to higher concentrations than the lower trophic level species. Because avian species are considered the sink species for the offpost food webs (see receptor identification), soil criteria that are developed with the MATCs and BMF for the sink species are assumed to be protective of lower trophic level organisms as well. However, to validate this assumption, a comparison of estimated intakes for lower trophic levels to their respective TRVs is necessary.

Tissue concentrations were predicted in the higher trophic level organisms in the terrestrial and aquatic food webs that were not sampled as part of the offpost RI (HLA, 1992) (Table H2-1 and Table H2-2 of Appendix H). The predicted tissue residues for the avian species were compared to the MATCs listed in Appendix H. The predicted tissue residues in birds feeding in zone 3 exceed the endrin MATC for the great horned owl and American kestrel. A summary of the ratio of predicted tissue concentrations to MATCs by birds feeding in the terrestrial web follows:

Ratio of Predicted Tissue Concentrations to MATC

	Terrestrial			
TCOC	Bald Eagle	Great horned Owl	American Kestrel	Ring-necked Pheasant
Aldrin	<1	<1	<1	<1
Dieldrin	<1	<1	<1	<1
Endrin	<1	4	4	<1
DDE	<1	<1	<1	<1
DDT	<1	<1	<1	<1

Endrin is indicated as a potential concern to the great horned owl and American kestrel; however, it should be noted that actual site data do not support the predicted tissues concentrations of endrin in lower trophic level organisms. Endrin was reported as BCRL (<0.036 mg/kg)

in each of the biota samples analyzed (HLA, 1992). Samples were analyzed from members of the following species, domestic cattle, domestic fowl, fathead minnows, carp, crayfish, algae, grasshoppers, earthworms, deer mice, prairie dogs, and pheasants. A detailed presentation of the various sample types collected from each species is in the RI Addendum (HLA, 1992).

Direct toxicity endpoints were also evaluated for the higher trophic level terrestrial species by adding soil, surface water, and dietary intakes to derive a total intake. Total intake was compared to TRVs (Volume II, Section 3.0 and Table 3.3.3-1), and an HQ value was calculated (Tables 5.3.1-1 through 5.3.1-3). Menzie and others (1992) describe a similar HQ approach to estimate potential health effects on birds. Their approach calculates an HQ ratio by comparing the dose of contaminant received in diet to a dietary dose as a concentration of contaminant in the diet associated with the LOAEL or NOAEL for a particular biological endpoint. The HQs were modified by the application of a home range or spatial adjustment factor to adjust for partial dietary intake from the areas within the Offpost OU potentially having the greatest impact (zones 3 and 4) relative to a particular species' home range. HQ ratios greater than 1 indicate a potential for an effect but do not indicate the magnitude (i.e., severity) or provide a measure of potential population level effects. Also, HQs do not represent the probability of an adverse effect occurring. The HQ ratio simply compares estimated doses to benchmarks. This comparison is very similar to the use of RfDs in the human health risk assessment and to the manner by which water quality criteria are applied (water concentrations compared to benchmarks, the criteria).

The estimated chemical intakes did not exceed the TRVs for bald eagles, based on the geometric mean soil concentration data for zone 3 and the surface-water data for both zone 3 and zone 4. HQs for the American kestrel and great horned owl were only exceeded for sulfate (HQ equals 2). The American kestrel HQ for dieldrin equaled 1. All remaining HQs for both species were less than 1. Home range or spatial adjustment factors were also applied to the calculations for these two species. Additional home range information on the principal receptors is in Appendix H.

Exposure estimates for deer mice (Table 5.3.1-4) and prairie dogs (Table 5.3.1-5) exceeded fluoride and sulfate TRVs. The mammal exposure estimates include surface-water and soil ingestion as well as dietary intake. These estimates are highly conservative because the small mammals are unlikely to ingest surface water; however, intake estimates would be protective of mammals not included as receptors in the food web that may ingest surface water (e.g., fox, coyote, skunks, raccoons). The fluoride and sulfate exceedances are probably the result of uncertainties in the TRV derivation process, as presented in Section 5.3.5.3. Only the zone 3 and zone 4 data were evaluated for potential adverse effects on wildlife because exposure concentrations are less for soil in other zones and no COC-contaminated surface water or sediment occurs in other zones.

5.3.2 Aquatic Food Web Ecological Risk

The bald eagle and great blue heron occupy the top trophic level of the aquatic food web. Predicted tissue concentrations (Table 5.2.5.4-1) were based on exposure point concentrations in surface water. Predicted tissue concentrations were then compared to MATCs to determine potential health effects to bald eagles, great blue heron, and mallard ducks feeding in the aquatic food web. The direct ingestion of sediment does not contribute significantly to the predicted tissue concentrations (Table 5.2.5.4-2).

MATCs for dieldrin, DDT, and DDE were not exceeded for bald eagles, great blue herons, and for the mallard duck. Aldrin and endrin were not evaluated because they were not detected in surface water.

Ratio of Predicted Tissue Concentrations to MATC

	Aquatic		
TCOC	Bald Eagle	Great Blue Heron	Mallard Duck
Dieldrin	<1	<1	<1
DDE	<1	1	<1
DDT	<1	<1	<1

The combined intakes from soil, water, and diet (Tables 5.3.2-1 and 5.3.2-2) for great blue herons and mallard ducks were compared to TRVs (Table 3.3.3-1) and an HQ calculated. The HQ for sulfate exceeded 1 for the mallard ducks. The great blue heron had no exceedances.

The HQ for bald eagles, including dietary uptake from both the aquatic and terrestrial food webs, is reported in Table 5.3.1-1. As described previously, the intake of the COCs did not exceed the TRVs; therefore, the resulting HQs were all less than one. Essentially, the aquatic food web pathway did not result in any predicted tissue concentrations for the COCs in the bald eagle; thus, only predicted tissue concentrations via the terrestrial food web can be compared to the MATC values. The intakes for most of the COCs from soil or water ingestion were minimal.

5.3.3 Underwater Aquatic Life

Risk to aquatic life was also evaluated by use of aquatic reference concentrations (Table 3.3-1). The observed concentration in surface water was compared to AWQC, LOAEL, or NOEL from the literature (Table 3.3-1). Residue toxicity was not evaluated for aquatic life because data regarding the toxicity of residues in tissue are largely lacking for these species. In addition, because aquatic life are continually surrounded in their exposure medium, it is likely that water concentrations are a better predictor of toxic effects than tissue levels. Chlordane, dieldrin, fluoride, and DDT appear to present a potential for an adverse effect to aquatic life in First Creek, based on a comparison of exposure point concentrations in surface water to TRVs (chronic AWQC values) for aquatic life. Background information for the aquatic reference concentrations was reviewed to determine whether any AWQC values were hardness dependent to make the criteria more site-specific. The EPA AWQC for the surface-water COCs are not dependent on water hardness.

5.3.4 Agricultural Life

Groundwater and soil exposure point concentrations for COCs (Tables 2.4.2.6-1 through 2.4.2.6-9) were compared to reference media concentrations for plants (Table 3.3-1). Reference media concentrations of the COCs in soil did not indicate any exceedances except for chloride as

applied in irrigation water. The total dissolved salts (free ions) in the irrigation water were elevated in the Offpost OU. An evaluation of whether exceedances of Colorado groundwater and surface-water standards occur is included in the ARARs portion of the Offpost OU FS.

The potential impact of contaminants in soil on poultry was evaluated by calculating the HQ as a ratio between the dose to the chicken from soil and the TRVs (Table 3.3.3-1). The HQs for chickens based on the zones 1, 2, and 6 (rural residential) soil concentration data sets, did not indicate a potential contamination impact on chickens (Table 5.3.4-1).

A hazard evaluation was performed to determine whether cattle maintained in the Offpost OU could potentially be affected as a result of exposure to COCs in soil and irrigation water through dietary consumption. The indirect exposure pathway includes consumption of plants grown in contaminated soil and irrigation water. HQs calculated for cattle for the different chemical compounds identified at the Offpost OU for zones 1, 2, and 6 are presented in Table H4-1 of Appendix H. No exceedances above 1 occurred; therefore, the potential for adverse health effects occurring to cattle is not indicated.

5.3.5 Ecological Risk Assessment Uncertainty

This section of the ecological risk assessment addresses the uncertainty associated with each element of the risk assessment and the overall impact on the risk assessment's conclusions. The elements of uncertainty include those associated with particular analyses, methods, and techniques. The discussion is limited to a qualitative presentation of uncertainty.

5.3.5.1 Site Characterization

Very little uncertainty is associated with the site characterization because onsite investigations were conducted and supplemented with historical data and aerial photographs. The ecological risk assessment site characterization was conducted in conjunction with the RI Addendum (HLA, 1992).

5.3.5.2 Exposure Assessment

The matrix used to select potential receptor organisms relied on site-specific and EPA guidance criteria, thus minimizing the uncertainty associated with this aspect of the ecological risk assessment. Receptors were selected from all pertinent trophic boxes to ensure a complete evaluation of the food web. The Offpost OU conceptual site model, as shown in Figure 5.2.2-1, indicates that all possible sources and exposure pathways were considered, thus reducing uncertainty.

The uncertainty associated with the food web models, dietary intake calculations, and the predicted tissue concentrations determined by the food web models may be high for reasons discussed below.

The sediment intake rate provided for small fish is difficult to validate because of the paucity of available information. Tissue residues predicted for the great blue heron can be influenced significantly by the sediment intake of small fish because the small fish constitutes 37 percent of the heron's diet. Because the great blue heron and mallard duck predicted tissue concentrations of COCs found in aquatic ecosystem appear to overestimate the observed data, a large degree of uncertainty is associated with aquatic food web model and input parameters. The sediment exposure point concentrations used in this assessment are based on a geometric mean of the chemical residues contained in the sediment matrix. Although the geometric mean value is less than the UCL95 of the arithmetic mean values used for the human health assessment, the use of total sediment concentrations may not be the most appropriate value to use to measure exposure. Recent reports indicate the free or bioavailable fraction of the total chemical present is the most important factor in potential aquatic toxicity (DiToro and others, 1991; Adams and others, 1992). Because the bioavailable fraction is not known for the Offpost OU sediment samples, it is difficult to determine whether the evaluations overestimated or underestimated the actual hazard to the aquatic receptors. Additional uncertainty exists for the hazard evaluation for the bald eagle and great blue heron through the application of the spatial adjustment based on home range information obtained from the open literature. Again, it is difficult to determine

whether the spatial adjustment resulted in an overestimation or underestimation of the potential hazards to these aquatic receptors.

The dietary intakes assume that the animal's intake is year round and from a very limited area in the Offpost OU. Although these assumptions may be valid for small mammals that have a limited home range and foraging area, the assumptions are not valid for more mobile species such as the avian receptors; thus, more uncertainty is associated with avian dietary intakes. The application of the spatial adjustment factor may reduce the uncertainty associated with raptor mobility relative to prey located in contaminated areas; however, no adjustment was made to account for temporal influences. Bald eagles, with few exceptions (e.g., the Barr Lake pair), winter at or near RMA for only a few months each year (November-March). During this time of year, the most likely offpost aquatic foraging sites for the bald eagle are either intermittent or frozen, thus reducing intake from the aquatic ecosystem (USFWS, 1989a and 1989b). Likewise, mallard ducks and the great blue heron are migratory. The USFWS report (1989a) indicates that only a fraction of the wintering bald eagles may return to RMA on an annual basis, indicating a fairly substantial turnover of the bald eagle population at the RMA roost. The report states that possibly 100 or more eagles visited the RMA roost during the 1988-1989 wintering season and that casual observation of the eagles in early November suggests that up to seven of the eagles may have returned from the previous year. Perhaps with more data, the probability of an individual eagle wintering in the Offpost OU during its lifetime could be determined to evaluate the temporal aspect of exposure to contaminated media more accurately. Similar data are also desirable for the other avian species. More definitive temporal and spatial data on the foraging habits of the receptors are required to reduce the uncertainty.

The exposure assessment for the agricultural receptors (i.e., chickens, cattle, and crops) has less uncertainty because the database on exposure, absorption factors, uptake models, and toxicity is more complete.

5.3.5.3 Risk Characterization

Inherent uncertainty is associated with the comparisons between the predicted tissue concentrations (food web models) and the MATCs and the dietary intakes compared to the TRVs (HQs) because the MATCs and TRVs are based on the extrapolation of field and/or experimental data from the open literature. The uncertainties pertaining to these comparisons is a combination of the uncertainty contained in the MATC and TRV derivation procedures in addition to uncertainty associated with the food web models and intake parameters. The uncertainties related to TRVs are presented in Section 3.5.

Some of the HQ exceedances (e.g., sulfate exceedances) may be an artifact of the TRV derivation process. The TRV derivation process, by necessity, is rather structured, with minimal opportunity for subjective scientific input. This approach was deemed most desirable because it allows a derivation process that can be easily applied by anyone once the critical toxicity study has been identified. A modifying factor addressing the quality of the toxicity study and its relevancy to an ecological receptor would reduce the uncertainty associated with the TRVs and their subsequent application to calculate HQs. However, because of the complexity of wildlife toxicity issues and to reduce criticism, such a modifying factor should only be developed by a consensus of scientific opinion from qualified individuals (a similar process as applied to RfDs).

The overall uncertainty with the ecological risk characterization could be reduced if site-specific documented temporal and spatial home range data were available as well as more refined MATCs and TRVs. The result of such adjustments would result in outcomes similar to RMEs used in the human health assessment.

5.4 SUMMARY

A quantitative assessment of important exposure pathways was performed for nonhuman receptors in the Offpost OU food webs. The results of the exposure assessment were expressed as tissue residues or as estimated chemical intakes from water, sediment, soil, and diet.

The tissue residues were compared to MATCs. The intakes were compared to TRVs as part of the risk characterization to obtain an HQ for each higher trophic level receptor and each COC.

Significance is only attached to those comparisons that exceeded MATC or TRV criteria. Uncertainties associated with the quantitative ecological risk assessment are related to assumptions, some conservative and others not, made during the calculation of exposure point concentrations, intakes, and adverse health effects. These assumptions are presented in the text but are summarized below for clarity. The assumptions are qualitatively assigned in order of impact on the risk characterization results.

1. The use of BAF and BCF values obtained from the open literature rather than site-specific values introduced uncertainty because biological, chemical, and physical characteristics unique to the Offpost OU may be very different from those present in the studies reviewed from the literature.

2. The application of the spatial adjustment factor based on literature home range information is another source of uncertainty. Although it is difficult to determine if the approach presented in this assessment over- or underestimated the potential hazards, it is generally known that the home ranges, per se, are not reflective of potential exposure, and for animals that have a wide home range, such as the bald eagle, the foraging area may only be a fraction of the total home range area.

3. Use of conservative soil, sediment, and surface-water intakes.

4. The equilibrium and steady-state assumptions for modeling are probably high (i.e., conservative), thus resulting in higher exposure estimates than the higher trophic level species will experience because they can move in and out of the ecosystem.

5. The use of uncertainty factors, LOAELs, and NOELs in developing health effects levels for TRVs is conservative.

6. The use of geometric mean exposure point concentrations for soil, sediment, and surface water probably represents a more realistic scenario than the UCL95 values used for the human health risk assessment; therefore, less uncertainty may be associated with this aspect of the hazard evaluation.

The results of the risk characterization indicate that minimal potential for adverse effects to receptor species in the aquatic and terrestrial food webs may exist. The available analytical data on likely prey for the bald eagles (prairie dogs and pheasants) exhibited fairly low and infrequent detections of the COCs (HLA, 1992). Other raptor species feeding in the terrestrial food web are also not likely to be at high concern for risk as predicted body burdens were less than or within an order of magnitude of the MATCs.

Species in the agricultural food web are not expected to be at risk because of exposure to the COCs. Plant life, cattle, and chickens will be relatively unaffected, based on the results of the risk characterization.

6.0 CONCLUSIONS

As indicated in the Preface to the EA, one of the objectives of the EA was to provide an analysis of risks in the absence of additional remediation (baseline risks) and to provide a basis for determining the need for remedial action at a site. The EA for the Offpost OU has determined the cumulative hypothetical carcinogenic risk is a maximum of 3×10^{-4} on the basis of the RME risks. The maximum risk is within the acceptable risk range as defined by EPA in the revised National Contingency Plan (EPA, 1990a) and in the Role of the Baseline Risk Assessment in Superfund Remedy Section Decisions (EPA, 1991c).

The calculated hazard indices presented in the EA and below 1.0, with the exception of zones 2, 3,and 4, where the HIs slightly exceed 1.0.

Although the need for Offpost OU remedial action is not warranted because the Offpost OU cumulative risk is 3×10^{-4}, the Army recognizes that there are several site-specific factors, when considered in totality, suggest remediation of groundwater is preferable to no action in the Offpost OU. Accordingly, a Feasibility Study has been prepared as a companion document to the EA for the Offpost OU.

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Table 4.0-1: Target Organ- or System-specific Chemicals of Concern

Target Organ or System	Chemical of Concern
Blood	Benzene Toluene
Cardiovascular	1,2-Dichloroethane Atrazine
Central Nervous System	DIMP[1] 1,4-Dithiane Malathion Manganese Oxathiane Toluene Xylenes, total
Gastrointestinal	Hexachlorocyclopentadiene
Liver	Aldrin Carbon tetrachloride Chloroform Chlorobenzene Chlordane, total CPMS CPMSO $CPMSO_2$ Dibromochloropropane Dicyclopentadiene Dichlorobenzenes, total DDE DDT Dieldrin 1,4-Dithiane Endrin Ethylbenzene Isodrin Tetrachloroethene Trichloroethene
Ocular	Toluene
Renal	Chlorobenzene Dibromochloropropane Ethylbenzene
Respiratory	1,2-Dichloroethane Toluene Xylenes, total
Skin	Arsenic, total

[1] Based on acute effects (EPA, 1989b).

Table 4.1.1-1: Summary of Residential Hypothetical Future Carcinogenic Risks: Reasonable Maximum Exposure

Zone	Combined Cancer Risk[1]	Major Chemicals of Concern[2]
1A	$<1 \times 10^{-4}$	Arsenic, atrazine, dieldrin
1B	$<1 \times 10^{-4}$	Arsenic, atrazine, dieldrin
1C	$<1 \times 10^{-4}$	Arsenic, atrazine, dieldrin
2	$<2 \times 10^{-4}$	Aldrin, arsenic, atrazine, chloroform, dibromochloropropane, dieldrin, tetrachloroethene
3	$<3 \times 10^{-4}$	Aldrin, atrazine, dieldrin, tetrachloroethene
4	$<2 \times 10^{-4}$	Aldrin, arsenic, atrazine, chlordane, 1,2-dichloroethane, dieldrin
6	7×10^{-5}	Aldrin, arsenic, dieldrin

Risks are rounded to one significant figure (EPA, 1989a).

[1] Includes all chemicals, all pathways, RME intakes, and 95 percent upper confidence limit. (The actual risk at the RME intake may be three-fold less, based on the uncertainty analysis.) The "less than" symbol (<) indicates risk is upper-bound risk and that the true RME risk is less than the risk indicated.

[2] These Chemicals of Concern account for more than 90 percent of risk.

RME = reasonable maximum exposure

Table 4.1.1-2: Summary of Residential Child Chronic Combined Noncarcinogenic Hazard Indices (HIs >1)

Zone	Target Organ/System	Hazard Index[1]	Chemicals of Concern[2]
2	Liver	2	Chloroform, dieldrin
	CNS	1.3	Manganese
3	Liver	2	Dicyclopentadiene, dieldrin
4	Liver	1.4	Chlordane
	CNS	4	DIMP[3]

[1] All chemicals in target system category, all pathways, RME intakes.
[2] Elimination of these Chemicals of Concern would reduce HI <1.
[3] CNS effects based on acute effects (EPA, 1989b).

CNS = central nervous system
RME = reaasonable maximum exposure

Table 4.1.1-3: Contribution of Dieldrin and Other Chemicals to the Child Acute Hepatic Hazard Index

Chemical	Hazard Index by Contamination Zone						
	1A	1B	1C	2	3	4	6
Dieldrin	0.76	0.96	0.76	1.0	3.8	1.5	0.76
Other	0.05	0.06	0.05	0.2	0.2	0.2	0.05
Total	0.81	1.02	0.81	1.2	4.0	1.7	0.81

Table 4.1.1-4: Summary of Residential Hypothetical Future Reasonable Maximum Exposure Subchronic Hazard Indices: Children

Zone	Chemical Target System	RME Subchronic Hazard Index (Possible Range)[1]	Hepatic Total Hazard Index (Possible Range)[1]
1B	Dieldrin (H)		
2	Chloroform (H) Dieldrin (H) Manganese (CNS)	2 - 4 1.1 - 3 0.9 - 2	4 - 7
3	Chlordane (H) Dieldrin (H)	0.8 - 2 4 - 10	5 - 14
4	Chlordane (H) Dieldrin (H) Manganese (CNS)	3 - 5 3 - 7 1.1 - 2	6- 13
5	Dieldrin (H)	1.3 - 4	2 - 4
6	Dieldrin (H)	1 - 3	1.2 - 3

[1] Low end of range is RME chronic intake divided by subchronic reference dose. High end of range is RME acute intake divided by subchronic reference dose.

CNS = central nervous system
H = hepatic (liver)
RME = reasonable maximum exposure
S = skin

Table 4.1.1-5: Summary of Residential Hypothetical Future Reasonable Maximum Exposure Subchronic Hazard Indices: Adult Females

Zone	Chemical Target System	RME Subchronic Hazard Index (Possible Range)[1]	Hepatic Total Hazard Index (Possible Range)[1]
3	Dieldrin (H)	0.5 - 1.5	0.8 - 2
4	Dieldrin (H) Manganese (CNS)	0.2 - 0.6 0.7 - 1.1	0.6 - 1.3

[1] Low end of range is RME chronic intake divided by subchronic reference dose. High end of range is RME acute intake by subchronic reference dose.

CNS = central nervous system
H = hepatic (liver)
RME = reasonable maximum exposure

Table 4.1.1-6: Comparison of Residential Reasonable Maximum Exposure and Most Likely Exposure Hypothetical Future Carcinogenic Risks by Zone

Zone	RME	MLE	RME : MLE
1A	1×10^{-4}	1×10^{-5}	8:1
1B	1×10^{-4}	1×10^{-5}	9:1
1C	1×10^{-4}	1×10^{-5}	8:1
2	2×10^{-4}	2×10^{-5}	12:1
3	3×10^{-4}	2×10^{-5}	12:1
4	2×10^{-4}	3×10^{-5}	8:1
6	7×10^{-5}	6×10^{-6}	12:1

Risks include all chemicals and all pathways at the upper 95 percent confidence level RME intake. RME risks may be overstated by three-fold, based on the uncertainty analysis.

MLE = most likely exposure
RME = reasonable maximum exposure

Table 5.1.2-1: Wildlife Species Observed in Offpost Operable Unit: Winter 1989-90

Mammals	
Coyote	*Canis latrans*
Striped (Common) skunk	*Mephitis mephitis*
Red fox	*Vulpes vulpes*
Black-tailed jackrabbit	*Lepus californicus*
Eastern cottontail	*Sylvilagus floridanus*
Desert cottontail	*Sylvilagus auduboni*
Black-tailed prairie dog	*Cynomys ludovicianus*
Deer mouse	*Peromyscus maniculatus*
House mouse	*Mus musculus*
Meadow vole	*Microtus pennsylvanicus*
Northern pocket gopher	*Thomomys talpoides*
Mule deer	*Odocoileus hemionus*
Raptors	
Northern harrier	*Circus cyaneus*
Ferruginous hawk	*Buteo regalis*
Golden eagle	*Aguila chrysaetos*
Other Bird Species	
Ring-necked pheasant	*Phasianus colchicus*
Mallard	*Anas platyrhynchos*
Killdeer	*Charadrius vociferus*
American white pelican	*Pelecanus erythrorhynchos*
Great blue heron	*Ardea herodias*
Western meadowlark	*Sturnella neglecta*
Red-winged blackbird	*Agelaius phoeniceus*

Table 5.1.4-1: Chemicals of Concern and Tissue Chemicals of Concern for the Offpost Ecological Risk Assessment

Analyte	Media				
	Ground-water	Surface Water	Soil	Sediment	Biota
Aldrin	x		x		x
Arsenic[1]	x	x		x	x
Atrazine	x				
Benzene	x				
Carbon tetrachloride	x				
Chlorobenzene	x				
Chlordane	x	x	x		
Chloride	x	x			
Chloroform	x				
CPMS	x				
CPMSO	x				
$CPMSO_2$	x				
Dibromochloropropane	x				
Dichlorobenzene	x				
1,2-Dichloroethane	x				
Dicyclopentadiene	x				
DDE[1]	x	x	x	x	x
DDT[1]	x	x	x	x	x
Dieldrin[1]	x	x	x	x	x
DIMP	x	x			
Dithiane	x				
Endrin[1]	x		x	x	x
Ethylbenzene	x				
Fluoride	x	x			
Hexachlorocyclopentadiene	x				
Isodrin	x				
Manganese	x				
Malathion	x				
Oxathiane	x				
Sulfate	x	x			
Tetrachloroethene	x				
Toluene	x				
Trichloroethene	x				
Xylene	x				

[1] Also a tissue chemical of concern.

Table 5.2.1-1: Terrestrial Species Selected as Indicators of Ecological Impacts

	Species Relation to Selection Criteria[2]								
Species[1]	1	2	3	4	5	6	7	8	9
Earthworm (sp.)	x	x		x				x	x
Grasshopper (sp.)	x	x		x				x	x
Deer mouse (sp.)	x	x		x				x	x
Prairie dog	x	x		x			x	x	x
Shrew								x	x
Vole	x			x				x	x
Ground squirrel		x						x	x
Skunk	x	x							
Raccoon		x							
Fox	x	x							
Coyote	x	x							
Mule deer	x	x				x	x		
White-tail deer		x				x	x		
Bald eagle	x	x	x		x		x	x	x
Golden eagle	x	x			x		x	x	x
Ferruginous hawk	x	x					x	x	x
Burrowing owl		x					x	x	x
Prairie falcon		x					x	x	x
Red-tailed hawk		x					x	x	x
Swainson's hawk		x					x	x	x
Northern harrier	x	x					x	x	x
Great-horned owl		x					x	x	x
American kestrel	x	x	x				x	x	x
Peregrine falcon					x		x	x	x
Pheasant	x	x		x		x		x	x

[1] Species in bold were selected as representative nonhuman terrestrial wildlife receptors or indicators.
[2] Selection criteria identified in Section 5.2, Exposure Assessment, of this report.

Table 5.2.1-2: Aquatic/Wetland Species in Relation to Indicator Species Selection Criteria

	Species Relation to Selection Criteria								
Species[1]	1	2	3	4	5	6	7	8	9
Green algae	x	x		x				x	x
Vascular plants	x	x							
Crayfish	x			x				x	
Fathead minnow				x				x	x
Centrarchid fish						x	x	x	x
Mallard	x	x	x			x	x	x	x
Pelican	x		x				x	x	x
Great blue heron	x	x					x	x	x
Bald eagle		x	x		x		x	x	x
Other waterfowl		x				x	x	x	x
Other shorebirds	x	x						x	x
Other raptors	x	x					x	x	x

[1] Species in bold were selected as representative nonhuman aquatic wildlife receptors.

Table 5.2.2-1: Potential Exposure Pathways for Biota

Contaminated Media	Route of Exposure	Exposure Point	Receptor[1]
Soil	Ingestion	Areas near the north boundary where soil has elevated concentrations with respect to background	Terrestrial mammals or birds
Surface water	Ingestion	From First Creek, First Creek Impoundment, or other surface-water bodies	Aquatic, terrestrial, avian, or mammalian species
Surface water	Direct contact	From First Creek, First Creek Impoundment, or other surface-water by aquatic life	Aquatic life
Sediment	Ingestion Direct contact	From First Creek, First Creek Impoundment, or other surface-water by aquatic life	Aquatic life
Groundwater	Ingestion	From shallow wells in the offpost area	Livestock
Groundwater	Direct contact	From shallow wells in the offpost area	Crops
Biota (plant)	Plant uptake	From contaminated soil and irrigation water	Crops
Biota (animal)	Ingestion of biota	From any area with contaminated biota in the offpost area	Aquatic or terrestrial consumers

[1] Refers to receptors from Tables 5.2.1-1 and 5.2.1-2.

Table 5.2.3-1: Exposure Point Concentrations for Soil, Surface Water, and Sediment Used for the Offpost Ecological Assessment

COC	Soil[1] (µg/kg)	Surface Water[1] (µg/l)	Sediment[1] (µg/kg)
Aldrin	5.08	NA	17
Arsenic	NA	3.5	NA
Chlordane	17.90	0.18	ND
DDE	4.12	0.05	3
DDT	9.49	0.05	5
DIMP	NA	11.9	NA
Dieldrin	43.45	0.12	18
Endrin	8.55	NA	6
Fluoride	NA	1706	NA
Sulfate	NA	282,840	NA

[1] Geometric mean.

µg/kg = micrograms per kilogram
µg/l = micrograms per liter
COC = chemical of concern
DDE = 2,2-Bis(p-chlorophenyl)-1,1-dichloroethene
DDT = 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane
DIMP = diisopropylmethylphosphonate
NA = not applicable
ND = not detected

Table 5.2.5.1-1: Dietary Fractions for Each of the Species in the Terrestrial Food Web

Species	Diet	Fraction[1]	Major Species
Earthworms	Soil	0.99	Worm
Plants	Soil	1.0	Plant
Insects	Plants	1.0	Insect
Deer mice	Plants	0.47	Small mammal
	Earthworms	0.03	
	Insects	0.48	
	Soil	0.02	
Prairie dogs	Plants	0.88	Medium mammal
	Soil	0.08	
	Insects	0.04	
Pheasants	Plants	0.17	Small bird
	Insects	0.72	
	Soil	0.06	
	Earthworm	0.05	
Owls	Small mammals	0.665	Raptor
	Medium mammals	0.25	
	Small bird	0.055	
	Soil	0.03	
Kestrels	Small mammals	0.093	Raptor
	Insects	0.86	
	Small bird	0.017	
	Soil	0.03	
Eagles	Medium mammals	0.915	Raptor
	Small bird	0.019	
	Small mammal	0.005	
	Soil	0.03	

[1] Source: Ebasco, 1992 (See Appendix H7).

Table 5.2.5.2-1: Predicted Tissue Concentrations (mg/kg) for the Terrestrial Food Web Ecological Receptors

Receptor	Aldrin	Dieldrin	Endrin	DDE	DDT
American kestrel	0.01	0.11	0.04	1.33	3.60
Great horned owl	0.01	0.10	0.04	0.72	1.66
Bald eagle	0.00	0.00	0.00	0.00	0.00
Prairie dog	0.01	0.06	0.01	0.03	0.07
Deer mouse	0.01	0.11	0.12	0.54	1.24
Pheasant	0.01	0.07	0.09	0.27	0.62
Insect	0.00	0.04	0.01	0.18	0.43
Worm	0.03	0.26	0.25	0.01	0.03
Plant	0.00	0.02	0.00	0.01	0.01

DDT = 2,2-Bis(p-chlorophenyl)-1,1-dichloroethene
DDT = 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane
mg/kg = milligrams per kilogram

Table 5.2.5.4-1: Predicted Tissue Concentrations (mg/kg) for the Aquatic Food Web Ecological Receptors on the Basis of Surface-Water Concentrations

Receptor	Aldrin	Dieldrin	Endrin	DDE	DDT	Arsenic
Bald eagle	0.0	0.0	0.0	0.0	0.0	0.0
Great blue heron	0.0	0.2	0.0	1.1	1.1	0.0
Mallard duck	0.0	0.6	0.0	0.4	0.2	4.2
Small fish	0.0	2.0	0.0	3.5	3.5	0.1
Invertebrates	0.0	1.1	0.0	0.5	0.5	0.1
Algae	0.0	0.0	0.0	0.1	0.1	1.5

DDE = 2,2-Bis(p-chlorophenyl)-1,1-dichloroethene
DDT = 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane
mg/kg = milligrams per kilogram

Table 5.2.5.4-2: Predicted Tissue Concentrations (mg/kg) for the Aquatic Food Web Ecological Receptors on the Basis of Sediment Concentrations

Receptor	Aldrin	Dieldrin	Endrin	DDE	DDT	Arsenic
Bald eagle	0.000	0.000	0.000	0.000	0.000	0.000
Great blue heron	0.000	0.000	0.000	0.000	0.000	0.000
Mallard duck	0.004	0.004	0.000	0.002	0.003	0.000
Small fish	0.000	0.000	0.000	0.001	0.001	0.000

DDE = 2,2-Bis(p-chlorophenyl)-1,1-dichloroethene
DDT = 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane
mg/kg = milligrams per kilogram

Table 5.3.1-1: Summary of Intakes From Zone 3 Soil, Surface Water, and Diet for the Bald Eagle

COC	Soil and Water Intake (mg/kg-bw/day)	Aquatic Dietary Intake (mg/kg-bw/day)	Terrestrial Dietary Intake (mg/kg-bw/day)	Total Intake (mg/kg-bw/day)	TRV (mg/kg-bw/day)	HQ
Aldrin	1.4E-07	NA	7.5E-07	8.9E-07	2.8E-03	<1
Arsenic	8.8E-04	7.6E-06	NA	8.8E-04	3.0E-02	<1
Chlordane	5.2E-07	NA	NA	5.2E-07	4.4E-03	<1
DDE	1.2E-07	7.2E-07	2.8E-06	3.7E-06	2.7E-02	<1
DDT	2.7E-07	3.6E-07	6.6E-06	7.2E-06	2.7E-02	<1
DIMP	2.7E-06	NA	NA	2.7E-06	3.8E-01	<1
Dieldrin	1.2E-06	1.1E-06	4.5E-06	6.8E-06	2.8E-03	<1
Endrin	2.3E-07	NA	9.2E-07	1.1E-06	9.4E-03	<1
Fluoride[1]	3.8E-04	NA	NA	3.8E-04	6.6E-01	<1
Sulfate[1]	6.4E-02	NA	NA	6.4E-02	4.7E+00	<1

TRVs reported in Table 3.3.3-1. Other raptors represented by bald eagle TRV.

[1] Cannot be addressed for dietary intake because (1) chemical is a naturally occurring component of diet or (2) cannot be modeled because of a lack of data.

COC = chemical of concern
DDE = 2,2-Bis(p-chlorophenyl)-1,1-dichloroethene
DDT = 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane
DIMP = diisopropylmethylphosphonate
HQ = hazard quotient
mg/kg-bw/day = milligrams per kilogram of body weight per day
NA = not applicable
TRV = toxicity reference value

Table 5.3.1-2: Summary of Intakes From Zone 3 Soil, Surface Water, and Diet for the American Kestrel

COC	Soil and Water Intake (mg/kg-bw/day)	Terrestrial Dietary Intake (mg/kg-bw/day)	Total Intake (mg/kg-bw/day)	TRV (mg/kg-bw/day)	HQ
Aldrin	3.0E-05	1.7E-04	2.0E-04	3.1E-03	<1
Arsenic	1.8E-04	NA	1.8E-04	2.4E-02	<1
Chlordane	1.2E-04	NA	1.2E-04	8.8E-03	<1
DDE	2.7E-05	3.7E-03	3.8E-03	3.1E-02	<1
DDT	5.9E-05	8.8E-03	8.9E-03	3.1E-02	<1
DIMP	6.0E-04	NA	6.0E-04	7.5E-01	<1
Dieldrin	2.7E-04	8.2E-04	1.1E-03	3.1E-03	<1
Endrin	5.1E-05	3.8E-04	4.3E-04	3.8E-04	1
Fluoride[1]	8.5E-02	NA	8.5E-02	1.8E+00	<1
Sulfate[1]	1.4E+01	NA	1.4E+01	9.4E+00	2

TRVs reported in Table 3.3.3-1.

[1] Cannot be addressed for dietary intake because (1) chemical is a naturally occurring component of diet or (2) cannot be modeled because of a lack of data.

COC = chemical of concern
DDE = 2,2-Bis(p-chlorophenyl)-1,1-dichloroethene
DDT = 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane
DIMP = diisopropylmethylphosphonate
HQ = hazard quotient
mg/kg-bw/day = milligrams per kilogram - body weight per day
NA = not applicable
TRV = toxicity reference value

Table 5.3.1-3: Summary of Intakes From Zone 3 Soil, Surface Water, and Diet for the Great Horned Owl

COC	Soil and Water Intake (mg/kg-bw/day)	Terrestrial Dietary Intake (mg/kg-bw/day)	Total Intake (mg/kg-bw/day)	TRV (mg/kg-bw/day)	HQ
Aldrin	9.1E-06	5.2E-05	6.1E-05	2.5E-02	<1
Arsenic	5.3E-05	NA	5.3E-05	2.4E-02	<1
Chlordane	3.5E-05	NA	3.5E-05	8.8E-03	<1
DDE	8.2E-06	2.0E-03	2.0E-03	3.0E-02	<1
DDT	1.8E-05	4.7E-03	4.7E-03	3.0E-02	<1
DIMP	1.8E-04	NA	1.8E-04	7.5E-01	<1
Dieldrin	8.0E-05	4.9E-04	5.7E-04	2.5E-02	<1
Endrin	1.5E-05	4.7E-04	4.8E-04	3.0E-03	<1
Fluoride[1]	2.6E-02	NA	2.6E-02	1.8E+00	<1
Sulfate[1]	4.2E+00	NA	4.2E+00	9.4E+00	<1

TRVs reported in Table 3.3.3-1.

[1] Cannot be addressed for dietary intake because (1) chemical is a naturally occurring component of diet or (2) cannot be modeled because of a lack of data.

COC = chemical of concern
DDE = 2,2-Bis(p-chlorophenyl)-1,1-dichloroethene
DDT = 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane
DIMP = diisopropylmethylphosphonate
HQ = hazard quotient
mg/kg-bw/day = milligrams per kilogram - body weight per day
NA = not applicable
TRV = toxicity reference value

Table 5.3.1-4: Summary of Intakes From Zone 3 Soil, Surface Water, and Diet for the Deer Mouse

COC	Soil and Water Intake (mg/kg-bw/day)	Dietary Intake (mg/kg-bw/day)	Total Intake (mg/kg-bw/day)	TRV (mg/kg-bw/day)	HQ
Aldrin	1.0E-04	9.0E-05	1.9E-04	2.7E-02	<1
Arsenic	8.8E-04	NA	8.8E-04	9.1E-02	<1
Chlordane	4.0E-04	NA	4.0E-04	7.5E-02	<1
DDE	9.5E-05	8.7E-03	8.8E-03	1.1E-01	<1
DDT	2.0E-04	2.1E-02	2.1E-02	1.1E-01	<1
DIMP	3.0E-03	NA	3.0E-03	1.9E+01	<1
Dieldrin	9.0E-04	2.7E-03	3.6E-03	2.7E-02	<1
Endrin	1.7E-04	1.2E-03	1.4E-03	1.8E-03	<1
Fluoride[1]	4.3E-01	NA	4.3E-01	1.6E-01	3
Sulfate[1]	7.1E+01	NA	7.1E+01	9.4E+00	7

Mammals were conservatively assumed to ingest the same amount of water per unit body weight as avian species.

[1] Cannot be addressed for dietary intake because (1) chemical is a naturally occurring component of diet or (2) cannot be modeled because of a lack of data.

< = less than
BAF = bioaccumulation factor
COC = chemical of concern
DDE = 2,2-Bis(p-chlorophenyl)-1,1-dichloroethene
DDT = 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane
DIMP = diisopropylmethylphosphonate
HQ = hazard quotient
mg/kg-bw/day = milligrams per kilogram - body weight per day
NA = not applicable
TRV = toxicity reference value

Table 5.3.1-5: Summary of Intakes From Zone 3 Soil, Surface Water, and Diet for the Prairie Dog

COC	Soil and Water Intake[1] (mg/kg-bw/day)	Dietary Intake (mg/kg-bw/day)	Total Intake (mg/kg-bw/day)	TRV (mg/kg-bw/day)	HQ
Aldrin	4.1E-04	0.0E+00	4.1E-04	2.7E-02	<1
Arsenic	8.8E-04	NA	8.8E-04	9.1E-02	<1
Chlordane	1.5E-03	NA	1.5E-03	7.5E-02	<1
DDE	3.4E-04	1.6E-03	1.9E-03	3.8E-02	<1
DDT	7.7E-04	2.6E-03	3.4E-03	3.8E-02	<1
DIMP	3.0E-03	NA	3.0E-03	9.4E+00	<1
Dieldrin	3.5E-03	1.9E-03	5.4E-03	2.7E-02	<1
Endrin	6.8E-04	4.0E-05	7.2E-04	1.8E-03	<1
Fluoride[2]	4.3E-01	NA	4.3E-01	1.6E-01	3
Sulfate[2]	7.1E+01	NA	7.1E+01	9.4E+00	7

[1] Mammals were conservatively assumed to ingest the same amount of water per unit body weight as avian species.

[2] Cannot be addressed for dietary intake because (1) chemical is a naturally occurring component of diet or (2) cannot be modeled because of a lack of data.

< = less than
BAF = bioaccumulation factor
COC = chemical of concern
DDE = 2,2-Bis(p-chlorophenyl)-1,1-dichloroethene
DDT = 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane
DIMP = diisopropylmethylphosphonate
HQ = hazard quotient
mg/kg-bw/day = milligrams per kilogram - body weight per day
NA = not applicable
TRV = toxicity reference value

Table 5.3.2-1: Summary of Intakes From Zone 3 Sediment, Surface Water, and Diet for the Great Blue Heron

COC	Sediment and Water Intake (mg/kg-bw/day)	Aquatic Dietary Intake (mg/kg-bw/day)	Terrestrial Dietary Intake (mg/kg-bw/day)	Total Intake (mg/kg-bw/day)	TRV[2] (mg/kg-bw/day)	HQ
Aldrin	6.8E-04	NA	3.6E-05	7.2E-04	6.0E-02	<1
Arsenic	3.5E-05	3.0E-04	NA	3.3E-04	5.9E-02	<1
Chlordane	1.8E-06	NA	NA	1.8E-06	8.8E-03	<1
DDE	5.3E-06	4.9E-03	1.9E-03	6.8E-03	5.5E-02	<1
DDT	8.5E-06	4.9E-03	4.3E-04	5.3E-03	5.5E-02	<1
DIMP	1.2E-04	NA	NA	1.2E-04	7.5E-01	<1
Dieldrin	3.0E-05	3.3E-03	3.9E-04	3.7E-03	6.0E-02	<1
Endrin	9.6E-06	NA	4.3E-04	4.4E-04	1.9E-02	<1
Fluoride[1]	1.7E-02	NA	NA	1.7E-02	1.3E+00	<1
Sulfate[1]	2.8E+00	NA	NA	2.8E+00	9.4E+00	<1

[1] Cannot be addressed for dietary intake because (1) chemical is a naturally occurring component of diet or (2) cannot be modeled because of a lack of data.

[2] TRVs from Table 3.3.3-1.

< = less than
BCF = bioconcentration factor
COC = chemical of concern
DDE = 2,2-Bis(p-chlorophenyl)-1,1-dichloroethene
DDT = 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane
DIMP = diisopropylmethylphosphonate
HQ = hazard quotient
NA = not applicable
TRV = toxicity reference value

Table 5.3.2-2: Summary of Intakes From Zone 3 Sediment, Surface Water, and Diet for the Mallard Duck

COC	Sediment and Water Intake[1] (mg/kg-bw/day)	Dietary Intake (mg/kg-bw/day)	Total Intake (mg/kg-bw/day)	TRV[2] (mg/kg-bw/day)	HQ
Aldrin	6.8E-04	0.0E+00	6.8E-04	4.0E-02	<1
Arsenic	8.8E-04	9.7E-02	9.7E-02	4.7E-01	<1
Chlordane	4.5E-05	NA	4.5E-05	6.3E+00	<1
DDE	1.3E-04	1.0E-02	1.0E-02	1.0E-01	<1
DDT	2.1E-04	1.0E-02	1.0E-02	1.0E-01	<1
DIMP	3.0E-03	NA	3.0E-03	1.0E+01	<1
Dieldrin	7.5E-04	8.4E-03	9.1E-03	4.0E-02	<1
Endrin	2.4E-04	NA	2.4E-04	1.5E-01	<1
Fluoride[1]	4.3E-01	NA	4.3E-01	1.1E+01	<1
Sulfate[1]	7.1E+01	NA	7.1E+01	9.4E+00	7

[1] Cannot be addressed for dietary intake because (1) chemical is a naturally occurring component of diet or (2) cannot be modeled because of a lack of data.
[2] TRVs from Table 3.3.3-1.

< = less than
BCF = bioconcentration factor
COC = chemical of concern
DDE = 2,2-Bis(p-chlorophenyl)-1,1-dichloroethene
DDT = 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane
DIMP = diisopropylmethylphosphonate
HQ = hazard quotient
NA = not applicable
TRV = toxicity reference value

Table 5.3.4-1: Summary of Chicken Hazard Quotient by Zone, Offpost Operable Unit

COC	Intake (mg/kg/day)	TRV (mg/kg/day)	Hazard Quotient[1]
Soil Zones 1, 2, and 6			
Aldrin/dieldrin	1.6 E-06	2.6 E-03	< 1
DDE/DDT	3.6 E-06	5.5 E-02	< 1
Endrin	3.3 E-07	5.2 E-03	< 1

[1] Indicates the ratio of intakes to TRVs for chickens.

< = less than
COC = chemical of concern
DDE = 2,2-Bis(p-chlorophenyl)-1,1-dichloroethene
DDT = 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane
mg/kg/day = milligrams per kilogram per day

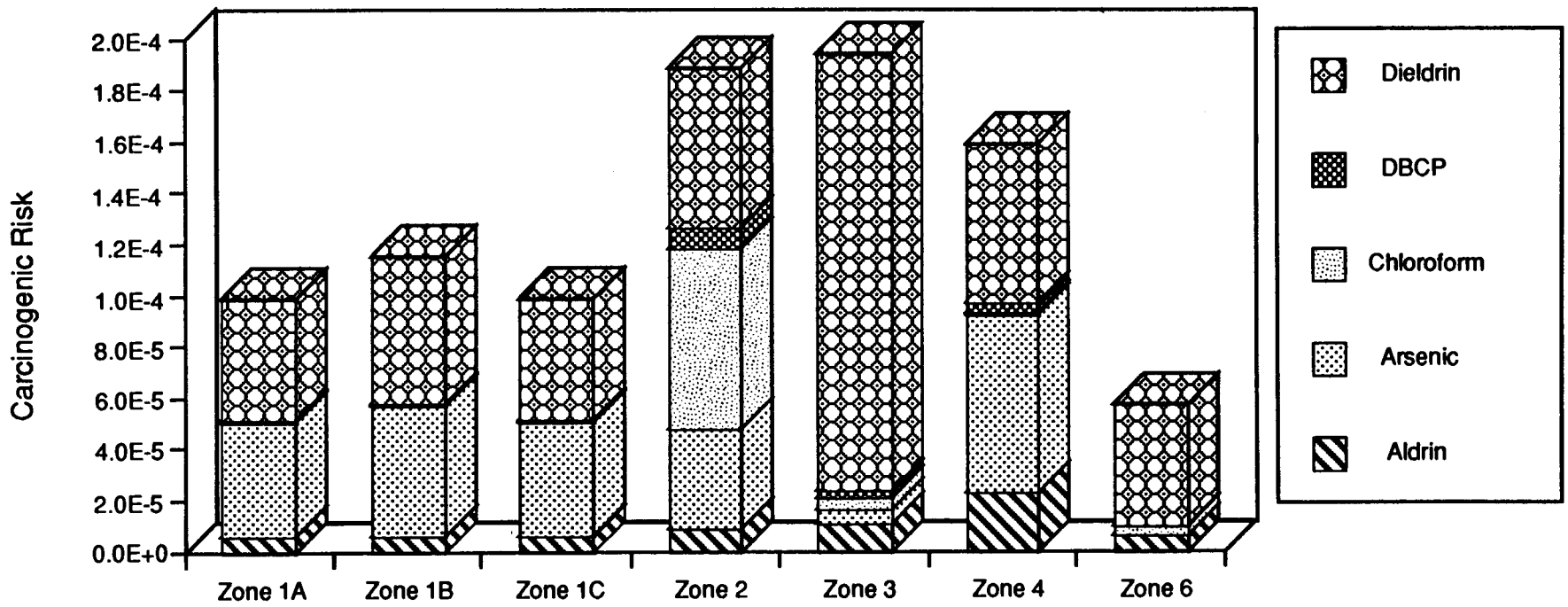

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Figure 4.1.1-1

OFFPOST OPERABLE UNIT COMBINED CARCINOGENIC RISKS (ALL PATHWAYS) BY GROUNDWATER ZONE - RESIDENTIAL SCENARIOS

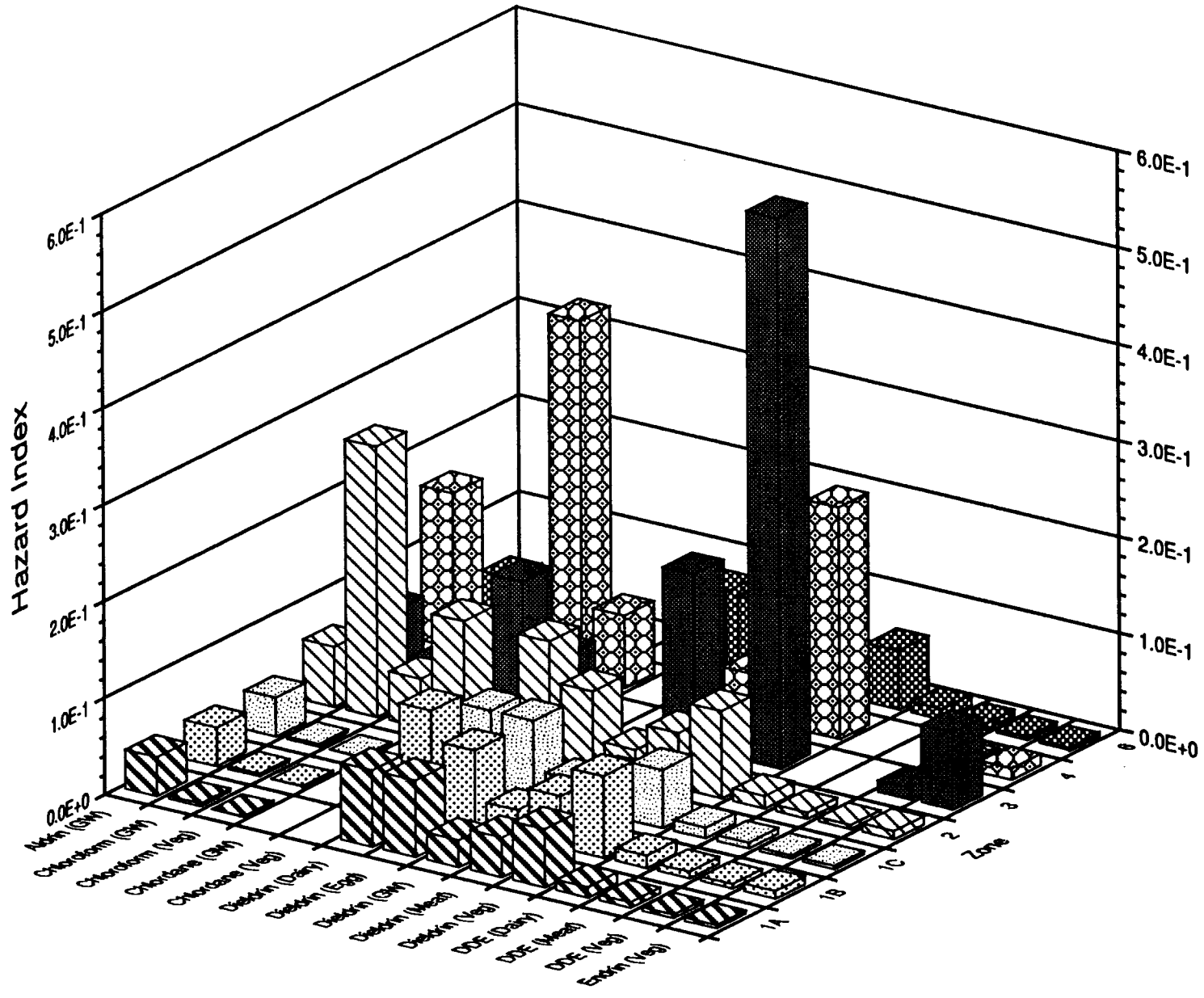

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Figure 4.1.1-2

OFFPOST OPERABLE UNIT CHILD RESIDENT HAZARD INDICES DESCRIBED FOR TOXIC CHEMICALS AND EXPOSURE PATHWAYS - RESIDENTIAL SCENARIOS

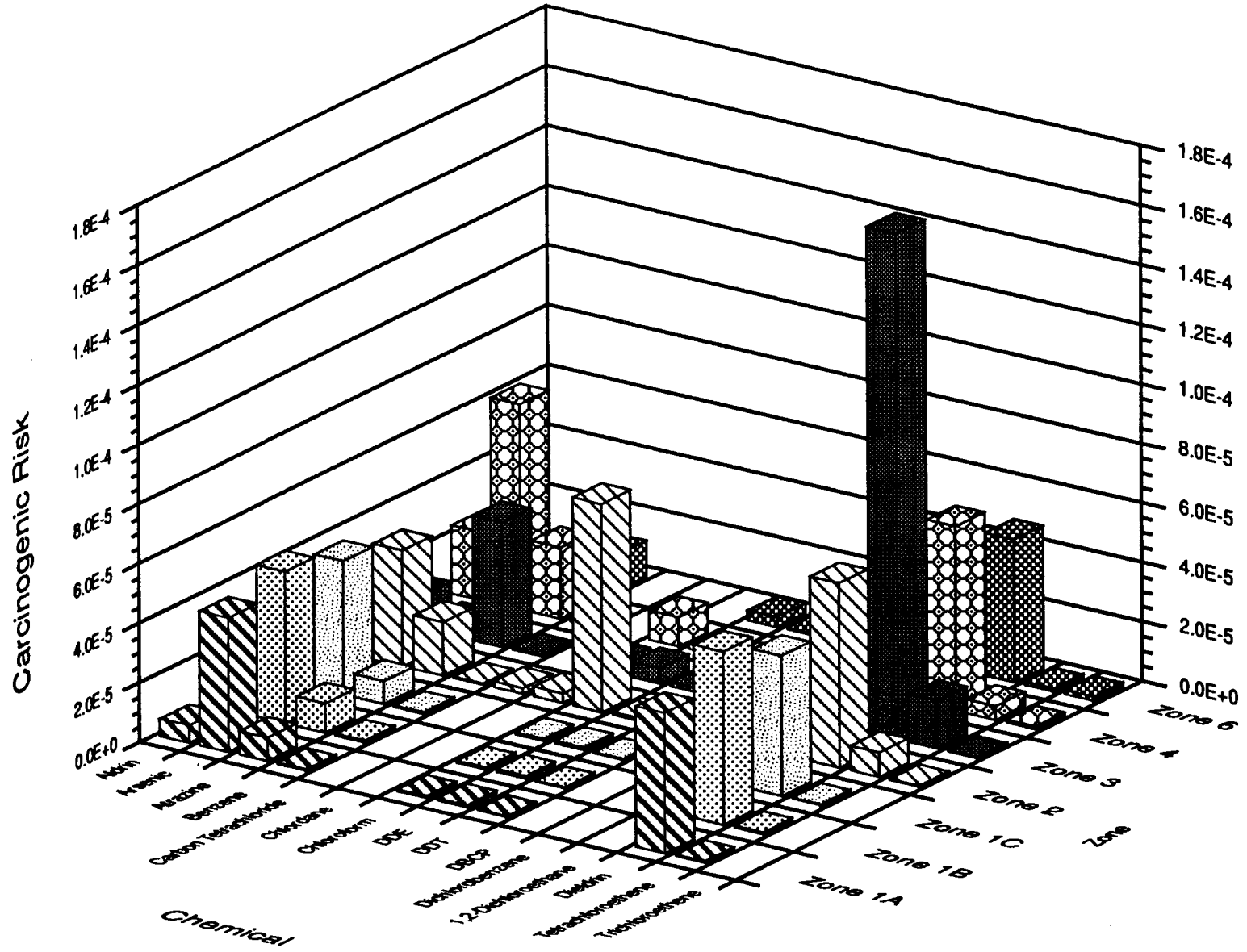

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Figure 4.1.1-3

OFFPOST OPERABLE UNIT CONTRIBUTORS TO CARCINOGENIC RISKS - RESIDENTIAL SCENARIO

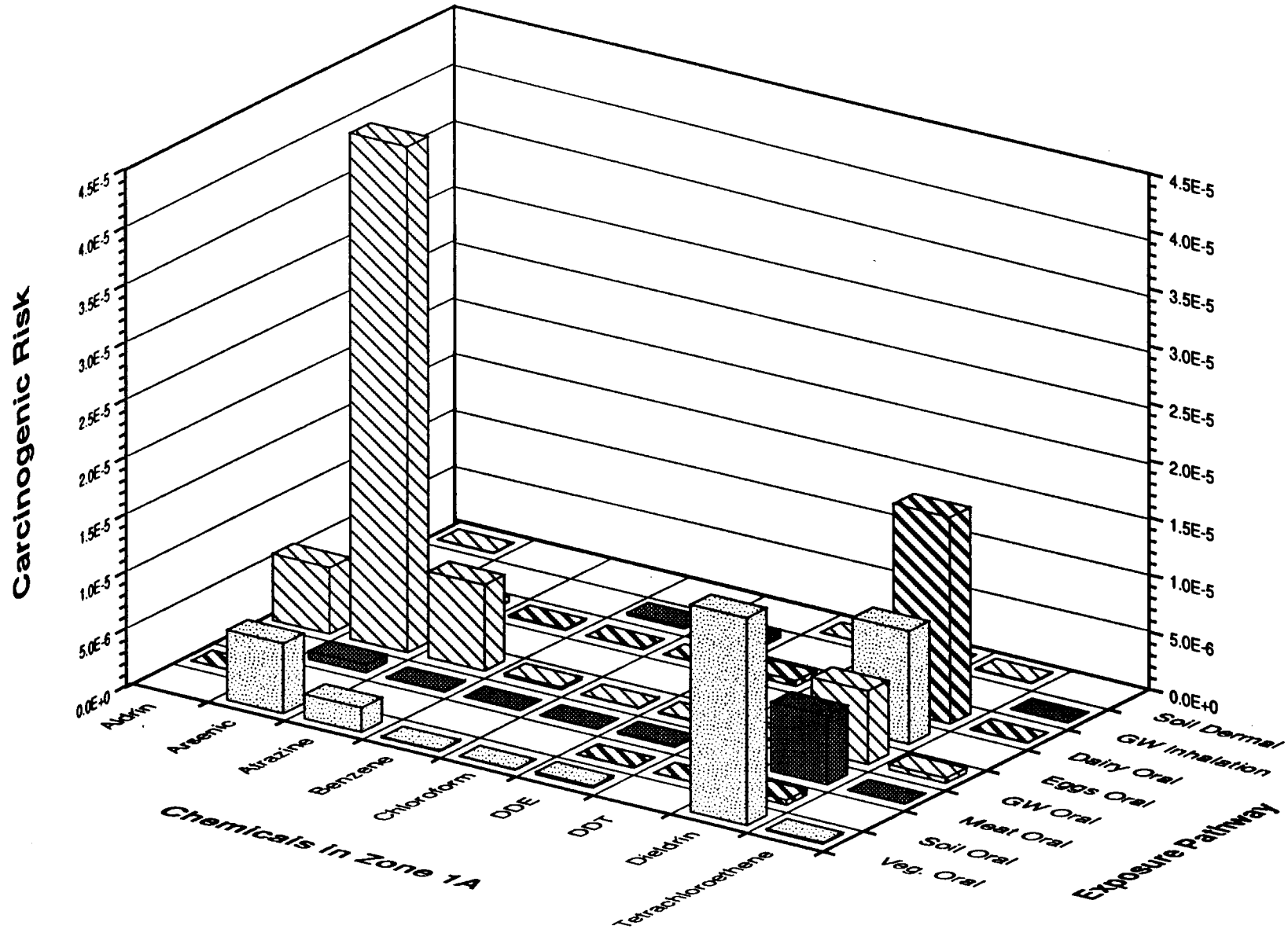

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Figure 4.1.1-4

CARCINOGENIC RISKS DESCRIBED BY CHEMICAL, MEDIUM, AND EXPOSURE PATHWAY-ZONE 1A, LIFETIME RURAL RESIDENT, RME

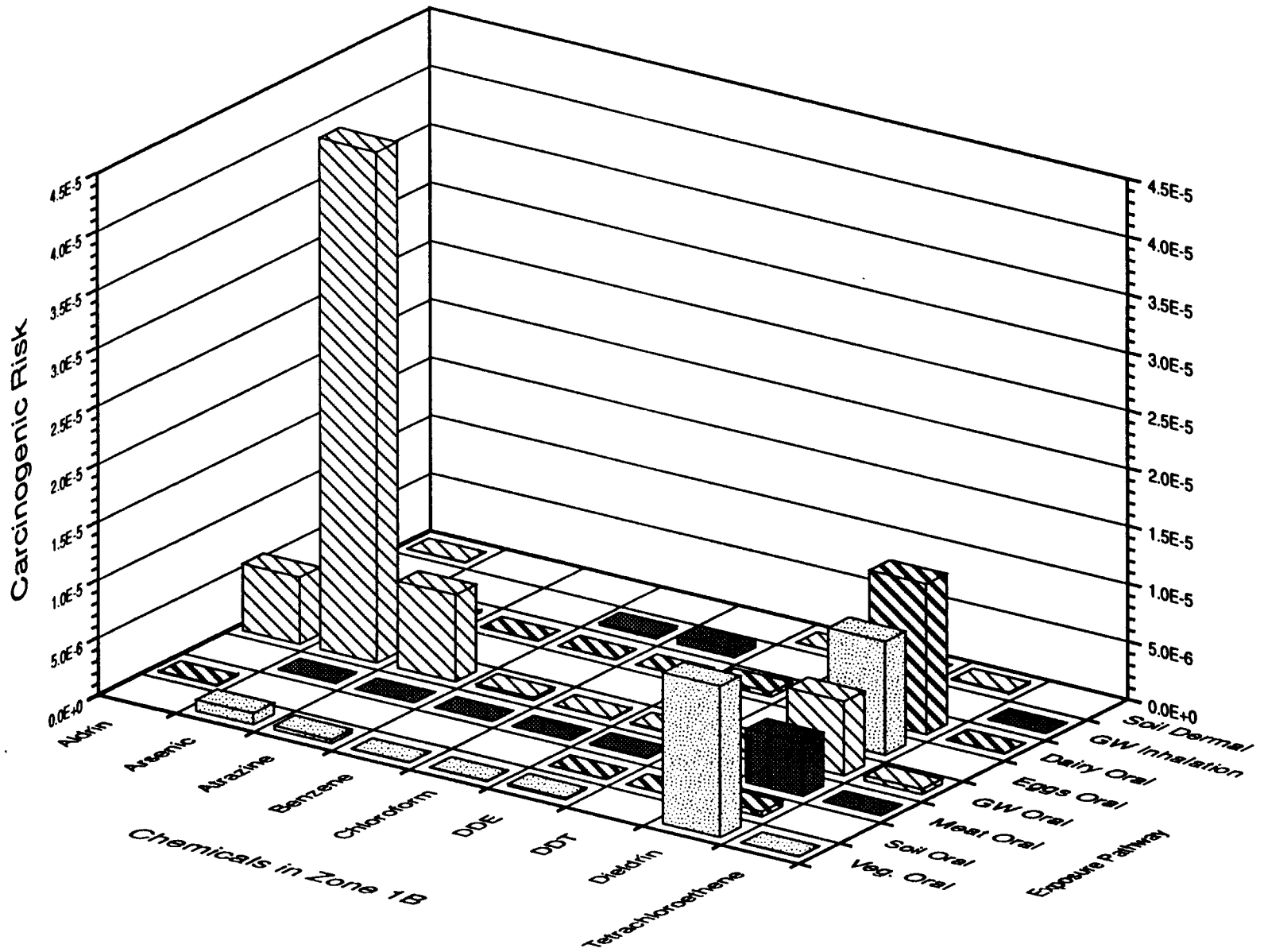

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Figure 4.1.1-5

CARCINOGENIC RISKS DESCRIBED BY CHEMICAL, MEDIUM, AND EXPOSURE PATHWAY-ZONE 1B, LIFETIME RURAL RESIDENT, RME

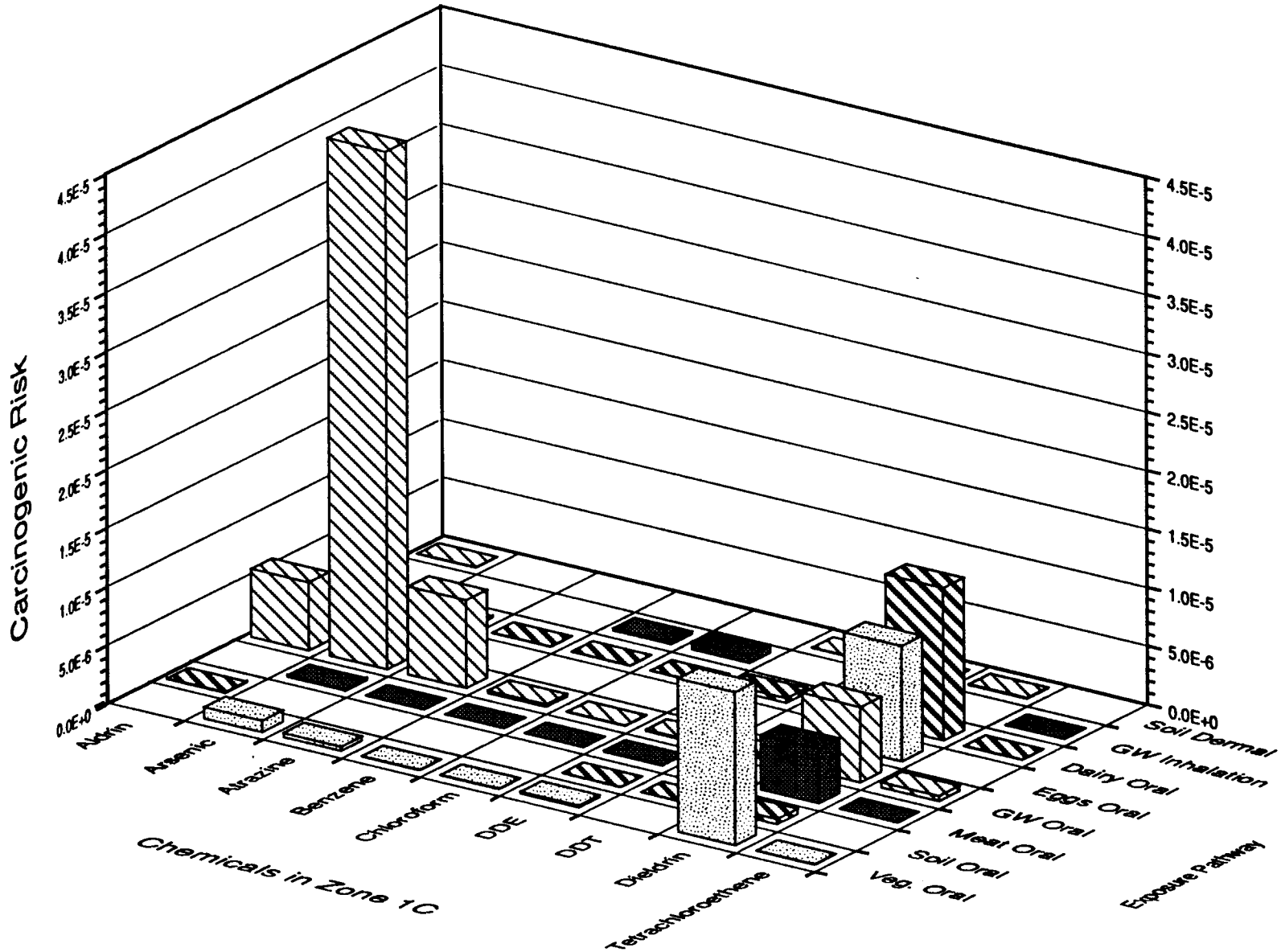

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Figure 4.1.1-6

CARCINOGENIC RISKS DESCRIBED BY CHEMICAL, MEDIUM, AND EXPOSURE PATHWAY-ZONE 1C, LIFETIME RURAL RESIDENT, RME

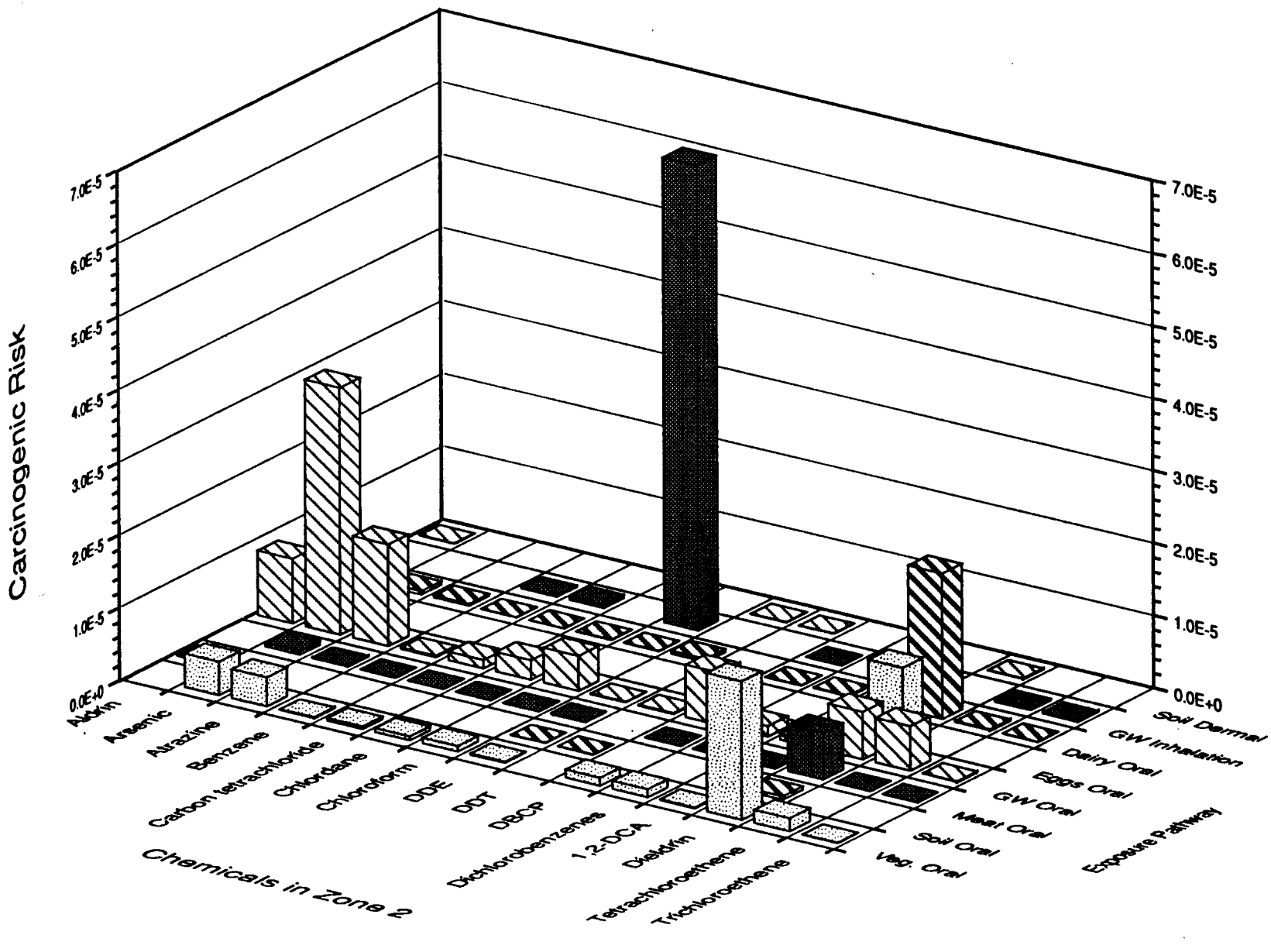

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Figure 4.1.1-7

CARCINOGENIC RISKS DESCRIBED BY CHEMICAL, MEDIUM, AND EXPOSRUE PATHWAY-ZONE 2, LIFETIME RURAL RESIDENT, RME

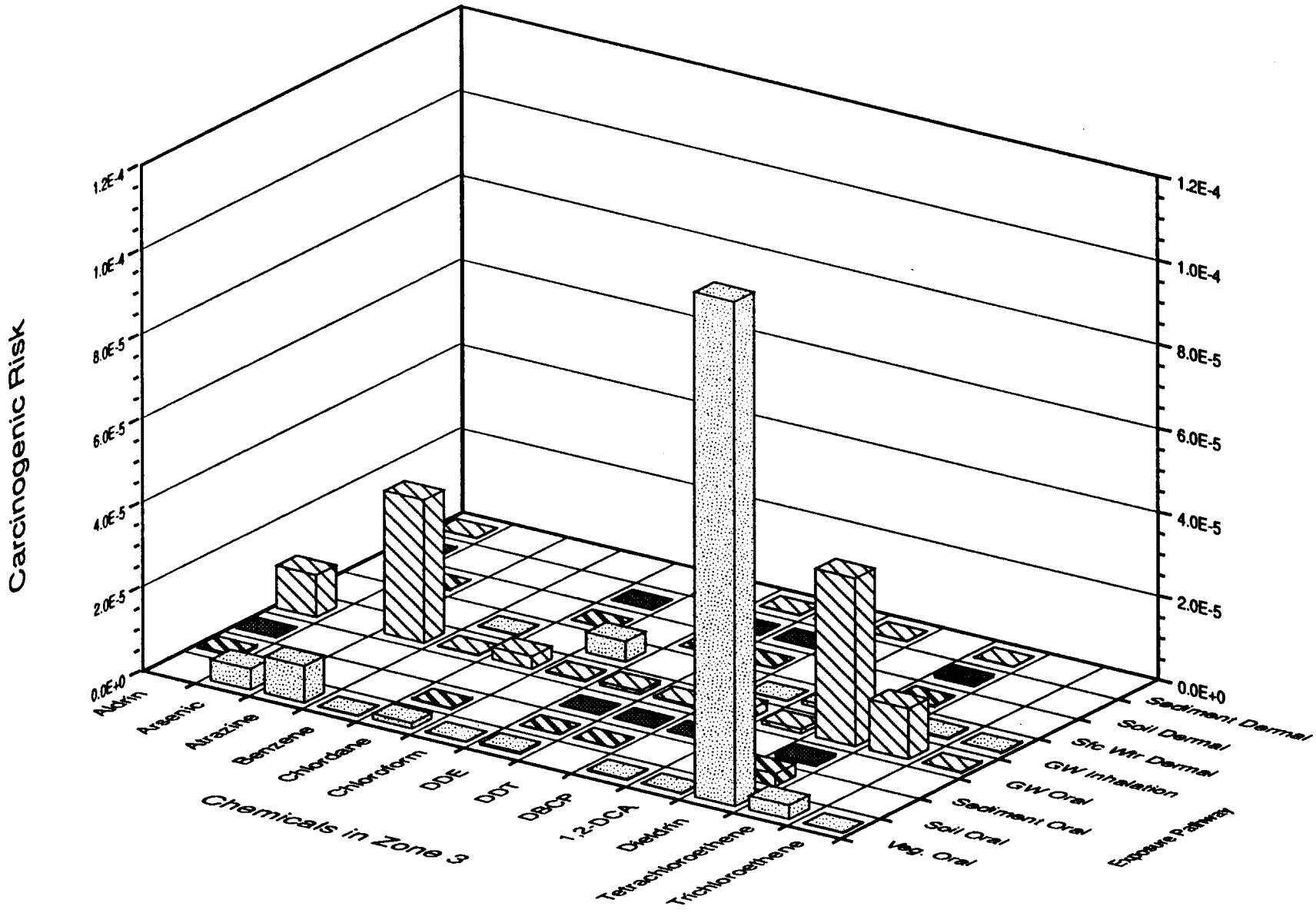

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Figure 4.1.1-8

CARCINOGENIC RISKS DESCRIBED BY CHEMICAL, MEDIUM, AND EXPOSURE PATHWAY-ZONE 3, LIFETIME URBAN RESIDENT, RME

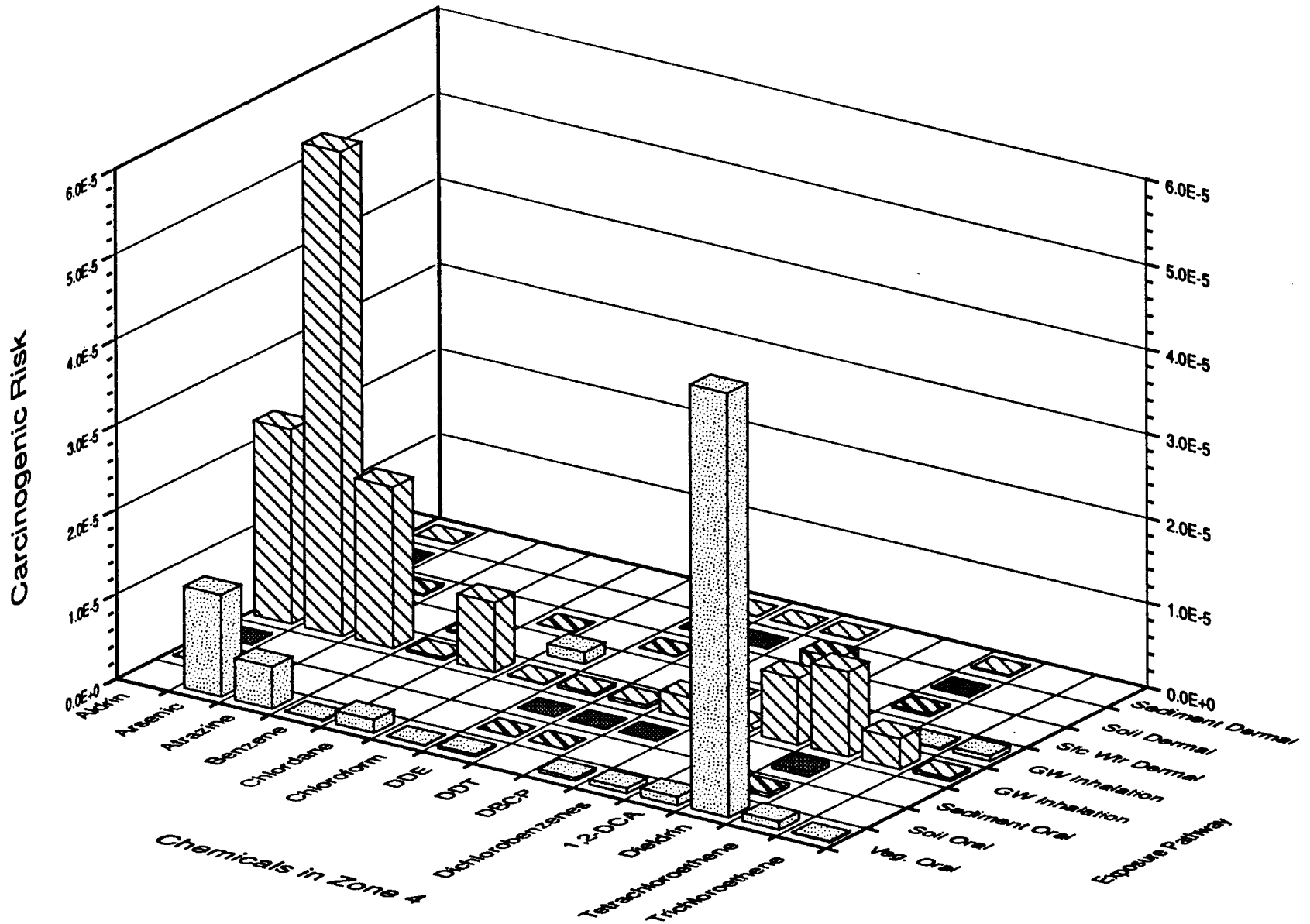

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Figure 4.1.1-9

CARCINOGENIC RISKS DESCRIBED BY CHEMICAL, MEDIUM, AND EXPOSURE PATHEWAY-ZONE 4, LIFETIME URBAN RESIDENT, RME

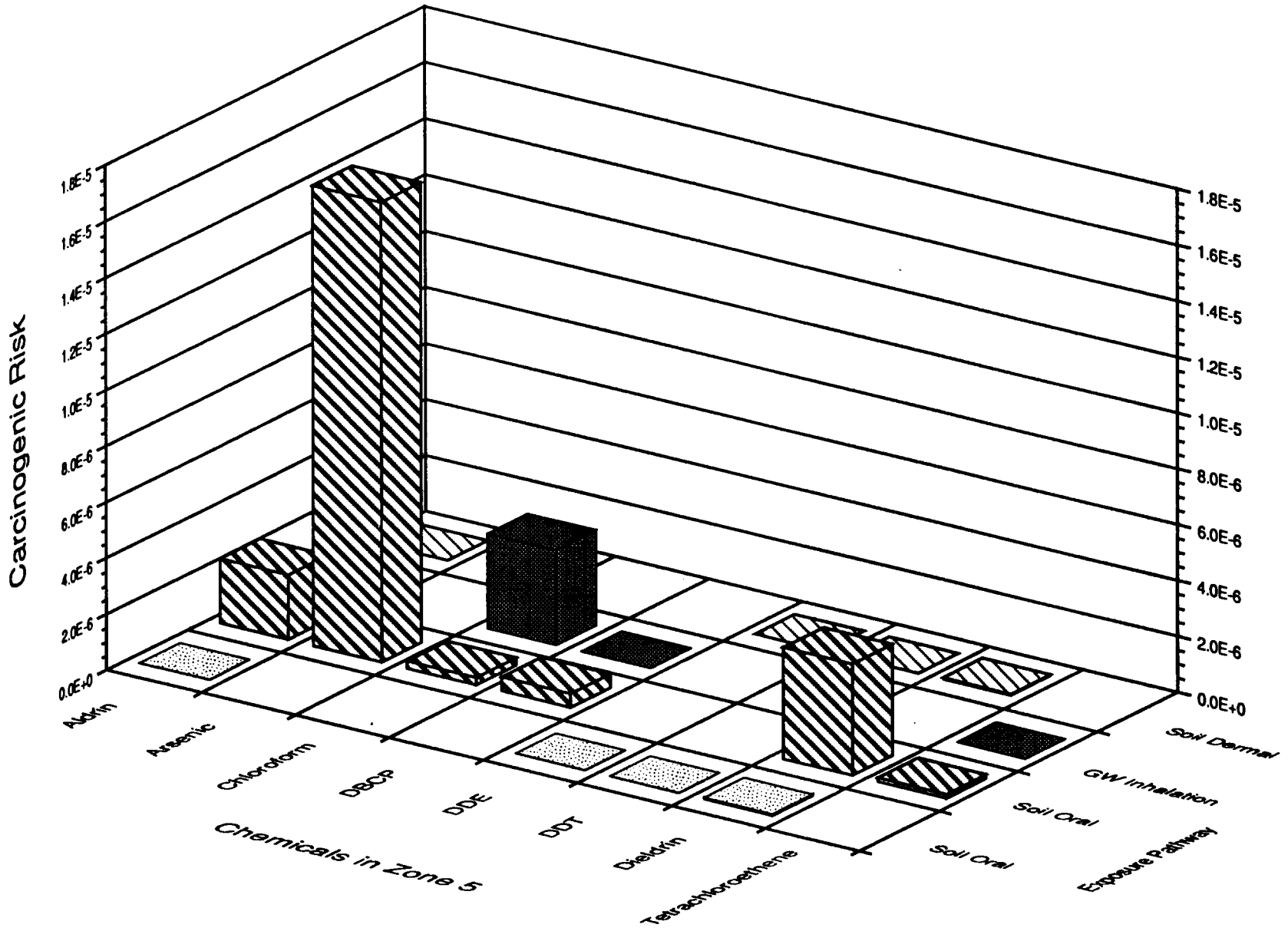

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Figure 4.1.1-10

CARCINOGENIC RISKS DESCRIBED BY CHEMICAL, MEDIUM, AND EXPOSURE PATHWAY-ZONE 5, COMMERCIAL/INDUSTRIAL, RME

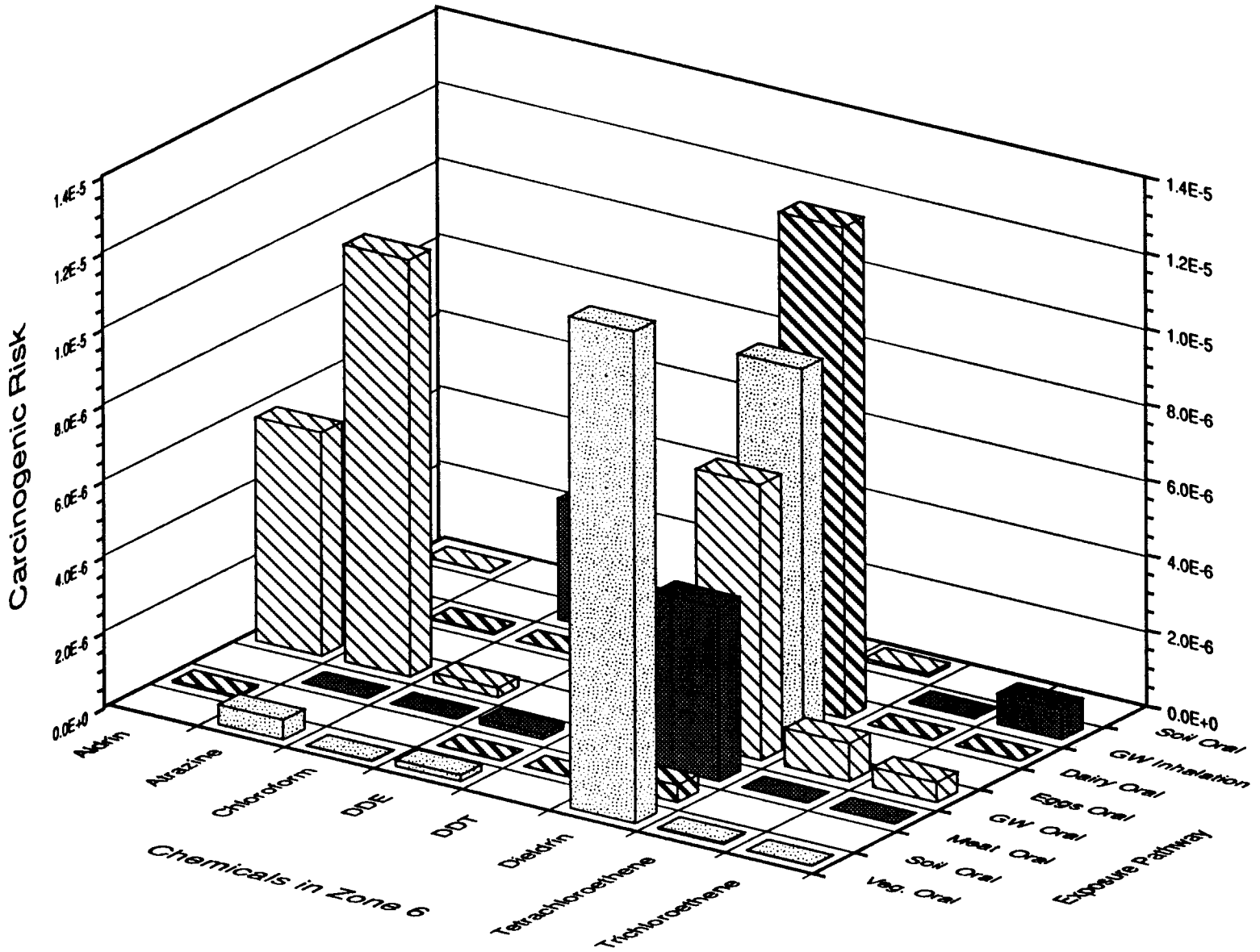

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Figure 4.1.1-11

CARCINOGENIC RISKS DESCRIBED BY CHEMICAL, MEDIUM, AND EXPOSURE PATHWAY-ZONE 6, LIFETIME RURAL RESIDENT, RME

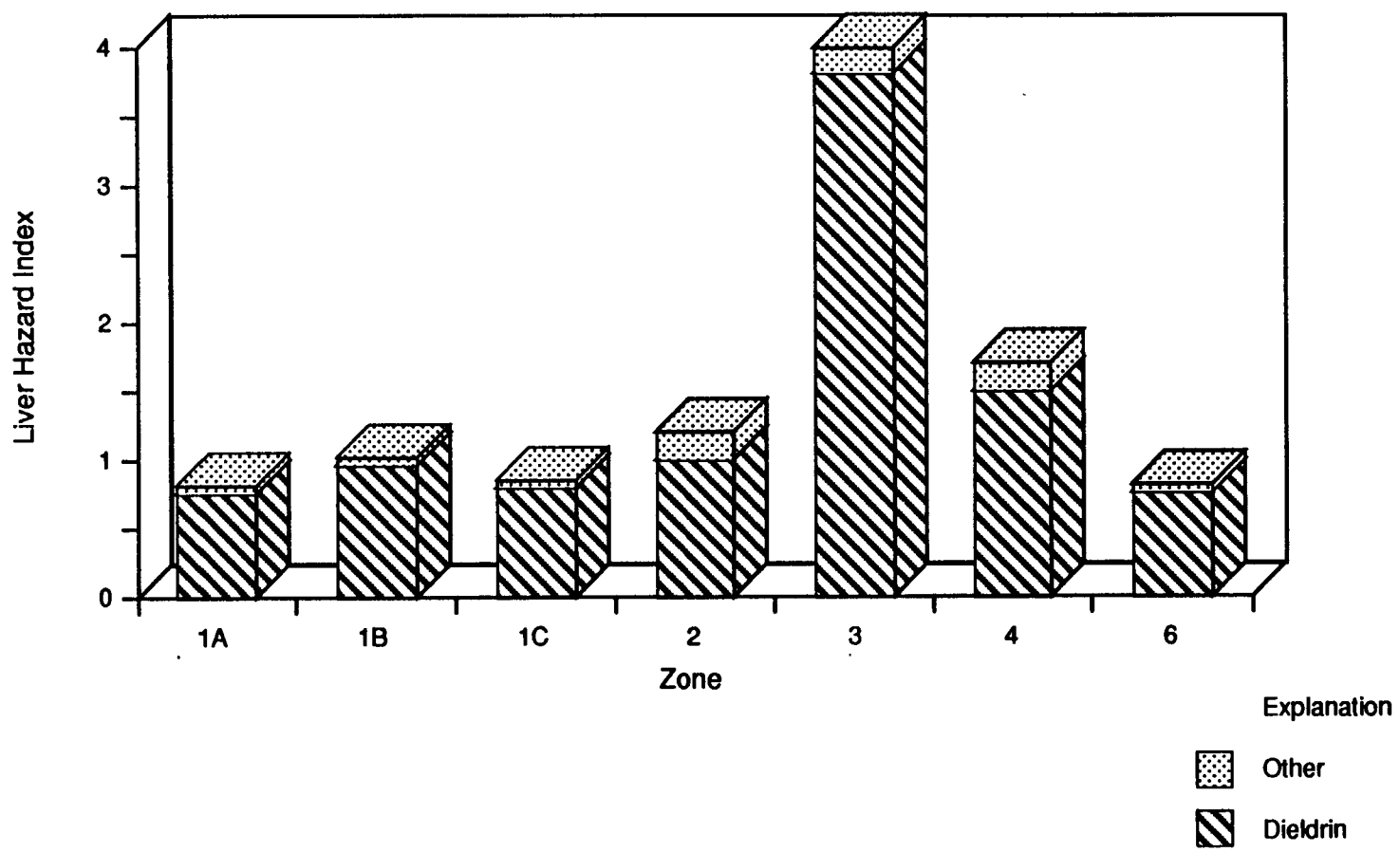

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Figure 4.1.1-12

CHILD ACUTE LIVER HAZARD INDICES

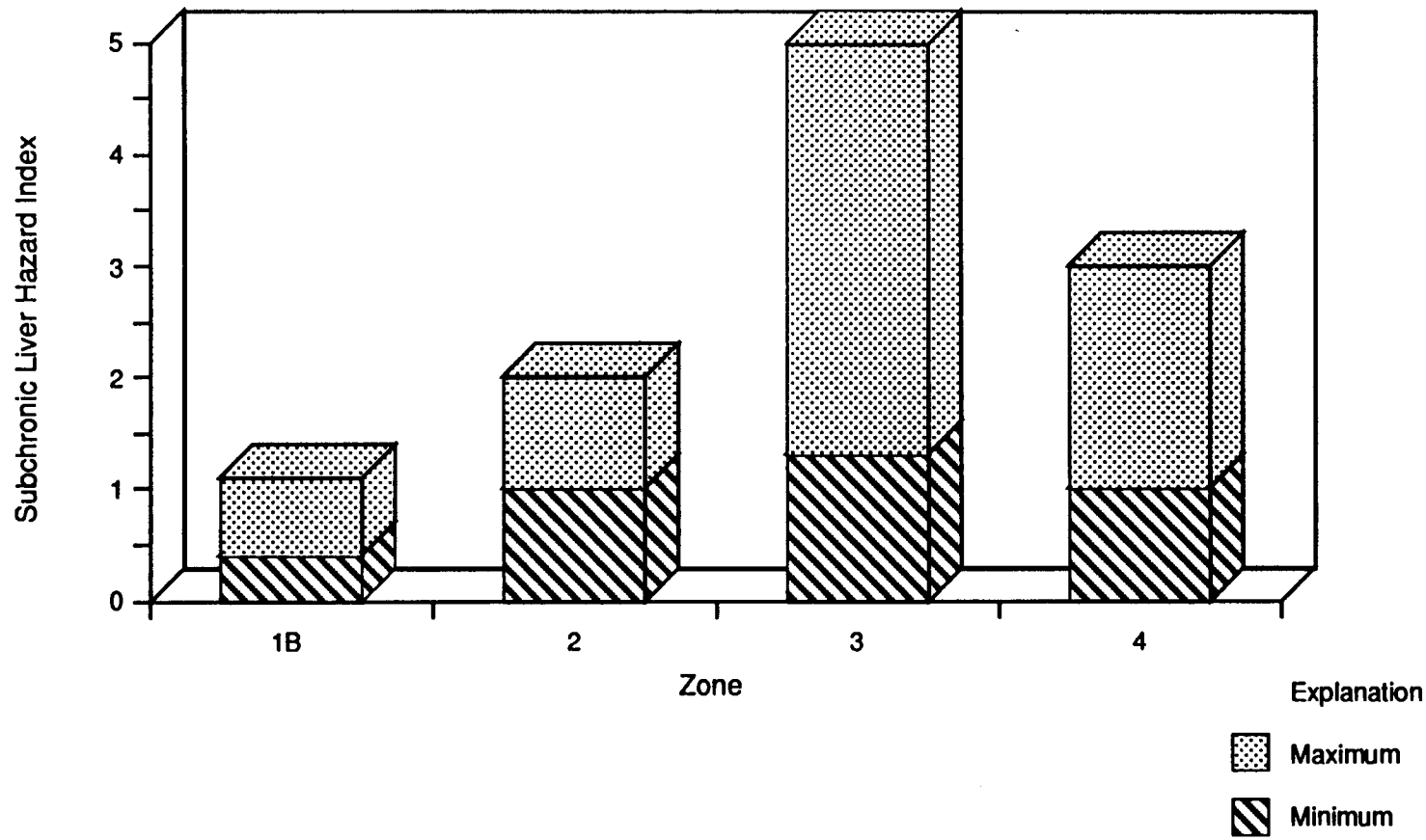

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Figure 4.1.1-13

SUBCHRONIC CHILD LIVER HAZARD INDICES, MAXIMUM AND MINIMUM OF RANGE

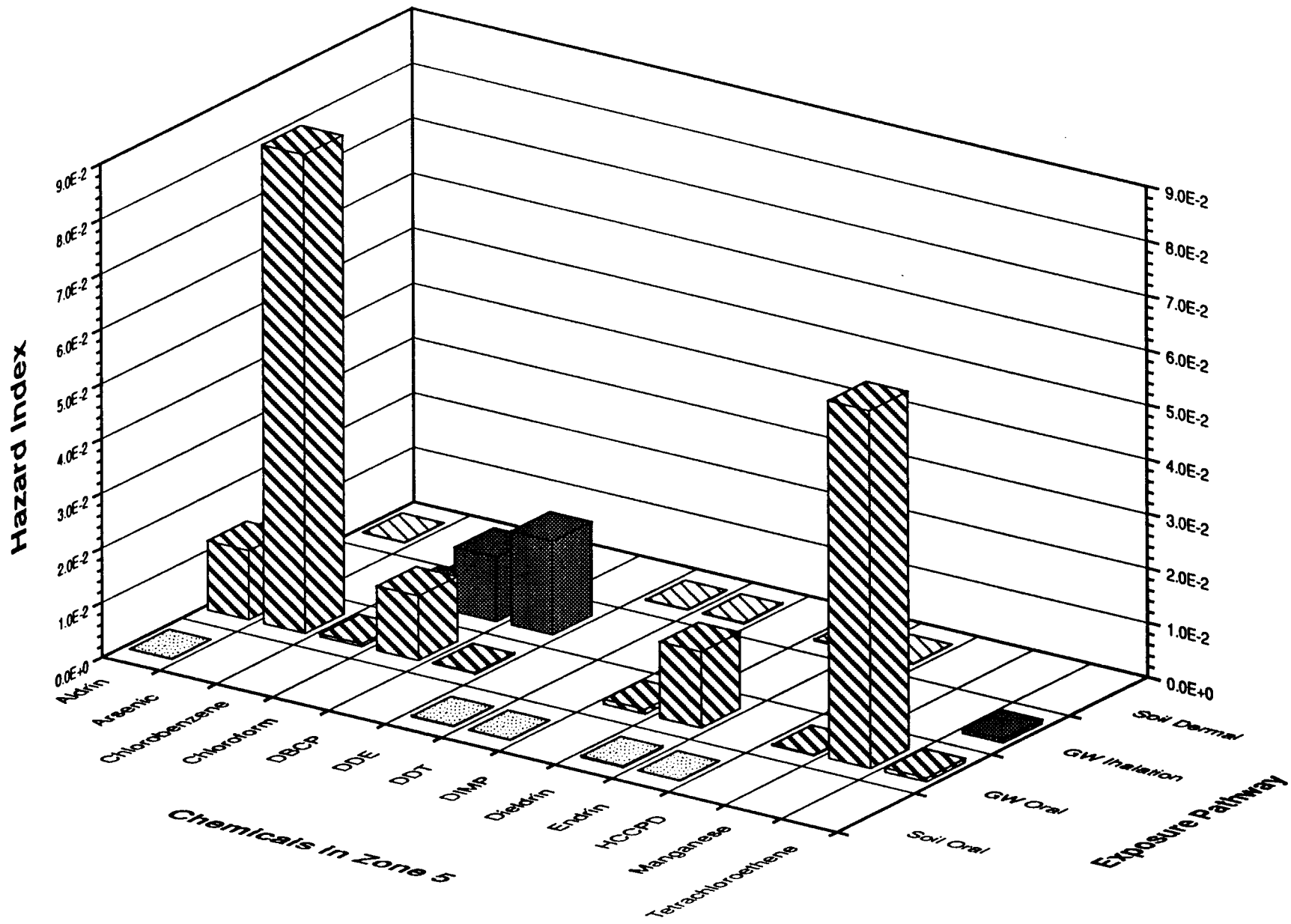

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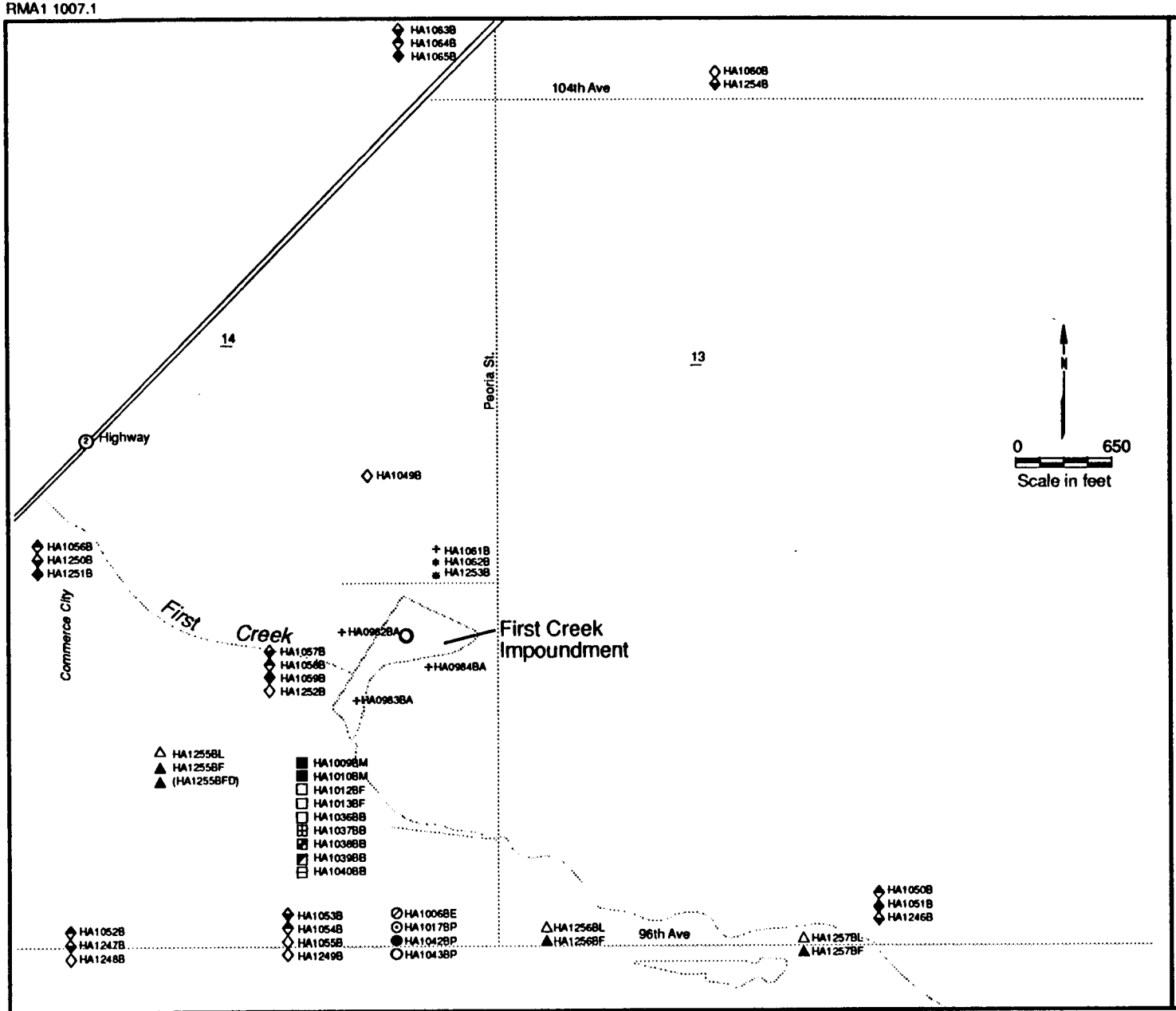
Figure 4.2.1-1

NONCARCINOGENIC HAZARD INDICES ZONE 5; ADULT COMMERCIAL/INDUSTRIAL; CHRONIC RME

RMA1 1007.1



EXPLANATION

Terrestrial Biota Sampling Locations
- Field Mice
- Prarie Dogs
- Grasshoppers
- Earthworms

Chicken Sampling Locations
- Chicken Egg
- Chicken Liver
- Chicken Fat/Skin
- Chicken Muscle

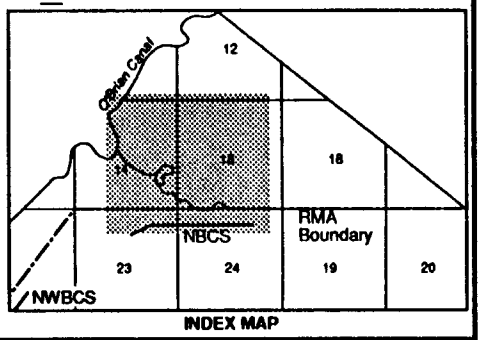
Aquatic Biota Sampling Locations
- Fish
- Crayfish
- Algae

Cow Sampling Locations
- Cow Milk
- Cow Fat
- Cow Brain
- Cow Muscle
- Cow Liver
- Cow Kidney

Pheasant Sampling Locations
- Pheasant Liver
- Pheasant Flesh

( ) Sample is a Duplicate

13 Section Number



INDEX MAP

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Figure 5.1.1-1

OFFPOST OPERABLE UNIT BIOTA SAMPLING LOCATIONS

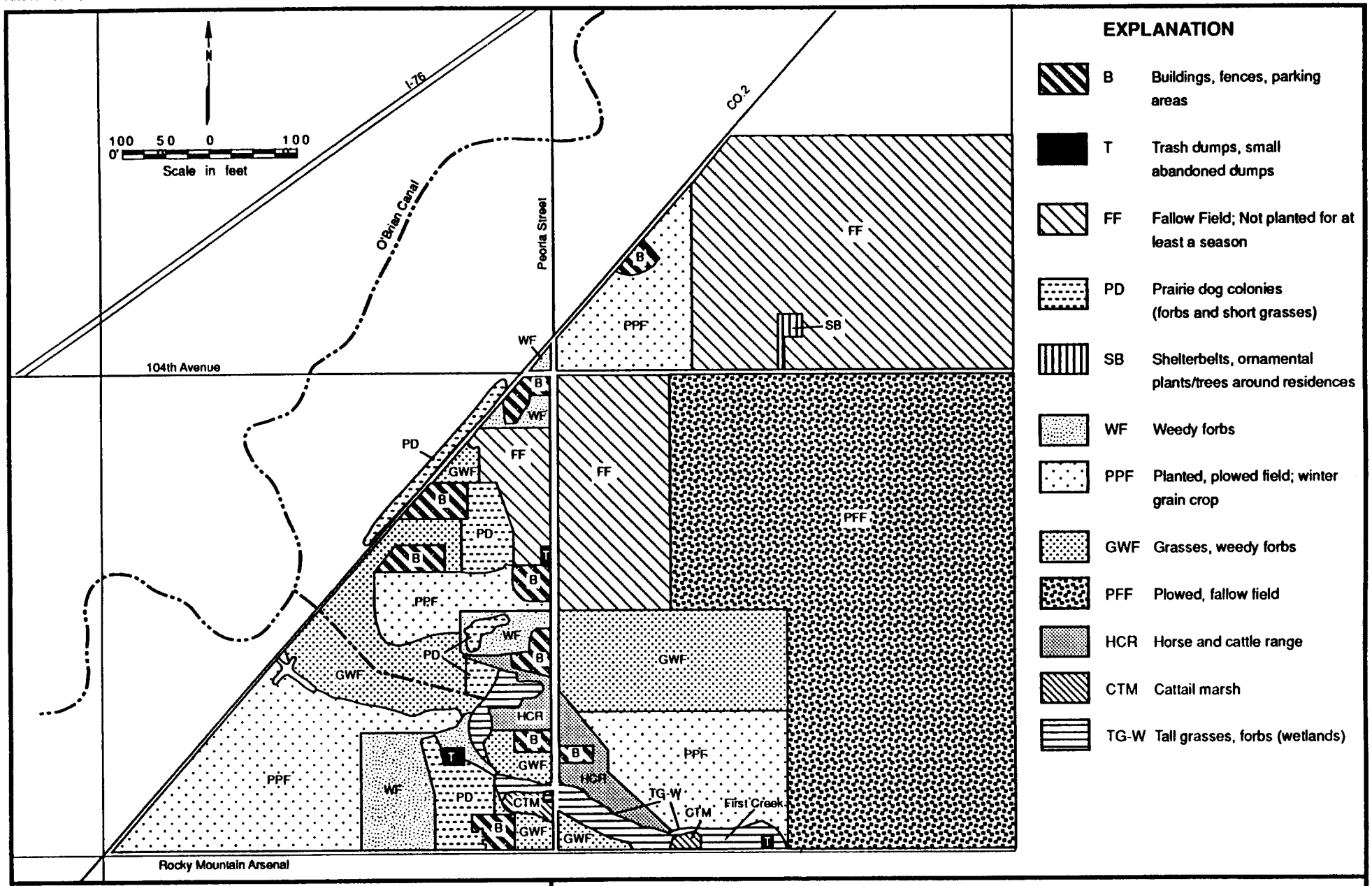

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Figure 5.1.1-2

HABITAT MAP FOR FIRST CREEK PORTION OF OFFPOST OPERABLE UNIT

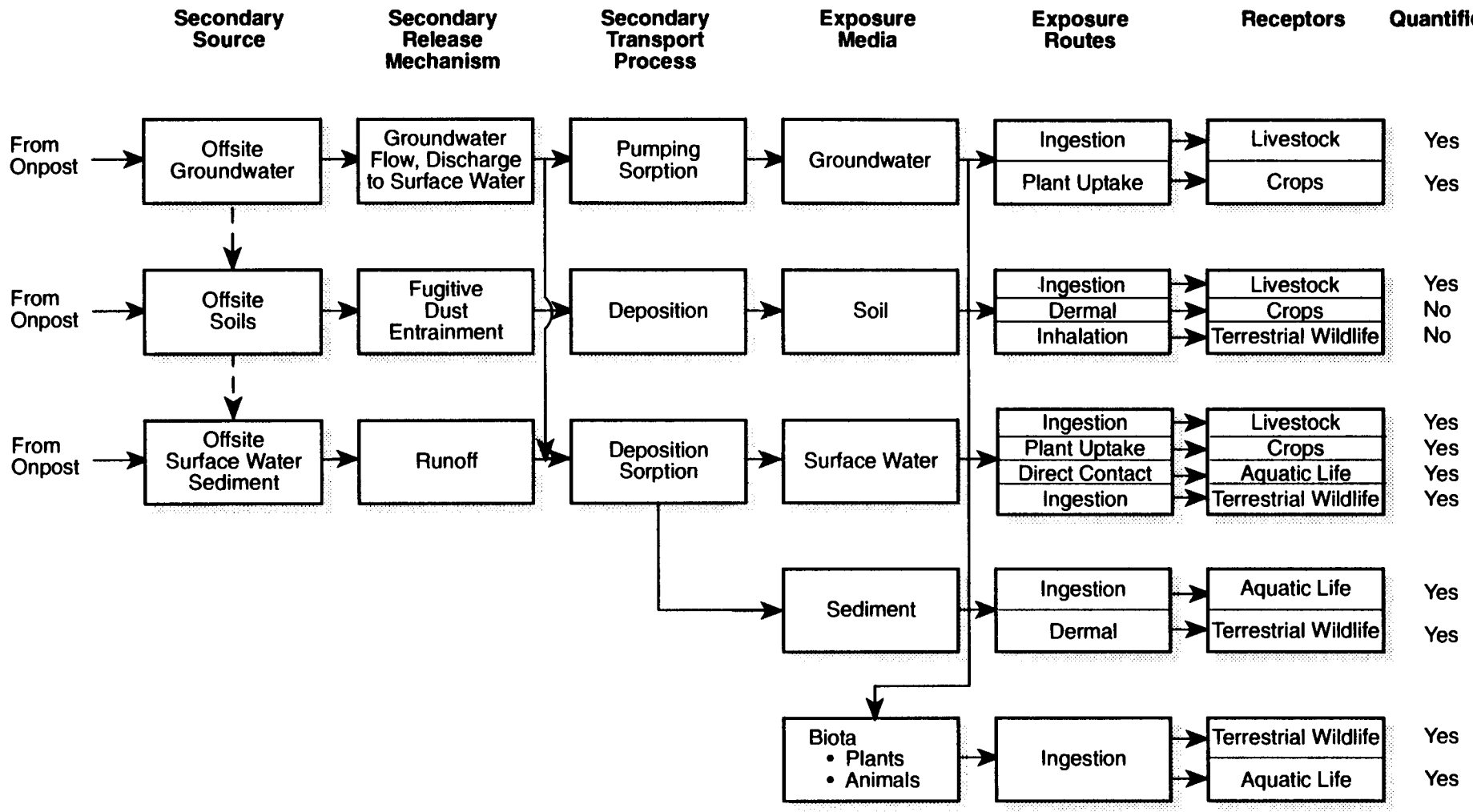

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Figure 5.2.2-1

ECOLOGICAL SITE CONCEPTUAL MODEL OFFPOST OPERABLE UNIT

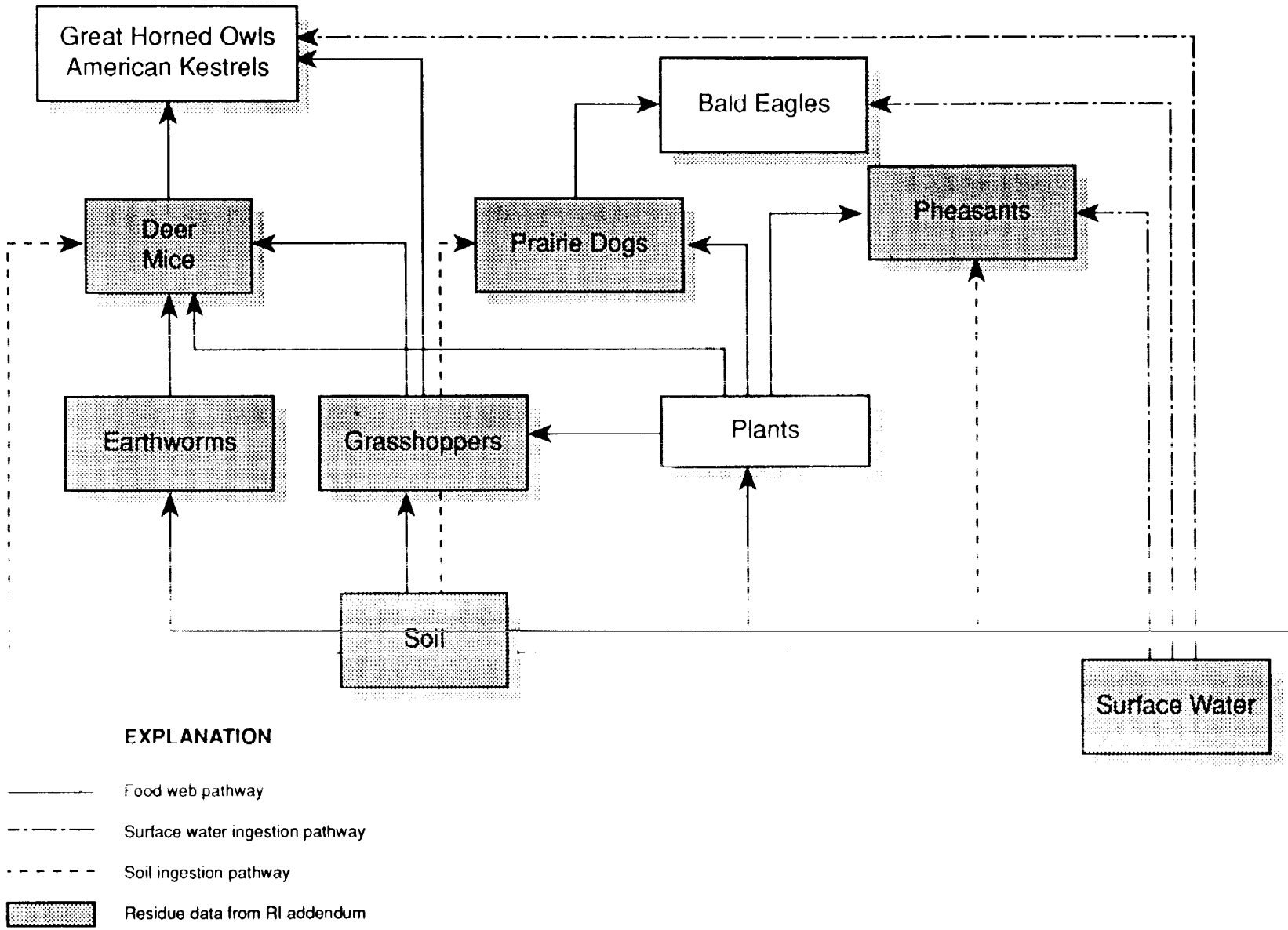

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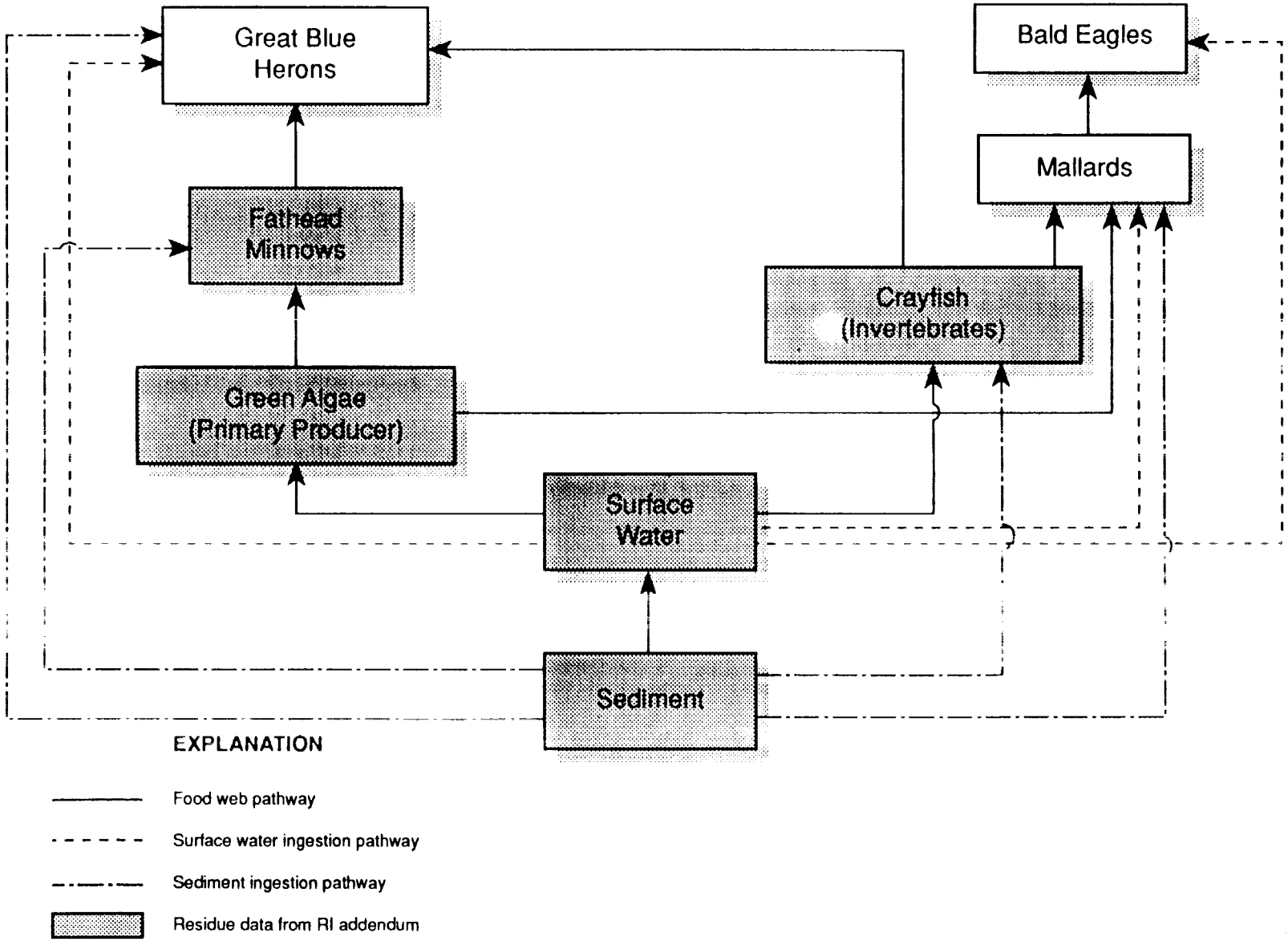
Figure 5.2.5.1-1

OFFPOST OPERABLE UNIT TERRESTRIAL FOOD WEB

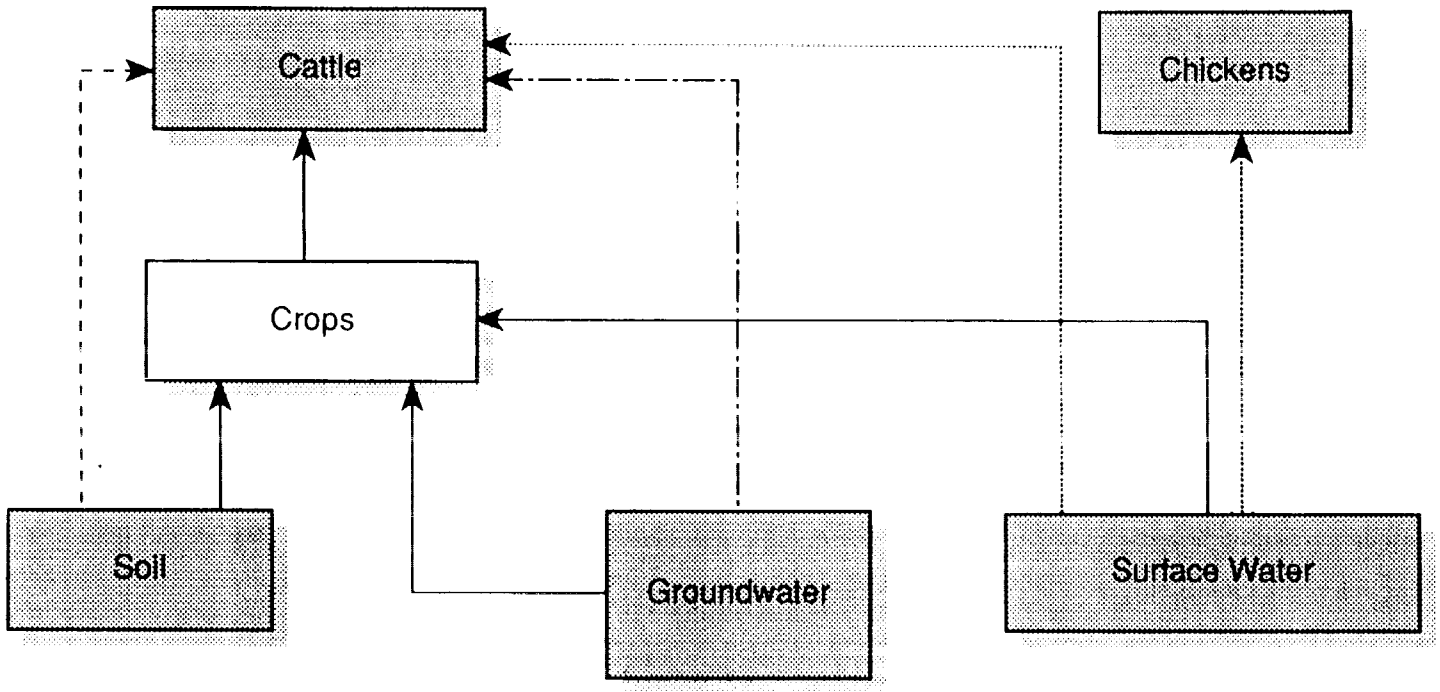


Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 5.2.5.3-1

OFFPOST OPERABLE UNIT AQUATIC FOOD WEB



EXPLANATION

- Food web pathway
- Surface water ingestion pathway
- Soil ingestion pathway
- Groundwater ingestion pathway
- Residue data from RI addendum

Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 5.2.6.5-1

OFFPOST OPERABLE UNIT AGRICULTURAL FOOD WEB

TECHNICAL SUPPORT FOR ROCKY MOUNTAIN ARSENAL

Offpost Operable Unit
Endangerment Assessment/Feasibility Study

Final Report

Volume IV of VIII
(EA Appendixes)

November 24, 1992
Contract Number DAAA15-88-0021
Task RIFS1 (Delivery Order 0001)

PREPARED BY

Harding Lawson Associates
Environmental Science and Engineering, Inc.

PREPARED FOR

PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL

THIS DOCUMENT IS INTENDED TO COMPLY WITH THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969.

THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATION RECORD FOR THIS CERCLA OPERABLE UNIT.

LIST OF APPENDIXES

VOLUME IV - ENDANGERMENT ASSESSMENT

Appendix A

RELEASE OF VOLATILE CONTAMINANTS FROM GROUNDWATER WITH SUBSEQUENT EXPOSURE IN BASEMENTS: SCREENING LEVEL ANALYSIS

Jury and others (1991) present a revised model for estimating flux of volatile contaminants from a water-table aquifer. This model has been applied to estimate inhalation intakes of chloroform and dibromochloropropane for a hypothetical residence in zone 2, the area having the highest concentrations of these contaminants in groundwater. These contaminants are likely to present the greatest risk by this pathway because of their concentrations in groundwater, volatility, and toxicity. It will be shown that intakes by this pathway are much fewer than other groundwater-related pathways.

Concentrations in indoor air in basements can be estimated by equating the rate of a contaminant entering the basement to the rate of removal by building ventilation as follows:

$$C_{air} = \text{Flux} \times \text{TAC} / \text{VAR} \qquad \text{A-1}$$

where:

Flux	=	flux of contaminant from water table to the foundation (milligrams per square meter per day [$mg/m^2/day$])
TAC	=	time for exchange of basement air (day)
VAR	=	ratio of basement volume to surface area in contact with soil (meter [m])

A range of values is reported for TAC. In a cost analysis of different strategies to reduce indoor radon, Moeller and Fujimoto (1984) used a value of 0.05 day. Mueller Associates (1986) indicated that TAC normally ranges from 0.028 to 0.083 day in single-family detached housing although values as high as 0.4 day were being attained in highly energy-efficient housing. Most homes in the offpost operable unit are older, less energy-efficient houses and would be expected to fall within the normal range. A reasonable maximum estimate of 0.2 day was used in this screening analysis.

VAR was estimated assuming the following basement dimensions: length, 10 m; width = 7 m; height = 2 m; and height below ground surface = 1 m; resulting in

VAR = 140 cubic meters (m^3)/104 m^2 = 1.35 m.

Flux is estimated from the model of Jury and others (1991), accounting for the effect of the capillary fringe:

$$\text{Flux} = D_{eff} \, H \, C_{gw} / L \qquad \text{A-2}$$

where:

D_{eff} = effective porous media diffusion coefficient (m^2/day)
H = Henry's Law constant for the contaminant (dimensionless)
C_{gw} = concentration of contaminant in groundwater (micrograms per liter [μg/L])
L = depth from basement floor to water table (m)

The effective porous media diffusion coefficient is obtained from:

$$D_{eff}/L = [H\ h_t/(n^{4/3}D_w) + (h_c-h_t)/D_t + (L-h_c)/D_u]^{-1} \quad \text{A-3}$$

where:

h_c = height of capillary fringe (m)
h_t = height of lower portion of capillary fringe where soil pores are saturated with water (m)
n = soil porosity (dimensionless)
D_w = molecular diffusivity of contaminant in water (m^2/day)
D_t = effective diffusivity in the upper portion of the capillary fringe or transition zone (m^2/day)
D_u = effective diffusivity in the unsaturated zone above the capillary fringe (m^2/day)

The effective diffusivities in the transition and unsaturated zones are estimated from:

$$D = D_a n_a^{10/3}/n^2 + (D_w/H)(n_w^{10/3}/n^2) \quad \text{A-4}$$

where:

D_a = molecular diffusivity of contaminant in air (m^2/day)
n_a = air-filled porosity
n_w = water-filled porosity (note: $n = n_a + n_w$)

Appropriate values for n_a and n_w are used in equation A-4 for the transition and unsaturated zones, respectively, to estimate D_t and D_u.

Jury and others (1991) recommend using field capacity to define n_w in the unsaturated zone ($n_{w,u}$) and using $n_{w,t} = (n + n_{w,u}) / 2$ for the transition zone.

For the Jury and others (1991) model to be applied, the following chemical-specific values must be defined: D_a, D_w, H, and C_{gw}. Reasonable maximum estimates of these values for chloroform and dibromochloropropane are defined in Table A1. Conservative estimates of the site-specific parameters required for the model (h_t, h_c, L, $n_{w,u}$, and n) are provided in Table A2. By this model, the concentration of contaminant in indoor air is inversely related to h_t, h_c, L, and

$n_{w,u}$. Therefore, a reasonable maximum intake estimate is obtained by using a conservatively small estimate for these parameters. The values selected are based on 10th percentiles over the distribution of these parameters expected in groundwater zone 2, where concentrations of chloroform and dibromochloropropane attain their highest values in the Offpost Operable Unit (OU). Total porosity, n, varies over a small range, and is expected to be correlated with n_a. Consequently, an average value of n was used.

Applying the values in Tables A1 and A2;

$n_{w,t} = (0.34 + 0.08) / 2 = 0.21$ and
$n_{a,t} = 0.34 - 0.21 = 0.13$.

For chloroform;

D_t $= 0.85(0.13^{10/3}/0.34^2) + (0.000085/0.17)(0.21^{10/3}/0.34^2)$
$= 0.0082\ m^2/day$

D_u $= 0.85(0.26^{10/3}/0.34^2) + (0.000085/0.17)(0.08^{10/3}/0.34^2)$
$= 0.082\ m^2/day$

D_{eff}/L $= [(0.17 \times 0.35)/(0.34^{4/3} \times 0.000085) + 0.18/0.0082 + 0.77/0.082]^{-1}$
$= [2900 + 22 + 9]^{-1}$
$= 0.00034\ m/day$

Flux $= 0.00034 \times 0.17 \times 67.5$
$= 0.0039\ mg/m^2/day$

C_{air} $= 0.0039\ (mg/m^2/day) \times 0.2\ (day) / 1.35\ (m)$
$= 0.00058\ mg/m^3$.

For dibromochloropropane, similar calculations result in:

D_t $= 0.0066\ m^2/day$
D_u $= 0.064\ m^2/day$
(D_{eff}/L) $= 0.0027\ m/day$
Flux $= 0.000018\ mg/m^2/day$
C_{air} $= 0.0000026\ mg/m^3$.

Intakes are estimated by assuming that eight hours per day are spent in the basement at a reasonable maximum exposure (RME) inhalation rate of 1.25 (cubic meters per hour [m^3/hr], resulting in a contact rate of 10 (cubic meters per day [m^3/day]. At a body weight of 70 (kilograms [kg]), the daily intake rate is given by:

I $= C_{air}\ (mg/m^3) \times 10\ (m^3/day) / 70\ (kg)$
$= 0.00081$ (milligrams per kilogram per day [mg/kg/day], for chloroform, and
$= 0.00000038$ mg/kg/day, for dibromochloropropane

These intake values may be compared to the intake associated with inhalation exposures as a result of volatilization during domestic use of the same groundwater, which is assumed (see Section 2.4.3) to result in a contact rate of 2 l/day by the inhalation route and an intake of 0.0019 mg/kg/day for chloroform and 0.000013 mg/kg/day for dibromochloropropane, given the exposure concentrations provided in Table A1. Thus, chloroform exposure by inhalation of contaminants volatilized off the water table are only 4 percent of inhalation intakes associated with volatilization during domestic use of the same water, and intakes of dibromochloropropane by this pathway are only 3 percent of intakes quantified in other pathways. Given the complexity of this model and the small contribution to total exposure, this pathway may be eliminated from further quantitative evaluation.

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Appendix B

ESTIMATE OF AMBIENT PARTICULATE MATTER IMPACT DUE TO WIND EROSION NEAR ROCKY MOUNTAIN ARSENAL

An estimate of ambient particulate matter impact due to wind erosion near the Rocky Mountain Arsenal (RMA) was derived in a two-step process. First, an emission estimate was developed for the subject area. Second, the emission estimate was applied to a dispersion model to quantify the typical and potential worst-case concentrations of dust from this source in the ambient air.

The emission estimate based on vehicle traffic and windborne dust was developed for the extreme SW 1/4 Quarter, Section 13, Township 2 South, Range 66 West, and the entire SE 1/4, Section 14, Township 2 South, Range 66 West. The windborne dust emission estimate was calculated using the Universal Soil Loss equation as presented by Cowherd (1974). The basic form of the equation is:

$$E_s = A \times I \times K \times C \times L' \times V' \qquad (1)$$

where:

E_s = suspended particulate matter emission rate, tons/acre/year

A = 0.025

I = soil erodibility

K = surface roughness factor, dimensionless

C = climate factor, dimensionless

L' = unsheltered field width factor, dimensionless

V' = vegetative cover factor, dimensionless

The soil erodibility is a function of the soil type in the study area. The five soil types in the area under consideration are Ascalon sandy loam, Ascalon-Vona sandy loam, Platner loam, loamy alluvial land, and wet alluvial land (Sampson and Baber, 1974). To be conservative, the entire area was considered a sandy loam with an I of 86 tons/acre/year. The remaining factors were assigned following Cowherd's guidelines, assuming the area was planted in grain hays. Equation 1 then becomes:

$$E_s = 0.025 \times 86 \text{ tons/year/acre} \times 0.8 \times 0.45 \times 0.8 \times 0.1 \qquad (2)$$

where:

$A = 0.025$

$I = 86$ tons/acre/year

$K = 0.8$

$C = 0.45$

$L' = 0.8$

$V' = 0.1$

thus,

$$E_s = 123.8 \text{ lb/year/acre} \quad (3)$$

Assuming that the windborne dust is generated during ten annual events with sustained winds greater than 6 m/s for 24 hours, the emission rate for each wind event is:

$$E_s = 0.065 \text{ g/sec/acre} \quad (4)$$

Because 25 percent of the study area is tilled land, this process must also be evaluated as a source of windborne dust. Agricultural tilling emissions may be estimated using the AP-42 (EPA, 1988) algorithm:

$$E_a = k(4.80)\ (s)^{0.6} \text{ lb/acre} \quad (5)$$

where:

E_a = agricultural emission rate (tons/acre/year)

k = particle size multiplier (dimensionless)

s = silt content (percent)

Given the soil type in the subject area, Equation 5 becomes:

$$E_a = 0.33\ (4.80)(40)^{0.6} \text{ lb/acre} \quad (6)$$

where:

$k = 0.33$

s = 40 percent

thus,

$$E_a = 14.5 \text{ lb/acre} \quad (7)$$

Assuming 25 percent of the total area is tilled, and the tilling is completed in five 24-hour periods, the windborne emission rate for this operation is:

$$E_a = 0.61 \text{ g/sec} \quad (8)$$

The vehicular traffic emission estimate was calculated using the unpaved road algorithm presented in AP-42. This algorithm is:

$$E_v = k(5.9)\,(s/12)(S/30)\,(W/S)^{0.7}\,(w/4)^{0.5}\,((365-P)/365) \text{ lb/VMT} \quad (9)$$

where:

E_v = vehical emission rate (lbs/day)

k = particle size multiplier (dimensionless)

s = silt content of road surface material (percent)

S = mean vehicle speed, MPH

W = mean vehicle weight, ton

w = mean number of wheels

p = number of days/year with >0.01 inches of precipitation

VMT = vehicle miles traveled

For this generally rural area of Adams county, the values of the various inputs are:

k = 0.80

s = 50 percent

S = 35 MPH

W = 2 tons

w = 4

p = 88 (NCDC, 1987)

thus,

$$E_v = 0.80 \times 5.9 \times (50/12)\ (35/30)\ (2/3)^{0.7}\ (4/4)^{0.5}\ ((365-88)/365)\ \text{lb/VMT} \quad (10)$$

$$E_v = 13.1\ \text{lb/VMT} \quad (11)$$

Assuming that 20 vehicle miles/day are travelled on the unpaved roads in the subject area, the daily emission rate is:

$$E_v = 13.1\ \text{lb/VMT} \times 20\ \text{VMT} \quad (12)$$

$$= 262\ \text{lb/day} = 1.38\ \text{g/sec} \quad (13)$$

The ambient concentration of particulate matter due to these emissions can be estimated following the procedures outlined by Turner (1970). In this situation, the appropriate equation is:

$$\phi(X,0,0,H) = [Q/\pi\sigma_y\sigma_z U]\ [\text{Exp}-1/2(H/\sigma_z)^2)] \quad (14)$$

where:

ϕ = ambient concentration (g/m^3)

Q = emission rate (g/sec)

U = wind speed (m/sec)

σ_y = horizontal dispersion coefficient (m)

σ_z = vertical dispersion coefficient (m)

H = effective stack height (m)

To estimate the ambient concentration conservatively, the wind was assumed to be from the southwest. This direction allows the maximum fetch across the SE 1/4 of Section 14. Because the model must treat an area source as a point source, the entire windborne dust emission was assumed to be calculated as a strip of land running from the southwest corner to the northeast corner of the quarter-section, a distance of 4000 feet. The width of the corridor is 330 feet, the distance the horizontal Gaussian distribution reaches 50 percent of the center line value. Thus, applying Equation 4 and Equation 8 to a centerline receptor at the northeast corner of the quarter-section

will give a conservative estimate of ambient particulate matter concentration. Given the above criteria,

$$E_s = \frac{0.065 \text{ g/sec/acre} \times 4{,}000 \text{ ft} \times 300 \text{ ft}}{43{,}560 \text{ ft/acre}} + 0.61 \text{ g/sec} \quad (15)$$

$$= 2.58 \text{ g/sec} \quad (16)$$

where:

E_s = source emission rate (g/sec)

For the worst case ambient concentration to be calculated, the total emission must be calculated. Assuming that the vehicle-generated dust also results from a point source emission in the center of the quarter section, then

$$E_t = E_s + E_v \quad (17)$$

$$E_t = 2.58 \text{ g/sec} + 1.38 \text{ g/sec} = 3.96 \text{ g/sec} \quad (18)$$

E_t = total emission rate (g/sec)

Substituting Equation 18 into Equation 14 and following Turner's procedures for determining σ_y and σ_z, the worst case ambient value is:

$$\phi = \frac{3.96 \text{ g/sec}}{\pi \times 42 \text{ m} \times 22 \text{m} \times 6 \text{ m/sec}} + \exp\left[-1/2(.5\text{m}/22)^2\right] \quad (19)$$

where:

$E_t = 3.96$ g/sec

$\sigma_y = 42$m (Stability Class D)

$\sigma_z = 22$m (Stability Class D)

U = 6 m/sec

H = 0.5 m

Reducing Equation 19 gives

$$\phi = 0.000227 \text{ g/m}^3 \qquad (20)$$
$$= 227 \ \mu\text{g/m}^3$$

Thus, a conservative worst-case estimated value of 227 μg/m^3 is obtained for the ambient total suspended particulate (TSP) matter concentration due to windblown dust from the study area. Based on AP-42, the ambient concentration of respirable particulate matter (PM_{10}) is estimated to be 113 μg/m^3.

A more reasonable "typical" ambient concentration may be calculated by considering only the vehicle-generated dust. Under this scenario, substituting Equation 13 into Equation 14 and following Turner's procedures for determining σ_y and σ_z yields

$$\phi = \frac{1.38 \text{ g/sec}}{\pi \text{ x } 42 \text{ m x } 22\text{m x } 6 \text{ m/sec}} + \exp\left[-1/2(.5\text{m}/22)^2\right] \qquad (21)$$

Reducing Equation 21 gives

$$\phi = 0.000079 \text{ g/m}^3 \qquad (20)$$
$$= 79 \ \mu\text{g/m}^3$$

Thus, a conservative "typical" baseline estimated value of 79 μg/m^3 is obtained for the ambient TSP concentration expected on a dry day. Based on AP-42, the ambient concentration of PM_{10} is estimated to be 35.6 μg/m^3 for this situation.

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Appendix C

EXPOSURE CONCENTRATIONS

WELLS IN RMA ZONE 1

13:36 Friday, November 6, 1992

SITEID
10100TW1
10150TWH
10720TWB
10791TWB
11010TWH
11071TW1
11295TW1
11460TWP
11755TWB
11810TWB
11830TW1
1185A
12001TWB
1234A
1305A
330A
372A
37342
37345
37346
37347
37348
37349
37350
37351
37352
37353
37354
37356
37357
37364
373D
37428
37429
37433
37434
37435
377A
416A
485A
540A
547A
550A
551A
561A
578A
578B
586B
603A
609A
981A
HA1169

WELLS in RMA ZONE 2

13:36 Friday, November 6, 1992 1

SITEID
10590TWH
13350TW1
37320
37321
37322
37327
37341
37344
37367
37368
37377
37378
37383
37391
37392
37395
37397
37402
37403
37404
37405
37406
37408
37410
BOLLER
HA1168

WELLS in RMA ZONE 3

13:36 Friday, November 6, 1992 1

SITEID
37308
37309
37318
37323
37338
37339
37362
37369
37376
37389
37390

WELLS in RMA ZONE 4

13:36 Friday, November 6, 1992 1

SITEID
37313
37316
37317
37343
37365
37370
37371
37372
37373
37374
37379
37380
37381
37387
37388
37396
37407
37418
37419
37420
HA1048

WELLS in RMA ZONE 5

13:36 Friday, November 6, 1992 1

SITEID
09200TW0
1325A
37330
37331
37332
37333
37334
37335
37382
37385
37386
37436
37437
37438
HA1171

WELLS in RMA ZONE 6

13:36 Friday, November 6, 1992 1

SITEID
37336
37355
37430
37439
37442
37443
37444
HA1069

EXPOSURE CONCENTRATIONS IN AGRICULTURAL PRODUCTS
11/6/92

	AREA	Cp	Cd	Cm	Ce
DIELDRIN	1A	1.7E-03	1.3E-04	6.6E-04	1.7E-03
DIELDRIN	1B	2.3E-03	1.8E-04	8.5E-04	1.7E-03
DIELDRIN	1C	1.7E-03	1.3E-04	6.6E-04	1.7E-03
DIELDRIN	2	2.5E-03	1.9E-04	9.1E-04	1.7E-03
DIELDRIN	3	1.6E-02	1.2E-03	5.8E-03	1.1E-02
DIELDRIN	4	6.6E-03	5.0E-04	2.1E-03	1.7E-03
DIELDRIN	5	2.9E-03	2.2E-04	1.0E-03	1.7E-03
DIELDRIN	6	1.7E-03	1.3E-04	6.6E-04	1.7E-03
ARSENIC	1A	1.2E-03	8.5E-06	1.4E-04	0.0E+00
ARSENIC	1B	7.4E-03	5.3E-05	8.9E-04	0.0E+00
ARSENIC	1C	1.2E-03	8.5E-06	1.4E-04	0.0E+00
ARSENIC	2	5.6E-03	4.0E-05	6.8E-04	0.0E+00
ARSENIC	3	6.1E-03	4.3E-05	7.4E-04	0.0E+00
ARSENIC	4	1.5E-02	1.0E-04	1.8E-03	0.0E+00
ARSENIC	5	9.2E-03	6.6E-05	1.1E-03	0.0E+00
ARSENIC	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ATRAZINE	1A	3.3E-03	1.5E-05	5.3E-05	0.0E+00
ATRAZINE	1B	2.1E-02	9.2E-05	3.3E-04	0.0E+00
ATRAZINE	1C	3.3E-03	1.5E-05	5.3E-05	0.0E+00
ATRAZINE	2	3.8E-02	1.7E-04	6.2E-04	0.0E+00
ATRAZINE	3	8.3E-02	3.7E-04	1.3E-03	0.0E+00
ATRAZINE	4	4.7E-02	2.1E-04	7.7E-04	0.0E+00
ATRAZINE	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ATRAZINE	6	5.0E-03	2.3E-05	8.1E-05	0.0E+00
BENZENE	1A	4.4E-04	1.2E-06	3.9E-06	0.0E+00
BENZENE	1B	2.8E-03	7.4E-06	2.5E-05	0.0E+00
BENZENE	1C	4.4E-04	1.2E-06	3.9E-06	0.0E+00
BENZENE	2	2.9E-03	7.7E-06	2.6E-05	0.0E+00
BENZENE	3	3.1E-03	8.2E-06	2.7E-05	0.0E+00
BENZENE	4	3.8E-03	1.0E-05	3.4E-05	0.0E+00
BENZENE	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
BENZENE	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CCL4	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CCL4	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CCL4	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CCL4	2	5.7E-03	2.7E-05	9.8E-05	0.0E+00
CCL4	3	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CCL4	4	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CCL4	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CCL4	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00

EXPOSURE CONCENTRATIONS IN AGRICULTURAL PRODUCTS

CHLORDANE	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CHLORDANE	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CHLORDANE	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CHLORDANE	2	8.9E-04	4.7E-06	1.4E-05	0.0E+00
CHLORDANE	3	2.2E-03	1.3E-05	5.5E-05	4.3E-03
CHLORDANE	4	2.5E-03	1.3E-05	4.1E-05	0.0E+00
CHLORDANE	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CHLORDANE	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CLBENZENE	1A	1.3E-03	6.0E-06	2.2E-05	0.0E+00
CLBENZENE	1B	8.0E-03	3.8E-05	1.4E-04	0.0E+00
CLBENZENE	1C	1.3E-03	6.0E-06	2.2E-05	0.0E+00
CLBENZENE	2	1.4E-02	6.6E-05	2.4E-04	0.0E+00
CLBENZENE	3	1.2E-02	5.9E-05	2.2E-04	0.0E+00
CLBENZENE	4	3.2E-02	1.5E-04	5.5E-04	0.0E+00
CLBENZENE	5	8.5E-03	4.0E-05	1.5E-04	0.0E+00
CLBENZENE	6	1.6E-03	7.5E-06	2.8E-05	0.0E+00
CHCL3	1A	4.6E-04	3.0E-07	9.5E-07	0.0E+00
CHCL3	1B	2.9E-03	1.9E-06	5.9E-06	0.0E+00
CHCL3	1C	4.6E-04	3.0E-07	9.5E-07	0.0E+00
CHCL3	2	2.8E-01	1.8E-04	5.9E-04	0.0E+00
CHCL3	3	1.9E-02	1.2E-05	3.9E-05	0.0E+00
CHCL3	4	5.7E-03	3.7E-06	1.2E-05	0.0E+00
CHCL3	5	5.0E-02	3.3E-05	1.0E-04	0.0E+00
CHCL3	6	2.2E-03	1.4E-06	4.6E-06	0.0E+00
CPMS	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMS	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMS	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMS	2	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMS	3	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMS	4	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMS	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMS	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMSO	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMSO	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMSO	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMSO	2	4.8E-02	3.1E-05	9.3E-05	0.0E+00
CPMSO	3	3.1E-02	2.0E-05	6.0E-05	0.0E+00
CPMSO	4	2.3E-02	1.5E-05	4.4E-05	0.0E+00
CPMSO	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMSO	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00

EXPOSURE CONCENTRATIONS IN AGRICULTURAL PRODUCTS

CPMSO2	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMSO2	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMSO2	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMSO2	2	1.4E-02	9.4E-06	2.8E-05	0.0E+00
CPMSO2	3	1.9E-02	1.3E-05	3.8E-05	0.0E+00
CPMSO2	4	1.5E-02	9.9E-06	3.0E-05	0.0E+00
CPMSO2	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CPMSO2	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DCPD	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DCPD	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DCPD	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DCPD	2	5.1E-02	1.4E-04	5.5E-04	0.0E+00
DCPD	3	2.1E+00	5.8E-03	2.2E-02	0.0E+00
DCPD	4	8.5E-01	2.4E-03	9.3E-03	0.0E+00
DCPD	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DCPD	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DDE	1A	1.0E-03	1.9E-04	9.3E-04	3.9E-03
DDE	1B	1.3E-03	2.2E-04	1.1E-03	3.9E-03
DDE	1C	1.0E-03	1.9E-04	9.3E-04	3.9E-03
DDE	2	1.3E-03	2.2E-04	1.0E-03	3.9E-03
DDE	3	3.3E-03	5.4E-04	2.5E-03	7.5E-03
DDE	4	1.8E-03	2.9E-04	1.3E-03	3.9E-03
DDE	5	9.8E-04	1.8E-04	9.1E-04	3.9E-03
DDE	6	9.8E-04	1.8E-04	9.1E-04	3.9E-03
DBCP	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DBCP	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DBCP	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DBCP	2	1.7E-03	1.3E-06	3.9E-06	0.0E+00
DBCP	3	4.9E-04	3.6E-07	1.1E-06	0.0E+00
DBCP	4	5.4E-04	4.0E-07	1.2E-06	0.0E+00
DBCP	5	4.0E-04	3.0E-07	9.2E-07	0.0E+00
DBCP	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DCLB	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DCLB	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DCLB	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DCLB	2	9.8E-02	7.5E-04	2.9E-03	0.0E+00
DCLB	3	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DCLB	4	5.1E-02	3.9E-04	1.5E-03	0.0E+00
DCLB	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DCLB	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00

EXPOSURE CONCENTRATIONS IN AGRICULTURAL PRODUCTS

12DCLE	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
12DCLE	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
12DCLE	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
12DCLE	2	2.7E-03	4.4E-06	1.4E-05	0.0E+00
12DCLE	3	3.0E-03	4.8E-06	1.5E-05	0.0E+00
12DCLE	4	2.4E-02	3.8E-05	1.2E-04	0.0E+00
12DCLE	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
12DCLE	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DIMP	1A	1.3E-01	1.1E-05	4.6E-05	0.0E+00
DIMP	1B	3.1E-01	2.6E-05	1.1E-04	0.0E+00
DIMP	1C	5.0E-02	4.2E-06	1.7E-05	0.0E+00
DIMP	2	3.5E+00	2.9E-04	1.2E-03	0.0E+00
DIMP	3	2.7E+00	2.3E-04	9.4E-04	0.0E+00
DIMP	4	2.2E+01	1.8E-03	7.6E-03	0.0E+00
DIMP	5	3.8E-02	3.2E-06	1.3E-05	0.0E+00
DIMP	6	3.7E-03	3.1E-07	1.3E-06	0.0E+00
DITHIANE	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DITHIANE	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DITHIANE	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DITHIANE	2	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DITHIANE	3	5.2E-03	2.1E-06	6.0E-06	0.0E+00
DITHIANE	4	1.1E-02	4.6E-06	1.3E-05	0.0E+00
DITHIANE	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
DITHIANE	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ETBENZENE	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ETBENZENE	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ETBENZENE	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ETBENZENE	2	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ETBENZENE	3	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ETBENZENE	4	6.2E-03	4.0E-05	1.5E-04	0.0E+00
ETBENZENE	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ETBENZENE	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ENDRIN	1A	5.6E-04	1.2E-05	4.3E-05	3.6E-04
ENDRIN	1B	1.3E-03	2.8E-05	9.3E-05	3.6E-04
ENDRIN	1C	5.6E-04	1.2E-05	4.3E-05	3.6E-04
ENDRIN	2	1.5E-03	3.2E-05	1.0E-04	3.6E-04
ENDRIN	3	1.4E-02	2.9E-04	9.4E-04	2.8E-03
ENDRIN	4	2.0E-03	4.1E-05	1.4E-04	3.6E-04
ENDRIN	5	4.1E-04	9.3E-06	3.3E-05	3.6E-04
ENDRIN	6	5.1E-04	1.1E-05	4.0E-05	3.6E-04

EXPOSURE CONCENTRATIONS IN AGRICULTURAL PRODUCTS

MALATHION	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
MALATHION	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
MALATHION	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
MALATHION	2	2.0E-03	9.1E-06	3.3E-05	0.0E+00
MALATHION	3	2.7E-03	1.2E-05	4.4E-05	0.0E+00
MALATHION	4	2.2E-03	1.0E-05	3.6E-05	0.0E+00
MALATHION	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
MALATHION	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00
MN	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
MN	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
MN	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
MN	2	1.0E+01	1.9E-01	1.8E-01	0.0E+00
MN	3	0.0E+00	0.0E+00	0.0E+00	0.0E+00
MN	4	7.1E+00	1.4E-01	1.3E-01	0.0E+00
MN	5	4.2E+00	8.2E-02	7.8E-02	0.0E+00
MN	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00
OXATHIANE	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
OXATHIANE	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
OXATHIANE	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
OXATHIANE	2	0.0E+00	0.0E+00	0.0E+00	0.0E+00
OXATHIANE	3	3.0E-03	4.8E-07	1.2E-06	0.0E+00
OXATHIANE	4	5.0E-03	8.0E-07	1.9E-06	0.0E+00
OXATHIANE	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
OXATHIANE	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00
TCLEE	1A	8.1E-04	3.7E-06	1.3E-05	0.0E+00
TCLEE	1B	5.1E-03	2.3E-05	8.2E-05	0.0E+00
TCLEE	1C	8.1E-04	3.7E-06	1.3E-05	0.0E+00
TCLEE	2	7.4E-02	3.4E-04	1.2E-03	0.0E+00
TCLEE	3	1.4E-01	6.2E-04	2.2E-03	0.0E+00
TCLEE	4	4.0E-02	1.8E-04	6.4E-04	0.0E+00
TCLEE	5	5.5E-03	2.5E-05	8.9E-05	0.0E+00
TCLEE	6	2.0E-03	8.9E-06	3.1E-05	0.0E+00
TOLUENE	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
TOLUENE	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
TOLUENE	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
TOLUENE	2	0.0E+00	0.0E+00	0.0E+00	0.0E+00
TOLUENE	3	8.0E-03	3.5E-05	1.2E-04	0.0E+00
TOLUENE	4	7.3E-03	3.2E-05	1.1E-04	0.0E+00
TOLUENE	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
TOLUENE	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00

EXPOSURE CONCENTRATIONS IN AGRICULTURAL PRODUCTS

TRCLE	1A	0.0E+00	0.0E+00	0.0E+00	0.0E+00
TRCLE	1B	0.0E+00	0.0E+00	0.0E+00	0.0E+00
TRCLE	1C	0.0E+00	0.0E+00	0.0E+00	0.0E+00
TRCLE	2	5.4E-03	2.5E-05	9.4E-05	0.0E+00
TRCLE	3	3.8E-03	1.8E-05	6.7E-05	0.0E+00
TRCLE	4	2.0E-02	9.5E-05	3.5E-04	0.0E+00
TRCLE	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
TRCLE	6	5.4E-03	2.5E-05	9.4E-05	0.0E+00
XYLENE	1A	1.4E-03	9.2E-06	3.5E-05	0.0E+00
XYLENE	1B	9.0E-03	5.8E-05	2.2E-04	0.0E+00
XYLENE	1C	1.4E-03	9.2E-06	3.5E-05	0.0E+00
XYLENE	2	0.0E+00	0.0E+00	0.0E+00	0.0E+00
XYLENE	3	0.0E+00	0.0E+00	0.0E+00	0.0E+00
XYLENE	4	1.2E-02	7.6E-05	2.9E-04	0.0E+00
XYLENE	5	0.0E+00	0.0E+00	0.0E+00	0.0E+00
XYLENE	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00
CL6CP	1A	2.0E-04	9.9E-07	4.0E-06	0.0E+00
CL6CP	1B	1.2E-03	6.2E-06	2.5E-05	0.0E+00
CL6CP	1C	2.0E-04	9.9E-07	4.0E-06	0.0E+00
CL6CP	2	1.4E-03	7.0E-06	2.8E-05	0.0E+00
CL6CP	3	1.7E-03	8.4E-06	3.4E-05	0.0E+00
CL6CP	4	1.6E-03	8.1E-06	3.3E-05	0.0E+00
CL6CP	5	1.5E-03	7.4E-06	3.0E-05	0.0E+00
CL6CP	6	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Appendix D

ESTIMATED REASONABLE MAXIMUM EXPOSURE INTAKES

Zone 1A; Lifetime Resident

ANALYTE (Weight of Evidence)		PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Aldrin	(B2)	6.5E-10	6.5E-10					3.4E-07		3.4E-09		3.5E-07	3.5E-07
Arsenic, total	(A)					5.3E-08		2.5E-05	6.3E-08		5.5E-07	2.6E-05	2.6E-05
Atrazine	(C)					9.3E-08		3.4E-05	2.3E-08		1.5E-06	3.5E-05	3.5E-05
Benzene	(A)			7.2E-06	7.2E-06	7.5E-09		7.2E-06	1.7E-09		2.1E-07	7.4E-06	1.5E-05
Chloroform	(B2)			8.0E-06	8.0E-06	1.9E-09		8.0E-06	4.2E-10		2.2E-07	8.2E-06	1.6E-05
DDE, p,p'-	(B2)	3.7E-09	3.7E-09			1.2E-06		3.4E-07	4.1E-07	2.4E-08	4.8E-07	2.4E-06	2.4E-06
DDT, p,p'-	(B2)	7.3E-09	7.3E-09					4.3E-07		4.7E-08		4.8E-07	4.8E-07
Dieldrin	(B2)	5.4E-09	5.4E-09			8.3E-07	6.1E-07	4.0E-07	2.9E-07	2.8E-08	8.0E-07	3.0E-06	3.0E-06
Tetrachloroethene	(B2)			8.2E-06	8.2E-06	2.3E-08		8.2E-06	5.8E-09		3.8E-07	8.6E-06	1.7E-05

Zone 1B; Lifetime Resident

ANALYTE (Weight of Evidence)		PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Aldrin	(B2)	6.5E-10	6.5E-10					3.4E-07		3.4E-09		3.5E-07	3.5E-07
Arsenic, total	(A)					3.3E-07		2.5E-05	3.9E-07		3.5E-06	2.9E-05	2.9E-05
Atrazine	(C)					5.8E-07		3.4E-05	1.5E-07		9.6E-06	4.4E-05	4.4E-05
Benzene	(A)			7.2E-06	7.2E-06	4.7E-08		7.2E-06	1.1E-08		1.3E-06	8.5E-06	1.6E-05
Chloroform	(B2)			8.0E-06	8.0E-06	1.2E-08		8.0E-06	2.6E-09		1.3E-06	9.4E-06	1.7E-05
DDE, p,p'-	(B2)	3.7E-09	3.7E-09			1.4E-06		3.4E-07	4.7E-07	2.4E-08	6.0E-07	2.8E-06	2.8E-06
DDT, p,p'-	(B2)	7.3E-09	7.3E-09					4.3E-07		4.7E-08		4.8E-07	4.8E-07
Dieldrin	(B2)	5.4E-09	5.4E-09			1.1E-06	6.1E-07	4.0E-07	3.7E-07	2.8E-08	1.1E-06	3.6E-06	3.7E-06
Tetrachloroethene	(B2)			8.2E-06	8.2E-06	1.5E-07		8.2E-06	3.6E-08		2.4E-06	1.1E-05	1.9E-05

Zone 1C; Lifetime Resident

ANALYTE (Weight of Evidence)		PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Aldrin	(B2)	6.5E-10	6.5E-10					3.4E-07		3.4E-09		3.5E-07	3.5E-07
Arsenic, total	(A)					5.3E-08		2.5E-05	6.3E-08		5.5E-07	2.6E-05	2.6E-05
Atrazine	(C)					9.3E-08		3.4E-05	2.3E-08		1.5E-06	3.5E-05	3.5E-05
Benzene	(A)			7.2E-06	7.2E-06	7.5E-09		7.2E-06	1.7E-09		2.1E-07	7.4E-06	1.5E-05
Chloroform	(B2)			8.0E-06	8.0E-06	1.9E-09		8.0E-06	4.2E-10		2.2E-07	8.2E-06	1.6E-05
DDE, p,p'-	(B2)	3.7E-09	3.7E-09			1.2E-06		3.4E-07	4.1E-07	2.4E-08	4.8E-07	2.4E-06	2.4E-06
DDT, p,p'-	(B2)	7.3E-09	7.3E-09					4.3E-07		4.7E-08		4.8E-07	4.8E-07
Dieldrin	(B2)	5.4E-09	5.4E-09			8.3E-07	6.1E-07	4.0E-07	2.9E-07	2.8E-08	8.0E-07	3.0E-06	3.0E-06
Tetrachloroethene	(B2)			8.2E-06	8.2E-06	2.3E-08		8.2E-06	5.8E-09		3.8E-07	8.6E-06	1.7E-05

Zone 2; Lifetime Resident

ANALYTE (Weight of Evidence)		PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Aldrin	(B2)	6.5E-10	6.5E-10					5.2E-07		3.4E-09		5.3E-07	5.3E-07
Arsenic, total	(A)					2.5E-07		1.9E-05	3.0E-07		2.6E-06	2.2E-05	2.2E-05
Atrazine	(C)					1.1E-06		6.2E-05	2.7E-07		1.8E-05	8.1E-05	8.1E-05
Benzene	(A)			7.5E-06	7.5E-06	4.9E-08		7.5E-06	1.1E-08		1.4E-06	8.9E-06	1.6E-05
Carbon tetrachloride	(B2)			8.9E-06	8.9E-06	1.7E-07		8.9E-06	4.3E-08		2.7E-06	1.2E-05	2.1E-05
Chlordane, total	(B2)					3.0E-08		2.1E-06	6.3E-09		4.2E-07	2.5E-06	2.5E-06
Chloroform	(B2)			7.9E-04	7.9E-04	1.1E-06		7.9E-04	2.6E-07		1.3E-04	9.3E-04	1.7E-03
DDE, p,p'-	(B2)	3.7E-09	3.7E-09			1.4E-06		3.3E-07	4.6E-07	2.4E-08	5.9E-07	2.8E-06	2.8E-06
DDT, p,p'-	(B2)	7.3E-09	7.3E-09					3.9E-07		4.7E-08		4.4E-07	4.5E-07
Dibromochloropropane	(B2)			5.2E-06	5.2E-06	8.0E-09		5.2E-06	1.7E-09		8.1E-07	6.0E-06	1.1E-05
Dichlorobenzenes, total	(C)			6.0E-05	6.0E-05	4.7E-06		6.0E-05	1.3E-06		4.6E-05	1.1E-04	1.7E-04
Dichloroethane, 1,2-	(B2)			9.0E-06	9.0E-06	2.8E-08		9.0E-06	6.0E-09		1.3E-06	1.0E-05	1.9E-05
Dieldrin	(B2)	5.4E-09	5.4E-09			1.2E-06	6.1E-07	4.1E-07	4.0E-07	2.8E-08	1.2E-06	3.9E-06	3.9E-06
Tetrachloroethene	(B2)			1.2E-04	1.2E-04	2.1E-06		1.2E-04	5.2E-07		3.5E-05	1.6E-04	2.8E-04
Trichloroethene	(B2)			7.6E-06	7.6E-06	1.6E-07		7.6E-06	4.1E-08		2.5E-06	1.0E-05	1.8E-05

Zone 3; Lifetime Resident

ANALYTE (Weight of Evidence)		PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sedi-ment	Soil	Surface Water	Total	Ground-water	Total	Ground-water	Sedi-ment	Soil	Vege-tables	Total	Grand Total
Aldrin	(B2)	6.0E-10	4.3E-09		4.9E-09			5.9E-07	3.1E-09	2.2E-08		6.1E-07	6.2E-07
Arsenic, total	(A)			1.2E-07	1.2E-07						2.8E-06	2.8E-06	3.0E-06
Atrazine	(C)							1.5E-04			3.9E-05	1.9E-04	1.9E-04
Benzene	(A)					8.8E-06	8.8E-06	8.8E-06			1.4E-06	1.0E-05	1.9E-05
Chlordane, total	(B2)		1.5E-08	1.2E-09	1.6E-08			2.2E-06		7.9E-08	1.0E-06	3.3E-06	3.4E-06
Chloroform	(B2)					5.9E-05	5.9E-05	5.9E-05			8.9E-06	6.8E-05	1.3E-04
DDE, p,p'-	(B2)	2.2E-11	6.0E-09	6.1E-10	6.6E-09			2.5E-06	1.4E-10	3.9E-08	1.6E-06	4.1E-06	4.1E-06
DDT, p,p'-	(B2)	3.7E-10	1.5E-08	3.2E-10	1.6E-08			1.3E-06	2.4E-09	1.0E-07		1.4E-06	1.4E-06
Dibromochloropropane	(B2)	4.2E-09			4.2E-09	1.6E-06	1.6E-06	1.6E-06	3.1E-08		2.3E-07	1.9E-06	3.5E-06
Dichloroethane, 1,2-	(B2)					1.1E-05	1.1E-05	1.1E-05			1.4E-06	1.2E-05	2.3E-05
Dieldrin	(B2)	7.3E-09	3.5E-08	1.8E-08	6.0E-08			2.5E-06	3.8E-08	1.8E-07	7.6E-06	1.0E-05	1.0E-05
Tetrachloroethene	(B2)					2.4E-04	2.4E-04	2.4E-04			6.4E-05	3.1E-04	5.5E-04
Trichloroethene	(B2)					6.0E-06	6.0E-06	6.0E-06			1.8E-06	7.8E-06	1.4E-05

Zone 4; Lifetime Resident

ANALYTE (Weight of Evidence)		PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sedi-ment	Soil	Surface Water	Total	Ground-water	Total	Ground-water	Sedi-ment	Soil	Vege-tables	Total	Grand Total
Aldrin	(B2)	6.0E-10	6.5E-10		1.3E-09			1.4E-06	3.1E-09	3.4E-09		1.4E-06	1.4E-06
Arsenic, total	(A)			1.2E-07	1.2E-07			3.3E-05			6.9E-06	4.0E-05	4.0E-05
Atrazine	(C)							8.6E-05			2.2E-05	1.1E-04	1.1E-04
Benzene	(A)					1.1E-05	1.1E-05	1.1E-05			1.8E-06	1.3E-05	2.4E-05
Chlordane, total	(B2)			1.2E-09	1.2E-09			6.3E-06			1.2E-06	7.5E-06	7.5E-06
Chloroform	(B2)					1.8E-05	1.8E-05	1.8E-05			2.7E-06	2.0E-05	3.8E-05
DDE, p,p'-	(B2)	2.2E-11	3.7E-09	6.1E-10	4.3E-09			9.9E-07	1.4E-10	2.4E-08	8.5E-07	1.9E-06	1.9E-06
DDT, p,p'-	(B2)	3.7E-10	7.3E-09	3.2E-10	8.0E-09			1.2E-06	2.4E-09	4.7E-08		1.2E-06	1.2E-06
Dibromochloropropane	(B2)	4.2E-09			4.2E-09	1.8E-06	1.8E-06	1.8E-06	3.1E-08		2.5E-07	2.1E-06	3.9E-06
Dichlorobenzenes, total	(C)					3.5E-05	3.5E-05	3.5E-05			2.4E-05	5.8E-05	9.3E-05
Dichloroethane, 1,2-	(B2)					8.6E-05	8.6E-05	8.6E-05			1.1E-05	9.7E-05	1.8E-04
Dieldrin	(B2)	7.3E-09	5.4E-09	1.8E-08	3.0E-08			6.5E-07	3.8E-08	2.8E-08	3.1E-06	3.8E-06	3.9E-06
Tetrachloroethene	(B2)					7.2E-05	7.2E-05	7.2E-05			1.9E-05	9.0E-05	1.6E-04
Trichloroethene	(B2)					3.2E-05	3.2E-05	3.2E-05			9.6E-06	4.1E-05	7.3E-05

Carcinogenic intakes

Zone 5; Adult Commercial/Industrial; Chronic RME

ANALYTE (Weight of Evidence)		PATHWAY							
		Dermal		Inhalation		Oral			
		MEDIUM		MEDIUM		MEDIUM			
		Soil	Total	GW	Total	GW	Soil	Total	Grand Total
Aldrin	(B2)	4.1E-10	4.1E-10			1.4E-07	3.3E-10	1.4E-07	1.4E-07
Arsenic	(A)					9.4E-06		9.4E-06	9.4E-06
Chloroform	(B2)			4.2E-05	4.2E-05	4.2E-05		4.2E-05	8.4E-05
Dibromochloropropane	(B2)			3.5E-07	3.5E-07	3.5E-07		3.5E-07	7.0E-07
DDE, p,p'-	(B2)	2.9E-09	2.9E-09				2.4E-09	2.4E-09	5.3E-09
DDT, p,p'-	(B2)	5.9E-09	5.9E-09				4.7E-09	4.7E-09	1.1E-08
Dieldrin	(B2)	3.5E-09	3.5E-09			2.5E-07	2.8E-09	2.5E-07	2.5E-07
Tetrachloroethene	(B2)			2.6E-06	2.6E-06	2.6E-06		2.6E-06	5.3E-06

Zone 6; Lifetime Resident

ANALYTE (Weight of Evidence)		PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Aldrin	(B2)	6.5E-10	6.5E-10					3.5E-07		3.4E-09		3.5E-07	3.5E-07
Atrazine	(C)					1.4E-07		5.2E-05	3.6E-08		2.4E-06	5.4E-05	5.4E-05
Chloroform	(B2)			3.9E-05	3.9E-05	9.1E-09		3.9E-05	2.0E-09		1.1E-06	4.0E-05	7.9E-05
DDE, p,p'-	(B2)	3.7E-09	3.7E-09			1.1E-06			4.0E-07	2.4E-08	4.6E-07	2.0E-06	2.0E-06
DDT, p,p'-	(B2)	7.3E-09	7.3E-09							4.7E-08		4.7E-08	5.5E-08
Dieldrin	(B2)	5.4E-09	5.4E-09			8.3E-07	6.1E-07	4.6E-07	2.9E-07	2.8E-08	8.0E-07	3.0E-06	3.0E-06
Tetrachloroethene	(B2)			2.0E-05	2.0E-05	5.6E-08		2.0E-05	1.4E-08		9.2E-07	2.1E-05	4.0E-05
Trichloroethene	(B2)			4.7E-05	4.7E-05	1.6E-07		4.7E-05	4.2E-08		2.6E-06	5.0E-05	9.8E-05

Zone 1A; Adult Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			1.7E-05	1.7E-05	4.9E-09		1.7E-05	4.1E-09		4.9E-07	1.7E-05	3.4E-05
Cardiovascular	Atrazine					6.1E-08		7.9E-05	5.5E-08		3.6E-06	8.2E-05	8.2E-05
CNS	DIMP					4.6E-08		1.7E-03	4.7E-08		1.5E-04	1.9E-03	1.9E-03
	Xylenes, total			2.1E-05	2.1E-05	3.8E-08		2.1E-05	3.6E-08		1.6E-06	2.2E-05	4.3E-05
Gastrointestinal	Hexachlorocyclopentadiene					4.1E-09		8.0E-07	4.1E-09		2.2E-07	1.0E-06	1.0E-06
Hepatic	Aldrin	1.5E-09	1.5E-09					8.0E-07		2.6E-09		8.0E-07	8.0E-07
	Benzene			1.7E-05	1.7E-05	4.9E-09		1.7E-05	4.1E-09		4.9E-07	1.7E-05	3.4E-05
	Chlorobenzene			2.8E-05	2.8E-05	2.5E-08		2.8E-05	2.3E-08		1.4E-06	2.9E-05	5.7E-05
	Chloroform			1.9E-05	1.9E-05	1.2E-09		1.9E-05	9.8E-10		5.0E-07	1.9E-05	3.8E-05
	DDE, p,p'-	8.6E-09	8.6E-09			7.7E-07		7.9E-07	9.6E-07	1.8E-08	1.1E-06	3.7E-06	3.7E-06
	DDT, p,p'-	1.7E-08	1.7E-08					1.0E-06		3.6E-08		1.0E-06	1.1E-06
	Dieldrin	1.3E-08	1.3E-08			5.4E-07	1.4E-06	9.3E-07	6.7E-07	2.2E-08	1.9E-06	5.5E-06	5.5E-06
	Endrin	3.0E-09	3.0E-09			5.1E-08		8.9E-07	4.4E-08	5.2E-09	6.1E-07	1.6E-06	1.6E-06
	Isodrin							7.6E-07				7.6E-07	7.6E-07
	Tetrachloroethene			1.9E-05	1.9E-05	1.5E-08		1.9E-05	1.3E-08		8.9E-07	2.0E-05	3.9E-05
Renal	Chlorobenzene			2.8E-05	2.8E-05	2.5E-08		2.8E-05	2.3E-08		1.4E-06	2.9E-05	5.7E-05
Respiratory	Xylenes, total			2.1E-05	2.1E-05								2.1E-05
Skin	Arsenic, total					3.5E-08		5.9E-05	1.5E-07		1.3E-06	6.0E-05	6.0E-05

Zone 1A; Child Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			2.5E-05	2.5E-05	3.6E-08		2.5E-05	1.2E-08		7.9E-07	2.6E-05	5.2E-05
Cardiovascular	Atrazine					4.4E-07		1.2E-04	1.7E-07		5.8E-06	1.3E-04	1.3E-04
CNS	DIMP					3.3E-07		2.6E-03	1.5E-07		2.4E-04	2.9E-03	2.9E-03
	Xylenes, total			3.1E-05	3.1E-05	2.8E-07		3.1E-05	1.1E-07		2.6E-06	3.4E-05	6.6E-05
Gastrointestinal	Hexachlorocyclopentadiene					3.0E-08		1.2E-06	1.3E-08		3.5E-07	1.6E-06	1.6E-06
Hepatic	Aldrin	3.1E-09	3.1E-09					1.2E-06		1.7E-08		1.2E-06	1.2E-06
	Benzene			2.5E-05	2.5E-05	3.6E-08		2.5E-05	1.2E-08		7.9E-07	2.6E-05	5.2E-05
	Chlorobenzene			4.2E-05	4.2E-05	1.8E-07		4.2E-05	7.0E-08		2.3E-06	4.5E-05	8.7E-05
	Chloroform			2.8E-05	2.8E-05	8.9E-09		2.8E-05	3.0E-09		8.2E-07	2.9E-05	5.8E-05
	DDE, p,p'-	1.8E-08	1.8E-08			5.6E-06		1.2E-06	2.9E-06	1.2E-07	1.8E-06	1.2E-05	1.2E-05
	DDT, p,p'-	3.5E-08	3.5E-08					1.5E-06		2.3E-07		1.7E-06	1.8E-06
	Dieldrin	2.6E-08	2.6E-08			4.0E-06	4.0E-06	1.4E-06	2.1E-06	1.4E-07	3.0E-06	1.5E-05	1.5E-05
	Endrin	6.2E-09	6.2E-09			3.7E-07		1.4E-06	1.3E-07	3.3E-08	9.9E-07	2.9E-06	2.9E-06
	Isodrin							1.1E-06				1.1E-06	1.1E-06
	Tetrachloroethene			2.9E-05	2.9E-05	1.1E-07		2.9E-05	4.1E-08		1.4E-06	3.1E-05	5.9E-05
Renal	Chlorobenzene			4.2E-05	4.2E-05	1.8E-07		4.2E-05	7.0E-08		2.3E-06	4.5E-05	8.7E-05
Respiratory	Xylenes, total			3.1E-05	3.1E-05								3.1E-05
Skin	Arsenic, total					2.5E-07		8.9E-05	4.5E-07		2.1E-06	9.2E-05	9.2E-05

Zone 1B; Adult Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			1.7E-05	1.7E-05	3.1E-08		1.7E-05	2.5E-08		3.0E-06	2.0E-05	3.7E-05
Cardiovascular	Atrazine					3.8E-07		7.9E-05	3.4E-07		2.3E-05	1.0E-04	1.0E-04
CNS	DIMP					1.1E-07		1.7E-03	1.1E-07		3.4E-04	2.1E-03	2.1E-03
	Xylenes, total			2.1E-05	2.1E-05	2.4E-07		2.1E-05	2.2E-07		9.8E-06	3.1E-05	5.2E-05
Gastrointestinal	Hexachlorocyclopentadiene					2.5E-08		8.0E-07	2.6E-08		1.3E-06	2.2E-06	2.2E-06
Hepatic	Aldrin	1.5E-09	1.5E-09					8.0E-07		2.6E-09		8.0E-07	8.0E-07
	Benzene			1.7E-05	1.7E-05	3.1E-08		1.7E-05	2.5E-08		3.0E-06	2.0E-05	3.7E-05
	Chlorobenzene			2.8E-05	2.8E-05	1.5E-07		2.8E-05	1.4E-07		8.7E-06	3.7E-05	6.5E-05
	Chloroform			1.9E-05	1.9E-05	7.6E-09		1.9E-05	6.1E-09		3.1E-06	2.2E-05	4.1E-05
	DDE, p,p'-	8.6E-09	8.6E-09			9.1E-07		7.9E-07	1.1E-06	1.8E-08	1.4E-06	4.2E-06	4.2E-06
	DDT, p,p'-	1.7E-08	1.7E-08					1.0E-06		3.6E-08		1.0E-06	1.1E-06
	Dieldrin	1.3E-08	1.3E-08			7.4E-07	1.4E-06	9.3E-07	8.7E-07	2.2E-08	2.6E-06	6.6E-06	6.6E-06
	Endrin	3.0E-09	3.0E-09			1.2E-07		8.9E-07	9.5E-08	5.2E-09	1.4E-06	2.5E-06	2.5E-06
	Isodrin							7.6E-07				7.6E-07	7.6E-07
	Tetrachloroethene			1.9E-05	1.9E-05	9.5E-08		1.9E-05	8.4E-08		5.6E-06	2.5E-05	4.4E-05
Renal	Chlorobenzene			2.8E-05	2.8E-05	1.5E-07		2.8E-05	1.4E-07		8.7E-06	3.7E-05	6.5E-05
Respiratory	Xylenes, total			2.1E-05	2.1E-05								2.1E-05
Skin	Arsenic, total					2.2E-07		5.9E-05	9.2E-07		8.1E-06	6.8E-05	6.8E-05

Zone 1B; Child Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			2.5E-05	2.5E-05	2.2E-07		2.5E-05	7.8E-08		4.9E-06	3.1E-05	5.6E-05
Cardiovascular	Atrazine					2.8E-06		1.2E-04	1.0E-06		3.7E-05	1.6E-04	1.6E-04
CNS	DIMP					7.8E-07		2.6E-03	3.4E-07		5.6E-04	3.2E-03	3.2E-03
	Xylenes, total			3.1E-05	3.1E-05	1.7E-06		3.1E-05	6.8E-07		1.6E-05	5.0E-05	8.1E-05
Gastrointestinal	Hexachlorocyclopentadiene					1.9E-07		1.2E-06	7.9E-08		2.2E-06	3.7E-06	3.7E-06
Hepatic	Aldrin	3.1E-09	3.1E-09					1.2E-06		1.7E-08		1.2E-06	1.2E-06
	Benzene			2.5E-05	2.5E-05	2.2E-07		2.5E-05	7.8E-08		4.9E-06	3.1E-05	5.6E-05
	Chlorobenzene			4.2E-05	4.2E-05	1.1E-06		4.2E-05	4.4E-07		1.4E-05	5.8E-05	1.0E-04
	Chloroform			2.8E-05	2.8E-05	5.5E-08		2.8E-05	1.9E-08		5.1E-06	3.4E-05	6.2E-05
	DDE, p,p'-	1.8E-08	1.8E-08			6.6E-06		1.2E-06	3.3E-06	1.2E-07	2.3E-06	1.4E-05	1.4E-05
	DDT, p,p'-	3.5E-08	3.5E-08					1.5E-06		2.3E-07		1.7E-06	1.8E-06
	Dieldrin	2.6E-08	2.6E-08			5.4E-06	4.0E-06	1.4E-06	2.7E-06	1.4E-07	4.2E-06	1.8E-05	1.8E-05
	Endrin	6.2E-09	6.2E-09			8.4E-07		1.4E-06	2.9E-07	3.3E-08	2.3E-06	4.8E-06	4.8E-06
	Isodrin							1.1E-06				1.1E-06	1.1E-06
	Tetrachloroethene			2.9E-05	2.9E-05	6.9E-07		2.9E-05	2.6E-07		9.0E-06	3.9E-05	6.8E-05
Renal	Chlorobenzene			4.2E-05	4.2E-05	1.1E-06		4.2E-05	4.4E-07		1.4E-05	5.8E-05	1.0E-04
Respiratory	Xylenes, total			3.1E-05	3.1E-05								3.1E-05
Skin	Arsenic, total					1.6E-06		8.9E-05	2.8E-06		1.3E-05	1.1E-04	1.1E-04

Zone 1C; Adult Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			1.7E-05	1.7E-05	4.9E-09		1.7E-05	4.1E-09		4.9E-07	1.7E-05	3.4E-05
Cardiovascular	Atrazine					6.1E-08		7.9E-05	5.5E-08		3.6E-06	8.2E-05	8.2E-05
CNS	DIMP					1.7E-08		1.7E-03	1.8E-08		5.5E-05	1.8E-03	1.8E-03
	Xylenes, total			2.1E-05	2.1E-05	3.8E-08		2.1E-05	3.6E-08		1.6E-06	2.2E-05	4.3E-05
Gastrointestinal	Hexachlorocyclopentadiene					4.1E-09		8.0E-07	4.1E-09		2.2E-07	1.0E-06	1.0E-06
Hepatic	Aldrin	1.5E-09	1.5E-09					8.0E-07		2.6E-09		8.0E-07	8.0E-07
	Benzene			1.7E-05	1.7E-05	4.9E-09		1.7E-05	4.1E-09		4.9E-07	1.7E-05	3.4E-05
	Chlorobenzene			2.8E-05	2.8E-05	2.5E-08		2.8E-05	2.3E-08		1.4E-06	2.9E-05	5.7E-05
	Chloroform			1.9E-05	1.9E-05	1.2E-09		1.9E-05	9.8E-10		5.0E-07	1.9E-05	3.8E-05
	DDE, p,p'-	8.6E-09	8.6E-09			7.7E-07		7.9E-07	9.6E-07	1.8E-08	1.1E-06	3.7E-06	3.7E-06
	DDT, p,p'-	1.7E-08	1.7E-08					1.0E-06		3.6E-08		1.0E-06	1.1E-06
	Dieldrin	1.3E-08	1.3E-08			5.4E-07	1.4E-06	9.3E-07	6.7E-07	2.2E-08	1.9E-06	5.5E-06	5.5E-06
	Endrin	3.0E-09	3.0E-09			5.1E-08		8.9E-07	4.4E-08	5.2E-09	6.1E-07	1.6E-06	1.6E-06
	Isodrin							7.6E-07				7.6E-07	7.6E-07
	Tetrachloroethene			1.9E-05	1.9E-05	1.5E-08		1.9E-05	1.3E-08		8.9E-07	2.0E-05	3.9E-05
Renal	Chlorobenzene			2.8E-05	2.8E-05	2.5E-08		2.8E-05	2.3E-08		1.4E-06	2.9E-05	5.7E-05
Respiratory	Xylenes, total			2.1E-05	2.1E-05								2.1E-05
Skin	Arsenic, total					3.5E-08		5.9E-05	1.5E-07		1.3E-06	6.0E-05	6.0E-05

Zone 1C; Child Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			2.5E-05	2.5E-05	3.6E-08		2.5E-05	1.2E-08		7.9E-07	2.6E-05	5.2E-05
Cardiovascular	Atrazine					4.4E-07		1.2E-04	1.7E-07		5.8E-06	1.3E-04	1.3E-04
CNS	DIMP					1.3E-07		2.6E-03	5.4E-08		8.9E-05	2.7E-03	2.7E-03
	Xylenes, total			3.1E-05	3.1E-05	2.8E-07		3.1E-05	1.1E-07		2.6E-06	3.4E-05	6.6E-05
Gastrointestinal	Hexachlorocyclopentadiene					3.0E-08		1.2E-06	1.3E-08		3.5E-07	1.6E-06	1.6E-06
Hepatic	Aldrin	3.1E-09	3.1E-09					1.2E-06		1.7E-08		1.2E-06	1.2E-06
	Benzene			2.5E-05	2.5E-05	3.6E-08		2.5E-05	1.2E-08		7.9E-07	2.6E-05	5.2E-05
	Chlorobenzene			4.2E-05	4.2E-05	1.8E-07		4.2E-05	7.0E-08		2.3E-06	4.5E-05	8.7E-05
	Chloroform			2.8E-05	2.8E-05	8.9E-09		2.8E-05	3.0E-09		8.2E-07	2.9E-05	5.8E-05
	DDE, p,p'-	1.8E-08	1.8E-08			5.6E-06		1.2E-06	2.9E-06	1.2E-07	1.8E-06	1.2E-05	1.2E-05
	DDT, p,p'-	3.5E-08	3.5E-08					1.5E-06		2.3E-07		1.7E-06	1.8E-06
	Dieldrin	2.6E-08	2.6E-08			4.0E-06	4.0E-06	1.4E-06	2.1E-06	1.4E-07	3.0E-06	1.5E-05	1.5E-05
	Endrin	6.2E-09	6.2E-09			3.7E-07		1.4E-06	1.3E-07	3.3E-08	9.9E-07	2.9E-06	2.9E-06
	Isodrin							1.1E-06				1.1E-06	1.1E-06
	Tetrachloroethene			2.9E-05	2.9E-05	1.1E-07		2.9E-05	4.1E-08		1.4E-06	3.1E-05	5.9E-05
Renal	Chlorobenzene			4.2E-05	4.2E-05	1.8E-07		4.2E-05	7.0E-08		2.3E-06	4.5E-05	8.7E-05
Respiratory	Xylenes, total			3.1E-05	3.1E-05								3.1E-05
Skin	Arsenic, total					2.5E-07		8.9E-05	4.5E-07		2.1E-06	9.2E-05	9.2E-05

Zone 2; Adult Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			1.7E-05	1.7E-05	3.2E-08		1.7E-05	2.6E-08		3.2E-06	2.1E-05	3.8E-05
Cardiovascular	Atrazine					7.0E-07		1.5E-04	6.3E-07		4.2E-05	1.9E-04	1.9E-04
	Dichloroethane, 1,2-					1.8E-08		2.1E-05	1.4E-08		3.0E-06	2.4E-05	2.4E-05
CNS	DIMP					1.2E-06		2.0E-02	1.2E-06		3.9E-03	2.3E-02	2.3E-02
	Malathion					3.7E-08		7.0E-06	3.4E-08		2.2E-06	9.3E-06	9.3E-06
	Manganese					7.9E-04		4.3E-02	1.9E-04		1.1E-02	5.5E-02	5.5E-02
Gastrointestinal	Hexachlorocyclopentadiene					2.9E-08		9.0E-07	2.9E-08		1.5E-06	2.5E-06	2.5E-06
Hepatic	Aldrin	1.5E-09	1.5E-09					1.2E-06		2.6E-09		1.2E-06	1.2E-06
	Benzene			1.7E-05	1.7E-05	3.2E-08		1.7E-05	2.6E-08		3.2E-06	2.1E-05	3.8E-05
	Carbon tetrachloride			2.1E-05	2.1E-05	1.1E-07		2.1E-05	1.0E-07		6.3E-06	2.7E-05	4.8E-05
	Chlordane, total					1.9E-08		4.9E-06	1.5E-08		9.7E-07	5.9E-06	5.9E-06
	Chlorobenzene			4.9E-05	4.9E-05	2.7E-07		4.9E-05	2.5E-07		1.5E-05	6.5E-05	1.1E-04
	Chloroform			1.8E-03	1.8E-03	7.5E-07		1.8E-03	6.0E-07		3.1E-04	2.2E-03	4.0E-03
	Chlorophenylmethyl sulfone, p-					3.9E-08		1.2E-04	2.9E-08		1.5E-05	1.3E-04	1.3E-04
	Chlorophenylmethyl sulfoxide, p-					1.3E-07		4.0E-04	9.6E-08		5.2E-05	4.5E-04	4.5E-04
	DDE, p,p'-	8.6E-09	8.6E-09			9.0E-07		7.8E-07	1.1E-06	1.8E-08	1.4E-06	4.2E-06	4.2E-06
	DDT, p,p'-	1.7E-08	1.7E-08					9.1E-07		3.6E-08		9.5E-07	9.7E-07
	Dibromochloropropane			1.2E-05	1.2E-05	5.2E-09		1.2E-05	4.0E-09		1.9E-06	1.4E-05	2.6E-05
	Dichlorobenzenes, total			1.4E-04	1.4E-04	3.1E-06		1.4E-04	3.0E-06		1.1E-04	2.5E-04	3.9E-04
	Dicyclopentadiene					5.9E-07		1.0E-04	5.7E-07		5.6E-05	1.6E-04	1.6E-04
	Dieldrin	1.3E-08	1.3E-08			8.0E-07	1.4E-06	9.5E-07	9.3E-07	2.2E-08	2.8E-06	6.9E-06	6.9E-06
	Endrin	3.0E-09	3.0E-09			1.3E-07		1.0E-06	1.1E-07	5.2E-09	1.6E-06	2.9E-06	2.9E-06
	Isodrin							9.6E-07				9.6E-07	9.6E-07
	Tetrachloroethene			2.8E-04	2.8E-04	1.4E-06		2.8E-04	1.2E-06		8.1E-05	3.6E-04	6.4E-04
	Trichloroethene			1.8E-05	1.8E-05	1.0E-07		1.8E-05	9.7E-08		5.9E-06	2.4E-05	4.1E-05
Renal	Chlorobenzene			4.9E-05	4.9E-05	2.7E-07		4.9E-05	2.5E-07		1.5E-05	6.5E-05	1.1E-04
	Dibromochloropropane			1.2E-05	1.2E-05	5.2E-09		1.2E-05	4.0E-09		1.9E-06	1.4E-05	2.6E-05
Respiratory	Dichloroethane, 1,2-			2.1E-05	2.1E-05								2.1E-05
Skin	Arsenic, total					1.6E-07		4.5E-05	7.0E-07		6.1E-06	5.2E-05	5.2E-05

Zone 2; Child Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			2.6E-05	2.6E-05	2.3E-07		2.6E-05	8.1E-08		5.2E-06	3.2E-05	5.8E-05
Cardiovascular	Atrazine					5.1E-06		2.2E-04	1.9E-06		6.8E-05	3.0E-04	3.0E-04
	Dichloroethane, 1,2-					1.3E-07		3.2E-05	4.3E-08		4.9E-06	3.7E-05	3.7E-05
CNS	DIMP					8.8E-06		3.0E-02	3.8E-06		6.3E-03	3.6E-02	3.6E-02
	Malathion					2.7E-07		1.1E-05	1.0E-07		3.6E-06	1.5E-05	1.5E-05
	Manganese					5.8E-03		6.6E-02	5.7E-04		1.8E-02	9.0E-02	9.0E-02
Gastrointestinal	Hexachlorocyclopentadiene					2.1E-07		1.4E-06	8.9E-08		2.5E-06	4.1E-06	4.1E-06
Hepatic	Aldrin	3.1E-09	3.1E-09					1.8E-06		1.7E-08		1.9E-06	1.9E-06
	Benzene			2.6E-05	2.6E-05	2.3E-07		2.6E-05	8.1E-08		5.2E-06	3.2E-05	5.8E-05
	Carbon tetrachloride			3.2E-05	3.2E-05	8.1E-07		3.2E-05	3.1E-07		1.0E-05	4.3E-05	7.4E-05
	Chlordane, total					1.4E-07		7.4E-06	4.5E-08		1.6E-06	9.2E-06	9.2E-06
	Chlorobenzene			7.4E-05	7.4E-05	2.0E-06		7.4E-05	7.6E-07		2.5E-05	1.0E-04	1.8E-04
	Chloroform			2.8E-03	2.8E-03	5.5E-06		2.8E-03	1.8E-06		5.0E-04	3.3E-03	6.1E-03
	Chlorophenylmethyl sulfone, p-					2.8E-07		1.8E-04	8.8E-08		2.5E-05	2.1E-04	2.1E-04
	Chlorophenylmethyl sulfoxide, p-					9.4E-07		6.0E-04	2.9E-07		8.5E-05	6.9E-04	6.9E-04
	DDE, p,p'-	1.8E-08	1.8E-08			6.6E-06		1.2E-06	3.3E-06	1.2E-07	2.3E-06	1.3E-05	1.3E-05
	DDT, p,p'-	3.5E-08	3.5E-08					1.4E-06		2.3E-07		1.6E-06	1.7E-06
	Dibromochloropropane			1.8E-05	1.8E-05	3.8E-08		1.8E-05	1.2E-08		3.1E-06	2.1E-05	4.0E-05
	Dichlorobenzenes, total			2.1E-04	2.1E-04	2.2E-05		2.1E-04	9.2E-06		1.7E-04	4.2E-04	6.3E-04
	Dicyclopentadiene					4.3E-06		1.5E-04	1.7E-06		9.0E-05	2.5E-04	2.5E-04
	Dieldrin	2.6E-08	2.6E-08			5.8E-06	4.0E-06	1.4E-06	2.9E-06	1.4E-07	4.5E-06	1.9E-05	1.9E-05
	Endrin	6.2E-09	6.2E-09			9.5E-07		1.5E-06	3.3E-07	3.3E-08	2.6E-06	5.5E-06	5.5E-06
	Isodrin							1.5E-06				1.5E-06	1.5E-06
	Tetrachloroethene			4.2E-04	4.2E-04	1.0E-05		4.2E-04	3.7E-06		1.3E-04	5.7E-04	9.9E-04
	Trichloroethene			2.7E-05	2.7E-05	7.6E-07		2.7E-05	3.0E-07		9.6E-06	3.7E-05	6.4E-05
Renal	Chlorobenzene			7.4E-05	7.4E-05	2.0E-06		7.4E-05	7.6E-07		2.5E-05	1.0E-04	1.8E-04
	Dibromochloropropane			1.8E-05	1.8E-05	3.8E-08		1.8E-05	1.2E-08		3.1E-06	2.1E-05	4.0E-05
Respiratory	Dichloroethane, 1,2-			3.2E-05	3.2E-05								3.2E-05
Skin	Arsenic, total					1.2E-06		6.8E-05	2.1E-06		9.9E-06	8.1E-05	8.1E-05

Zone 3; Adult Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Blood	Benzene					2.0E-05	2.0E-05	2.0E-05			3.4E-06	2.4E-05	4.4E-05
	Toluene							3.5E-05			8.7E-06	4.4E-05	4.4E-05
Cardiovascular	Atrazine							3.5E-04			9.1E-05	4.5E-04	4.5E-04
	Dichloroethane, 1,2-							2.5E-05			3.2E-06	2.8E-05	2.8E-05
CNS	DIMP			3.7E-06	3.7E-06			1.6E-02			3.0E-03	1.9E-02	1.9E-02
	Dithiane, 1,4-							5.4E-05			5.7E-06	6.0E-05	6.0E-05
	Malathion							1.0E-05			2.9E-06	1.3E-05	1.3E-05
	Oxathiane, 1,4-							3.6E-05			3.3E-06	4.0E-05	4.0E-05
	Toluene					3.5E-05	3.5E-05						3.5E-05
Ocular	Toluene					3.5E-05	3.5E-05						3.5E-05
Gastrointestinal	Hexachlorocyclopentadiene							1.2E-06			1.8E-06	3.0E-06	3.0E-06
Hepatic	Aldrin	1.4E-09	1.0E-08		1.1E-08			1.4E-06	2.4E-09	1.7E-08		1.4E-06	1.4E-06
	Benzene					2.0E-05	2.0E-05	2.0E-05			3.4E-06	2.4E-05	4.4E-05
	Chlordane, total		3.5E-08	2.9E-09	3.8E-08			5.2E-06		6.1E-08	2.4E-06	7.7E-06	7.7E-06
	Chlorobenzene					4.9E-05	4.9E-05	4.9E-05			1.4E-05	6.2E-05	1.1E-04
	Chloroform					1.4E-04	1.4E-04	1.4E-04			2.1E-05	1.6E-04	3.0E-04
	Chlorophenylmethyl sulfone, p-							1.8E-04			2.1E-05	2.0E-04	2.0E-04
	Chlorophenylmethyl sulfoxide, p-							2.8E-04			3.4E-05	3.2E-04	3.2E-04
	DDE, p,p'-	5.1E-11	1.4E-08	1.4E-09	1.5E-08			5.9E-06	1.1E-10	3.0E-08	3.6E-06	9.6E-06	9.6E-06
	DDT, p,p'-	8.5E-10	3.6E-08	7.4E-10	3.8E-08			2.9E-06	1.8E-09	7.7E-08		3.0E-06	3.0E-06
	Dibromochloropropane	9.7E-09			9.7E-09	3.8E-06	3.8E-06	3.8E-06	2.4E-08		5.4E-07	4.4E-06	8.2E-06
	Dicyclopentadiene			1.6E-07	1.6E-07			4.5E-03			2.3E-03	6.7E-03	6.7E-03
	Dieldrin	1.7E-08	8.1E-08	4.1E-08	1.4E-07			5.8E-06	2.9E-08	1.4E-07	1.8E-05	2.4E-05	2.4E-05
	Dithiane, 1,4-							5.4E-05			5.7E-06	6.0E-05	6.0E-05
	Endrin	4.7E-10	2.3E-08		2.3E-08			2.0E-05	8.0E-10	3.9E-08	1.5E-05	3.5E-05	3.5E-05
	Isodrin							1.3E-06				1.3E-06	1.3E-06
	Tetrachloroethene					5.7E-04	5.7E-04	5.7E-04			1.5E-04	7.2E-04	1.3E-03
	Trichloroethene					1.4E-05	1.4E-05	1.4E-05			4.2E-06	1.8E-05	3.2E-05
Renal	Chlorobenzene					4.9E-05	4.9E-05	4.9E-05			1.4E-05	6.2E-05	1.1E-04
	Dibromochloropropane	9.7E-09			9.7E-09	3.8E-06	3.8E-06	3.8E-06	2.4E-08		5.4E-07	4.4E-06	8.2E-06

(CONTINUED)

Zone 3; Adult Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sedi-ment	Soil	Surface Water	Total	Ground-water	Total	Ground-water	Sedi-ment	Soil	Vege-tables	Total	Grand Total
Respiratory	Dichloroethane, 1,2-					2.5E-05	2.5E-05						2.5E-05
	Toluene					3.5E-05	3.5E-05						3.5E-05
Skin	Arsenic, total			2.8E-07	2.8E-07						6.6E-06	6.6E-06	6.9E-06

Zone 3; Child Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Blood	Benzene					3.1E-05	3.1E-05	3.1E-05			5.4E-06	3.6E-05	6.8E-05
	Toluene							5.3E-05			1.4E-05	6.7E-05	6.7E-05
Cardiovascular	Atrazine							5.4E-04			1.5E-04	6.9E-04	6.9E-04
	Dichloroethane, 1,2-							3.8E-05			5.3E-06	4.4E-05	4.4E-05
CNS	DIMP			7.5E-06	7.5E-06			2.5E-02			4.9E-03	2.9E-02	2.9E-02
	Dithiane, 1,4-							8.2E-05			9.2E-06	9.1E-05	9.1E-05
	Malathion							1.6E-05			4.8E-06	2.1E-05	2.1E-05
	Oxathiane, 1,4-							5.5E-05			5.3E-06	6.0E-05	6.0E-05
	Toluene					5.3E-05	5.3E-05						5.3E-05
Ocular	Toluene					5.3E-05	5.3E-05						5.3E-05
Gastrointestinal	Hexachlorocyclopentadiene							1.8E-06			3.0E-06	4.8E-06	4.8E-06
Hepatic	Aldrin	2.9E-09	2.0E-08		2.3E-08			2.1E-06	1.5E-08	1.1E-07		2.2E-06	2.2E-06
	Benzene					3.1E-05	3.1E-05	3.1E-05			5.4E-06	3.6E-05	6.8E-05
	Chlordane, total		7.2E-08	5.9E-09	7.8E-08			8.0E-06		3.9E-07	3.9E-06	1.2E-05	1.2E-05
	Chlorobenzene					7.4E-05	7.4E-05	7.4E-05			2.2E-05	9.6E-05	1.7E-04
	Chloroform					2.1E-04	2.1E-04	2.1E-04			3.4E-05	2.4E-04	4.5E-04
	Chlorophenylmethyl sulfone, p-							2.8E-04			3.4E-05	3.1E-04	3.1E-04
	Chlorophenylmethyl sulfoxide, p-							4.3E-04			5.5E-05	4.9E-04	4.9E-04
	DDE, p,p'-	1.0E-10	2.9E-08	2.9E-09	3.2E-08			8.9E-06	7.0E-10	1.9E-07	5.9E-06	1.5E-05	1.5E-05
	DDT, p,p'-	1.7E-09	7.4E-08	1.5E-09	7.7E-08			4.4E-06	1.2E-08	4.9E-07		4.9E-06	5.0E-06
	Dibromochloropropane	2.0E-08			2.0E-08	5.8E-06	5.8E-06	5.8E-06	1.5E-07		8.7E-07	6.8E-06	1.3E-05
	Dicyclopentadiene			3.3E-07	3.3E-07			6.8E-03			3.7E-03	1.0E-02	1.0E-02
	Dieldrin	3.5E-08	1.7E-07	8.4E-08	2.8E-07			8.8E-06	1.9E-07	8.8E-07	2.9E-05	3.9E-05	3.9E-05
	Dithiane, 1,4-							8.2E-05			9.2E-06	9.1E-05	9.1E-05
	Endrin	9.6E-10	4.7E-08		4.8E-08			3.0E-05	5.1E-09	2.5E-07	2.4E-05	5.5E-05	5.5E-05
	Isodrin							2.0E-06				2.0E-06	2.0E-06
	Tetrachloroethene					8.6E-04	8.6E-04	8.6E-04			2.4E-04	1.1E-03	2.0E-03
	Trichloroethene					2.1E-05	2.1E-05	2.1E-05			6.8E-06	2.8E-05	4.9E-05
Renal	Chlorobenzene					7.4E-05	7.4E-05	7.4E-05			2.2E-05	9.6E-05	1.7E-04
	Dibromochloropropane	2.0E-08			2.0E-08	5.8E-06	5.8E-06	5.8E-06	1.5E-07		8.7E-07	6.8E-06	1.3E-05

(CONTINUED)

Zone 3; Child Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Respiratory	Dichloroethane, 1,2-					3.8E-05	3.8E-05						3.8E-05
	Toluene					5.3E-05	5.3E-05						5.3E-05
Skin	Arsenic, total			5.7E-07	5.7E-07						1.1E-05	1.1E-05	1.1E-05

Zone 4; Adult Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Blood	Benzene					2.5E-05	2.5E-05	2.5E-05			4.2E-06	3.0E-05	5.5E-05
	Toluene							3.2E-05			8.0E-06	4.0E-05	4.0E-05
Cardiovascular	Atrazine							2.0E-04			5.2E-05	2.5E-04	2.5E-04
	Dichloroethane, 1,2-							2.0E-04			2.6E-05	2.3E-04	2.3E-04
CNS	DIMP			3.7E-06	3.7E-06			1.4E-01			2.4E-02	1.6E-01	1.6E-01
	Dithiane, 1,4-							1.2E-04			1.2E-05	1.3E-04	1.3E-04
	Malathion							8.6E-06			2.4E-06	1.1E-05	1.1E-05
	Manganese							3.4E-02			7.8E-03	4.2E-02	4.2E-02
	Oxathiane, 1,4-							6.1E-05			5.5E-06	6.6E-05	6.6E-05
	Toluene					3.2E-05	3.2E-05						3.2E-05
	Xylenes, total					3.0E-05	3.0E-05	3.0E-05			1.3E-05	4.3E-05	7.4E-05
Ocular	Toluene					3.2E-05	3.2E-05						3.2E-05
Gastrointestinal	Hexachlorocyclopentadiene							1.2E-06			1.8E-06	2.9E-06	2.9E-06
Hepatic	Aldrin	1.4E-09	1.5E-09		2.9E-09			3.2E-06	2.4E-09	2.6E-09		3.2E-06	3.2E-06
	Benzene					2.5E-05	2.5E-05	2.5E-05			4.2E-06	3.0E-05	5.5E-05
	Chlordane, total			2.9E-09	2.9E-09			1.5E-05			2.8E-06	1.8E-05	1.8E-05
	Chlorobenzene					1.2E-04	1.2E-04	1.2E-04			3.5E-05	1.6E-04	2.8E-04
	Chloroform					4.1E-05	4.1E-05	4.1E-05			6.2E-06	4.8E-05	8.9E-05
	Chlorophenylmethyl sulfone, p-							1.4E-04			1.6E-05	1.6E-04	1.6E-04
	Chlorophenylmethyl sulfoxide, p-							2.1E-04			2.5E-05	2.4E-04	2.4E-04
	DDE, p,p'-	5.1E-11	8.6E-09	1.4E-09	1.0E-08			2.3E-06	1.1E-10	1.8E-08	2.0E-06	4.3E-06	4.3E-06
	DDT, p,p'-	8.5E-10	1.7E-08	7.4E-10	1.9E-08			2.7E-06	1.8E-09	3.6E-08		2.8E-06	2.8E-06
	Dibromochloropropane	9.7E-09			9.7E-09	4.2E-06	4.2E-06	4.2E-06	2.4E-08		5.9E-07	4.8E-06	9.0E-06
	Dichlorobenzenes, total					8.1E-05	8.1E-05	8.1E-05			5.6E-05	1.4E-04	2.2E-04
	Dicyclopentadiene			1.6E-07	1.6E-07			1.8E-03			9.3E-04	2.8E-03	2.8E-03
	Dieldrin	1.7E-08	1.3E-08	4.1E-08	7.1E-08			1.5E-06	2.9E-08	2.2E-08	7.3E-06	8.8E-06	8.9E-06
	Dithiane, 1,4-							1.2E-04			1.2E-05	1.3E-04	1.3E-04
	Endrin	4.7E-10	3.0E-09		3.5E-09			1.6E-06	8.0E-10	5.2E-09	2.1E-06	3.7E-06	3.7E-06
	Ethylbenzene					1.6E-05	1.6E-05	1.6E-05			6.8E-06	2.2E-05	3.8E-05

(CONTINUED)

Zone 4; Adult Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Hepatic	Isodrin							1.6E-06				1.6E-06	1.6E-06
	Tetrachloroethene					1.7E-04	1.7E-04	1.7E-04			4.4E-05	2.1E-04	3.8E-04
	Trichloroethene					7.4E-05	7.4E-05	7.4E-05			2.2E-05	9.6E-05	1.7E-04
Renal	Chlorobenzene					1.2E-04	1.2E-04	1.2E-04			3.5E-05	1.6E-04	2.8E-04
	Dibromochloropropane	9.7E-09			9.7E-09	4.2E-06	4.2E-06	4.2E-06	2.4E-08		5.9E-07	4.8E-06	9.0E-06
	Ethylbenzene					1.6E-05	1.6E-05	1.6E-05			6.8E-06	2.2E-05	3.8E-05
Respiratory	Dichloroethane, 1,2-					2.0E-04	2.0E-04						2.0E-04
	Toluene					3.2E-05	3.2E-05						3.2E-05
	Xylenes, total					3.0E-05	3.0E-05						3.0E-05
Skin	Arsenic, total			2.8E-07	2.8E-07			7.6E-05			1.6E-05	9.2E-05	9.3E-05

Zone 4; Child Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Blood	Benzene					3.9E-05	3.9E-05	3.9E-05			6.8E-06	4.5E-05	8.4E-05
	Toluene							4.9E-05			1.3E-05	6.2E-05	6.2E-05
Cardiovascular	Atrazine							3.1E-04			8.4E-05	3.9E-04	3.9E-04
	Dichloroethane, 1,2-							3.0E-04			4.2E-05	3.5E-04	3.5E-04
CNS	DIMP			7.5E-06	7.5E-06			2.1E-01			4.0E-02	2.5E-01	2.5E-01
	Dithiane, 1,4-							1.8E-04			2.0E-05	1.9E-04	1.9E-04
	Malathion							1.3E-05			4.0E-06	1.7E-05	1.7E-05
	Manganese							5.2E-02			1.3E-02	6.5E-02	6.5E-02
	Oxathiane, 1,4-							9.2E-05			9.0E-06	1.0E-04	1.0E-04
	Toluene					4.9E-05	4.9E-05						4.9E-05
	Xylenes, total					4.6E-05	4.6E-05	4.6E-05			2.1E-05	6.7E-05	1.1E-04
Ocular	Toluene					4.9E-05	4.9E-05						4.9E-05
Gastrointestinal	Hexachlorocyclopentadiene							1.8E-06			2.9E-06	4.6E-06	4.6E-06
Hepatic	Aldrin	2.9E-09	3.1E-09		6.0E-09			4.8E-06	1.5E-08	1.7E-08		4.8E-06	4.8E-06
	Benzene					3.9E-05	3.9E-05	3.9E-05			6.8E-06	4.5E-05	8.4E-05
	Chlordane, total			5.9E-09	5.9E-09			2.2E-05			4.5E-06	2.7E-05	2.7E-05
	Chlorobenzene					1.9E-04	1.9E-04	1.9E-04			5.6E-05	2.4E-04	4.3E-04
	Chloroform					6.3E-05	6.3E-05	6.3E-05			1.0E-05	7.3E-05	1.4E-04
	Chlorophenylmethyl sulfone, p-							2.1E-04			2.6E-05	2.4E-04	2.4E-04
	Chlorophenylmethyl sulfoxide, p-							3.2E-04			4.1E-05	3.6E-04	3.6E-04
	DDE, p,p'-	1.0E-10	1.8E-08	2.9E-09	2.1E-08			3.5E-06	7.0E-10	1.2E-07	3.2E-06	6.9E-06	6.9E-06
	DDT, p,p'-	1.7E-09	3.5E-08	1.5E-09	3.8E-08			4.2E-06	1.2E-08	2.3E-07		4.4E-06	4.4E-06
	Dibromochloropropane	2.0E-08			2.0E-08	6.4E-06	6.4E-06	6.4E-06	1.5E-07		9.6E-07	7.5E-06	1.4E-05
	Dichlorobenzenes, total					1.2E-04	1.2E-04	1.2E-04			9.0E-05	2.1E-04	3.3E-04
	Dicyclopentadiene			3.3E-07	3.3E-07			2.8E-03			1.5E-03	4.3E-03	4.3E-03
	Dieldrin	3.5E-08	2.6E-08	8.4E-08	1.5E-07			2.3E-06	1.9E-07	1.4E-07	1.2E-05	1.4E-05	1.5E-05
	Dithiane, 1,4-							1.8E-04			2.0E-05	1.9E-04	1.9E-04
	Endrin	9.6E-10	6.2E-09		7.1E-09			2.4E-06	5.1E-09	3.3E-08	3.5E-06	5.9E-06	5.9E-06
	Ethylbenzene					2.4E-05	2.4E-05	2.4E-05			1.1E-05	3.5E-05	5.9E-05

(CONTINUED)

Zone 4; Child Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sedi-ment	Soil	Surface Water	Total	Ground-water	Total	Ground-water	Sedi-ment	Soil	Vege-tables	Total	Grand Total
Hepatic	Isodrin							2.4E-06				2.4E-06	2.4E-06
	Tetrachloroethene					2.5E-04	2.5E-04	2.5E-04			7.1E-05	3.2E-04	5.8E-04
	Trichloroethene					1.1E-04	1.1E-04	1.1E-04			3.6E-05	1.5E-04	2.6E-04
Renal	Chlorobenzene					1.9E-04	1.9E-04	1.9E-04			5.6E-05	2.4E-04	4.3E-04
	Dibromochloropropane	2.0E-08			2.0E-08	6.4E-06	6.4E-06	6.4E-06	1.5E-07		9.6E-07	7.5E-06	1.4E-05
	Ethylbenzene					2.4E-05	2.4E-05	2.4E-05			1.1E-05	3.5E-05	5.9E-05
Respiratory	Dichloroethane, 1,2-					3.0E-04	3.0E-04						3.0E-04
	Toluene					4.9E-05	4.9E-05						4.9E-05
	Xylenes, total					4.6E-05	4.6E-05						4.6E-05
Skin	Arsenic, total			5.7E-07	5.7E-07			1.2E-04			2.6E-05	1.4E-04	1.4E-04

Noncarcinogenic intakes
Zone 5; Adult Commercial/Industrial; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY								
		Dermal		Inhalation		Oral				
		MEDIUM		MEDIUM		MEDIUM				
		Soil	Total	GW	Total	GW	Soil	Total	Grand Total
CNS	DIMP					7.5E-05		7.5E-05	7.5E-05
	Manganese					6.6E-03		6.6E-03	6.6E-03
Gastrointestinal	Hexachlorocyclo-pentadiene					3.4E-07		3.4E-07	3.4E-07
Hepatic	Aldrin	1.2E-09	1.2E-09			3.8E-07	9.2E-10	3.8E-07	3.8E-07
	Dibromochloropropane			9.8E-07	9.8E-07	9.8E-07		9.8E-07	2.0E-06
	Chlorobenzene			1.1E-05	1.1E-05	1.1E-05		1.1E-05	2.1E-05
	Chloroform			1.2E-04	1.2E-04	1.2E-04		1.2E-04	2.3E-04
	DDE, p,p'-	8.2E-09	8.2E-09				6.6E-09	6.6E-09	1.5E-08
	DDT, p,p'-	1.6E-08	1.6E-08				1.3E-08	1.3E-08	3.0E-08
	Dieldrin	9.9E-09	9.9E-09			6.9E-07	7.9E-09	7.0E-07	7.1E-07
	Endrin	2.3E-09	2.3E-09				1.8E-09	1.8E-09	4.2E-09
	Tetrachloroethene			7.3E-06	7.3E-06	7.3E-06		7.3E-06	1.5E-05
Renal	Chlorobenzene			1.1E-05	1.1E-05	1.1E-05		1.1E-05	2.1E-05
	Dibromochloropropane			9.8E-07	9.8E-07	9.8E-07		9.8E-07	2.0E-06
Skin	Arsenic, total					2.6E-05		2.6E-05	2.6E-05

Zone 6; Adult Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Cardiovascular	Atrazine					9.3E-08		1.2E-04	8.4E-08		5.5E-06	1.3E-04	1.3E-04
CNS	DIMP					1.3E-09		1.3E-04	1.3E-09		4.1E-06	1.3E-04	1.3E-04
Hepatic	Aldrin	1.5E-09	1.5E-09					8.2E-07		2.6E-09		8.2E-07	8.2E-07
	Chlorobenzene			3.5E-05	3.5E-05	3.1E-08		3.5E-05	2.8E-08		1.7E-06	3.7E-05	7.1E-05
	Chloroform			9.1E-05	9.1E-05	5.9E-09		9.1E-05	4.8E-09		2.5E-06	9.4E-05	1.9E-04
	DDE, p,p'-	8.6E-09	8.6E-09			7.5E-07			9.3E-07	1.8E-08	1.1E-06	2.8E-06	2.8E-06
	DDT, p,p'-	1.7E-08	1.7E-08							3.6E-08		3.6E-08	5.4E-08
	Dieldrin	1.3E-08	1.3E-08			5.5E-07	1.4E-06	1.1E-06	6.8E-07	2.2E-08	1.9E-06	5.6E-06	5.6E-06
	Endrin	3.0E-09	3.0E-09			4.6E-08			4.1E-08	5.2E-09	5.6E-07	6.5E-07	6.5E-07
	Isodrin							1.1E-06				1.1E-06	1.1E-06
	Tetrachloroethene			4.6E-05	4.6E-05	3.7E-08		4.6E-05	3.2E-08		2.1E-06	4.8E-05	9.4E-05
	Trichloroethene			1.1E-04	1.1E-04	1.0E-07		1.1E-04	9.7E-08		6.0E-06	1.2E-04	2.3E-04
Renal	Chlorobenzene			3.5E-05	3.5E-05	3.1E-08		3.5E-05	2.8E-08		1.7E-06	3.7E-05	7.1E-05

Zone 6; Child Resident; Chronic

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Cardiovascular	Atrazine					6.8E-07		1.8E-04	2.6E-07		8.9E-06	1.9E-04	1.9E-04
CNS	DIMP					9.2E-09		1.9E-04	4.0E-09		6.6E-06	2.0E-04	2.0E-04
Hepatic	Aldrin	3.1E-09	3.1E-09					1.2E-06		1.7E-08		1.3E-06	1.3E-06
	Chlorobenzene			5.3E-05	5.3E-05	2.2E-07		5.3E-05	8.7E-08		2.8E-06	5.6E-05	1.1E-04
	Chloroform			1.4E-04	1.4E-04	4.3E-08		1.4E-04	1.5E-08		4.0E-06	1.4E-04	2.8E-04
	DDE, p,p'-	1.8E-08	1.8E-08			5.4E-06			2.9E-06	1.2E-07	1.7E-06	1.0E-05	1.0E-05
	DDT, p,p'-	3.5E-08	3.5E-08							2.3E-07		2.3E-07	2.7E-07
	Dieldrin	2.6E-08	2.6E-08			4.0E-06	4.0E-06	1.6E-06	2.1E-06	1.4E-07	3.0E-06	1.5E-05	1.5E-05
	Endrin	6.2E-09	6.2E-09			3.4E-07			1.2E-07	3.3E-08	9.1E-07	1.4E-06	1.4E-06
	Isodrin							1.7E-06				1.7E-06	1.7E-06
	Tetrachloroethene			6.9E-05	6.9E-05	2.7E-07		6.9E-05	9.9E-08		3.5E-06	7.3E-05	1.4E-04
	Trichloroethene			1.7E-04	1.7E-04	7.6E-07		1.7E-04	3.0E-07		9.7E-06	1.8E-04	3.5E-04
Renal	Chlorobenzene			5.3E-05	5.3E-05	2.2E-07		5.3E-05	8.7E-08		2.8E-06	5.6E-05	1.1E-04

Zone 1A; Adult Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			2.0E-05	2.0E-05	7.3E-09		2.0E-05	1.4E-08		1.9E-06	2.2E-05	4.1E-05
Cardiovascular	Atrazine					9.1E-08		9.3E-05	1.8E-07		1.4E-05	1.1E-04	1.1E-04
CNS	DIMP					6.9E-08		2.0E-03	1.6E-07		5.7E-04	2.6E-03	2.6E-03
	Xylenes, total			2.4E-05	2.4E-05	5.7E-08		2.4E-05	1.2E-07		6.1E-06	3.1E-05	5.5E-05
Gastrointestinal	Hexachlorocyclopentadiene					6.1E-09		9.4E-07	1.4E-08		8.4E-07	1.8E-06	1.8E-06
Hepatic	Aldrin	1.8E-09	1.8E-09					9.4E-07		3.1E-09		9.4E-07	9.4E-07
	Benzene			2.0E-05	2.0E-05	7.3E-09		2.0E-05	1.4E-08		1.9E-06	2.2E-05	4.1E-05
	Chlorobenzene			3.3E-05	3.3E-05	3.7E-08		3.3E-05	7.6E-08		5.5E-06	3.8E-05	7.1E-05
	Chloroform			2.2E-05	2.2E-05	1.8E-09		2.2E-05	3.3E-09		2.0E-06	2.4E-05	4.6E-05
	DDE, p,p'-	1.0E-08	1.0E-08			1.2E-06		9.4E-07	3.2E-06	2.2E-08	4.4E-06	9.7E-06	9.7E-06
	DDT, p,p'-	2.0E-08	2.0E-08					1.2E-06		4.3E-08		1.2E-06	1.2E-06
	Dieldrin	1.5E-08	1.5E-08			8.1E-07	3.1E-06	1.1E-06	2.2E-06	2.6E-08	7.3E-06	1.5E-05	1.5E-05
	Endrin	3.6E-09	3.6E-09			7.6E-08		1.0E-06	1.5E-07	6.1E-09	2.4E-06	3.7E-06	3.7E-06
	Isodrin							8.9E-07				8.9E-07	8.9E-07
	Tetrachloroethene			2.2E-05	2.2E-05	2.3E-08		2.2E-05	4.5E-08		3.5E-06	2.6E-05	4.8E-05
Renal	Chlorobenzene			3.3E-05	3.3E-05	3.7E-08		3.3E-05	7.6E-08		5.5E-06	3.8E-05	7.1E-05
Respiratory	Xylenes, total			2.4E-05	2.4E-05								2.4E-05
Skin	Arsenic, total					5.2E-08		6.9E-05	4.9E-07		5.0E-06	7.5E-05	7.5E-05

Zone 1A; Child Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			2.7E-05	2.7E-05	4.7E-08		2.7E-05	2.4E-08		4.8E-06	3.1E-05	5.8E-05
Cardiovascular	Atrazine					5.9E-07		1.2E-04	3.2E-07		3.5E-05	1.6E-04	1.6E-04
CNS	DIMP					4.4E-07		2.7E-03	2.8E-07		1.4E-03	4.2E-03	4.2E-03
	Xylenes, total			3.3E-05	3.3E-05	3.7E-07		3.3E-05	2.1E-07		1.5E-05	4.9E-05	8.2E-05
Gastrointestinal	Hexachlorocyclopentadiene					3.9E-08		1.3E-06	2.4E-08		2.1E-06	3.4E-06	3.4E-06
Hepatic	Aldrin	3.2E-09	3.2E-09					1.3E-06		2.1E-08		1.3E-06	1.3E-06
	Benzene			2.7E-05	2.7E-05	4.7E-08		2.7E-05	2.4E-08		4.8E-06	3.1E-05	5.8E-05
	Chlorobenzene			4.4E-05	4.4E-05	2.4E-07		4.4E-05	1.3E-07		1.4E-05	5.8E-05	1.0E-04
	Chloroform			3.0E-05	3.0E-05	1.2E-08		3.0E-05	5.7E-09		4.9E-06	3.5E-05	6.4E-05
	DDE, p,p'-	1.8E-08	1.8E-08			7.5E-06		1.3E-06	5.6E-06	1.5E-07	1.1E-05	2.6E-05	2.6E-05
	DDT, p,p'-	3.6E-08	3.6E-08					1.6E-06		3.0E-07		1.9E-06	1.9E-06
	Dieldrin	2.7E-08	2.7E-08			5.3E-06	8.9E-06	1.5E-06	3.9E-06	1.8E-07	1.8E-05	3.8E-05	3.8E-05
	Endrin	6.5E-09	6.5E-09			4.9E-07		1.4E-06	2.6E-07	4.2E-08	6.0E-06	8.2E-06	8.2E-06
	Isodrin							1.2E-06				1.2E-06	1.2E-06
	Tetrachloroethene			3.0E-05	3.0E-05	1.5E-07		3.0E-05	7.9E-08		8.8E-06	3.9E-05	6.9E-05
Renal	Chlorobenzene			4.4E-05	4.4E-05	2.4E-07		4.4E-05	1.3E-07		1.4E-05	5.8E-05	1.0E-04
Respiratory	Xylenes, total			3.3E-05	3.3E-05								3.3E-05
Skin	Arsenic, total					3.4E-07		9.3E-05	8.6E-07		1.3E-05	1.1E-04	1.1E-04

Zone 1B; Adult Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			2.0E-05	2.0E-05	4.6E-08		2.0E-05	8.4E-08		1.2E-05	3.2E-05	5.1E-05
Cardiovascular	Atrazine					5.7E-07		9.3E-05	1.1E-06		8.8E-05	1.8E-04	1.8E-04
CNS	DIMP					1.6E-07		2.0E-03	3.7E-07		1.3E-03	3.4E-03	3.4E-03
	Xylenes, total			2.4E-05	2.4E-05	3.5E-07		2.4E-05	7.4E-07		3.8E-05	6.4E-05	8.8E-05
Gastrointestinal	Hexachlorocyclopentadiene					3.8E-08		9.4E-07	8.6E-08		5.3E-06	6.3E-06	6.3E-06
Hepatic	Aldrin	1.8E-09	1.8E-09					9.4E-07		3.1E-09		9.4E-07	9.4E-07
	Benzene			2.0E-05	2.0E-05	4.6E-08		2.0E-05	8.4E-08		1.2E-05	3.2E-05	5.1E-05
	Chlorobenzene			3.3E-05	3.3E-05	2.3E-07		3.3E-05	4.7E-07		3.4E-05	6.8E-05	1.0E-04
	Chloroform			2.2E-05	2.2E-05	1.1E-08		2.2E-05	2.0E-08		1.2E-05	3.4E-05	5.6E-05
	DDE, p,p'-	1.0E-08	1.0E-08			1.4E-06		9.4E-07	3.6E-06	2.2E-08	5.5E-06	1.1E-05	1.1E-05
	DDT, p,p'-	2.0E-08	2.0E-08					1.2E-06		4.3E-08		1.2E-06	1.2E-06
	Dieldrin	1.5E-08	1.5E-08			1.1E-06	3.1E-06	1.1E-06	2.9E-06	2.6E-08	1.0E-05	1.8E-05	1.8E-05
	Endrin	3.6E-09	3.6E-09			1.7E-07		1.0E-06	3.2E-07	6.1E-09	5.6E-06	7.1E-06	7.1E-06
	Isodrin							8.9E-07				8.9E-07	8.9E-07
	Tetrachloroethene			2.2E-05	2.2E-05	1.4E-07		2.2E-05	2.8E-07		2.2E-05	4.5E-05	6.7E-05
Renal	Chlorobenzene			3.3E-05	3.3E-05	2.3E-07		3.3E-05	4.7E-07		3.4E-05	6.8E-05	1.0E-04
Respiratory	Xylenes, total			2.4E-05	2.4E-05								2.4E-05
Skin	Arsenic, total					3.3E-07		6.9E-05	3.1E-06		3.2E-05	1.0E-04	1.0E-04

Zone 1B; Child Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			2.7E-05	2.7E-05	3.0E-07		2.7E-05	1.5E-07		3.0E-05	5.7E-05	8.3E-05
Cardiovascular	Atrazine					3.7E-06		1.2E-04	2.0E-06		2.2E-04	3.5E-04	3.5E-04
CNS	DIMP					1.0E-06		2.7E-03	6.5E-07		3.4E-03	6.1E-03	6.1E-03
	Xylenes, total			3.3E-05	3.3E-05	2.3E-06		3.3E-05	1.3E-06		9.7E-05	1.3E-04	1.7E-04
Gastrointestinal	Hexachlorocyclopentadiene					2.5E-07		1.3E-06	1.5E-07		1.3E-05	1.5E-05	1.5E-05
Hepatic	Aldrin	3.2E-09	3.2E-09					1.3E-06		2.1E-08		1.3E-06	1.3E-06
	Benzene			2.7E-05	2.7E-05	3.0E-07		2.7E-05	1.5E-07		3.0E-05	5.7E-05	8.3E-05
	Chlorobenzene			4.4E-05	4.4E-05	1.5E-06		4.4E-05	8.3E-07		8.6E-05	1.3E-04	1.8E-04
	Chloroform			3.0E-05	3.0E-05	7.4E-08		3.0E-05	3.6E-08		3.1E-05	6.1E-05	9.0E-05
	DDE, p,p'-	1.8E-08	1.8E-08			8.8E-06		1.3E-06	6.4E-06	1.5E-07	1.4E-05	3.0E-05	3.0E-05
	DDT, p,p'-	3.6E-08	3.6E-08					1.6E-06		3.0E-07		1.9E-06	1.9E-06
	Dieldrin	2.7E-08	2.7E-08			7.2E-06	8.9E-06	1.5E-06	5.1E-06	1.8E-07	2.5E-05	4.8E-05	4.8E-05
	Endrin	6.5E-09	6.5E-09			1.1E-06		1.4E-06	5.6E-07	4.2E-08	1.4E-05	1.7E-05	1.7E-05
	Isodrin							1.2E-06				1.2E-06	1.2E-06
	Tetrachloroethene			3.0E-05	3.0E-05	9.2E-07		3.0E-05	4.9E-07		5.5E-05	8.6E-05	1.2E-04
Renal	Chlorobenzene			4.4E-05	4.4E-05	1.5E-06		4.4E-05	8.3E-07		8.6E-05	1.3E-04	1.8E-04
Respiratory	Xylenes, total			3.3E-05	3.3E-05								3.3E-05
Skin	Arsenic, total					2.1E-06		9.3E-05	5.4E-06		7.9E-05	1.8E-04	1.8E-04

Zone 1C; Adult Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			2.0E-05	2.0E-05	7.3E-09		2.0E-05	1.4E-08		1.9E-06	2.2E-05	4.1E-05
Cardiovascular	Atrazine					9.1E-08		9.3E-05	1.8E-07		1.4E-05	1.1E-04	1.1E-04
CNS	DIMP					2.6E-08		2.0E-03	5.9E-08		2.1E-04	2.3E-03	2.3E-03
	Xylenes, total			2.4E-05	2.4E-05	5.7E-08		2.4E-05	1.2E-07		6.1E-06	3.1E-05	5.5E-05
Gastrointestinal	Hexachlorocyclopentadiene					6.1E-09		9.4E-07	1.4E-08		8.4E-07	1.8E-06	1.8E-06
Hepatic	Aldrin	1.8E-09	1.8E-09					9.4E-07		3.1E-09		9.4E-07	9.4E-07
	Benzene			2.0E-05	2.0E-05	7.3E-09		2.0E-05	1.4E-08		1.9E-06	2.2E-05	4.1E-05
	Chlorobenzene			3.3E-05	3.3E-05	3.7E-08		3.3E-05	7.6E-08		5.5E-06	3.8E-05	7.1E-05
	Chloroform			2.2E-05	2.2E-05	1.8E-09		2.2E-05	3.3E-09		2.0E-06	2.4E-05	4.6E-05
	DDE, p,p'-	1.0E-08	1.0E-08			1.2E-06		9.4E-07	3.2E-06	2.2E-08	4.4E-06	9.7E-06	9.7E-06
	DDT, p,p'-	2.0E-08	2.0E-08					1.2E-06		4.3E-08		1.2E-06	1.2E-06
	Dieldrin	1.5E-08	1.5E-08			8.1E-07	3.1E-06	1.1E-06	2.2E-06	2.6E-08	7.3E-06	1.5E-05	1.5E-05
	Endrin	3.6E-09	3.6E-09			7.6E-08		1.0E-06	1.5E-07	6.1E-09	2.4E-06	3.7E-06	3.7E-06
	Isodrin							8.9E-07				8.9E-07	8.9E-07
	Tetrachloroethene			2.2E-05	2.2E-05	2.3E-08		2.2E-05	4.5E-08		3.5E-06	2.6E-05	4.8E-05
Renal	Chlorobenzene			3.3E-05	3.3E-05	3.7E-08		3.3E-05	7.6E-08		5.5E-06	3.8E-05	7.1E-05
Respiratory	Xylenes, total			2.4E-05	2.4E-05								2.4E-05
Skin	Arsenic, total					5.2E-08		6.9E-05	4.9E-07		5.0E-06	7.5E-05	7.5E-05

Zone 1C; Child Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			2.7E-05	2.7E-05	4.7E-08		2.7E-05	2.4E-08		4.8E-06	3.1E-05	5.8E-05
Cardiovascular	Atrazine					5.9E-07		1.2E-04	3.2E-07		3.5E-05	1.6E-04	1.6E-04
CNS	DIMP					1.7E-07		2.7E-03	1.0E-07		5.4E-04	3.3E-03	3.3E-03
	Xylenes, total			3.3E-05	3.3E-05	3.7E-07		3.3E-05	2.1E-07		1.5E-05	4.9E-05	8.2E-05
Gastrointestinal	Hexachlorocyclopentadiene					3.9E-08		1.3E-06	2.4E-08		2.1E-06	3.4E-06	3.4E-06
Hepatic	Aldrin	3.2E-09	3.2E-09					1.3E-06		2.1E-08		1.3E-06	1.3E-06
	Benzene			2.7E-05	2.7E-05	4.7E-08		2.7E-05	2.4E-08		4.8E-06	3.1E-05	5.8E-05
	Chlorobenzene			4.4E-05	4.4E-05	2.4E-07		4.4E-05	1.3E-07		1.4E-05	5.8E-05	1.0E-04
	Chloroform			3.0E-05	3.0E-05	1.2E-08		3.0E-05	5.7E-09		4.9E-06	3.5E-05	6.4E-05
	DDE, p,p'-	1.8E-08	1.8E-08			7.5E-06		1.3E-06	5.6E-06	1.5E-07	1.1E-05	2.6E-05	2.6E-05
	DDT, p,p'-	3.6E-08	3.6E-08					1.6E-06		3.0E-07		1.9E-06	1.9E-06
	Dieldrin	2.7E-08	2.7E-08			5.3E-06	8.9E-06	1.5E-06	3.9E-06	1.8E-07	1.8E-05	3.8E-05	3.8E-05
	Endrin	6.5E-09	6.5E-09			4.9E-07		1.4E-06	2.6E-07	4.2E-08	6.0E-06	8.2E-06	8.2E-06
	Isodrin							1.2E-06				1.2E-06	1.2E-06
	Tetrachloroethene			3.0E-05	3.0E-05	1.5E-07		3.0E-05	7.9E-08		8.8E-06	3.9E-05	6.9E-05
Renal	Chlorobenzene			4.4E-05	4.4E-05	2.4E-07		4.4E-05	1.3E-07		1.4E-05	5.8E-05	1.0E-04
Respiratory	Xylenes, total			3.3E-05	3.3E-05								3.3E-05
Skin	Arsenic, total					3.4E-07		9.3E-05	8.6E-07		1.3E-05	1.1E-04	1.1E-04

Zone 2; Adult Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			2.1E-05	2.1E-05	4.8E-08		2.1E-05	8.8E-08		1.2E-05	3.3E-05	5.4E-05
Cardiovascular	Atrazine					1.1E-06		1.7E-04	2.1E-06		1.6E-04	3.4E-04	3.4E-04
	Dichloroethane, 1,2-					2.7E-08		2.5E-05	4.7E-08		1.2E-05	3.6E-05	3.6E-05
CNS	DIMP					1.8E-06		2.3E-02	4.2E-06		1.5E-02	3.8E-02	3.8E-02
	Malathion					5.6E-08		8.3E-06	1.1E-07		8.6E-06	1.7E-05	1.7E-05
	Manganese					1.2E-03		5.1E-02	6.3E-04		4.3E-02	9.5E-02	9.5E-02
Gastrointestinal	Hexachlorocyclopentadiene					4.3E-08		1.1E-06	9.7E-08		5.9E-06	7.1E-06	7.1E-06
Hepatic	Aldrin	1.8E-09	1.8E-09					1.4E-06		3.1E-09		1.4E-06	1.4E-06
	Benzene			2.1E-05	2.1E-05	4.8E-08		2.1E-05	8.8E-08		1.2E-05	3.3E-05	5.4E-05
	Carbon tetrachloride			2.5E-05	2.5E-05	1.7E-07		2.5E-05	3.3E-07		2.5E-05	5.0E-05	7.4E-05
	Chlordane, total					2.9E-08		5.7E-06	4.9E-08		3.8E-06	9.6E-06	9.6E-06
	Chlorobenzene			5.8E-05	5.8E-05	4.1E-07		5.8E-05	8.3E-07		6.0E-05	1.2E-04	1.8E-04
	Chloroform			2.2E-03	2.2E-03	1.1E-06		2.2E-03	2.0E-06		1.2E-03	3.4E-03	5.6E-03
	Chlorophenylmethyl sulfone, p-					5.8E-08		1.4E-04	9.6E-08		6.0E-05	2.0E-04	2.0E-04
	Chlorophenylmethyl sulfoxide, p-					1.9E-07		4.7E-04	3.2E-07		2.0E-04	6.7E-04	6.7E-04
	DDE, p,p'-	1.0E-08	1.0E-08			1.3E-06		9.2E-07	3.6E-06	2.2E-08	5.4E-06	1.1E-05	1.1E-05
	DDT, p,p'-	2.0E-08	2.0E-08					1.1E-06		4.3E-08		1.1E-06	1.1E-06
	Dibromochloropropane			1.4E-05	1.4E-05	7.9E-09		1.4E-05	1.3E-08		7.4E-06	2.2E-05	3.6E-05
	Dichlorobenzenes, total			1.7E-04	1.7E-04	4.6E-06		1.7E-04	1.0E-05		4.2E-04	6.0E-04	7.7E-04
	Dicyclopentadiene					8.9E-07		1.2E-04	1.9E-06		2.2E-04	3.4E-04	3.4E-04
	Dieldrin	1.5E-08	1.5E-08			1.2E-06	3.1E-06	1.1E-06	3.1E-06	2.6E-08	1.1E-05	1.9E-05	1.9E-05
	Endrin	3.6E-09	3.6E-09			2.0E-07		1.2E-06	3.6E-07	6.1E-09	6.4E-06	8.1E-06	8.1E-06
	Isodrin							1.1E-06				1.1E-06	1.1E-06
	Tetrachloroethene			3.3E-04	3.3E-04	2.1E-06		3.3E-04	4.1E-06		3.2E-04	6.5E-04	9.8E-04
	Trichloroethene			2.1E-05	2.1E-05	1.6E-07		2.1E-05	3.2E-07		2.3E-05	4.4E-05	6.5E-05
Renal	Chlorobenzene			5.8E-05	5.8E-05	4.1E-07		5.8E-05	8.3E-07		6.0E-05	1.2E-04	1.8E-04
	Dibromochloropropane			1.4E-05	1.4E-05	7.9E-09		1.4E-05	1.3E-08		7.4E-06	2.2E-05	3.6E-05
Respiratory	Dichloroethane, 1,2-			2.5E-05	2.5E-05								2.5E-05
Skin	Arsenic, total					2.5E-07		5.3E-05	2.3E-06		2.4E-05	7.9E-05	7.9E-05

Zone 2; Child Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							Grand Total
		MEDIUM		MEDIUM		MEDIUM						Total	
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables		
Blood	Benzene			2.8E-05	2.8E-05	3.1E-07		2.8E-05	1.5E-07		3.1E-05	5.9E-05	8.7E-05
Cardiovascular	Atrazine					6.8E-06		2.3E-04	3.7E-06		4.1E-04	6.5E-04	6.5E-04
	Dichloroethane, 1,2-					1.8E-07		3.3E-05	8.2E-08		2.9E-05	6.3E-05	6.3E-05
CNS	DIMP					1.2E-05		3.1E-02	7.3E-06		3.8E-02	6.9E-02	6.9E-02
	Malathion					3.6E-07		1.1E-05	2.0E-07		2.2E-05	3.3E-05	3.3E-05
	Manganese					7.7E-03		6.8E-02	1.1E-03		1.1E-01	1.8E-01	1.8E-01
Gastrointestinal	Hexachlorocyclopentadiene					2.8E-07		1.4E-06	1.7E-07		1.5E-05	1.7E-05	1.7E-05
Hepatic	Aldrin	3.2E-09	3.2E-09					1.9E-06		2.1E-08		2.0E-06	2.0E-06
	Benzene			2.8E-05	2.8E-05	3.1E-07		2.8E-05	1.5E-07		3.1E-05	5.9E-05	8.7E-05
	Carbon tetrachloride			3.3E-05	3.3E-05	1.1E-06		3.3E-05	5.9E-07		6.2E-05	9.7E-05	1.3E-04
	Chlordane, total					1.9E-07		7.7E-06	8.6E-08		9.6E-06	1.8E-05	1.8E-05
	Chlorobenzene			7.7E-05	7.7E-05	2.6E-06		7.7E-05	1.5E-06		1.5E-04	2.3E-04	3.1E-04
	Chloroform			2.9E-03	2.9E-03	7.3E-06		2.9E-03	3.5E-06		3.1E-03	6.0E-03	8.9E-03
	Chlorophenylmethyl sulfone, p-					3.7E-07		1.9E-04	1.7E-07		1.5E-04	3.4E-04	3.4E-04
	Chlorophenylmethyl sulfoxide, p-					1.2E-06		6.3E-04	5.6E-07		5.2E-04	1.1E-03	1.1E-03
	DDE, p,p'-	1.8E-08	1.8E-08			8.7E-06		1.2E-06	6.3E-06	1.5E-07	1.4E-05	3.0E-05	3.0E-05
	DDT, p,p'-	3.6E-08	3.6E-08					1.4E-06		3.0E-07		1.7E-06	1.8E-06
	Dibromochloropropane			1.9E-05	1.9E-05	5.1E-08		1.9E-05	2.4E-08		1.9E-05	3.8E-05	5.7E-05
	Dichlorobenzenes, total			2.2E-04	2.2E-04	3.0E-05		2.2E-04	1.8E-05		1.1E-03	1.3E-03	1.6E-03
	Dicyclopentadiene					5.7E-06		1.6E-04	3.3E-06		5.5E-04	7.1E-04	7.1E-04
	Dieldrin	2.7E-08	2.7E-08			7.7E-06	8.9E-06	1.5E-06	5.5E-06	1.8E-07	2.7E-05	5.1E-05	5.1E-05
	Endrin	6.5E-09	6.5E-09			1.3E-06		1.6E-06	6.3E-07	4.2E-08	1.6E-05	2.0E-05	2.0E-05
	Isodrin							1.5E-06				1.5E-06	1.5E-06
	Tetrachloroethene			4.4E-04	4.4E-04	1.3E-05		4.4E-04	7.1E-06		8.0E-04	1.3E-03	1.7E-03
	Trichloroethene			2.8E-05	2.8E-05	1.0E-06		2.8E-05	5.6E-07		5.8E-05	8.8E-05	1.2E-04
Renal	Chlorobenzene			7.7E-05	7.7E-05	2.6E-06		7.7E-05	1.5E-06		1.5E-04	2.3E-04	3.1E-04
	Dibromochloropropane			1.9E-05	1.9E-05	5.1E-08		1.9E-05	2.4E-08		1.9E-05	3.8E-05	5.7E-05
Respiratory	Dichloroethane, 1,2-			3.3E-05	3.3E-05								3.3E-05
Skin	Arsenic, total					1.6E-06		7.1E-05	4.1E-06		6.0E-05	1.4E-04	1.4E-04

Zone 3; Adult Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Blood	Benzene					2.4E-05	2.4E-05	2.4E-05			1.3E-05	3.7E-05	6.1E-05
	Toluene							4.1E-05			3.4E-05	7.5E-05	7.5E-05
Cardiovascular	Atrazine							4.2E-04			3.6E-04	7.7E-04	7.7E-04
	Dichloroethane, 1,2-							3.0E-05			1.3E-05	4.2E-05	4.2E-05
CNS	DIMP			2.4E-05	2.4E-05			1.9E-02			1.2E-02	3.1E-02	3.1E-02
	Dithiane, 1,4-							6.4E-05			2.2E-05	8.6E-05	8.6E-05
	Malathion							1.2E-05			1.2E-05	2.4E-05	2.4E-05
	Oxathiane, 1,4-							4.3E-05			1.3E-05	5.6E-05	5.6E-05
	Toluene					4.1E-05	4.1E-05						4.1E-05
Ocular	Toluene					4.1E-05	4.1E-05						4.1E-05
Gastrointestinal	Hexachlorocyclopentadiene							1.4E-06			7.1E-06	8.6E-06	8.6E-06
Hepatic	Aldrin	9.4E-09	1.2E-08		2.1E-08			1.6E-06	1.6E-08	2.0E-08		1.7E-06	1.7E-06
	Benzene					2.4E-05	2.4E-05	2.4E-05			1.3E-05	3.7E-05	6.1E-05
	Chlordane, total		4.2E-08	1.9E-08	6.1E-08			6.2E-06		7.1E-08	9.3E-06	1.6E-05	1.6E-05
	Chlorobenzene					5.7E-05	5.7E-05	5.7E-05			5.3E-05	1.1E-04	1.7E-04
	Chloroform					1.6E-04	1.6E-04	1.6E-04			8.1E-05	2.4E-04	4.0E-04
	Chlorophenylmethyl sulfone, p-							2.1E-04			8.3E-05	3.0E-04	3.0E-04
	Chlorophenylmethyl sulfoxide, p-							3.3E-04			1.3E-04	4.7E-04	4.7E-04
	DDE, p,p'-	3.4E-10	1.6E-08	9.4E-09	2.6E-08			7.0E-06	7.3E-10	3.5E-08	1.4E-05	2.1E-05	2.1E-05
	DDT, p,p'-	5.7E-09	4.3E-08	4.9E-09	5.3E-08			3.5E-06	1.2E-08	9.1E-08		3.6E-06	3.6E-06
	Dibromochloropropane	6.5E-08			6.5E-08	4.5E-06	4.5E-06	4.5E-06	1.6E-07		2.1E-06	6.8E-06	1.1E-05
	Dicyclopentadiene			1.1E-06	1.1E-06			5.3E-03			8.8E-03	1.4E-02	1.4E-02
	Dieldrin	1.1E-07	9.5E-08	2.7E-07	4.8E-07			6.8E-06	1.9E-07	1.6E-07	6.9E-05	7.6E-05	7.7E-05
	Dithiane, 1,4-							6.4E-05			2.2E-05	8.6E-05	8.6E-05
	Endrin	3.1E-09	2.7E-08		3.0E-08			2.3E-05	5.3E-09	4.6E-08	5.8E-05	8.1E-05	8.1E-05
	Isodrin							1.5E-06				1.5E-06	1.5E-06
	Tetrachloroethene					6.7E-04	6.7E-04	6.7E-04			5.8E-04	1.3E-03	1.9E-03
	Trichloroethene					1.6E-05	1.6E-05	1.6E-05			1.6E-05	3.3E-05	4.9E-05
Renal	Chlorobenzene					5.7E-05	5.7E-05	5.7E-05			5.3E-05	1.1E-04	1.7E-04
	Dibromochloropropane	6.5E-08			6.5E-08	4.5E-06	4.5E-06	4.5E-06	1.6E-07		2.1E-06	6.8E-06	1.1E-05

(CONTINUED)

Zone 3; Adult Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Respiratory	Dichloroethane, 1,2-					3.0E-05	3.0E-05						3.0E-05
	Toluene					4.1E-05	4.1E-05						4.1E-05
Skin	Arsenic, total			1.9E-06	1.9E-06						2.6E-05	2.6E-05	2.8E-05

Zone 3; Child Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Blood	Benzene					3.2E-05	3.2E-05	3.2E-05			3.3E-05	6.5E-05	9.8E-05
	Toluene							5.5E-05			8.6E-05	1.4E-04	1.4E-04
Cardiovascular	Atrazine							5.6E-04			9.0E-04	1.5E-03	1.5E-03
	Dichloroethane, 1,2-							4.0E-05			3.2E-05	7.2E-05	7.2E-05
CNS	DIMP			4.4E-05	4.4E-05			2.6E-02			3.0E-02	5.5E-02	5.5E-02
	Dithiane, 1,4-							8.5E-05			5.6E-05	1.4E-04	1.4E-04
	Malathion							1.6E-05			2.9E-05	4.5E-05	4.5E-05
	Oxathiane, 1,4-							5.7E-05			3.2E-05	9.0E-05	9.0E-05
	Toluene					5.5E-05	5.5E-05						5.5E-05
Ocular	Toluene					5.5E-05	5.5E-05						5.5E-05
Gastrointestinal	Hexachlorocyclopentadiene							1.9E-06			1.8E-05	2.0E-05	2.0E-05
Hepatic	Aldrin	1.7E-08	2.1E-08		3.8E-08			2.2E-06	1.1E-07	1.4E-07		2.4E-06	2.5E-06
	Benzene					3.2E-05	3.2E-05	3.2E-05			3.3E-05	6.5E-05	9.8E-05
	Chlordane, total		7.6E-08	3.5E-08	1.1E-07			8.3E-06		4.9E-07	2.3E-05	3.2E-05	3.2E-05
	Chlorobenzene					7.7E-05	7.7E-05	7.7E-05			1.3E-04	2.1E-04	2.9E-04
	Chloroform					2.2E-04	2.2E-04	2.2E-04			2.0E-04	4.2E-04	6.4E-04
	Chlorophenylmethyl sulfone, p-							2.9E-04			2.1E-04	5.0E-04	5.0E-04
	Chlorophenylmethyl sulfoxide, p-							4.5E-04			3.3E-04	7.8E-04	7.8E-04
	DDE, p,p'-	6.1E-10	3.0E-08	1.7E-08	4.7E-08			9.3E-06	5.0E-09	2.4E-07	3.6E-05	4.5E-05	4.5E-05
	DDT, p,p'-	1.0E-08	7.7E-08	8.9E-09	9.6E-08			4.6E-06	8.4E-08	6.3E-07		5.4E-06	5.4E-06
	Dibromochloropropane	1.2E-07			1.2E-07	6.0E-06	6.0E-06	6.0E-06	1.1E-06		5.3E-06	1.2E-05	1.9E-05
	Dicyclopentadiene			1.9E-06	1.9E-06			7.1E-03			2.2E-02	2.9E-02	2.9E-02
	Dieldrin	2.1E-07	1.7E-07	5.0E-07	8.7E-07			9.2E-06	1.3E-06	1.1E-06	1.7E-04	1.9E-04	1.9E-04
	Dithiane, 1,4-							8.5E-05			5.6E-05	1.4E-04	1.4E-04
	Endrin	5.7E-09	4.9E-08		5.5E-08			3.2E-05	3.7E-08	3.2E-07	1.5E-04	1.8E-04	1.8E-04
	Isodrin							2.0E-06				2.0E-06	2.0E-06
	Tetrachloroethene					9.0E-04	9.0E-04	9.0E-04			1.5E-03	2.4E-03	3.3E-03
	Trichloroethene					2.2E-05	2.2E-05	2.2E-05			4.2E-05	6.4E-05	8.6E-05
Renal	Chlorobenzene					7.7E-05	7.7E-05	7.7E-05			1.3E-04	2.1E-04	2.9E-04
	Dibromochloropropane	1.2E-07			1.2E-07	6.0E-06	6.0E-06	6.0E-06	1.1E-06		5.3E-06	1.2E-05	1.9E-05

(CONTINUED)

Zone 3; Child Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Respiratory	Dichloroethane, 1,2-					4.0E-05	4.0E-05						4.0E-05
	Toluene					5.5E-05	5.5E-05						5.5E-05
Skin	Arsenic, total			3.4E-06	3.4E-06						6.5E-05	6.5E-05	6.9E-05

Zone 4; Adult Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Blood	Benzene					3.0E-05	3.0E-05	3.0E-05			1.6E-05	4.6E-05	7.6E-05
	Toluene							3.8E-05			3.1E-05	6.9E-05	6.9E-05
Cardiovascular	Atrazine							2.4E-04			2.0E-04	4.4E-04	4.4E-04
	Dichloroethane, 1,2-							2.4E-04			1.0E-04	3.4E-04	3.4E-04
CNS	DIMP			2.4E-05	2.4E-05			1.6E-01			9.5E-02	2.5E-01	2.5E-01
	Dithiane, 1,4-							1.4E-04			4.8E-05	1.8E-04	1.8E-04
	Malathion							1.0E-05			9.5E-06	2.0E-05	2.0E-05
	Manganese							4.0E-02			3.0E-02	7.1E-02	7.1E-02
	Oxathiane, 1,4-							7.1E-05			2.2E-05	9.3E-05	9.3E-05
	Toluene					3.8E-05	3.8E-05						3.8E-05
	Xylenes, total					3.6E-05	3.6E-05	3.6E-05			5.1E-05	8.7E-05	1.2E-04
Ocular	Toluene					3.8E-05	3.8E-05						3.8E-05
Gastrointestinal	Hexachlorocyclopentadiene							1.4E-06			6.9E-06	8.3E-06	8.3E-06
Hepatic	Aldrin	9.4E-09	1.8E-09		1.1E-08			3.7E-06	1.6E-08	3.1E-09		3.8E-06	3.8E-06
	Benzene					3.0E-05	3.0E-05	3.0E-05			1.6E-05	4.6E-05	7.6E-05
	Chlordane, total			1.9E-08	1.9E-08			1.7E-05			1.1E-05	2.8E-05	2.8E-05
	Chlorobenzene					1.5E-04	1.5E-04	1.5E-04			1.4E-04	2.8E-04	4.3E-04
	Chloroform					4.9E-05	4.9E-05	4.9E-05			2.4E-05	7.3E-05	1.2E-04
	Chlorophenylmethyl sulfone, p-							1.6E-04			6.4E-05	2.3E-04	2.3E-04
	Chlorophenylmethyl sulfoxide, p-							2.5E-04			9.8E-05	3.5E-04	3.5E-04
	DDE, p,p'-	3.4E-10	1.0E-08	9.4E-09	2.0E-08			2.7E-06	7.3E-10	2.2E-08	7.7E-06	1.1E-05	1.1E-05
	DDT, p,p'-	5.7E-09	2.0E-08	4.9E-09	3.1E-08			3.2E-06	1.2E-08	4.3E-08		3.3E-06	3.3E-06
	Dibromochloropropane	6.5E-08			6.5E-08	4.9E-06	4.9E-06	4.9E-06	1.6E-07		2.3E-06	7.4E-06	1.2E-05
	Dichlorobenzenes, total					9.5E-05	9.5E-05	9.5E-05			2.2E-04	3.1E-04	4.1E-04
	Dicyclopentadiene			1.1E-06	1.1E-06			2.2E-03			3.6E-03	5.8E-03	5.8E-03
	Dieldrin	1.1E-07	1.5E-08	2.7E-07	4.0E-07			1.8E-06	1.9E-07	2.6E-08	2.8E-05	3.0E-05	3.1E-05
	Dithiane, 1,4-							1.4E-04			4.8E-05	1.8E-04	1.8E-04
	Endrin	3.1E-09	3.6E-09		6.7E-09			1.9E-06	5.3E-09	6.1E-09	8.3E-06	1.0E-05	1.0E-05
	Ethylbenzene					1.8E-05	1.8E-05	1.8E-05			2.7E-05	4.5E-05	6.3E-05

(CONTINUED)

Zone 4; Adult Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Hepatic	Isodrin							1.9E-06				1.9E-06	1.9E-06
	Tetrachloroethene					2.0E-04	2.0E-04	2.0E-04			1.7E-04	3.7E-04	5.6E-04
	Trichloroethene					8.7E-05	8.7E-05	8.7E-05			8.7E-05	1.7E-04	2.6E-04
Renal	Chlorobenzene					1.5E-04	1.5E-04	1.5E-04			1.4E-04	2.8E-04	4.3E-04
	Dibromochloropropane	6.5E-08			6.5E-08	4.9E-06	4.9E-06	4.9E-06	1.6E-07		2.3E-06	7.4E-06	1.2E-05
	Ethylbenzene					1.8E-05	1.8E-05	1.8E-05			2.7E-05	4.5E-05	6.3E-05
Respiratory	Dichloroethane, 1,2-					2.4E-04	2.4E-04						2.4E-04
	Toluene					3.8E-05	3.8E-05						3.8E-05
	Xylenes, total					3.6E-05	3.6E-05						3.6E-05
Skin	Arsenic, total			1.9E-06	1.9E-06			9.0E-05			6.3E-05	1.5E-04	1.5E-04

Zone 4; Child Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Blood	Benzene					4.0E-05	4.0E-05	4.0E-05			4.1E-05	8.1E-05	1.2E-04
	Toluene							5.1E-05			7.9E-05	1.3E-04	1.3E-04
Cardiovascular	Atrazine							3.2E-04			5.1E-04	8.3E-04	8.3E-04
	Dichloroethane, 1,2-							3.2E-04			2.5E-04	5.7E-04	5.7E-04
CNS	DIMP			4.4E-05	4.4E-05			2.1E-01			2.4E-01	4.5E-01	4.5E-01
	Dithiane, 1,4-							1.8E-04			1.2E-04	3.0E-04	3.0E-04
	Malathion							1.4E-05			2.4E-05	3.8E-05	3.8E-05
	Manganese							5.4E-02			7.6E-02	1.3E-01	1.3E-01
	Oxathiane, 1,4-							9.6E-05			5.4E-05	1.5E-04	1.5E-04
	Toluene					5.1E-05	5.1E-05						5.1E-05
	Xylenes, total					4.8E-05	4.8E-05	4.8E-05			1.3E-04	1.8E-04	2.2E-04
Ocular	Toluene					5.1E-05	5.1E-05						5.1E-05
Gastrointestinal	Hexachlorocyclopentadiene							1.8E-06			1.7E-05	1.9E-05	1.9E-05
Hepatic	Aldrin	1.7E-08	3.2E-09		2.0E-08			5.0E-06	1.1E-07	2.1E-08		5.2E-06	5.2E-06
	Benzene					4.0E-05	4.0E-05	4.0E-05			4.1E-05	8.1E-05	1.2E-04
	Chlordane, total			3.5E-08	3.5E-08			2.3E-05			2.7E-05	5.1E-05	5.1E-05
	Chlorobenzene					2.0E-04	2.0E-04	2.0E-04			3.4E-04	5.4E-04	7.3E-04
	Chloroform					6.6E-05	6.6E-05	6.6E-05			6.2E-05	1.3E-04	1.9E-04
	Chlorophenylmethyl sulfone, p-							2.2E-04			1.6E-04	3.8E-04	3.8E-04
	Chlorophenylmethyl sulfoxide, p-							3.3E-04			2.5E-04	5.8E-04	5.8E-04
	DDE, p,p'-	6.1E-10	1.8E-08	1.7E-08	3.6E-08			3.7E-06	5.0E-09	1.5E-07	2.0E-05	2.3E-05	2.3E-05
	DDT, p,p'-	1.0E-08	3.6E-08	8.9E-09	5.6E-08			4.3E-06	8.4E-08	3.0E-07		4.7E-06	4.8E-06
	Dibromochloropropane	1.2E-07			1.2E-07	6.6E-06	6.6E-06	6.6E-06	1.1E-06		5.8E-06	1.4E-05	2.0E-05
	Dichlorobenzenes, total					1.3E-04	1.3E-04	1.3E-04			5.5E-04	6.8E-04	8.0E-04
	Dicyclopentadiene			1.9E-06	1.9E-06			2.9E-03			9.2E-03	1.2E-02	1.2E-02
	Dieldrin	2.1E-07	2.7E-08	5.0E-07	7.3E-07			2.4E-06	1.3E-06	1.8E-07	7.2E-05	7.6E-05	7.6E-05
	Dithiane, 1,4-							1.8E-04			1.2E-04	3.0E-04	3.0E-04
	Endrin	5.7E-09	6.5E-09		1.2E-08			2.5E-06	3.7E-08	4.2E-08	2.1E-05	2.4E-05	2.4E-05
	Ethylbenzene					2.5E-05	2.5E-05	2.5E-05			6.7E-05	9.2E-05	1.2E-04

(CONTINUED)

Zone 4; Child Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Hepatic	Isodrin							2.5E-06				2.5E-06	2.5E-06
	Tetrachloroethene					2.6E-04	2.6E-04	2.6E-04			4.3E-04	7.0E-04	9.6E-04
	Trichloroethene					1.2E-04	1.2E-04	1.2E-04			2.2E-04	3.4E-04	4.5E-04
Renal	Chlorobenzene					2.0E-04	2.0E-04	2.0E-04			3.4E-04	5.4E-04	7.3E-04
	Dibromochloropropane	1.2E-07			1.2E-07	6.6E-06	6.6E-06	6.6E-06	1.1E-06		5.8E-06	1.4E-05	2.0E-05
	Ethylbenzene					2.5E-05	2.5E-05	2.5E-05			6.7E-05	9.2E-05	1.2E-04
Respiratory	Dichloroethane, 1,2-					3.2E-04	3.2E-04						3.2E-04
	Toluene					5.1E-05	5.1E-05						5.1E-05
	Xylenes, total					4.8E-05	4.8E-05						4.8E-05
Skin	Arsenic, total			3.4E-06	3.4E-06			1.2E-04			1.6E-04	2.8E-04	2.8E-04

Zone 6; Adult Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Cardiovascular	Atrazine					1.4E-07		1.4E-04	2.8E-07		2.2E-05	1.6E-04	1.6E-04
CNS	DIMP					1.9E-09		1.5E-04	4.4E-09		1.6E-05	1.7E-04	1.7E-04
Hepatic	Aldrin	1.8E-09	1.8E-09					9.6E-07		3.1E-09		9.7E-07	9.7E-07
	Chlorobenzene			4.1E-05	4.1E-05	4.6E-08		4.1E-05	9.5E-08		6.8E-06	4.8E-05	8.9E-05
	Chloroform			1.1E-04	1.1E-04	8.9E-09		1.1E-04	1.6E-08		9.6E-06	1.2E-04	2.2E-04
	DDE, p,p'-	1.0E-08	1.0E-08			1.1E-06			3.1E-06	2.2E-08	4.2E-06	8.4E-06	8.5E-06
	DDT, p,p'-	2.0E-08	2.0E-08							4.3E-08		4.3E-08	6.3E-08
	Dieldrin	1.5E-08	1.5E-08			8.2E-07	3.1E-06	1.3E-06	2.3E-06	2.6E-08	7.3E-06	1.5E-05	1.5E-05
	Endrin	3.6E-09	3.6E-09			7.0E-08			1.4E-07	6.1E-09	2.2E-06	2.4E-06	2.4E-06
	Isodrin							1.3E-06				1.3E-06	1.3E-06
	Tetrachloroethene			5.4E-05	5.4E-05	5.5E-08		5.4E-05	1.1E-07		8.3E-06	6.2E-05	1.2E-04
	Trichloroethene			1.3E-04	1.3E-04	1.6E-07		1.3E-04	3.2E-07		2.3E-05	1.5E-04	2.8E-04
Renal	Chlorobenzene			4.1E-05	4.1E-05	4.6E-08		4.1E-05	9.5E-08		6.8E-06	4.8E-05	8.9E-05

Zone 6; Child Resident; Acute

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Cardiovascular	Atrazine					9.0E-07		1.9E-04	4.9E-07		5.4E-05	2.5E-04	2.5E-04
CNS	DIMP					1.2E-08		2.0E-04	7.6E-09		4.0E-05	2.4E-04	2.4E-04
Hepatic	Aldrin	3.2E-09	3.2E-09					1.3E-06		2.1E-08		1.3E-06	1.3E-06
	Chlorobenzene			5.5E-05	5.5E-05	3.0E-07		5.5E-05	1.7E-07		1.7E-05	7.3E-05	1.3E-04
	Chloroform			1.4E-04	1.4E-04	5.7E-08		1.4E-04	2.8E-08		2.4E-05	1.7E-04	3.1E-04
	DDE, p,p'-	1.8E-08	1.8E-08			7.2E-06			5.5E-06	1.5E-07	1.1E-05	2.3E-05	2.3E-05
	DDT, p,p'-	3.6E-08	3.6E-08							3.0E-07		3.0E-07	3.3E-07
	Dieldrin	2.7E-08	2.7E-08			5.3E-06	8.9E-06	1.7E-06	4.0E-06	1.8E-07	1.8E-05	3.8E-05	3.8E-05
	Endrin	6.5E-09	6.5E-09			4.5E-07			2.4E-07	4.2E-08	5.5E-06	6.2E-06	6.2E-06
	Isodrin							1.7E-06				1.7E-06	1.7E-06
	Tetrachloroethene			7.2E-05	7.2E-05	3.5E-07		7.2E-05	1.9E-07		2.1E-05	9.4E-05	1.7E-04
	Trichloroethene			1.8E-04	1.8E-04	1.0E-06		1.8E-04	5.7E-07		5.9E-05	2.4E-04	4.1E-04
Renal	Chlorobenzene			5.5E-05	5.5E-05	3.0E-07		5.5E-05	1.7E-07		1.7E-05	7.3E-05	1.3E-04

Appendix E

UNCERTAINTY ANALYSIS

PROCEDURAL NOTES

Procedures used in this uncertainty analysis are described in Section 2.4.5. Generally, the uncertainty analysis duplicates the intake estimation equations, but substitutes a probability distribution instead of a point (reasonable maximum exposure [RME] or most likely exposure [MLE]) value for each of the input parameters. @RISK® randomly samples from the distributions using the Latin-hypercube sampling procedure. The procedures may be reviewed, and the calculations duplicated, using @RISK® spreadsheets that are incorporated by reference and are a part of the administrative record.

To achieve the objectives of this uncertainty analysis, additional algorithms were developed that were not pertinent to the RME analysis. The most important of these algorithms was used to determine the age of hypothetically exposed individuals for use in intake calculations that are sensitive to the age of the individual at exposure (see discussion in Section 2.4.5.5.1). These exposure pathways are the incidental direct ingestion of soil and the ingestion of dairy products. Intakes, in milligrams per kilogram per day (mg/kg/day), by these pathways are very sensitive to the age of the individual. In the RME analysis it was conservatively assumed that the exposure duration is 30 years, and that the age of the individual at exposure is from ages 1 to 31. Any other age assumption would result in lower intake estimates by these pathways. The objective of this uncertainty analysis was not to single out the most exposed individual, but rather to fairly represent the range of exposures that may occur among members of the exposed population. Consequently, in the lifetime intake calculations that may be used to estimate carcinogenic risk, the uncertainty analysis used the following procedure:

1. For each iteration (which corresponds to one hypothetical individual from the exposed population), determine the exposure duration (ED). The distribution used for ED is from the Exposure Factors Handbook (U.S. Environmental Protection Agency [EPA], 1989c).

2. Assume that exposure to carcinogens is most likely to generate a carcinogenic response if it occurs before the age of 70. This assumption is consistent with standard carcinogenic risk assessment practices that reference to exposure over a "70 year lifetime."

3. Based on assumption 2, an individual exposed for ED years, must establish residency in the Offpost Operable Unit between the ages of 1 and (70 - ED).

4. Assume that there is an equal probability that residency will start at any time from ages 1 to (70 - ED). Thus, the starting age of exposure is sampled from a uniform distribution over those ages. The ending age is, obviously, the starting age plus ED.

5a. Soil ingestion rates for this individual are determined from the age-specific information provided in Table 2.4.3.2-1a.

5b. Dairy ingestion rates for this individual are sampled from age-specific distributions derived from Rao and others (1982). Body weights are provided in Table 2.4.3.2-1a.

Additional logic was also developed to define the distribution of consumption of locally produced vegetables. The relative importance of this pathway to total exposure under residential scenarios dictated special care in development of this algorithm. Additional information pertinent to the development of input parameters for consumption of vegetables was also provided in the response to comments in the draft final of the Offpost Endangerment Assessment (EA) (HLA, 1992).

It was assumed that a resident either has or does not have a home garden. Residents with their own gardens are assumed to consume more locally produced vegetables than residents without a garden. However, residents without a garden may purchase locally produced vegetables, or their neighbors may share some produce from their own gardens. The first step in each iteration is to determine whether the simulated individual has a garden of not, using a discrete distribution (61 percent, yes; 39 percent, no; EPA, 1989c national rural value; EPA, 1989c, also reported that 53 percent of Rocky Mountain Region residents have gardens). Individuals with gardens were assumed to consume twice as much locally produced vegetables as individuals without gardens. A homegrown fraction of stem/leafy and root/tuber vegetable consumption is calculated next by random sampling from normal distributions that were derived from the Exposure Factors Handbook. Finally the homegrown fraction is multiplied by the distribution of total vegetable consumption for the two vegetable categories, which was derived from data presented by Rao and others (1982).

DEFINITIONS

In some cases, variable names used here differ from those used in the main body of the report.

Definitions are as follows:

CD (milligrams per kilogram [mg/kg])	concentration of chemical of concern (COC) in milk
CEGG (mg/kg)	concentration of COC in eggs
Cgw1...Cgw6 (milligrams per liter [mg/l])	concentration in groundwater by zone
CM (mg/kg)	concentration of COC in meat
Cs1 (mg/kg)	concentration in soils outside of zone 3
Cs2 (mg/kg)	concentration in soils, zone 3 (also referred to as CS3)
Cs3 (mg/kg)	see Cs2
Csw2 (mg/l)	concentration in canals downstream of First Creek
Csw3 (mg/l)	concentration in First Creek (also referred to as Csw4)
Csw4 (mg/l)	see Csw3
CV (mg/kg)	concentration of COC in vegetables (composite)
ED (year)	exposure duration
fe (dimensionless)	the fraction of aboveground vegetables consumed that represent exposed produced (grains are not exposed)
FID (dimensionless)	locally produced fraction of total milk consumption
FIM (dimensionless)	locally produced fraction of total meat consumption
FIR (dimensionless)	locally produced fraction of total root/tuber vegetable consumption
FIS (dimensionless)	locally produced fraction of total aboveground vegetable consumption
GWF1 (dimensionless)	the fraction of agricultural water supply provided by groundwater in zones 3 and 4
GWF2 (dimensionless)	the fraction of agricultural water supply provided by groundwater in zones 1, 1c, and 6
GWF3 (dimensionless)	the fraction of agricultural water supply provided by groundwater in zones 1b, 2, and 5

ID (mg/kg/day)	intake by ingestion of milk and milk products
IEGG (mg/kg/day)	intake by ingestion of eggs
IGW (mg/kg/day)	intake by ingestion of groundwater
IORAL (mg/kg/day)	total oral intake
IRd (kilograms per day [kg/day])	WDTOTAL x FID, consumption of locally produced milk
IRe (kg/day)	see WE
IRm (kg/day)	WMTOTAL x FIM, consumption of locally produced meat
IRv (kg/day)	(RVC x FIR) + (SVC x FIS) consumption of locally produced vegetables
IRw (liters per day [l/day])	see VW
IV (mg/kg/day)	intake by ingestion of vegetables
Kdep (liters per kilogram [l/kg])	partition coefficient for deposition from spray (see also Section 2.2.2.2.2 and 2.4.2.3.3)
Kpd (dimensionless)	partition coefficient relating concentration in milk to concentration in animal feed
Kpm (dimensionless)	partition coefficient relating concentration in meat to concentration in animal feed
Kse (dimensionless)	partition coefficient relating concentration in eggs to concentration in soil
Ksp (dimensionless)	partition coefficient relating concentration in above-ground vegetables to soil concentration
Ksr (dimensionless)	partition coefficient relating concentration in root/tuber vegetables to soil concentration
Kwp (l/kg)	partition coefficient relating concentration in above-ground vegetables to soil aqueous phase
Kwr (l/kg)	partition coefficient relating concentration in root/tuber vegetables to soil aqueous phase
RVC (kg/day)	total consumption of root/tuber vegetables
SVC (kg/day)	total consumption of aboveground vegetables
VW (l/day)	volume of water ingested per day (also referred to as IRw)

VWi (l/day)	exposure factor for inhalation of volatile chemicals in domestic water
WDTOTAL (kg/day)	total consumption of milk and milk products
WE (kg/day)	consumption of eggs (also referred to as IRe)
WMTOTAL (kg/day)	total consumption of meat

GENERIC PARAMETERS

	DISTRIBUTION	PARAMETERS
GWF1	UNIFORM	MIN = 0 MAX = 1
GWF2	TRIANGULAR	MIN = 0.05 MED = 0.075 MAX = 0.2
fe	TRUNCATED NORMAL	MEAN = 0.62 ST. DEV = 0.371 MIN = 0 MAX = 1
Kdep	NORMAL	MEAN = 2.42 ST. DEV = 0.84
VW (ADULT)	NORMAL	MEAN = 1.4 ST. DEV =0.45
VW (CHILD)	NORMAL	MEAN = .547 ST. DEV = 0.176
ED	CUMULATIVE	PROVIDED BY EPA(1989C)

WD = WDTOTAL * FID

WDTOTAL	AGE SPECIFIC CUMULATIVE	PAO AND OTHERS (1982); SEE SECTION 2.4.3.2
FID	TRUNCATED NORMAL	MEAN = 0.4 ST. DEV = 0.27 MIN = 0 MAX = 1

WM = WMTOTAL * FIM

WMTOTAL	AGE SPECIFIC CUMULATIVE	PAO AND OTHERS (1982); SEE SECTION 2.4.3.2
FIM	TRUNCATED NORMAL	MEAN = 0.44 ST. DEV. = .24 MIN = 0 MAX = 1
WE	AGE SPECIFIC CUMULATIVE	PAO AND OTHERS (1982); SEE SECTION 2.4.3.2

IRV = (RVC * FIR) + (SVC * FIS)

RVC 0.0313	TRUNCATED NORMAL	MEAN = 0.0415 ST. DEV = MIN = 0 MAX = 0.2
FIR	TRUNCATED NORMAL	MEAN = 0.31 ST. DEV = 0.06 MIN = 0 MAX = 1

NOTE: FIR DISTRIBUTION IS APPLIED FOR 61% OF POPULATION ASSUMED TO HAVE GARDENS. THE REMAINING 39% ARE ASSUMED TO CONSUME LESS THAN GARDENERS (HALF AS MUCH ON AVERAGE).

SVC 0.0095	TRUNCATED NORMAL	MEAN = 0.0278 ST. DEV = MIN = 0 MAX = 0.14
FIS	TRUNCATED NORMAL	MEAN = 0.71 ST. DEV = 0.15 MIN = 0 MAX = 1

NOTE: FIS DISTRIBUTION IS APPLIED FOR 61% OF POPULATION ASSUMED TO HAVE GARDENS. THE REMAINING 39% ARE ASSUMED TO CONSUME LESS THAN GARDENERS (HALF AS MUCH ON AVERAGE).

ARSENIC

Parameter	Distribution	Arithmetic Mean	Standard Deviation
Kwr	NA		
Ksr	Lognormal	2.87E-2	6.42E-2
Kwp	NA		
Ksp	Lognormal	2.87E-2	6.42E-2
Kpd	Normal	4.7E-3	1.8E-3
Kpm	Normal	1.03E-1	2.8E-2
Kse	NA		
Cgw1	NA		
Cgw2	NA		
Cgw3	NA		
Cgw4	Normal	2.02E-3	4.2E-4
Cgw5	NA		
Cgw6	NA		
Csw2	NA		
Csw3	Lognormal	7.79E-3	6.03E-3
Cs1	NA		
Cs2	NA		
VWi	NA		

CHLOROFORM

Parameter	Distribution	Arithmetic Mean	Standard Deviation
Kwr	Lognormal	1.76E0	8.4E-1
Ksr	NA		
Kwp	Lognormal	1.12E0	7.8E-1
Ksp	NA		
Kpd	Lognormal	3.69E-4	3.25E-3
Kpm	Lognormal	1.62E-3	1.46E-2
Kse	NA		
Cgw1	NA		
Cgw2	Lognormal	2.1E-2	2.8E-2
Cgw3	NA		
Cgw4	NA		
Cgw5	NA		
Cgw6	NA		
Csw2	NA		
Csw3	NA		
Cs1	NA		
Cs2	NA		
VWi	Lognormal	8.76E-1	1.17E0

DBCP

Parameter	Distribution	Arithmetic Mean	Standard Deviation
Kwr	Normal	1.7E0	5.9E-1
Ksr	NA		
Kwp	Lognormal	8.9E-1	3.7E-1
Ksp	NA		
Kpd	Lognormal	4.50E-4	4.02E-3
Kpm	Lognormal	1.97E-3	1.75E-2
Kse	NA		
Cgw1	NA		
Cgw2	Lognormal	2.04E-2	6.1E-4
Cgw3	NA		
Cgw4	NA		
Cgw5	NA		
Cgw6	NA		
Csw2	NA		
Csw3	NA		
Cs1	NA		
Cs2	NA		
VWi	Lognormal	8.76E-1	1.17E0

DIELDRIN

Parameter	Distribution	Arithmetic Mean	Standard Deviation
Kwr	NA		
Ksr	Lognormal	3.44E-1	2.22E-1
Kwp	NA		
Ksp	Lognormal	7.23E-2	4.89E-2
Kpd	Normal	1.26E-1	1.8E-2
Kpm	Normal	6.32E-1	9.4E-2
Kse	Lognormal	4.9E-2	2E-2
Cgw1AL	Normal	2.7E-5	1.3E-6
Cgw1DL	Normal	2.9E-5	3.1E-6
Cgw2AL	NA		
Cgw2DL	NA		
Cgw3AL	Lognormal	3.7E-5	7.8E-6
Cgw3DL	Lognormal	1.05E-4	6.4E-5
Cgw4AL	NA		
Cgw4DL	NA		
Cgw5AL	NA		
Cgw5DL	NA		
Cgw6AL	Normal	2.7E-5	1.8E-6
Cgw6DL	Normal	3.4E-5	3.1E-6
Csw2AL	NA		
Csw2DL	NA		
Csw3AL	NA		
Csw3DL	Lognormal	6.74E-4	1.17E-3
Cs1AL	Normal	1.65E-3	2.4E-4
Cs1DL	Lognormal	1.2E-2	4.E-3
Cs2AL	Normal	1.00E-2	2.2E-3
Cs2DL	Normal	8.3E-2	1.7E-2
VWi	NA		

DIMP

Parameter	Distribution	Arithmetic Mean	Standard Deviation
Kwr	Normal	1.57E0	3.6E-1
Ksr	NA		
Kwp	Normal	3.34E0	8.3E-1
Ksp	NA		
Kpd	Lognormal	2.50E-4	2.25E-3
Kpm	Lognormal	1.12E-3	1.05E-2
Kse	NA		
Cgw1	NA		
Cgw2	NA		
Cgw3	NA		
Cgw4	See Below		
Cgw5	NA		
Cgw6	NA		
Csw2	NA		
Csw3	Lognormal	7.47E-2	9.45E-2
Cs1	NA		
Cs2	NA		
VWi	NA		

Cgw4 defined empirically from the cumulative distribution of observed values with a minimum of 0 mg/L, maximum of 4.95 mg/L, and the following percentiles:

16.7 percent < 0.00039 mg/L
25 percent < 0.0037
35 percent < 0.016
45 percent < 0.028
55 percent < 0.048
65 percent < 0.225
75 percent < 0.75
85 percent < 1.85
95 percent < 3.45

ARSENIC

Parameter	Distribution	Arithmetic Mean	Standard Deviation
Ksr	Lognormal	2.87E-2	6.42E-2
Ksp	Lognormal	2.87E-2	6.42E-2
Kpd	Normal	4.7E-3	1.8E-3
Kpm	Normal	1.03E-1	2.8E-2
Cgw4	Normal	2.58E-3	2.8E-4
Csw3	Lognormal	7.79E-3	6.03E-3

CHLOROFORM

Parameter	Distribution	Arithmetic Mean	Standard Deviation
Kwr	Lognormal	1.76E0	8.4E-1
Kwp	Lognormal	1.12E0	7.8E-1
Kpd	Lognormal	3.69E-4	3.25E-3
Kpm	Lognormal	1.62E-3	1.46E-2
Cgw2	Lognormal	1.68E-1	1.49E-1
VWi	Lognormal	8.76E-1	1.17E0

DBCP

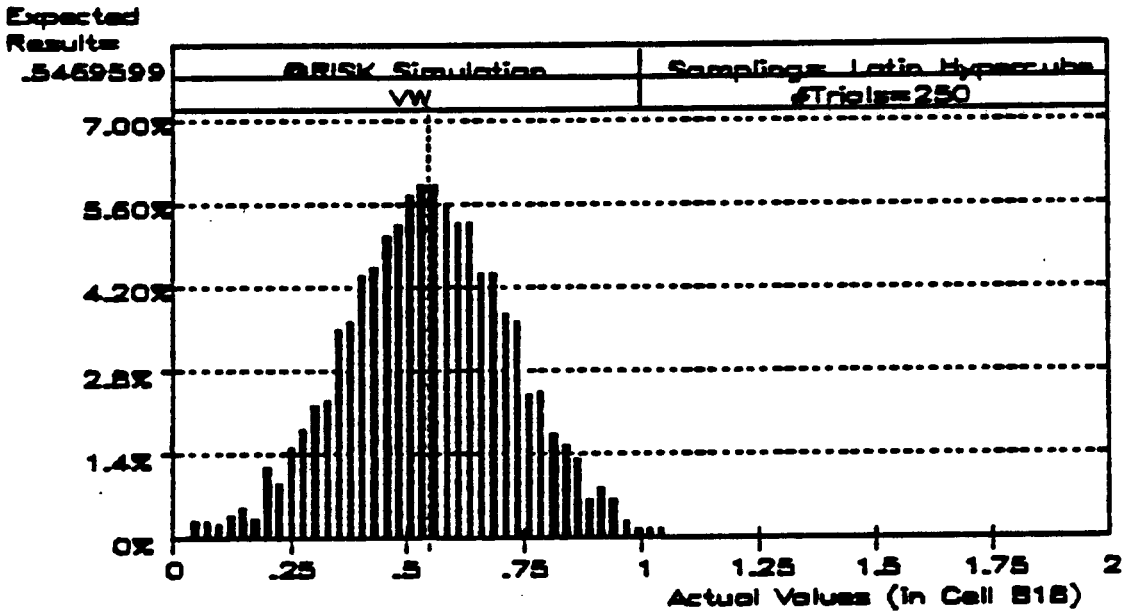
Parameter	Distribution	Arithmetic Mean	Standard Deviation
Kwr	Normal	1.7E0	5.9E-1
Kwp	Lognormal	8.9E-1	3.7E-1
Kpd	Lognormal	4.50E-4	4.02E-3
Kpm	Lognormal	1.97E-3	1.75E-2
Cgw2	Lognormal	2.04E-2	6.1E-4
VWi	Lognormal	8.76E-1	1.17E0

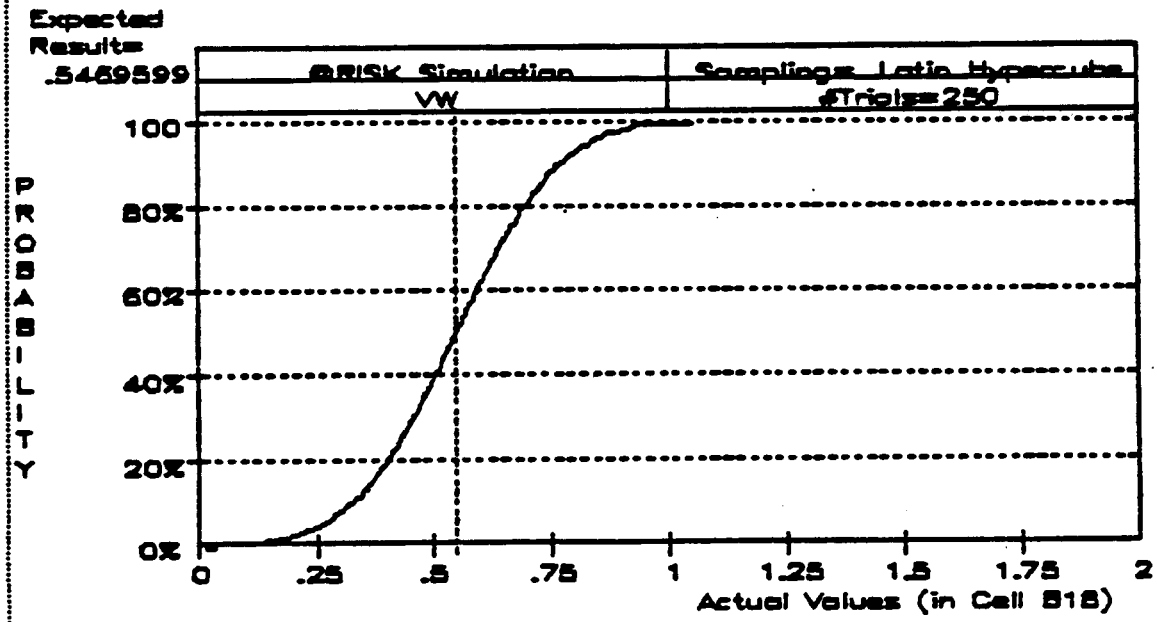
DIMP

Parameter	Distribution	Arithmetic Mean	Standard Deviation
Kwr	Normal	1.57E0	3.6E-1
Kwp	Normal	3.34E0	8.3E-1
Kpd	Lognormal	2.50E-4	2.25E-3
Kpm	Lognormal	1.12E-3	1.05E-2
Cgw4	Normal	2.04E0	2.56E-1
Csw3	Lognormal	7.47E-2	9.45E-2

EXPOSURE FACTORS CHILD CHRONIC

IRw (in Cell B18)





IRw (in Cell B18)

@RISK Risk Analysis 18-Jul-1991

Expected/Mean Result = .5469599
Maximum Result = 1.054711
Minimum Result = 3.459874E-02
Range of Possible Results = 1.020112
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = .1754905
Skewness = -4.477569E-03
Kurtosis = 2.906926
Variance = 3.079693E-02
Simulations Executed = 1
Iterations = 250

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Actual Values)

<= .0346	= 0%
<= .2529	= 5%
<= .3216	= 10%
<= .3631	= 15%
<= .3988	= 20%
<= .4273	= 25%
<= .4549	= 30%
<= .4781	= 35%
<= .5018	= 40%
<= .5242	= 45%
<= .5468	= 50%
<= .5686	= 55%
<= .5919	= 60%
<= .6137	= 65%
<= .6395	= 70%
<= .6644	= 75%
<= .6952	= 80%
<= .7276	= 85%
<= .7734	= 90%
<= .8346	= 95%

IRd (in Cell B28)

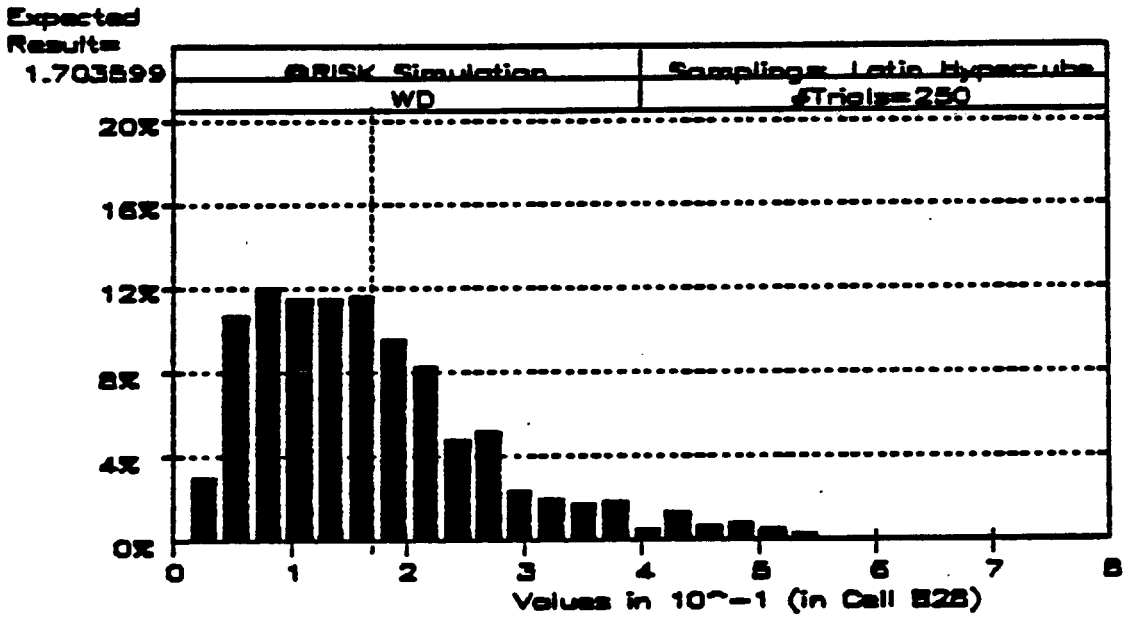
@RISK Risk Analysis 18-Jul-1991

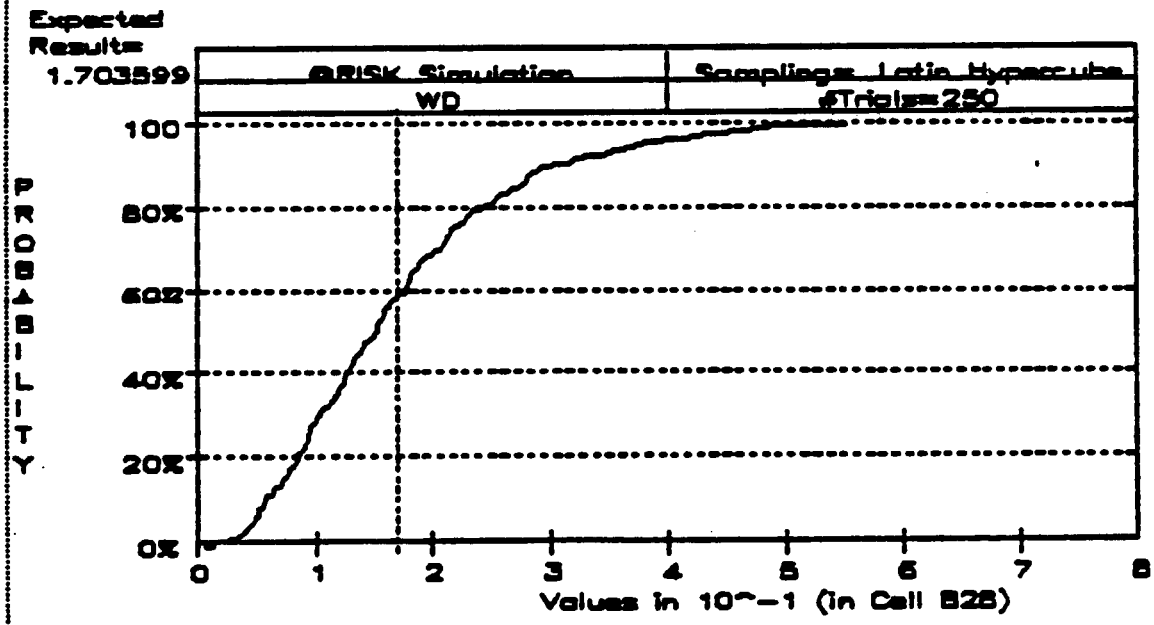
Expected/Mean Result = .1703599
Maximum Result = .5530421
Minimum Result = 1.331797E-02
Range of Possible Results = .5397242
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = .1033125
Skewness = 1.175814
Kurtosis = 4.363242
Variance = 1.067348E-02
Simulations Executed = 1
Iterations = 250

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-1)

<= .1332 = 0%
<= .4596 = 5%
<= .571 = 10%
<= .7123 = 15%
<= .8526 = 20%
<= .9384 = 25%
<= 1.024 = 30%
<= 1.1794 = 35%
<= 1.2643 = 40%
<= 1.3746 = 45%
<= 1.5114 = 50%
<= 1.5861 = 55%
<= 1.7561 = 60%
<= 1.8298 = 65%
<= 2.0505 = 70%
<= 2.1618 = 75%
<= 2.4317 = 80%
<= 2.7226 = 85%
<= 3.099 = 90%
<= 3.7529 = 95%
<= 5.5304 = 100%

IRd (in Cell B28)





IRV (in Cell B26)

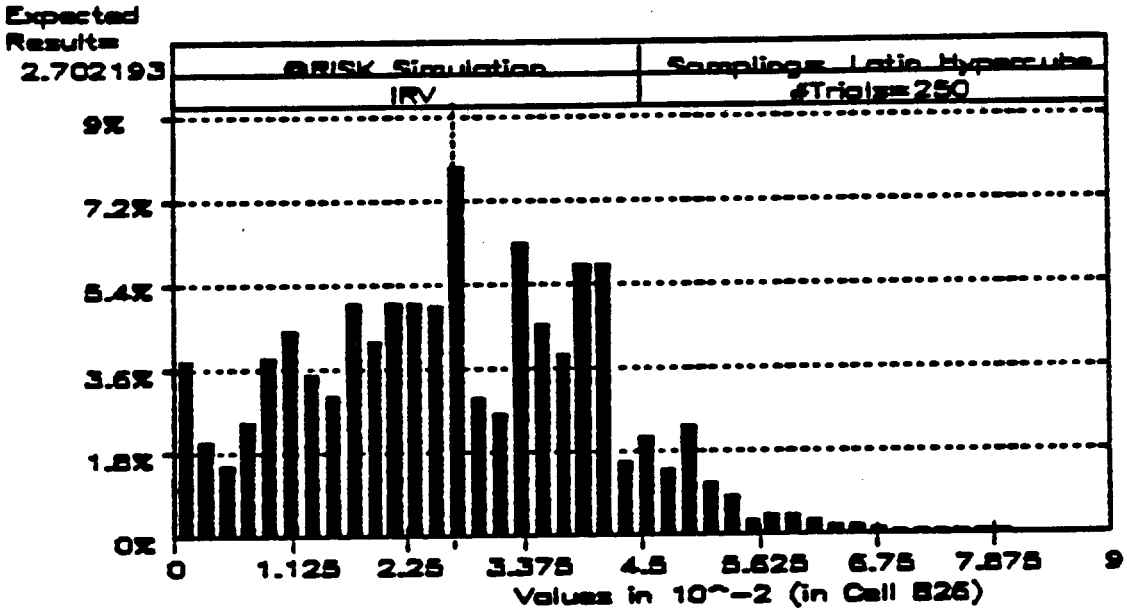
@RISK Risk Analysis 18-Jul-1991

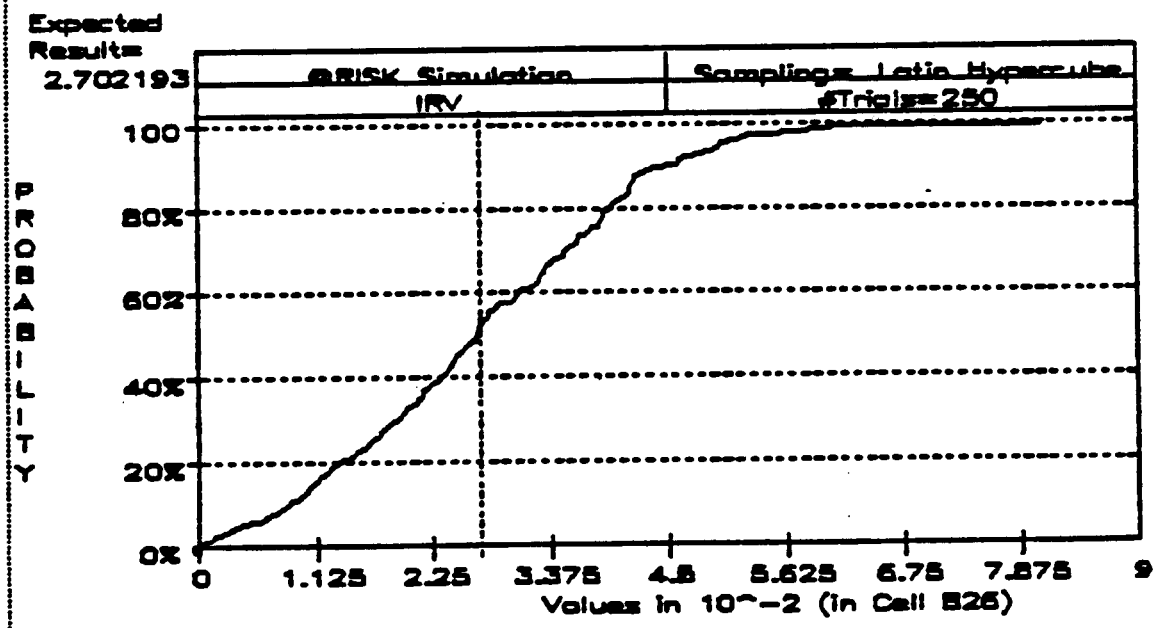
Expected/Mean Result = 2.702192E-02
Maximum Result = 8.075474E-02
Minimum Result = 9.793816E-05
Range of Possible Results = .0806568
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.447063E-02
Skewness = .3281962
Kurtosis = 3.09766
Variance = 2.093991E-04
Simulations Executed = 1
Iterations = 250

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-2)

<= .0098 = 0%
<= .3113 = 5%
<= .8334 = 10%
<= 1.0565 = 15%
<= 1.3197 = 20%
<= 1.6369 = 25%
<= 1.8644 = 30%
<= 2.096 = 35%
<= 2.2972 = 40%
<= 2.4637 = 45%
<= 2.6603 = 50%
<= 2.7831 = 55%
<= 3.0599 = 60%
<= 3.3082 = 65%
<= 3.5216 = 70%
<= 3.7543 = 75%
<= 3.9366 = 80%
<= 4.1368 = 85%
<= 4.5307 = 90%
<= 5.0061 = 95%
<= 8.0755 = 100%

IRV (in Cell B26)





IRm (in Cell B30)

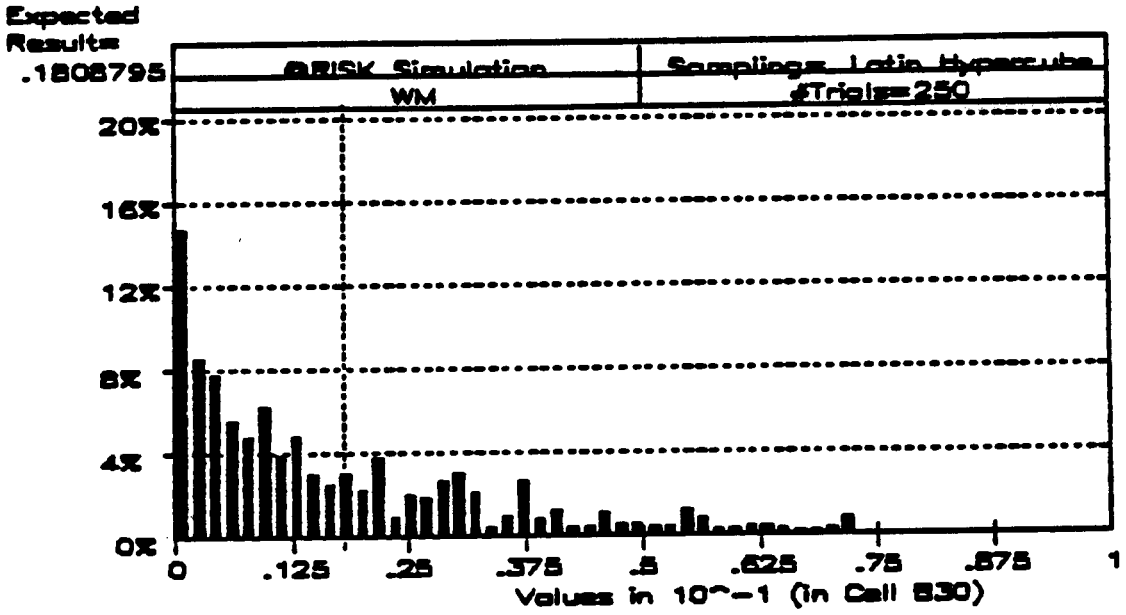
@RISK Risk Analysis 18-Jul-1991

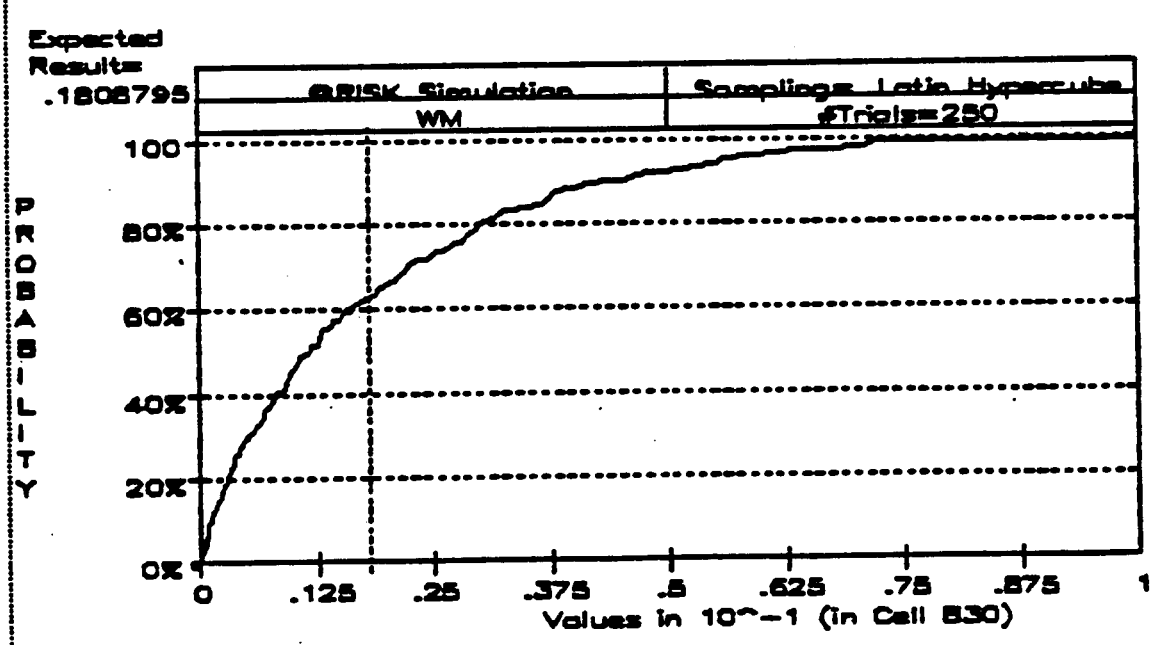
Expected/Mean Result = 1.908795E-02
Maximum Result = .1733204
Minimum Result = 1.568517E-06
Range of Possible Results = .1733188
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 2.011173E-02
Skewness = 2.684945
Kurtosis = 16.70631
Variance = 4.044816E-04
Simulations Executed = 1
Iterations = 250

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-1)

<= .00001 = 0%
<= .0068 = 5%
<= .0105 = 10%
<= .0178 = 15%
<= .0279 = 20%
<= .0376 = 25%
<= .05 = 30%
<= .0672 = 35%
<= .0812 = 40%
<= .0965 = 45%
<= .1134 = 50%
<= .1306 = 55%
<= .1601 = 60%
<= .1908 = 65%
<= .2213 = 70%
<= .2674 = 75%
<= .3005 = 80%
<= .365 = 85%
<= .436 = 90%
<= .5557 = 95%
<= 1.7332 = 100%

IRm (in Cell B30)





IRe (in Cell B32)

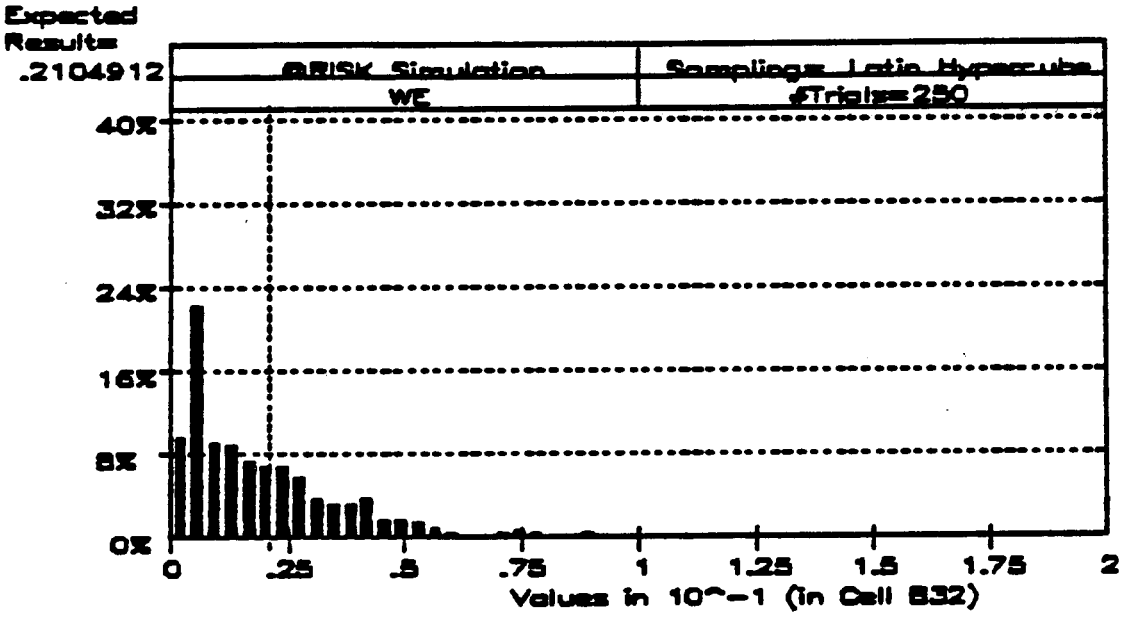
@RISK Risk Analysis 18-Jul-1991

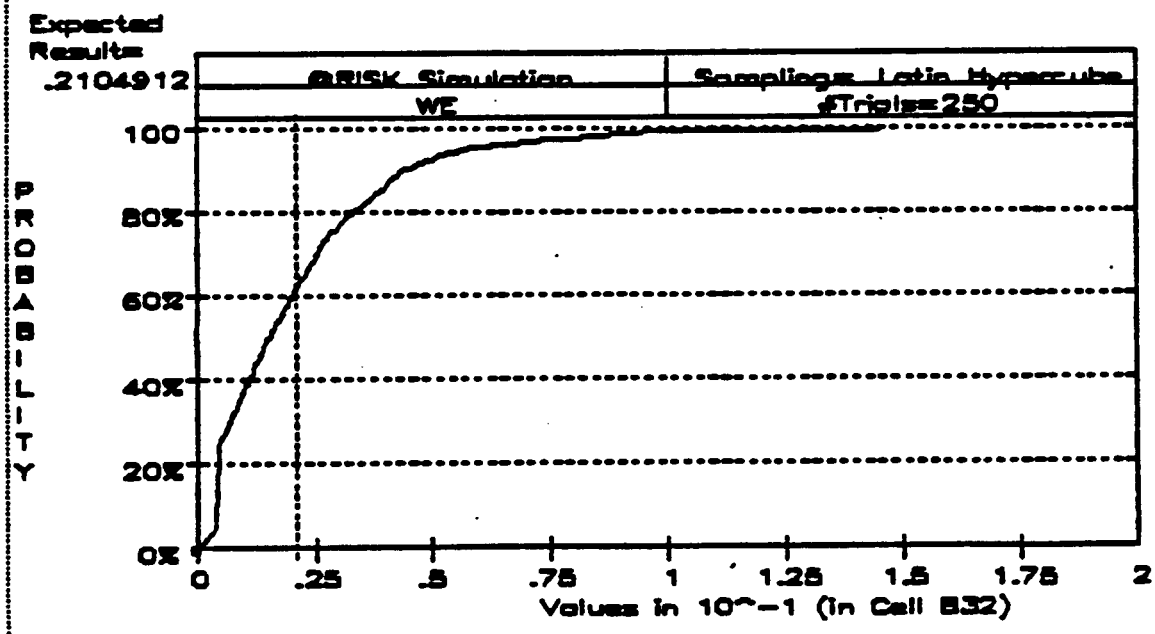
Expected/Mean Result = 2.104912E-02
Maximum Result = .1451401
Minimum Result = 2.300748E-04
Range of Possible Results = .14491
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = .0211583
Skewness = 2.368225
Kurtosis = 11.15753
Variance = 4.476736E-04
Simulations Executed = 1
Iterations = 250

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-1)

<= .0023 = 0%
<= .0344 = 5%
<= .0387 = 10%
<= .0413 = 15%
<= .0442 = 20%
<= .0469 = 25%
<= .0677 = 30%
<= .087 = 35%
<= .1082 = 40%
<= .1285 = 45%
<= .15 = 50%
<= .1752 = 55%
<= .2022 = 60%
<= .2273 = 65%
<= .2534 = 70%
<= .2794 = 75%
<= .3318 = 80%
<= .3846 = 85%
<= .4392 = 90%
<= .5637 = 95%
<= 1.4514 = 100%

IRe (in Cell B32)





DIELDRIN, CHILD CHRONIC
ZONE 3

IORAL3,CHLD,DLD (in Cell U15)

@RISK Risk Analysis 27-Aug-1992

==========

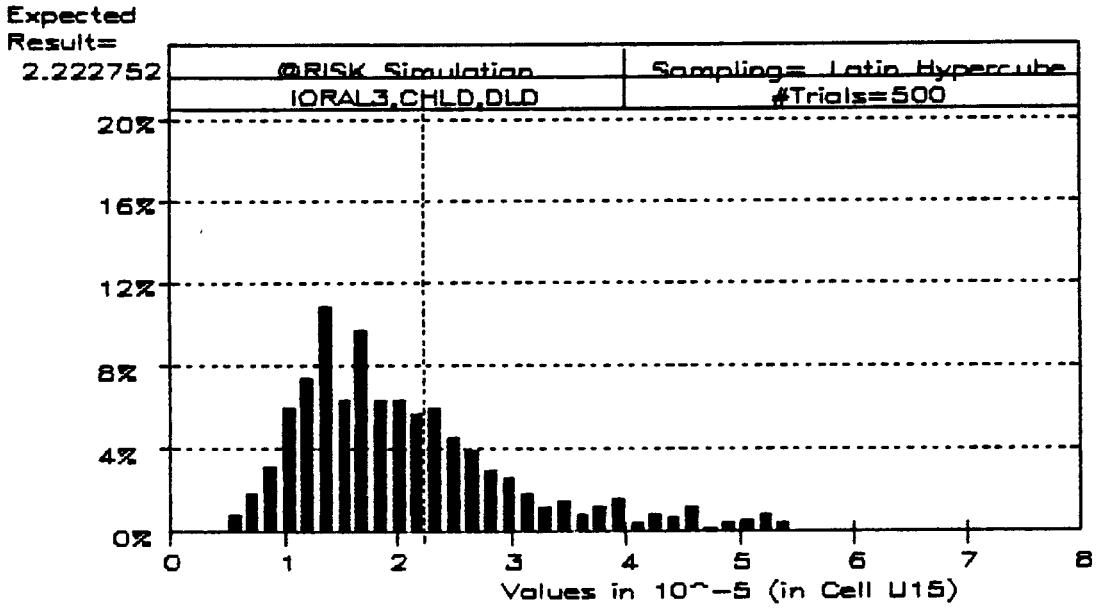
Expected/Mean Result = 2.222752E-05
Maximum Result = 1.657802E-04
Minimum Result = 4.743323E-06
Range of Possible Results = 1.610369E-04
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.505289E-05
Skewness = 4.183239
Kurtosis = 31.59883
Variance = 2.265895E-10
Simulations Executed = 1
Iterations = 500

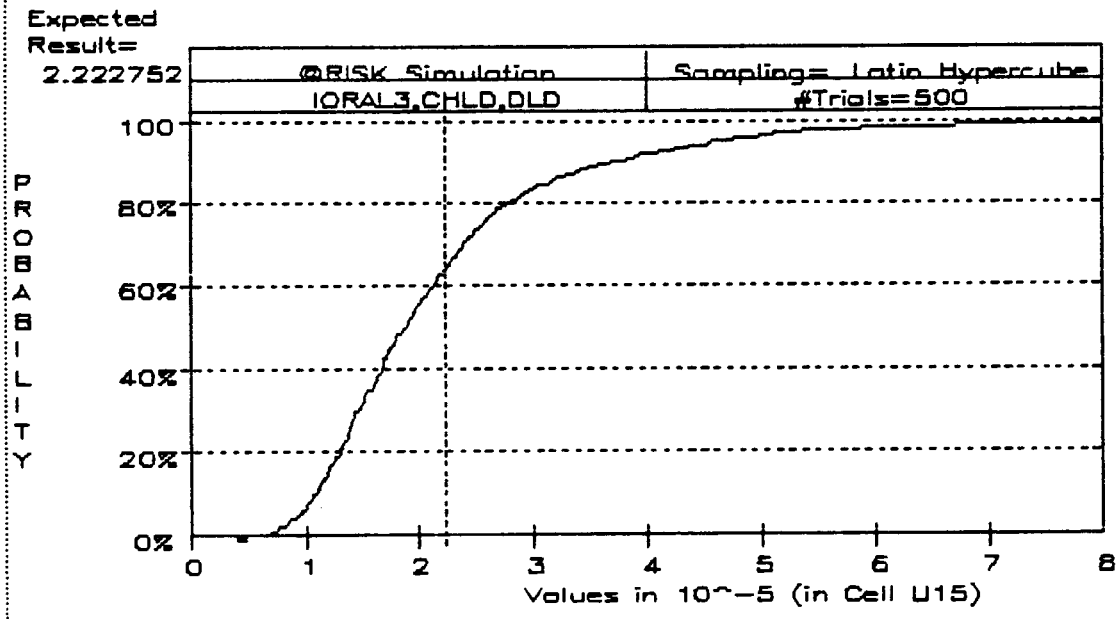
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-4)

==========

<= .0474 = 0%
<= .0904 = 5%
<= .1066 = 10%
<= .1178 = 15%
<= .1292 = 20%
<= .1373 = 25%
<= .1437 = 30%
<= .1552 = 35%
<= .1658 = 40%
<= .1742 = 45%
<= .1866 = 50%
<= .1976 = 55%
<= .2118 = 60%
<= .2271 = 65%
<= .2389 = 70%
<= .2575 = 75%
<= .279 = 80%
<= .3132 = 85%
<= .3772 = 90%
<= .456 = 95%
<= 1.6578 = 100%

IORAL3,CHLD,DLD (in Cell U15)





IV3,CHILD,DLD (in Cell P15)

@RISK Risk Analysis 27-Aug-1992

==========

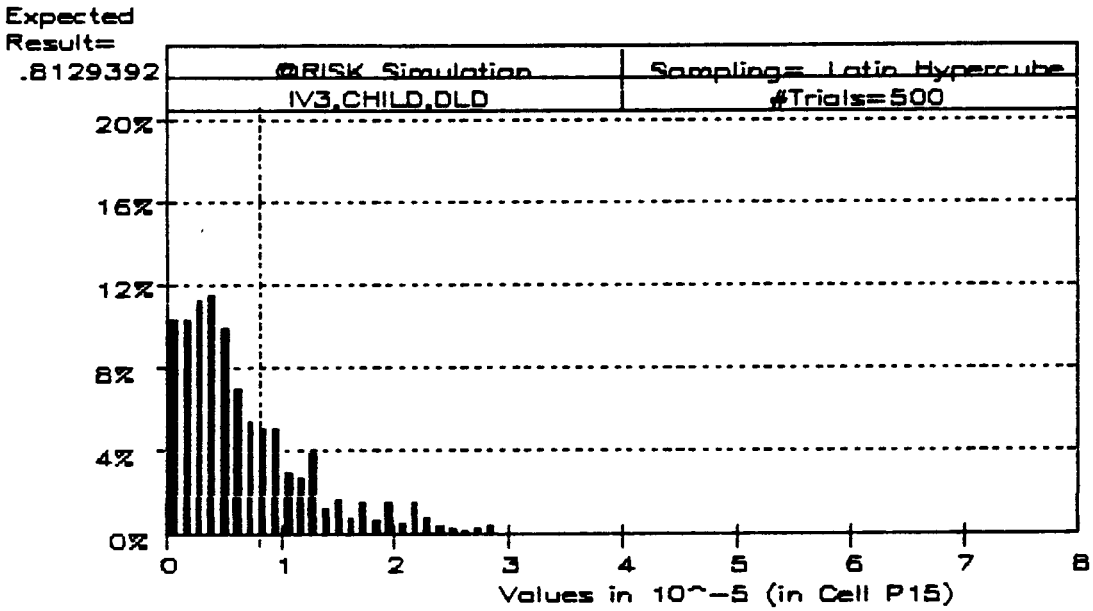
Expected/Mean Result = 8.129392E-06
Maximum Result = 1.112375E-04
Minimum Result = 2.280334E-08
Range of Possible Results = 1.112147E-04
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.048704E-05
Skewness = 5.129442
Kurtosis = 42.05853
Variance = 1.099779E-10
Simulations Executed = 1
Iterations = 500

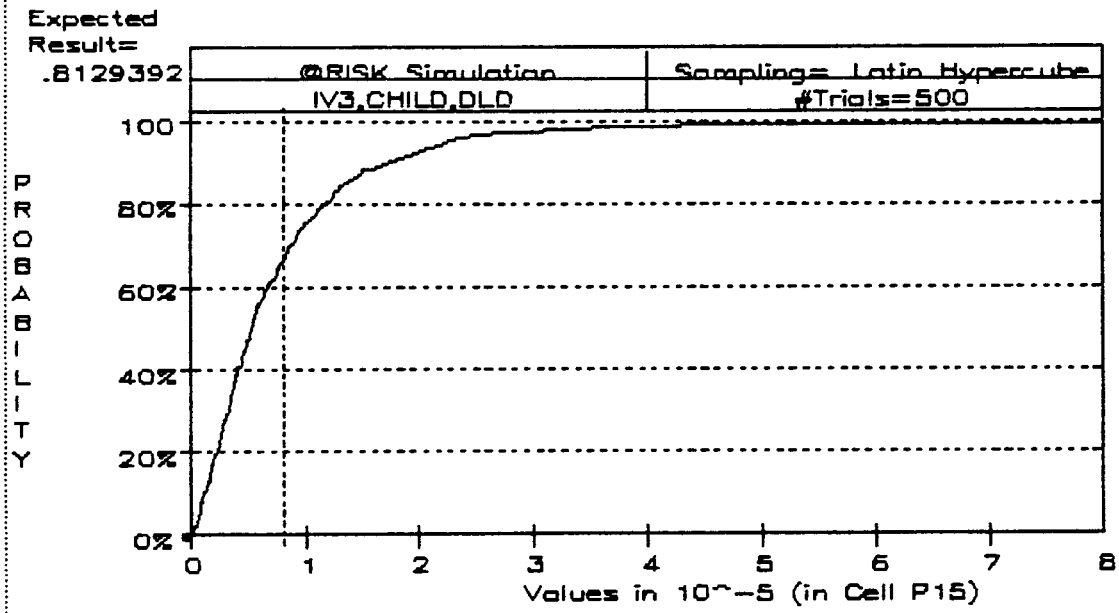
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-4)

==========

<= .0002 = 0%
<= .0066 = 5%
<= .0109 = 10%
<= .0162 = 15%
<= .0218 = 20%
<= .0271 = 25%
<= .0323 = 30%
<= .0363 = 35%
<= .0415 = 40%
<= .0472 = 45%
<= .0522 = 50%
<= .0578 = 55%
<= .0658 = 60%
<= .0771 = 65%
<= .0874 = 70%
<= .0987 = 75%
<= .1176 = 80%
<= .1327 = 85%
<= .1744 = 90%
<= .2215 = 95%
<= 1.1124 = 100%

IV3,CHILD,DLD (in Cell P15)





IEGG3,CHLD,DLD (in Cell S15)

@RISK Risk Analysis 27-Aug-1992

==========

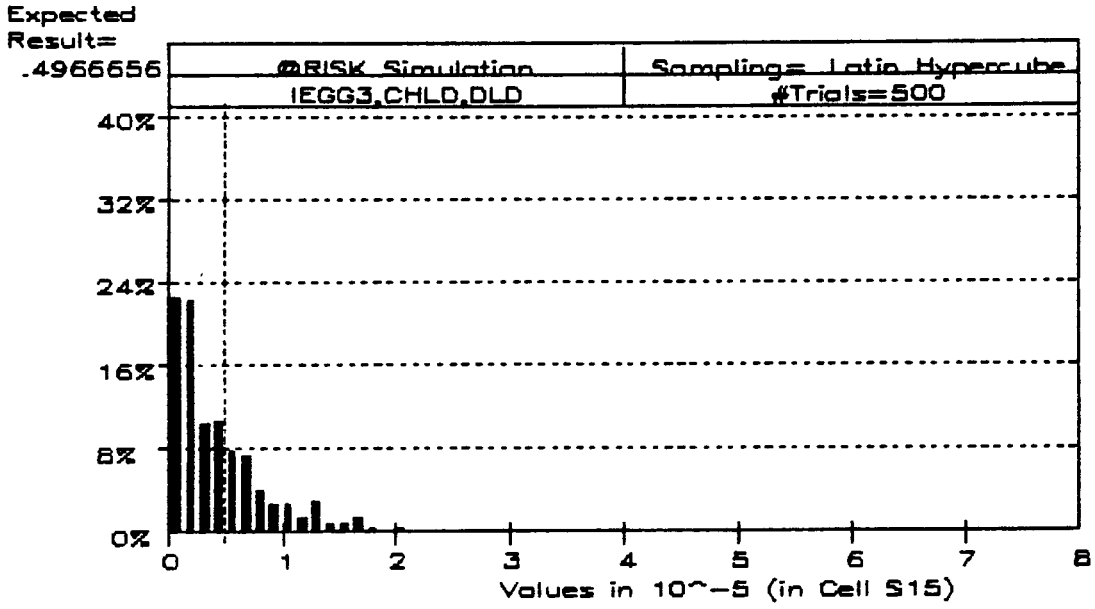
Expected/Mean Result = 4.966656E-06
Maximum Result = 4.925442E-05
Minimum Result = 1.134936E-08
Range of Possible Results = 4.924307E-05
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 5.7305E-06
Skewness = 3.104525
Kurtosis = 17.60491
Variance = 3.283863E-11
Simulations Executed = 1
Iterations = 500

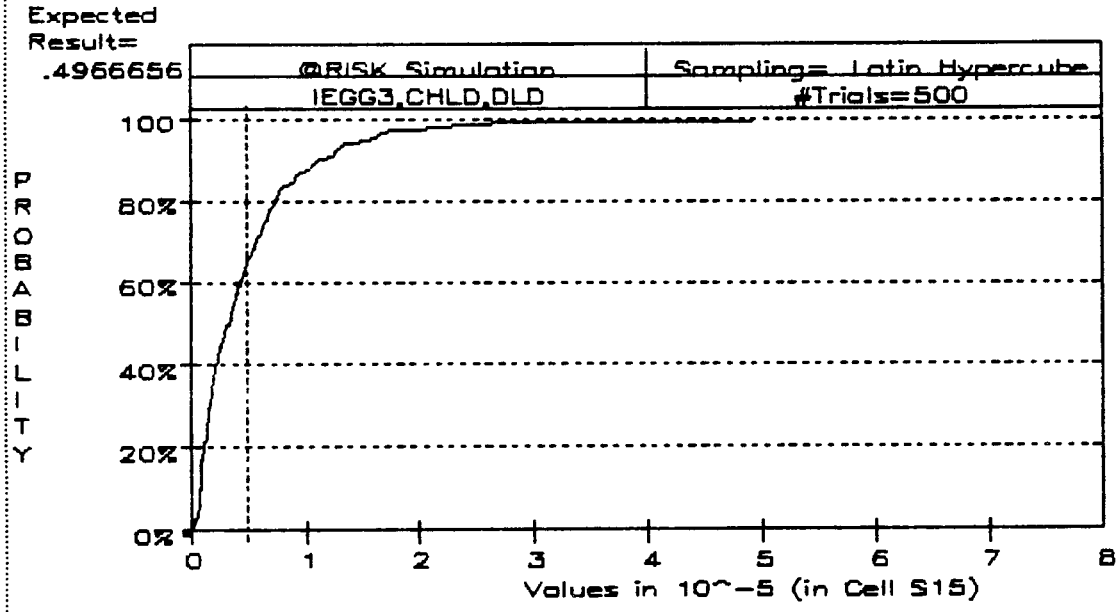
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-5)

==========

<= .0011 = 0%
<= .0521 = 5%
<= .0708 = 10%
<= .0847 = 15%
<= .1156 = 20%
<= .1307 = 25%
<= .156 = 30%
<= .1862 = 35%
<= .2194 = 40%
<= .2558 = 45%
<= .3137 = 50%
<= .3754 = 55%
<= .4279 = 60%
<= .4918 = 65%
<= .5675 = 70%
<= .6457 = 75%
<= .7374 = 80%
<= .8923 = 85%
<= 1.1247 = 90%
<= 1.5554 = 95%
<= 4.9254 = 100%

IEGG3,CHLD,DLD (in Cell S15)





CEGG3,DLDRN (in Cell K15)

@RISK Risk Analysis 27-Aug-1992

==========

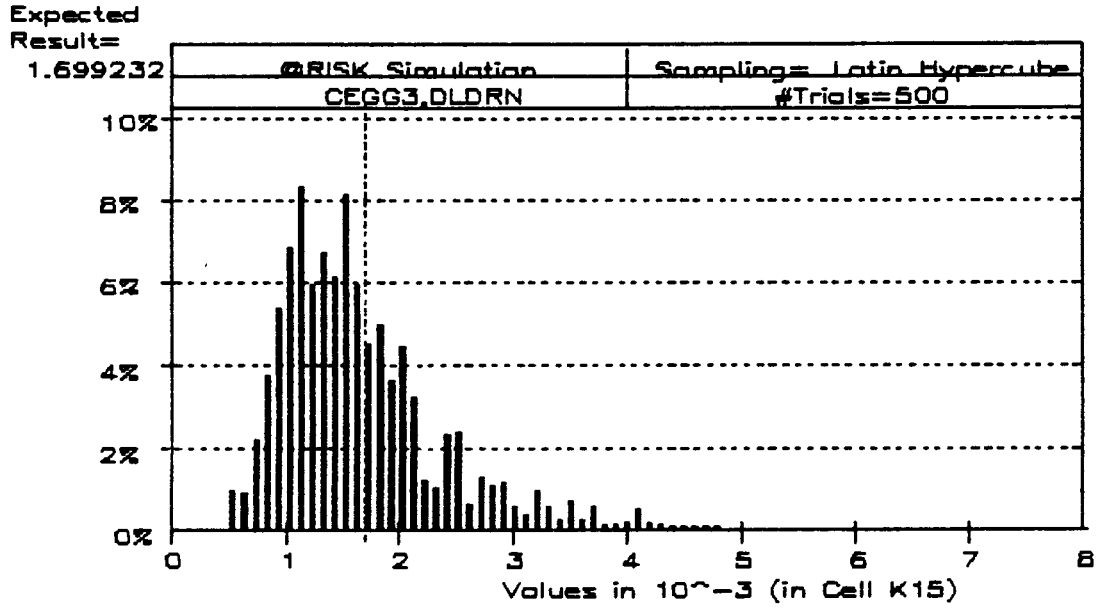
Expected/Mean Result = 1.699232E-03
Maximum Result = 1.036901E-02
Minimum Result = 4.854961E-04
Range of Possible Results = 9.883517E-03
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 8.635922E-04
Skewness = 3.121693
Kurtosis = 24.50373
Variance = 7.457915E-07
Simulations Executed = 1
Iterations = 500

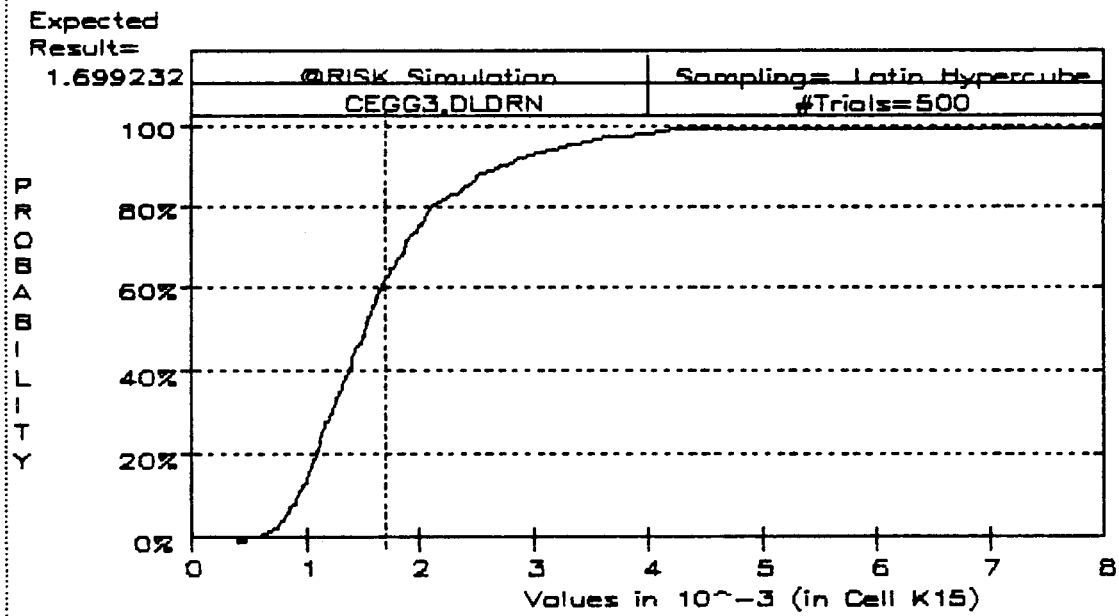
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-2)

==========

<= .0485 = 0%
<= .0806 = 5%
<= .092 = 10%
<= .1011 = 15%
<= .108 = 20%
<= .1135 = 25%
<= .1224 = 30%
<= .1291 = 35%
<= .1359 = 40%
<= .1437 = 45%
<= .1518 = 50%
<= .1573 = 55%
<= .1657 = 60%
<= .1764 = 65%
<= .1865 = 70%
<= .1986 = 75%
<= .2108 = 80%
<= .2394 = 85%
<= .2714 = 90%
< .3258 = 95%
<= 1.0369 = 100%

CEGG3,DLDRN (in Cell K15)





DIMP, CHILD, CHRONIC
ZONE 4

IORAL4,DIMP (in Cell U16)

@RISK Risk Analysis 01-Sep-1992

==========

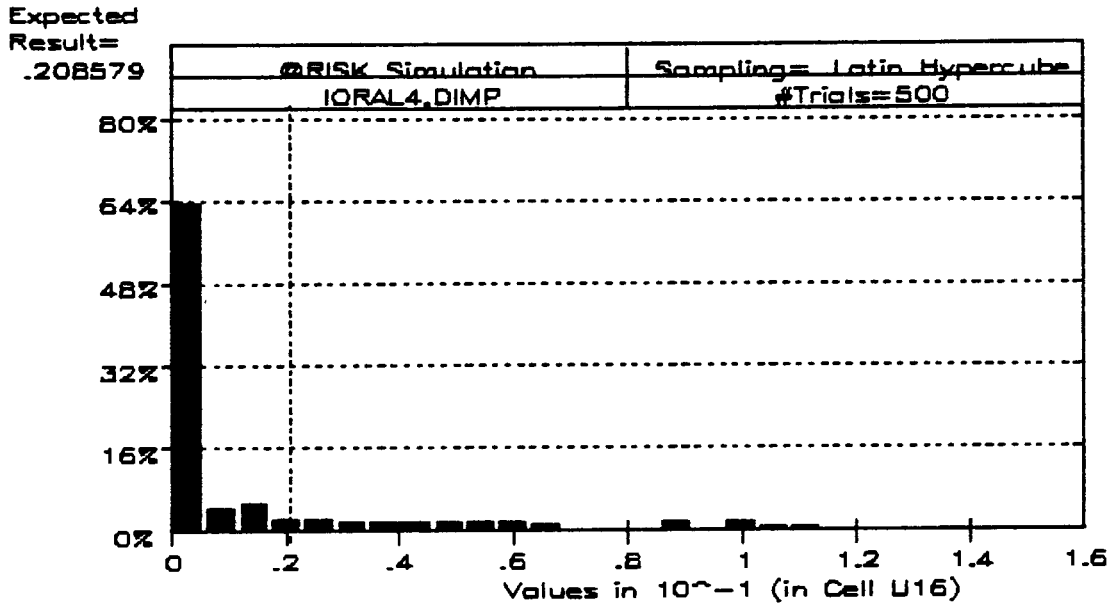
Expected/Mean Result = .0208579
Maximum Result = .227971
Minimum Result = 6.453389E-06
Range of Possible Results = .2279646
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 3.801867E-02
Skewness = 2.304313
Kurtosis = 8.165299
Variance = 1.445419E-03
Simulations Executed = 1
Iterations = 500

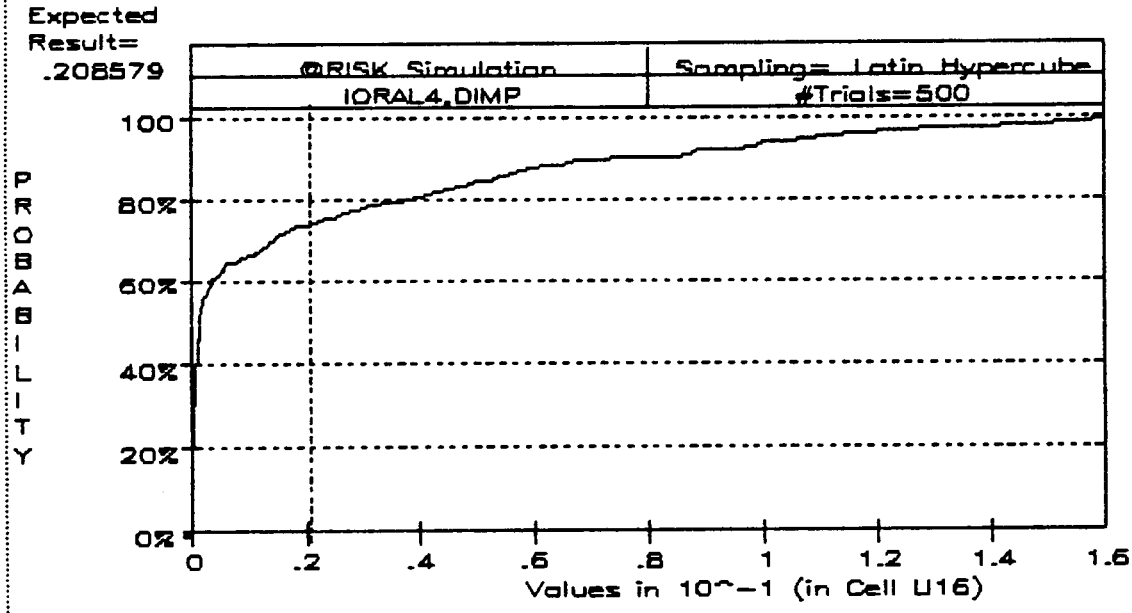
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-1)

==========

<= .00006 = 0%
<= .0003 = 5%
<= .0007 = 10%
<= .0012 = 15%
<= .0016 = 20%
<= .004 = 25%
<= .0046 = 30%
<= .0066 = 35%
<= .0082 = 40%
<= .0105 = 45%
<= .0134 = 50%
<= .0194 = 55%
<= .0346 = 60%
<= .076 = 65%
<= .1411 = 70%
<= .2299 = 75%
<= .3832 = 80%
<= .5259 = 85%
<= .7886 = 90%
<= 1.0832 = 95%
<= 2.2797 = 100%

IORAL4,DIMP (in Cell U16)





IGW4,DIMP (in Cell N16)

@RISK Risk Analysis 01-Sep-1992

==========

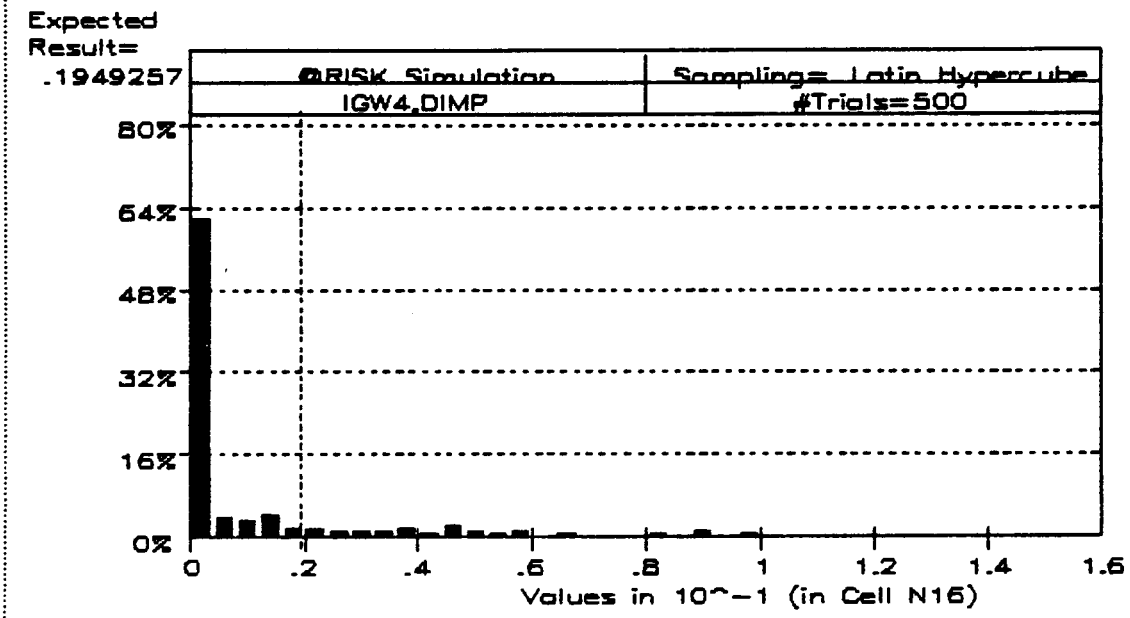
Expected/Mean Result = 1.949256E-02
Maximum Result = .217327
Minimum Result = -1.433941E-07
Range of Possible Results = .2173271
Probability of Positive Result = 99.8%
Probability of Negative Result = .2%
Standard Deviation = 3.600002E-02
Skewness = 2.328165
Kurtosis = 8.314244
Variance = 1.296001E-03
Simulations Executed = 1
Iterations = 500

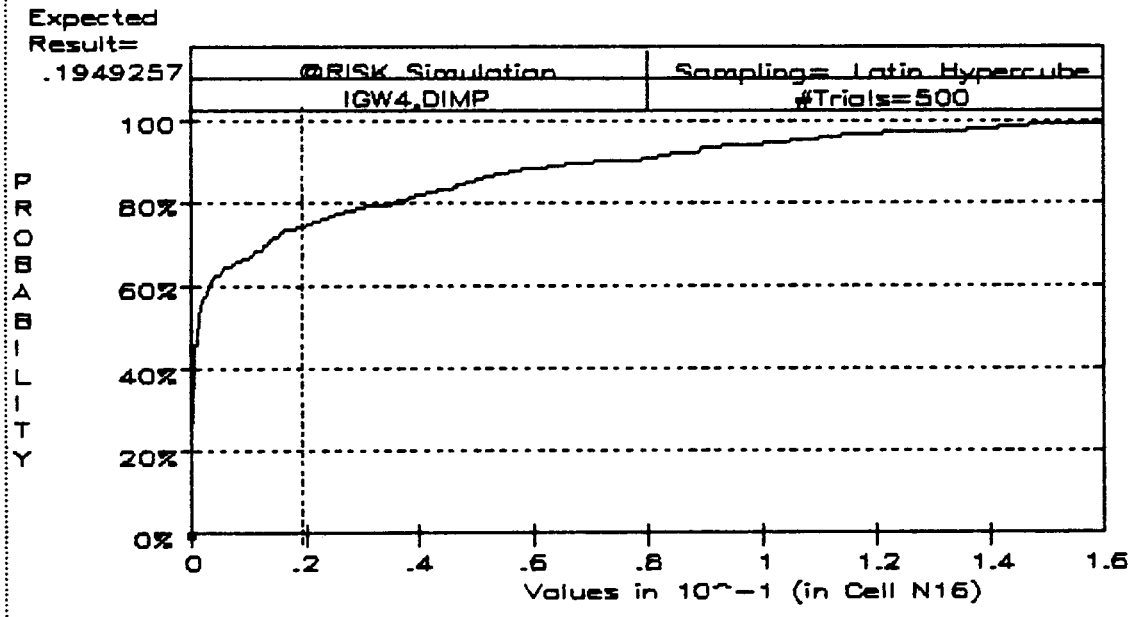
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-1)

==========

<=-.000001= 0%
<= .00002 = 5%
<= .00006 = 10%
<= .0001 = 15%
<= .0004 = 20%
<= .001 = 25%
<= .0025 = 30%
<= .0046 = 35%
<= .0065 = 40%
<= .008 = 45%
<= .0112 = 50%
<= .0166 = 55%
<= .0306 = 60%
<= .0658 = 65%
<= .1298 = 70%
<= .2059 = 75%
<= .3584 = 80%
<= .4759 = 85%
<= .7511 = 90%
<= 1.0224 = 95%
<= 2.1733 = 100%

IGW4,DIMP (in Cell N16)





CGW4,DIMP (in Cell F18)

@RISK Risk Analysis 01-Sep-1992

==========

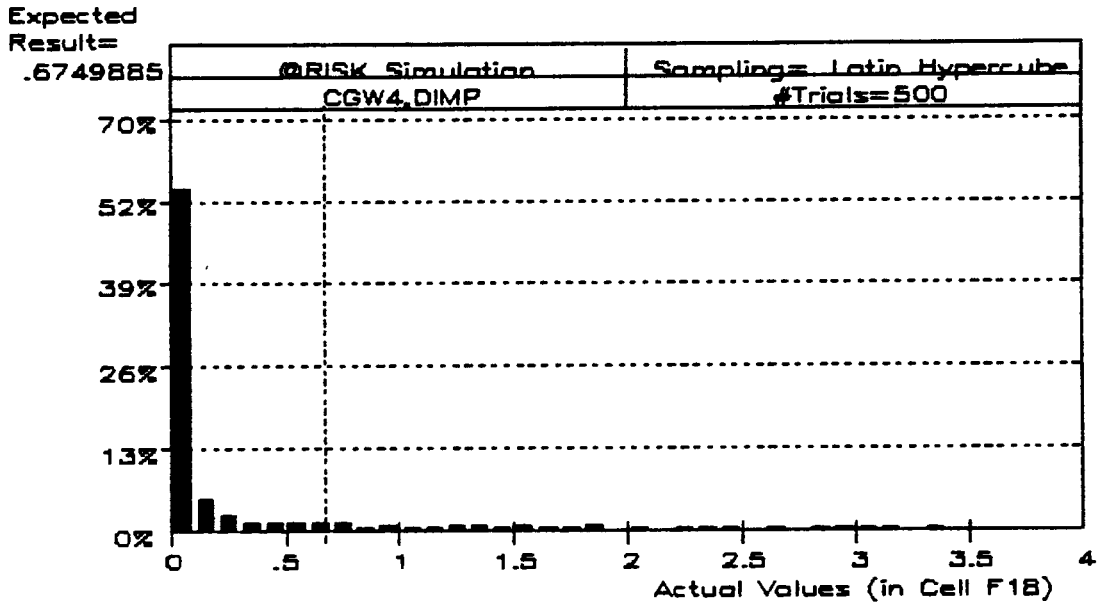
Expected/Mean Result = .6749885
Maximum Result = 4.936796
Minimum Result = 2.4893E-06
Range of Possible Results = 4.936794
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.16999
Skewness = 1.909123
Kurtosis = 5.673878
Variance = 1.368876
Simulations Executed = 1
Iterations = 500

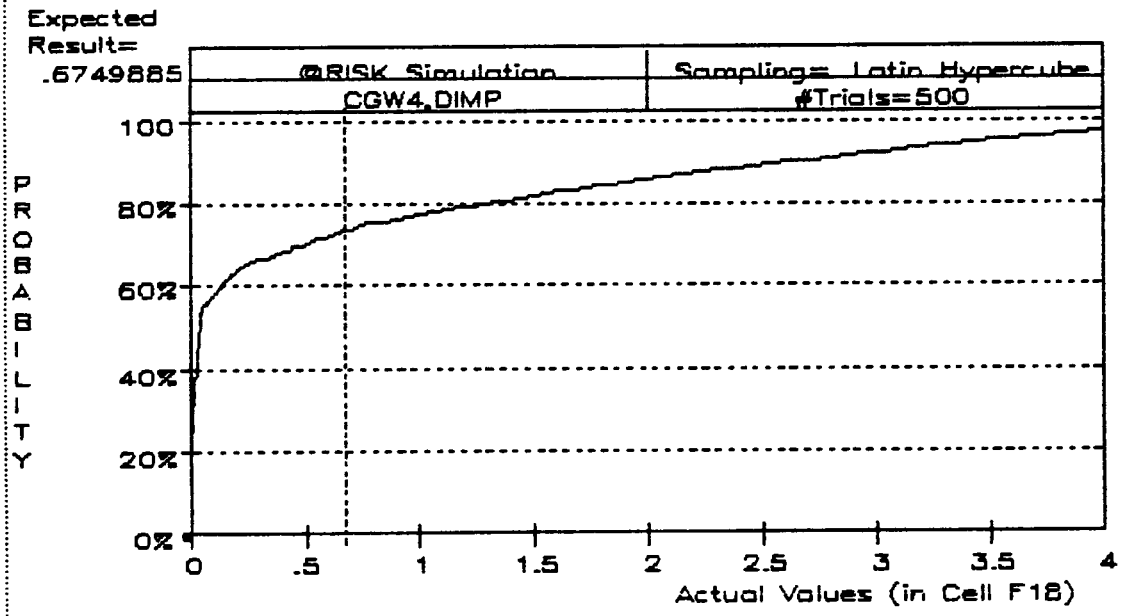
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Actual Values)

==========

<= .000002= 0%
<= .0001 = 5%
<= .0002 = 10%
<= .0003 = 15%
<= .0017 = 20%
<= .0036 = 25%
<= .0098 = 30%
<= .016 = 35%
<= .022 = 40%
<= .028 = 45%
<= .0379 = 50%
<= .0478 = 55%
<= .1332 = 60%
<= .223 = 65%
<= .482 = 70%
<= .742 = 75%
<= 1.2821 = 80%
<= 1.849 = 85%
<= 2.6395 = 90%
<= 3.4248 = 95%
<= 4.9368 = 100%

CGW4,DIMP (in Cell F18)





EXPOSURE FACTORS, LIFETIME

ED (in Cell B20)

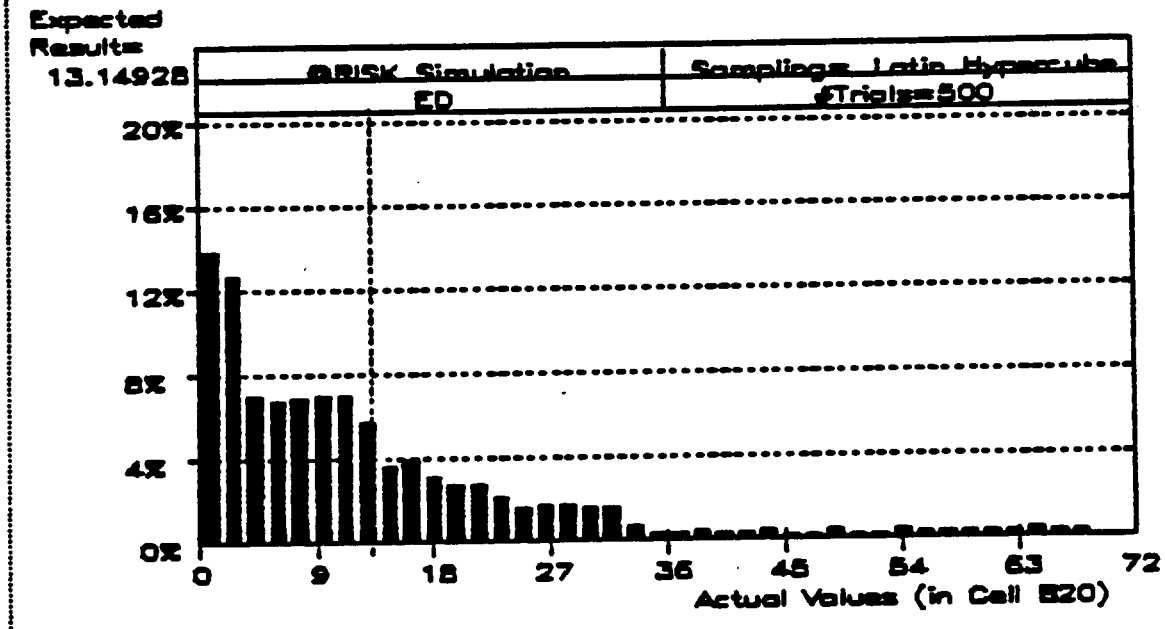
@RISK Risk Analysis 18-Jul-1991

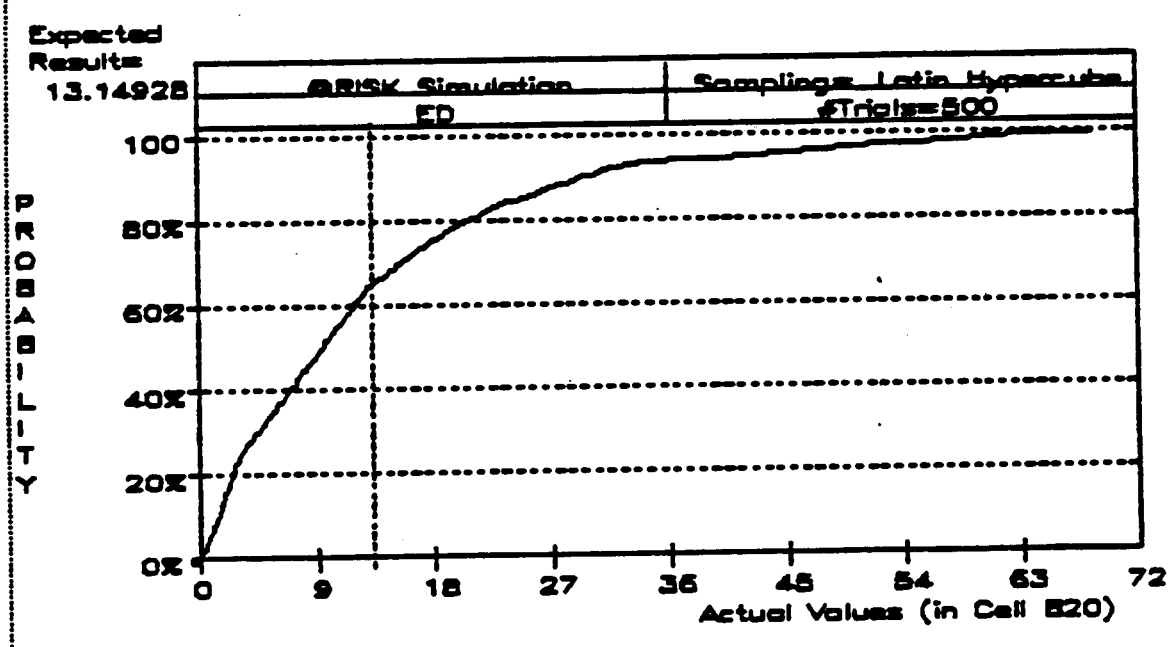
Expected/Mean Result = 13.14928
Maximum Result = 68.61511
Minimum Result = 9.690826E-03
Range of Possible Results = 68.60543
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 13.50083
Skewness = 1.85694
Kurtosis = 6.719521
Variance = 182.2724
Simulations Executed = 1
Iterations = 500

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Actual Values)

<= .0097 = 0%
<= .6655 = 5%
<= 1.2744 = 10%
<= 1.8766 = 15%
<= 2.4677 = 20%
<= 3.1076 = 25%
<= 4.3509 = 30%
<= 5.6104 = 35%
<= 6.861 = 40%
<= 8.1032 = 45%
<= 9.357 = 50%
<= 10.5698= 55%
<= 11.8185= 60%
<= 13.1041= 65%
<= 15.4205= 70%
<= 17.6454= 75%
<= 20.7478= 80%
<= 24.3948= 85%
<= 29.6592= 90%
<= 42.6662= 95%
<= 68.6151= 100%

ED (in Cell B20)





IRV (in Cell B26)

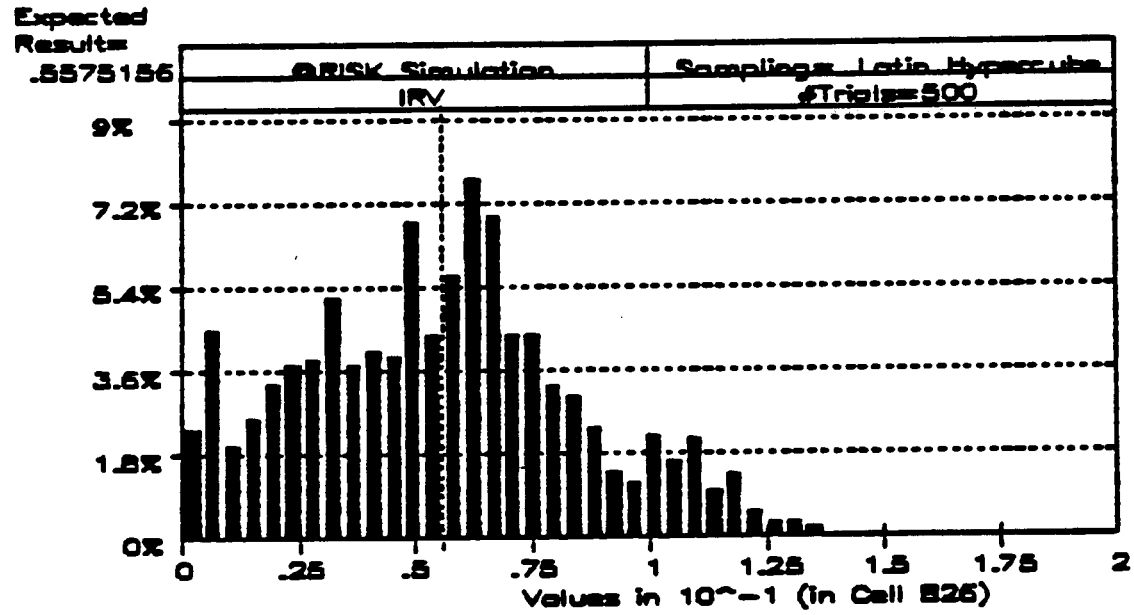
@RISK Risk Analysis 18-Jul-1991

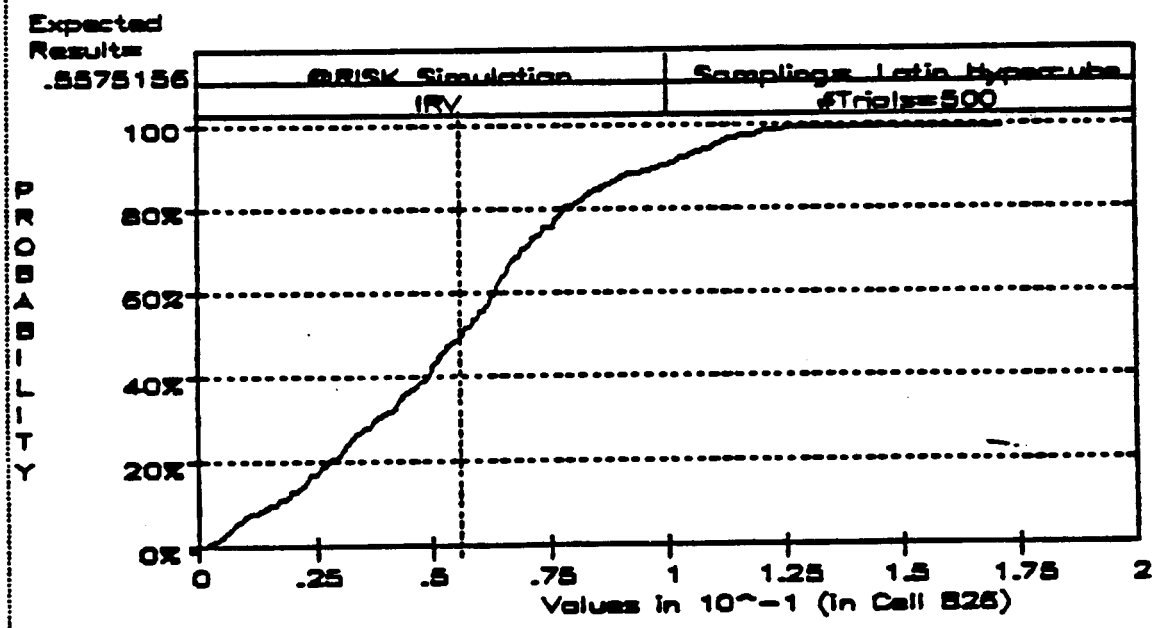
Expected/Mean Result = 5.576156E-02
Maximum Result = .1716846
Minimum Result = 1.223063E-04
Range of Possible Results = .1715623
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 3.043128E-02
Skewness = .3730482
Kurtosis = 2.955324
Variance = 9.260629E-04
Simulations Executed = 1
Iterations = 500

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-1)

<= .0012 = 0%
<= .07 = 5%
<= .1502 = 10%
<= .2206 = 15%
<= .272 = 20%
<= .3215 = 25%
<= .3735 = 30%
<= .4301 = 35%
<= .4867 = 40%
<= .514 = 45%
<= .5598 = 50%
<= .6002 = 55%
<= .6301 = 60%
<= .6563 = 65%
<= .6868 = 70%
<= .7357 = 75%
<= .778 = 80%
<= .8601 = 85%
<= .9907 = 90%
<= 1.0981 = 95%
<= 1.7168 = 100%

IRV (in Cell B26)





IRD (in Cell B28)

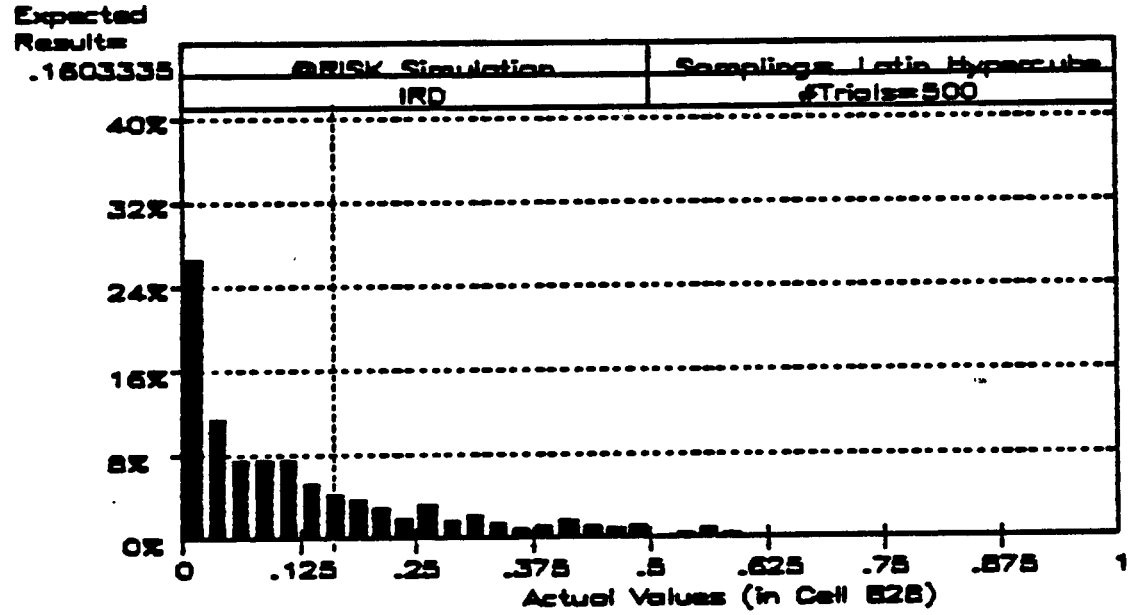
@RISK Risk Analysis 18-Jul-1991

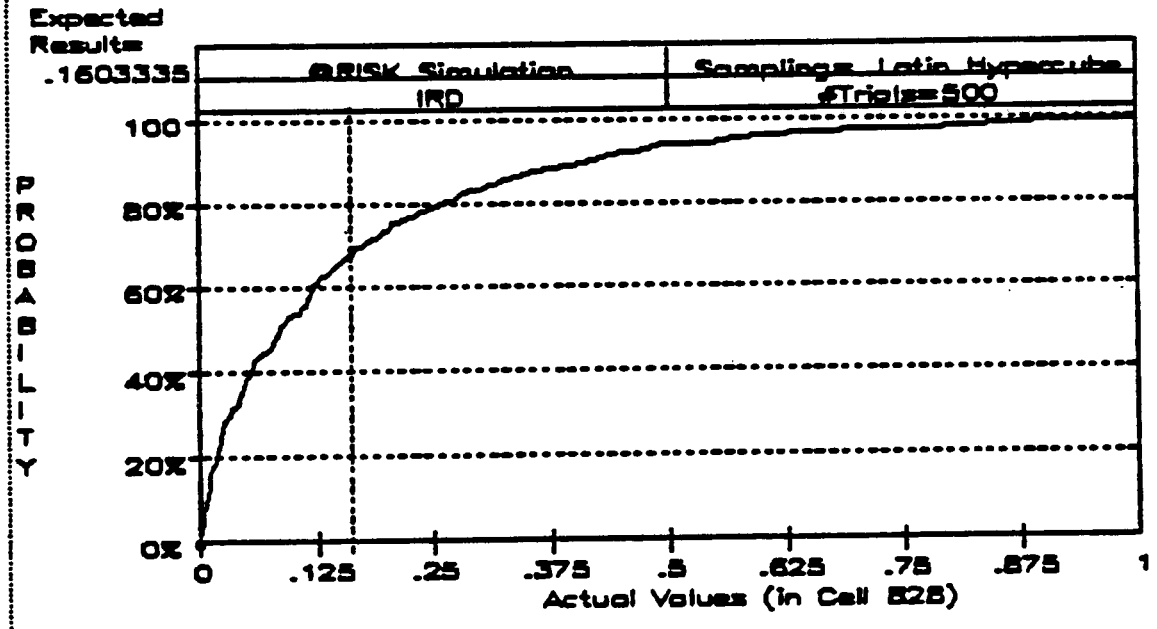
Expected/Mean Result = .1603336
Maximum Result = 1.719767
Minimum Result = -1.172976E-04
Range of Possible Results = 1.719884
Probability of Positive Result = 99.8%
Probability of Negative Result = .2%
Standard Deviation = .2131363
Skewness = 2.861653
Kurtosis = 14.72996
Variance = 4.542708E-02
Simulations Executed = 1
Iterations = 500

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Actual Values)

<=-.0001 = 0%
<= .0031 = 5%
<= .0063 = 10%
<= .0102 = 15%
<= .0173 = 20%
<= .023 = 25%
<= .04 = 30%
<= .0441 = 35%
<= .0537 = 40%
<= .0705 = 45%
<= .0856 = 50%
<= .1095 = 55%
<= .1219 = 60%
<= .1446 = 65%
<= .1736 = 70%
<= .206 = 75%
<= .25 = 80%
<= .3147 = 85%
<= .4171 = 90%
<= .5585 = 95%
<= 1.7198 = 100%

IRD (in Cell B28)





IRM (in Cell B30)

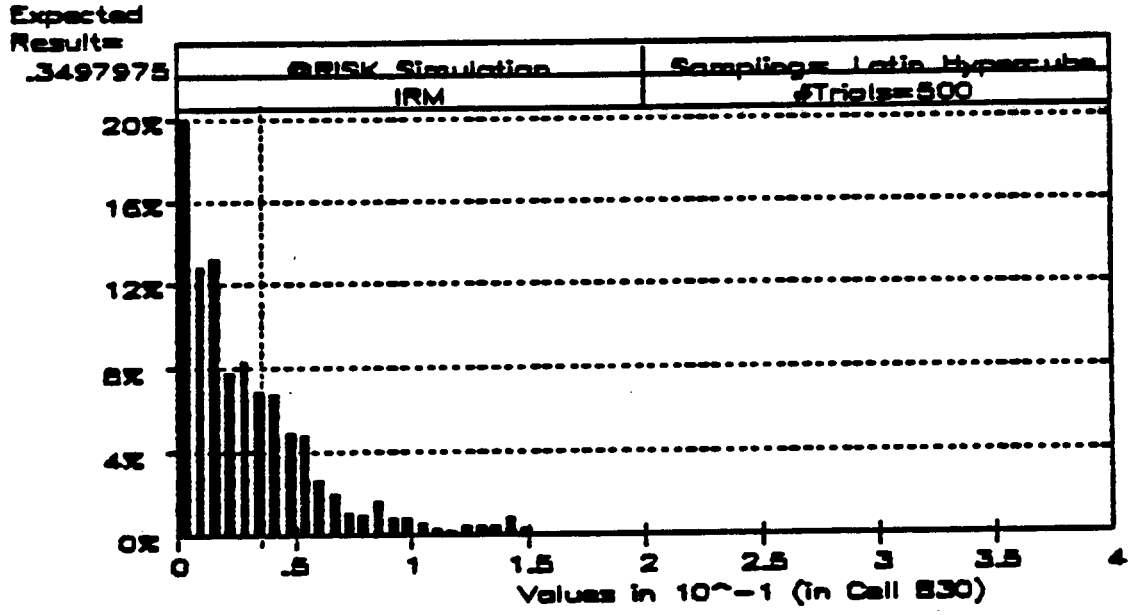
@RISK Risk Analysis 18-Jul-1991

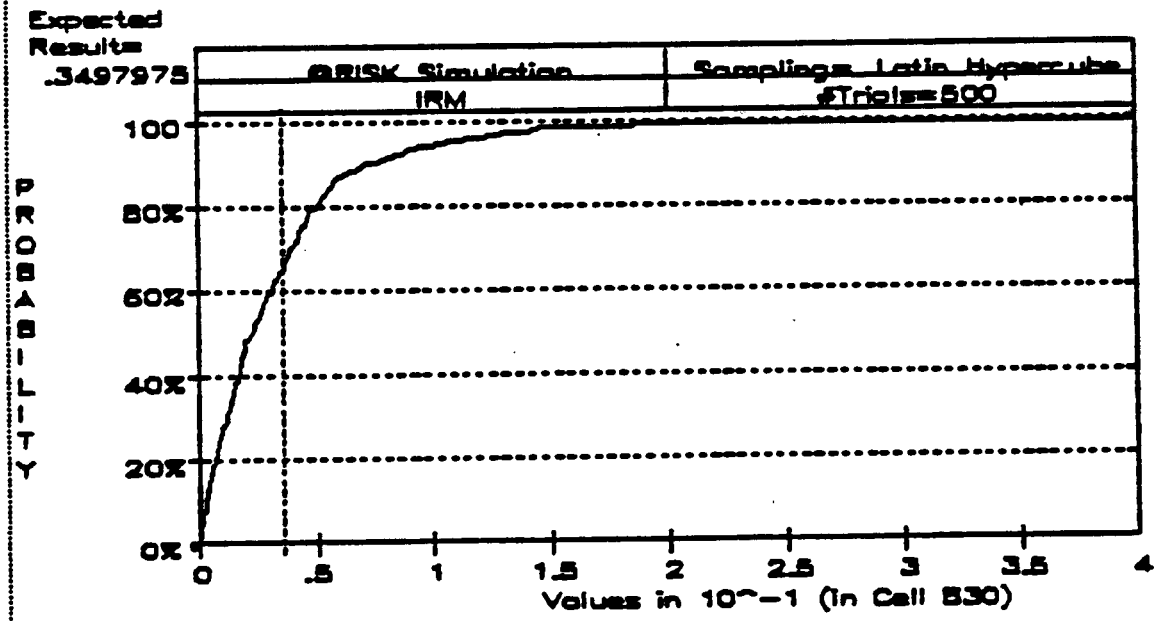
Expected/Mean Result = 3.497975E-02
Maximum Result = .6327763
Minimum Result = 1.088908E-05
Range of Possible Results = .6327654
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 4.979028E-02
Skewness = 5.90473
Kurtosis = 57.24623
Variance = 2.479072E-03
Simulations Executed = 1
Iterations = 500

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-1)

<= .0001 = 0%
<= .0112 = 5%
<= .0237 = 10%
<= .0443 = 15%
<= .0655 = 20%
<= .0844 = 25%
<= .1143 = 30%
<= .141 = 35%
<= .1645 = 40%
<= .1865 = 45%
<= .2204 = 50%
<= .2607 = 55%
<= .3034 = 60%
<= .3537 = 65%
<= .3955 = 70%
<= .4409 = 75%
<= .5004 = 80%
<= .5708 = 85%
<= .7187 = 90%
<= 1.044 = 95%
<= 6.3278 = 100%

IRM (in Cell B30)





IRW (in Cell B18)

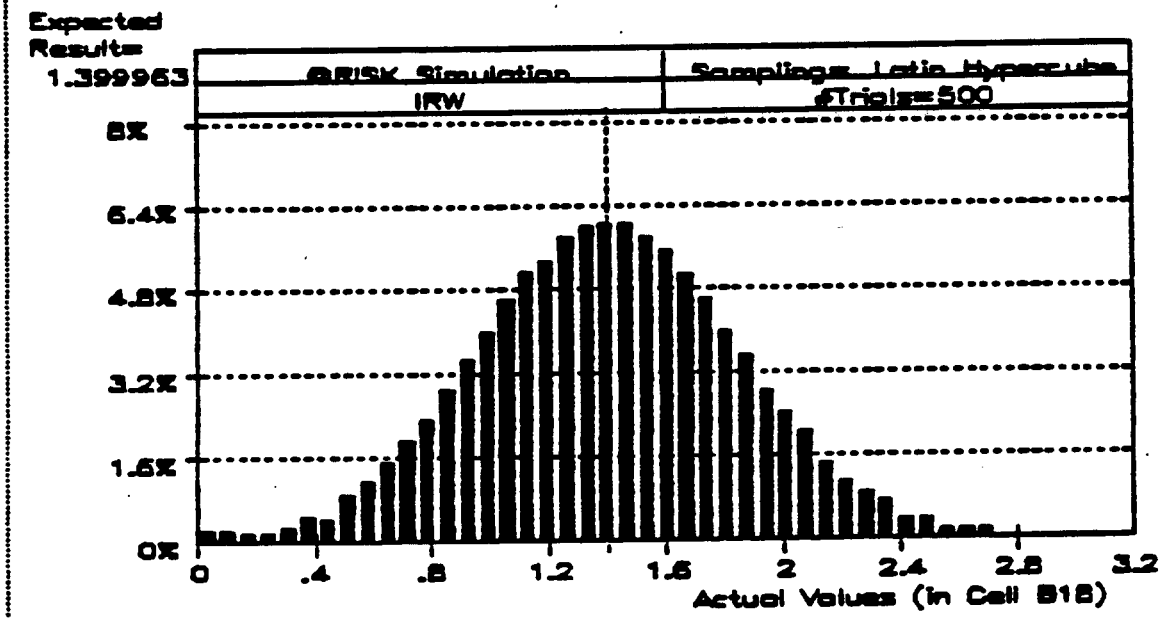
@RISK Risk Analysis 18-Jul-1991

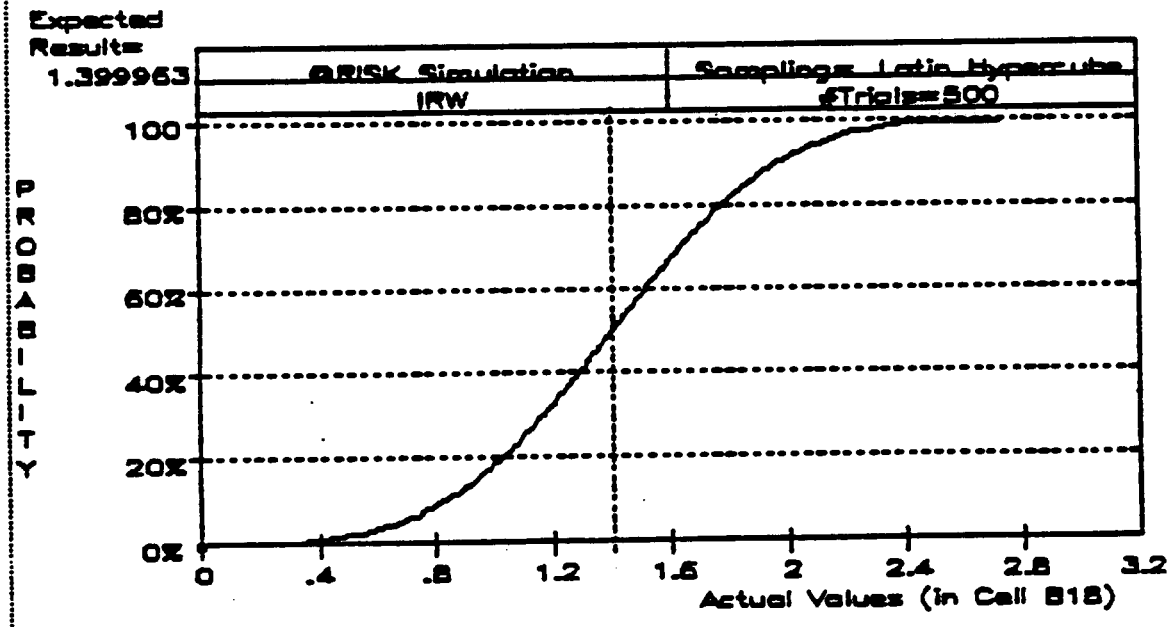
Expected/Mean Result = 1.399963
Maximum Result = 2.72537
Minimum Result = -1.213325E-02
Range of Possible Results = 2.737503
Probability of Positive Result = 99.8%
Probability of Negative Result = .2%
Standard Deviation = .4495891
Skewness = -6.900043E-03
Kurtosis = 2.961382
Variance = .2021304
Simulations Executed = 1
Iterations = 500

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Actual Values)

<=-.0121 = 0%
<= .6569 = 5%
<= .823 = 10%
<= .9321 = 15%
<= 1.02 = 20%
<= 1.0943 = 25%
<= 1.1619 = 30%
<= 1.2258 = 35%
<= 1.2841 = 40%
<= 1.3412 = 45%
<= 1.3991 = 50%
<= 1.4557 = 55%
<= 1.5133 = 60%
<= 1.5731 = 65%
<= 1.6345 = 70%
<= 1.7018 = 75%
<= 1.7771 = 80%
<= 1.8662 = 85%
<= 1.9732 = 90%
<= 2.1331 = 95%
<= 2.7254 = 100%

IRW (in Cell B18)





VWI (in Cell D27)

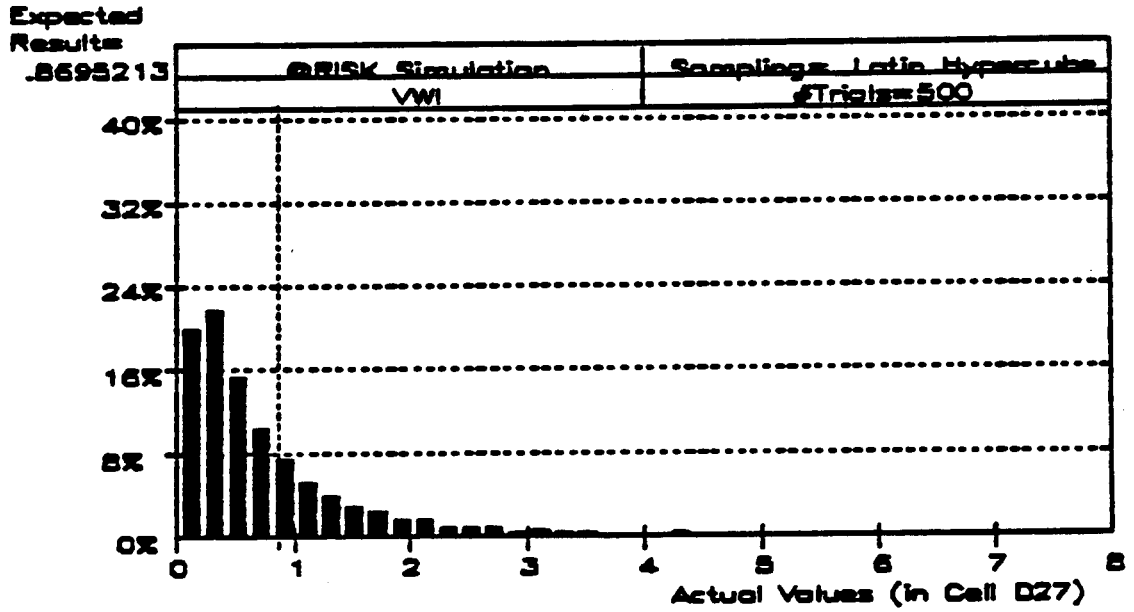
@RISK Risk Analysis 18-Jul-1991

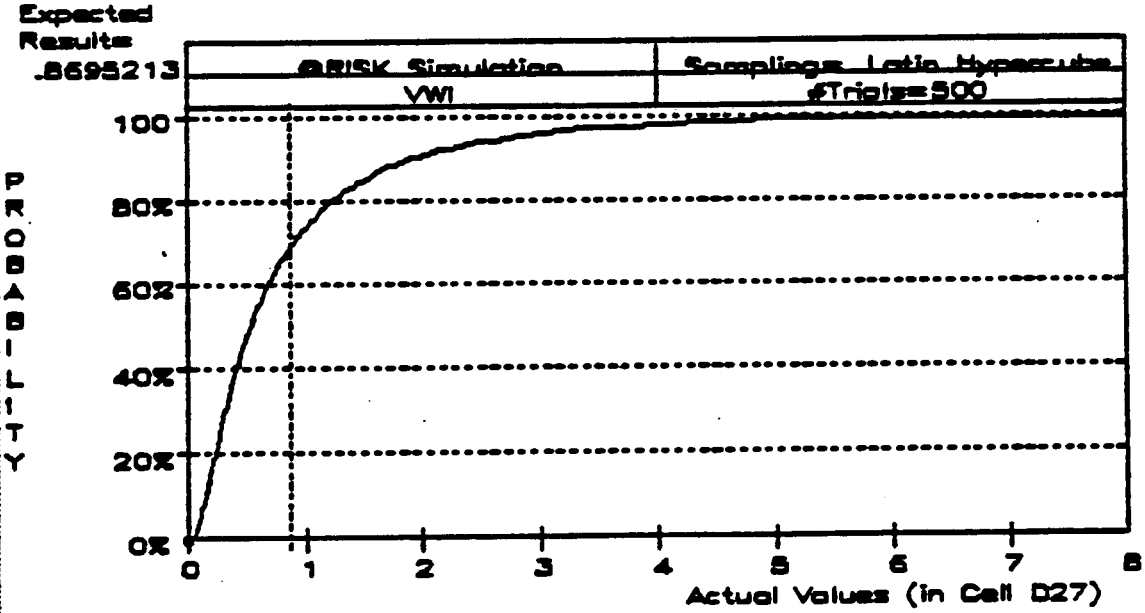
Expected/Mean Result = .8695213
Maximum Result = 9.986055
Minimum Result = 2.490607E-02
Range of Possible Results = 9.961149
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.077082
Skewness = 3.711659
Kurtosis = 22.85656
Variance = 1.160105
Simulations Executed = 1
Iterations = 500

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Actual Values)

<= .0249 = 0%
<= .0992 = 5%
<= .1433 = 10%
<= .1841 = 15%
<= .2243 = 20%
<= .2648 = 25%
<= .3088 = 30%
<= .3551 = 35%
<= .4064 = 40%
<= .4616 = 45%
<= .5251 = 50%
<= .5955 = 55%
<= .6794 = 60%
<= .7765 = 65%
<= .8912 = 70%
<= 1.0359 = 75%
<= 1.2247 = 80%
<= 1.4904 = 85%
<= 1.9138 = 90%
<= 2.7407 = 95%
<= 9.9861 = 100%

VWI (in Cell D27)





CHLOROFORM, LIFETIME
ZONE 2

IORAL2,CHCL3 (in Cell U14)

@RISK Risk Analysis 15-Aug-1992

==========

Expected/Mean Result = 7.923596E-05

Maximum Result = 1.498648E-03

Minimum Result = 7.690184E-08

Range of Possible Results = 1.498571E-03

Probability of Positive Result = 100%

Probability of Negative Result = 0%

Standard Deviation = 1.493586E-04

Skewness = 4.933606

Kurtosis = 35.91797

Variance = 2.230799E-08

Simulations Executed = 1

Iterations = 500

Percentile Probabilities:

(Chance of Result <= Shown Value)

(Values in 10^-3)

==========

<= .00007 = 0%

<= .0011 = 5%

<= .0025 = 10%

<= .0046 = 15%

<= .0076 = 20%

<= .0094 = 25%

<= .0122 = 30%

<= .0154 = 35%

<= .0201 = 40%

<= .0262 = 45%

<= .0317 = 50%

<= .0396 = 55%

<= .0477 = 60%

<= .0559 = 65%

<= .0694 = 70%

<= .0798 = 75%

<= .0965 = 80%

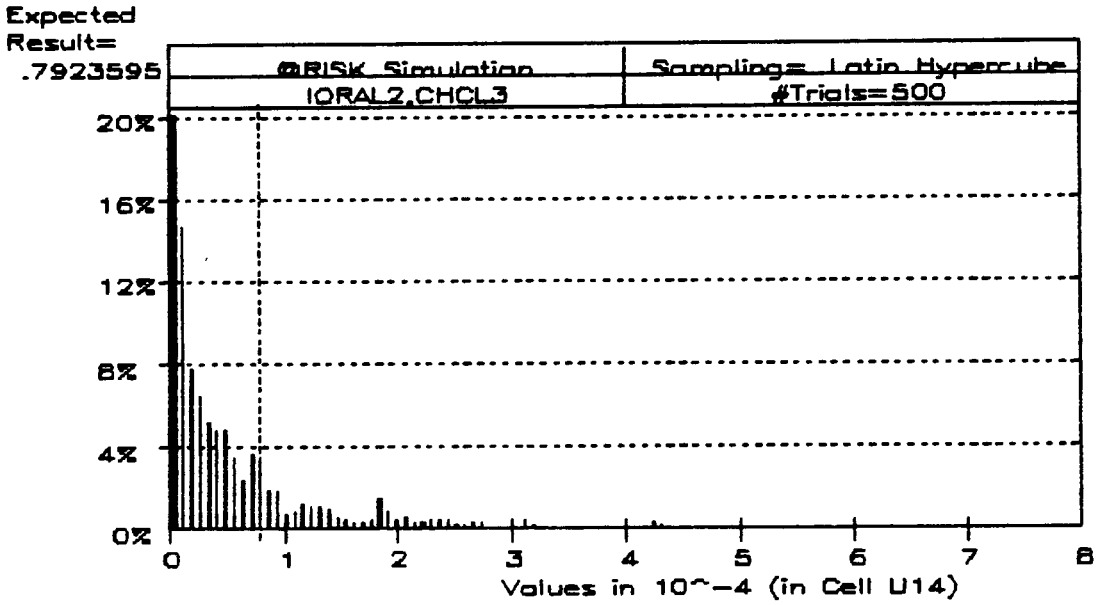
<= .1349 = 85%

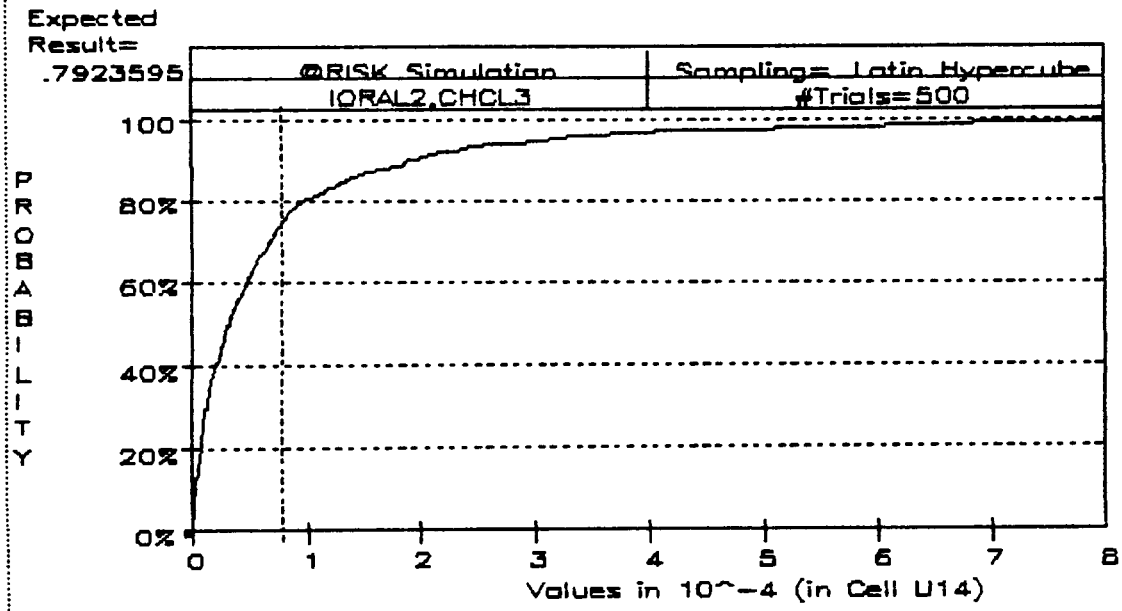
<= .1906 = 90%

<= .3102 = 95%

<= 1.4986 = 100%

IORAL2,CHCL3 (in Cell U14)





IGW2,CHCL3 (in Cell N14)

@RISK Risk Analysis 15-Aug-1992

==========

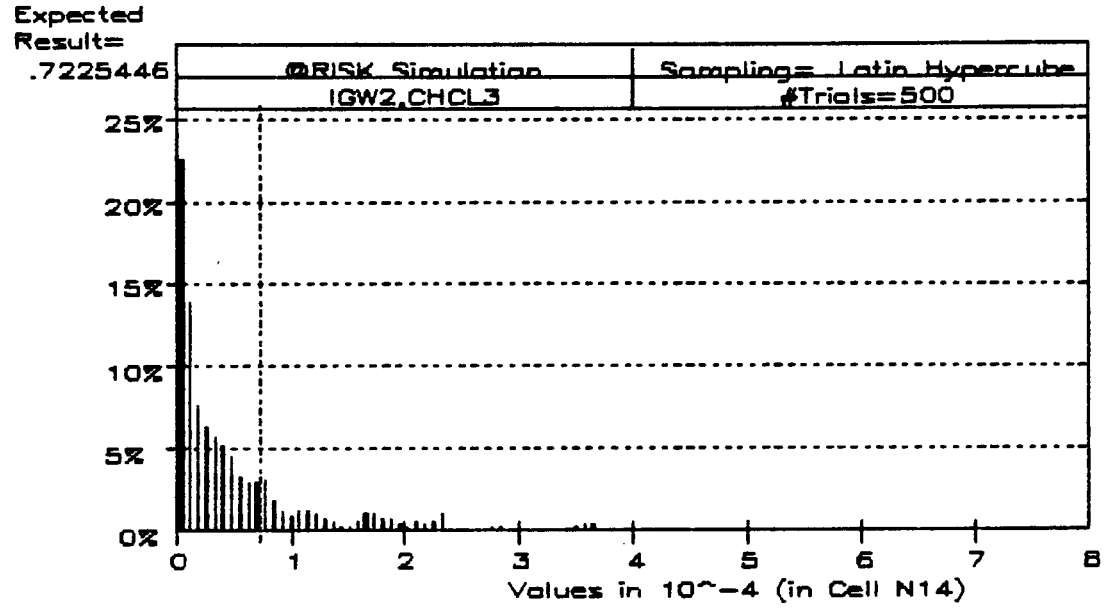
Expected/Mean Result = 7.225446E-05
Maximum Result = 1.473407E-03
Minimum Result = 7.172273E-08
Range of Possible Results = 1.473335E-03
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.383848E-04
Skewness = 5.2346
Kurtosis = 40.56313
Variance = 1.915035E-08
Simulations Executed = 1
Iterations = 500

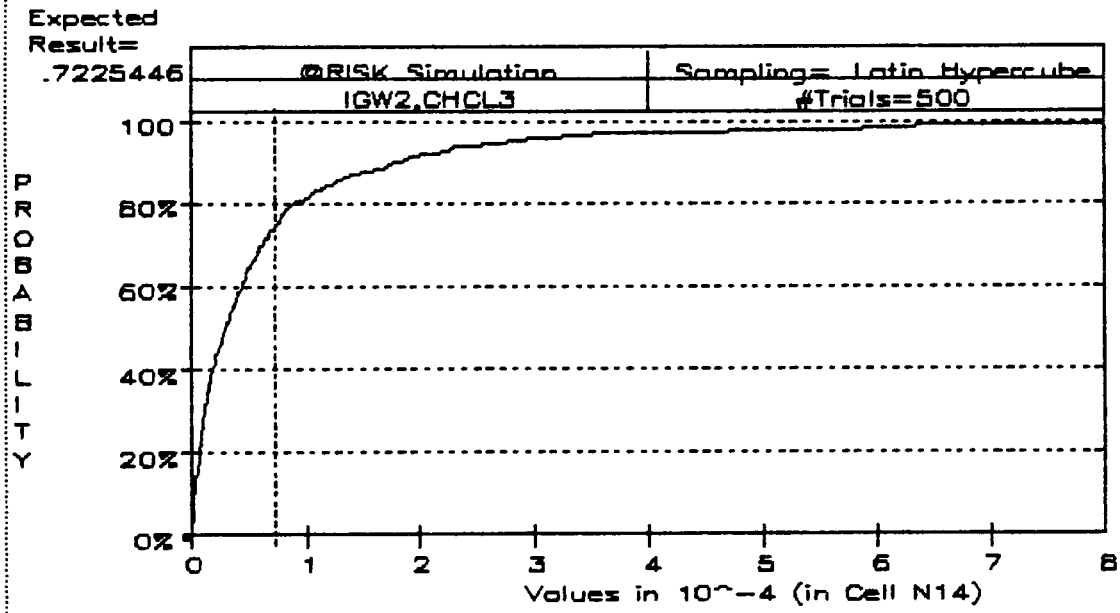
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-3)

==========

<= .00007 = 0%
<= .0011 = 5%
<= .0023 = 10%
<= .004 = 15%
<= .0066 = 20%
<= .0088 = 25%
<= .0112 = 30%
<= .014 = 35%
<= .0187 = 40%
<= .0231 = 45%
<= .0294 = 50%
<= .0359 = 55%
<= .0428 = 60%
<= .0505 = 65%
<= .0617 = 70%
<= .074 = 75%
<= .089 = 80%
<= .1232 = 85%
<= .1775 = 90%
<= .2708 = 95%
<= 1.4734 = 100%

IGW2,CHCL3 (in Cell N14)





IINH2,CHCL3 (in Cell T14)

@RISK Risk Analysis 15-Aug-1992

==========

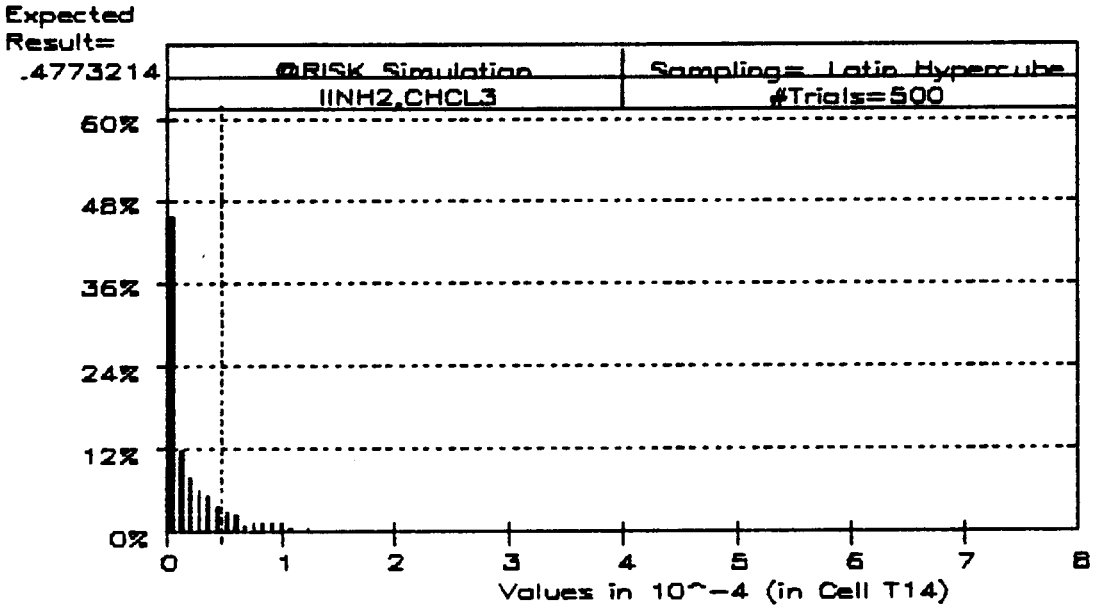
Expected/Mean Result = 4.773214E-05
Maximum Result = 1.592305E-03
Minimum Result = 1.64426E-08
Range of Possible Results = 1.592289E-03
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.429819E-04
Skewness = 7.611153
Kurtosis = 69.74676
Variance = 2.044381E-08
Simulations Executed = 1
Iterations = 500

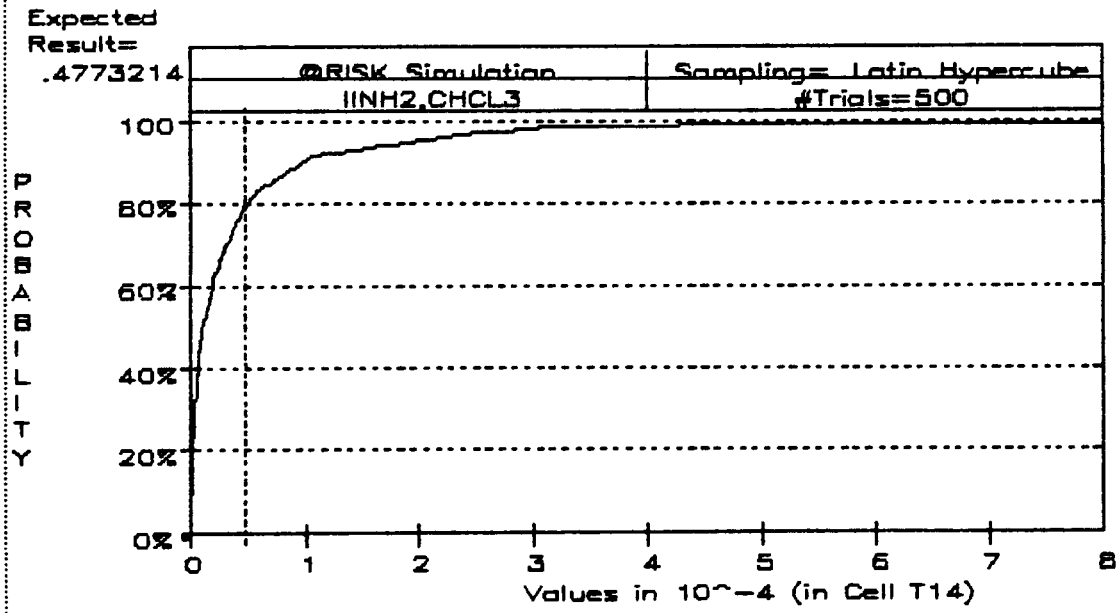
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-3)

==========

<= .00001 = 0%
<= .0003 = 5%
<= .0008 = 10%
<= .0012 = 15%
<= .0017 = 20%
<= .0028 = 25%
<= .0035 = 30%
<= .0043 = 35%
<= .0059 = 40%
<= .0077 = 45%
<= .01 = 50%
<= .0146 = 55%
<= .0193 = 60%
<= .0239 = 65%
<= .0306 = 70%
<= .039 = 75%
<= .0493 = 80%
<= .0692 = 85%
<= .0988 = 90%
<= .1871 = 95%
<= 1.5923 = 100%

IINH2,CHCL3 (in Cell T14)





CGW2,CHCL3 (in Cell F16)

@RISK Risk Analysis 15-Aug-1992

==========

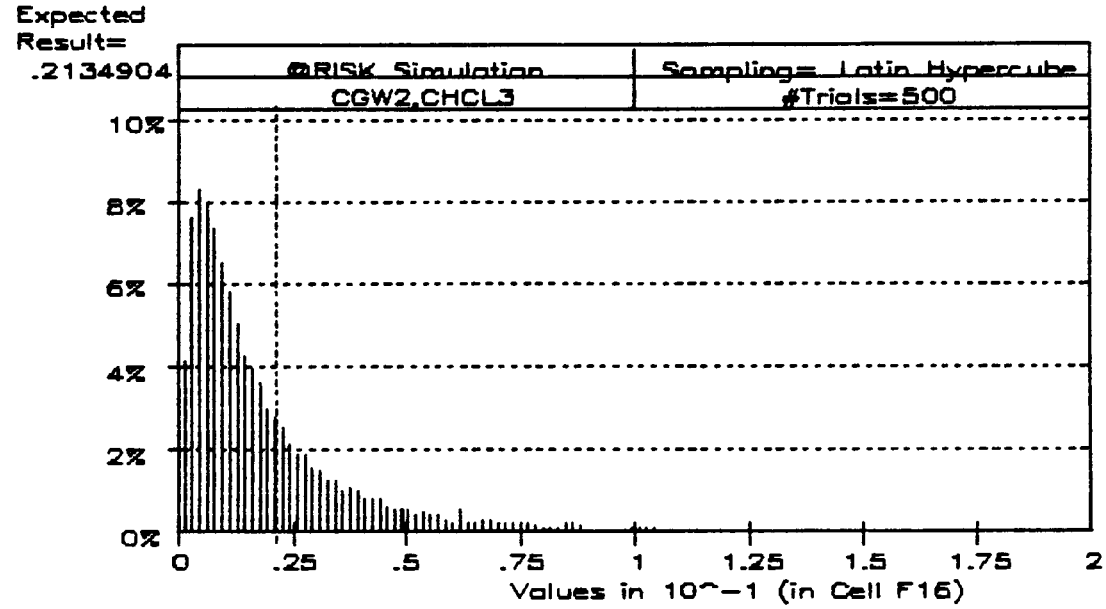
Expected/Mean Result = 2.134904E-02
Maximum Result = .3270929
Minimum Result = 6.066921E-04
Range of Possible Results = .3264862
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 2.791944E-02
Skewness = 4.784484
Kurtosis = 39.65606
Variance = 7.794949E-04
Simulations Executed = 1
Iterations = 500

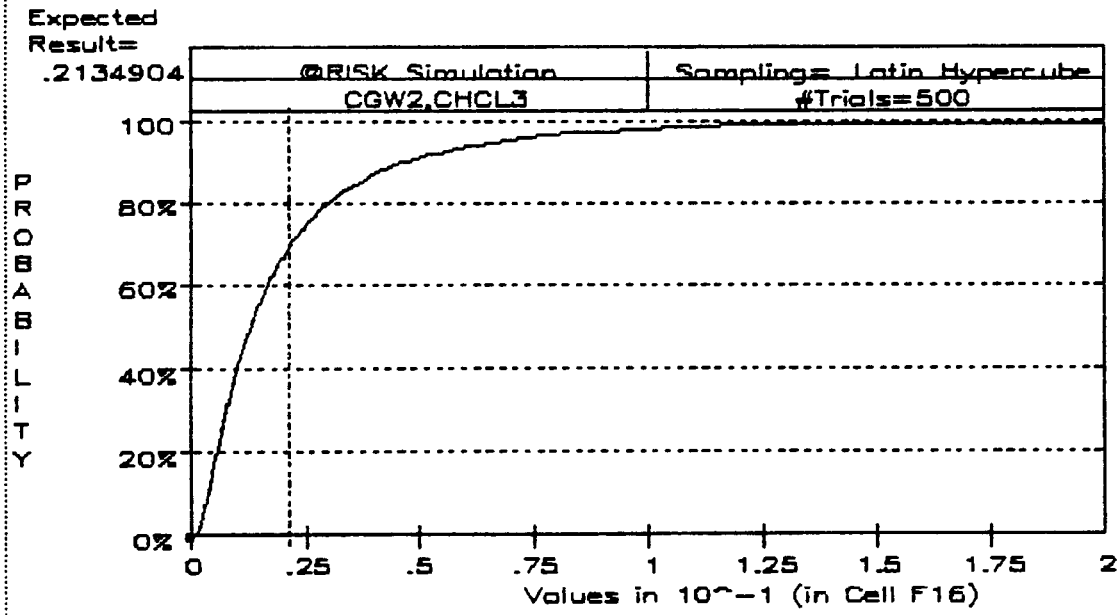
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-1)

==========

<= .007 = 0%
<= .0244 = 5%
<= .0353 = 10%
<= .0454 = 15%
<= .0551 = 20%
<= .0653 = 25%
<= .0757 = 30%
<= .087 = 35%
<= .0997 = 40%
<= .1131 = 45%
<= .1286 = 50%
<= .1455 = 55%
<= .1651 = 60%
<= .1891 = 65%
<= .2171 = 70%
<= .252 = 75%
<= .2987 = 80%
<= .3641 = 85%
<= .4607 = 90%
<= .6636 = 95%
<= 3.2709 = 100%

CGW2,CHCL3 (in Cell F16)





DIELDRIN, LIFETIME
ZONE 1B

IORAL1B,DLDRN (in Cell U12)

@RISK Risk Analysis 15-Aug-1992

==========

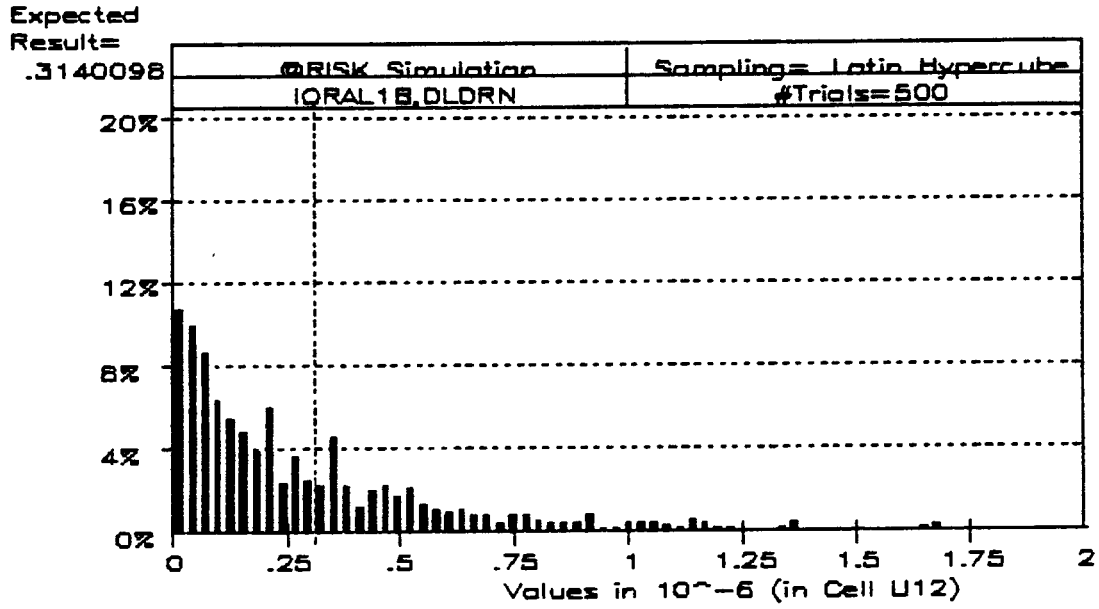
Expected/Mean Result = 3.140098E-07
Maximum Result = 2.81581E-06
Minimum Result = 2.437515E-10
Range of Possible Results = 2.815566E-06
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 3.531877E-07
Skewness = 2.287439
Kurtosis = 10.68421
Variance = 1.247415E-13
Simulations Executed = 1
Iterations = 500

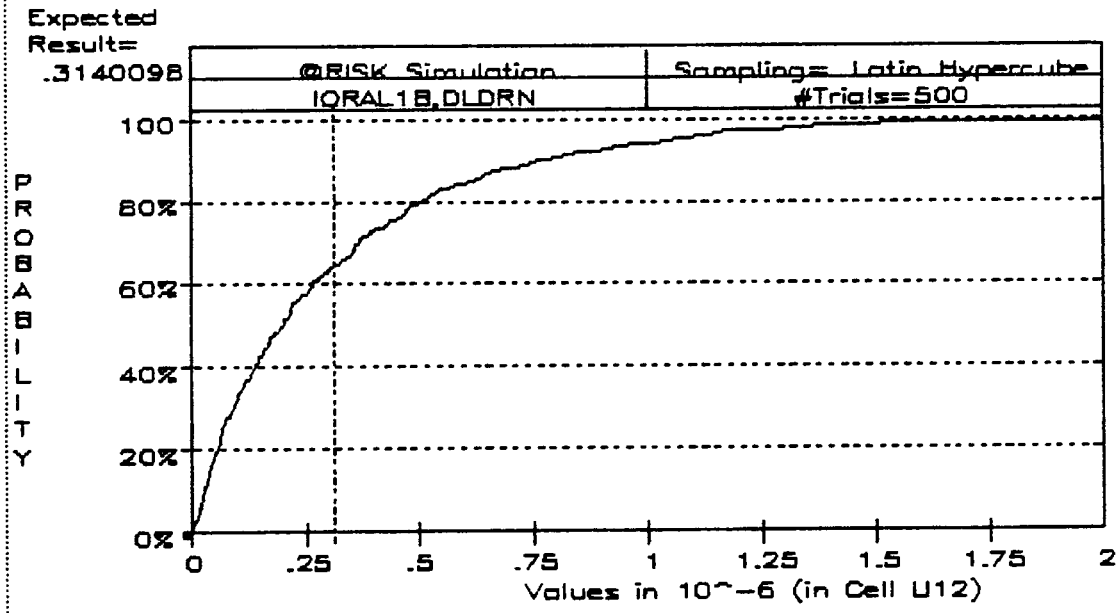
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-6)

==========

<= .0002 = 0%
<= .0141 = 5%
<= .0276 = 10%
<= .0372 = 15%
<= .0553 = 20%
<= .066 = 25%
<= .0895 = 30%
<= .1102 = 35%
<= .1353 = 40%
<= .1647 = 45%
<= .1987 = 50%
<= .2214 = 55%
<= .2668 = 60%
<= .3189 = 65%
<= .3624 = 70%
<= .4331 = 75%
<= .502 = 80%
<= .5978 = 85%
<= .7627 = 90%
<= 1.0412 = 95%
<= 2.8158 = 100%

IORAL1B,DLDRN (in Cell U12)





IGW1B,DLDRN (in Cell N12)

@RISK Risk Analysis 15-Aug-1992

==========

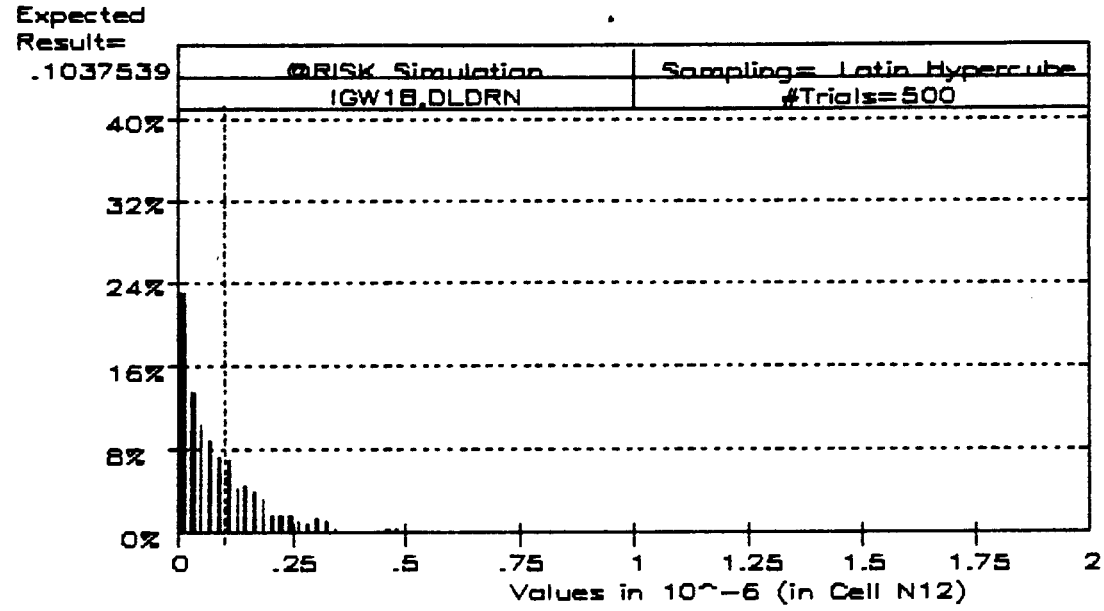
Expected/Mean Result = 1.037539E-07
Maximum Result = 7.814352E-07
Minimum Result = 1.353147E-10
Range of Possible Results = 7.812999E-07
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.192936E-07
Skewness = 2.354394
Kurtosis = 9.987419
Variance = 1.423097E-14
Simulations Executed = 1
Iterations = 500

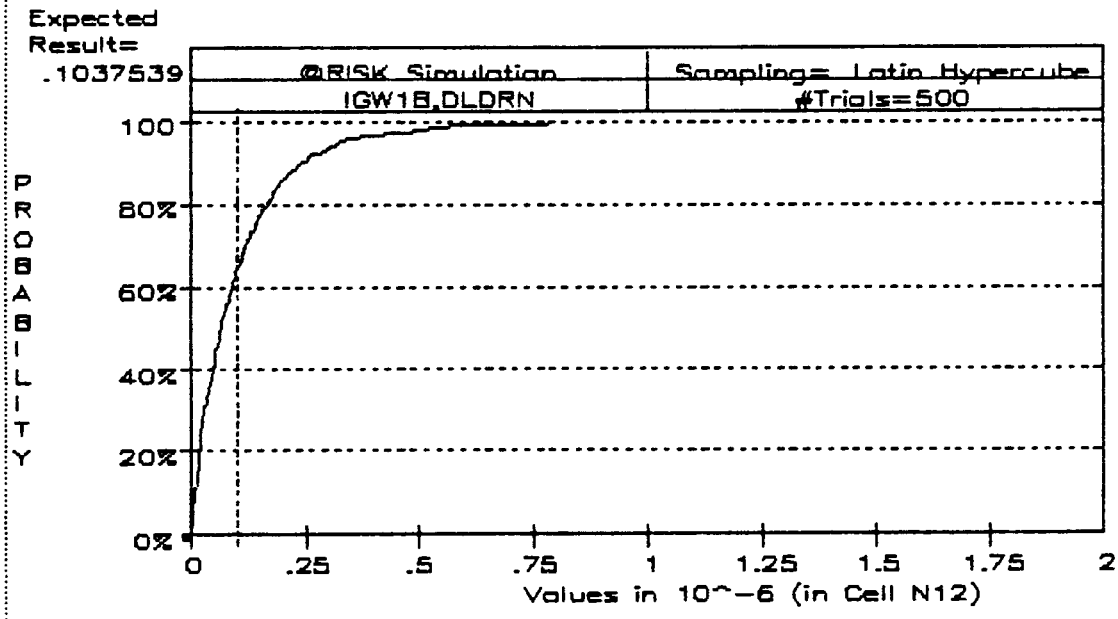
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-7)

==========

<= .0014 = 0%
<= .0382 = 5%
<= .0876 = 10%
<= .1385 = 15%
<= .1759 = 20%
<= .2216 = 25%
<= .2832 = 30%
<= .3638 = 35%
<= .4826 = 40%
<= .5532 = 45%
<= .6346 = 50%
<= .7643 = 55%
<= .8765 = 60%
<= 1.033 = 65%
<= 1.1738 = 70%
<= 1.3987 = 75%
<= 1.675 = 80%
<= 1.9194 = 85%
<= 2.4439 = 90%
<= 3.2129 = 95%
<= 7.8144 = 100%

IGW1B,DLDRN (in Cell N12)





IV1B,DLDRN (in Cell P12)

@RISK Risk Analysis 15-Aug-1992

==========

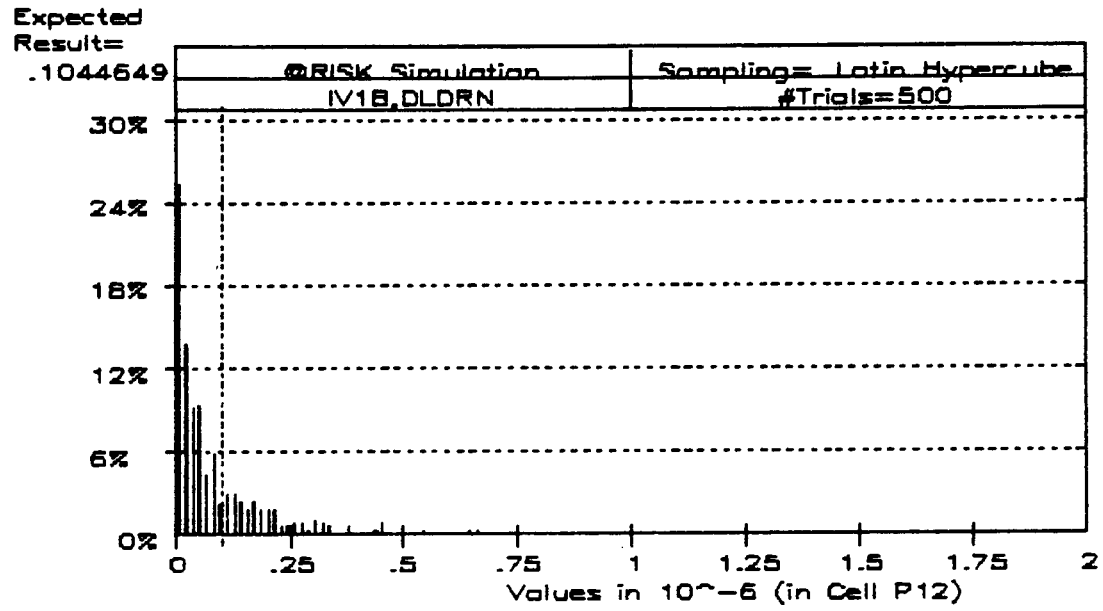
Expected/Mean Result = 1.044649E-07
Maximum Result = 1.487448E-06
Minimum Result = 8.762708E-12
Range of Possible Results = 1.48744E-06
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.533149E-07
Skewness = 3.358438
Kurtosis = 20.42264
Variance = 2.350545E-14
Simulations Executed = 1
Iterations = 500

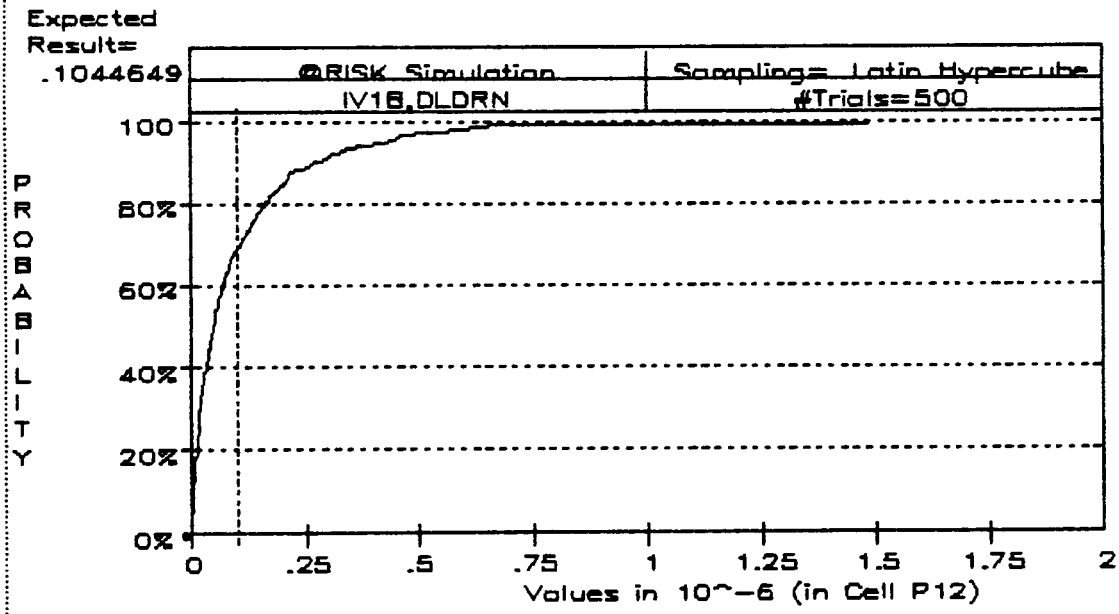
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-6)

==========

<= .000008= 0%
<= .0019 = 5%
<= .0045 = 10%
<= .0076 = 15%
<= .0107 = 20%
<= .0148 = 25%
<= .0182 = 30%
<= .025 = 35%
<= .0312 = 40%
<= .04 = 45%
<= .0492 = 50%
<= .0569 = 55%
<= .068 = 60%
<= .0813 = 65%
<= .1074 = 70%
<= .1308 = 75%
<= .1645 = 80%
<= .2006 = 85%
<= .272 = 90%
<= .4139 = 95%
<= 1.4874 = 100%

IV1B,DLDRN (in Cell P12)





CGW1,ALDRN+DLDR (in Cell D15)

@RISK Risk Analysis 15-Aug-1992

==========

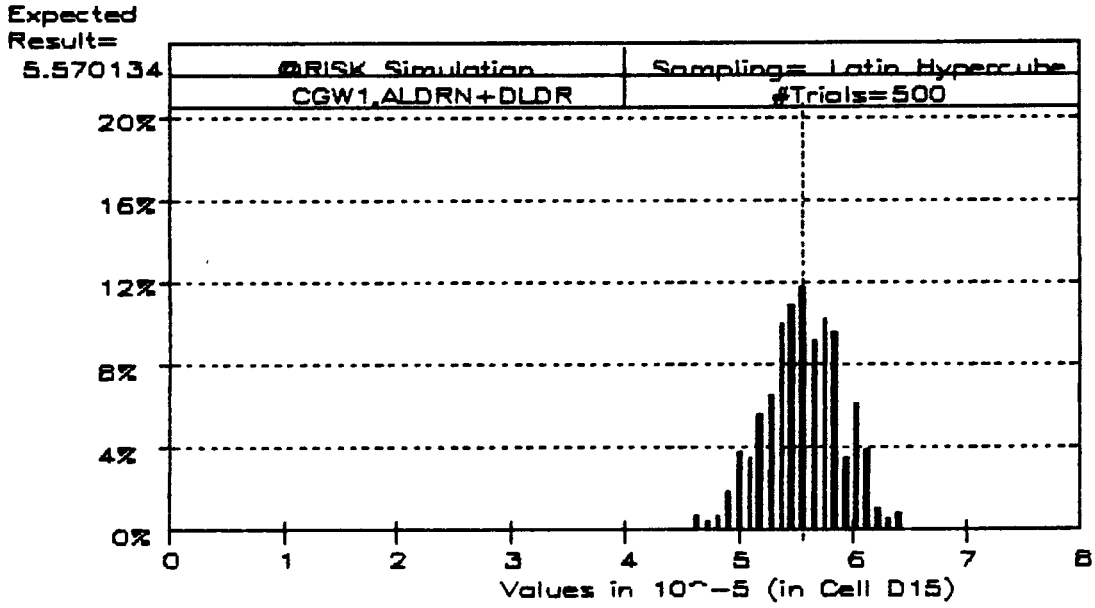
Expected/Mean Result = 5.570134E-05
Maximum Result = 6.45377E-05
Minimum Result = 4.579452E-05
Range of Possible Results = 1.874318E-05
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 3.36603E-06
Skewness = -8.987856E-02
Kurtosis = 2.78983
Variance = 1.133016E-11
Simulations Executed = 1
Iterations = 500

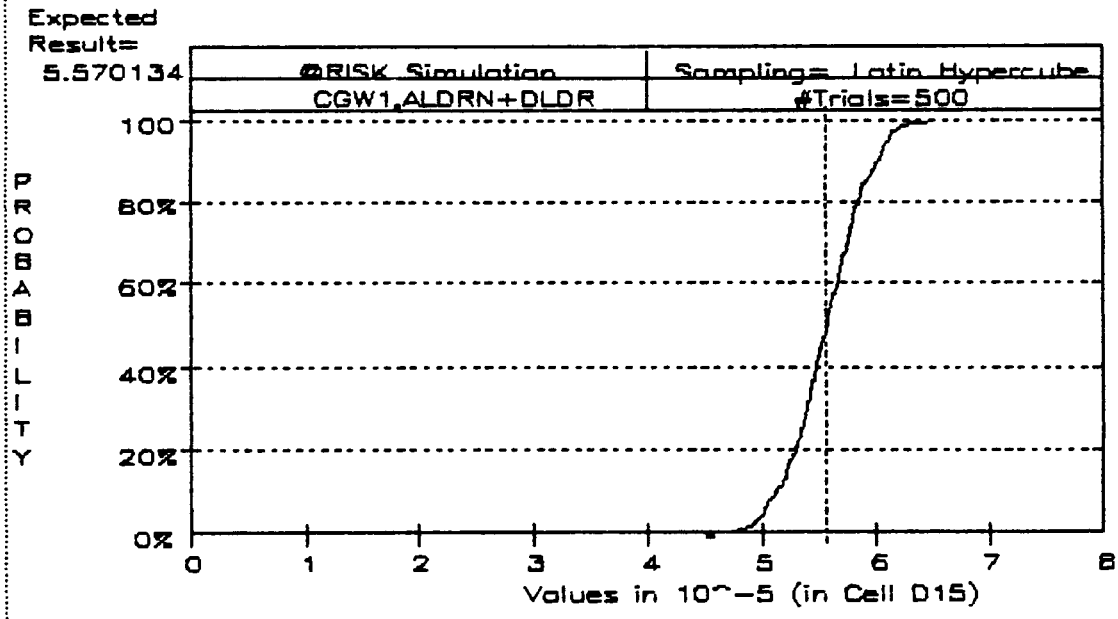
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-5)

==========

<= 4.5795 = 0%
<= 5.0115 = 5%
<= 5.1247 = 10%
<= 5.2218 = 15%
<= 5.2925 = 20%
<= 5.3553 = 25%
<= 5.3921 = 30%
<= 5.4382 = 35%
<= 5.4737 = 40%
<= 5.5284 = 45%
<= 5.5727 = 50%
<= 5.6084 = 55%
<= 5.6631 = 60%
<= 5.707 = 65%
<= 5.7617 = 70%
<= 5.8029 = 75%
<= 5.8552 = 80%
<= 5.9184 = 85%
<= 6.0333 = 90%
<= 6.1038 = 95%
<= 6.4538 = 100%

CGW1,ALDRN+DLDR (in Cell D15)





CGW1,DLDRN (in Cell F15)

@RISK Risk Analysis 15-Aug-1992

==========

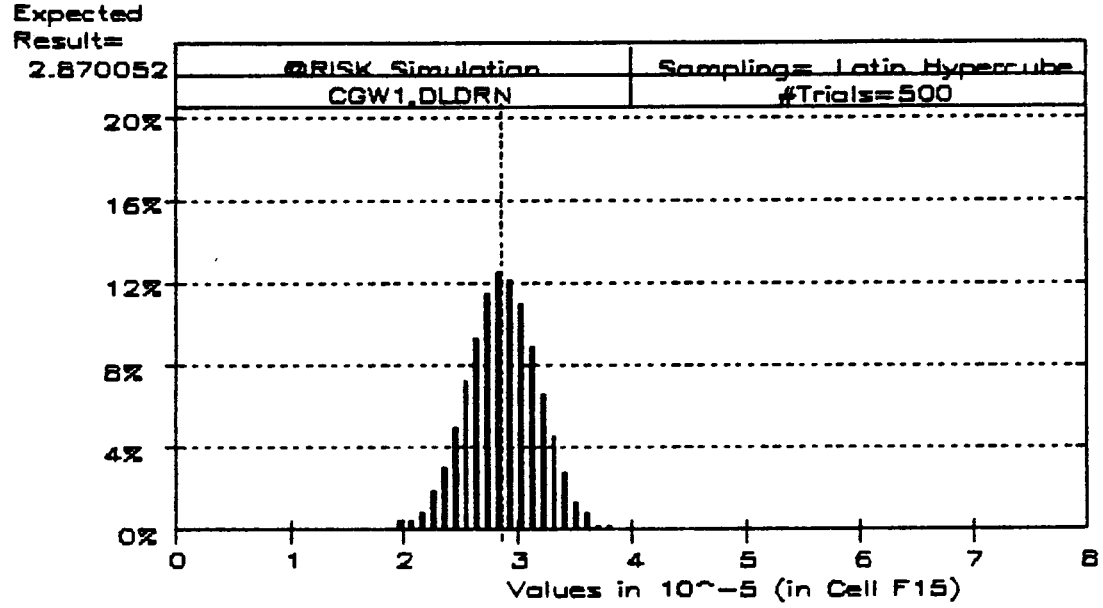
Expected/Mean Result = 2.870052E-05
Maximum Result = 3.848036E-05
Minimum Result = 1.914874E-05
Range of Possible Results = 1.933162E-05
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 3.098723E-06
Skewness = 4.00846E-03
Kurtosis = 2.967813
Variance = 9.602085E-12
Simulations Executed = 1
Iterations = 500

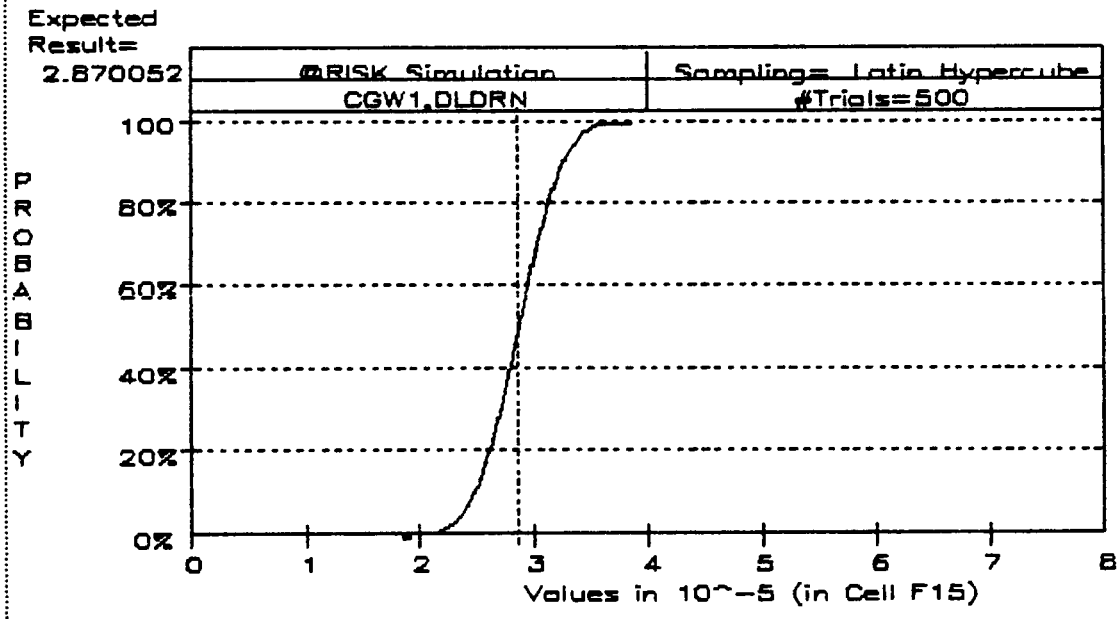
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-5)

==========

<= 1.9149 = 0%
<= 2.3572 = 5%
<= 2.4702 = 10%
<= 2.5472 = 15%
<= 2.6082 = 20%
<= 2.6604 = 25%
<= 2.7065 = 30%
<= 2.749 = 35%
<= 2.79 = 40%
<= 2.8298 = 45%
<= 2.8693 = 50%
<= 2.908 = 55%
<= 2.9482 = 60%
<= 2.988 = 65%
<= 3.0309 = 70%
<= 3.0787 = 75%
<= 3.1291 = 80%
<= 3.1891 = 85%
<= 3.2656 = 90%
<= 3.3744 = 95%
<= 3.848 = 100%

CGW1,DLDRN (in Cell F15)





CV1B,DLDRN (in Cell H12)

@RISK Risk Analysis 15-Aug-1992

==========

Expected/Mean Result = 7.207418E-04

Maximum Result = 2.751053E-03

Minimum Result = 1.289416E-04

Range of Possible Results = 2.622112E-03

Probability of Positive Result = 100%

Probability of Negative Result = 0%

Standard Deviation = 3.849909E-04

Skewness = 1.507547

Kurtosis = 6.552472

Variance = 1.48218E-07

Simulations Executed = 1

Iterations = 500

Percentile Probabilities:

(Chance of Result <= Shown Value)

(Values in 10^-3)

==========

<= .1289 = 0%

<= .2553 = 5%

<= .3039 = 10%

<= .3705 = 15%

<= .4124 = 20%

<= .4534 = 25%

<= .482 = 30%

<= .5156 = 35%

<= .5708 = 40%

<= .6015 = 45%

<= .6412 = 50%

<= .6823 = 55%

<= .738 = 60%

<= .7904 = 65%

<= .8423 = 70%

<= .8935 = 75%

<= .9653 = 80%

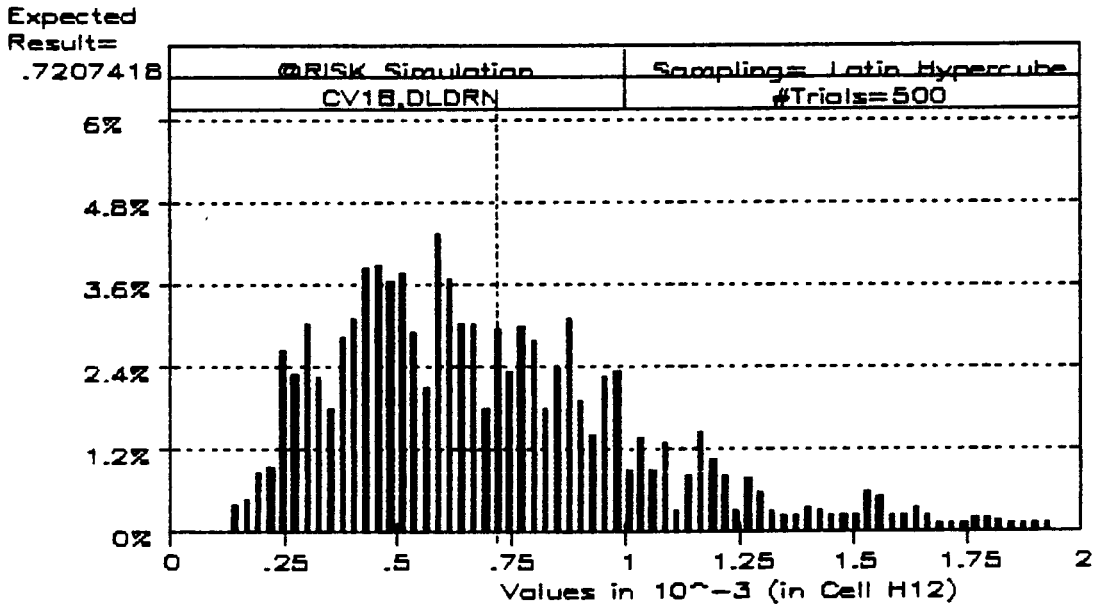
<= 1.0521 = 85%

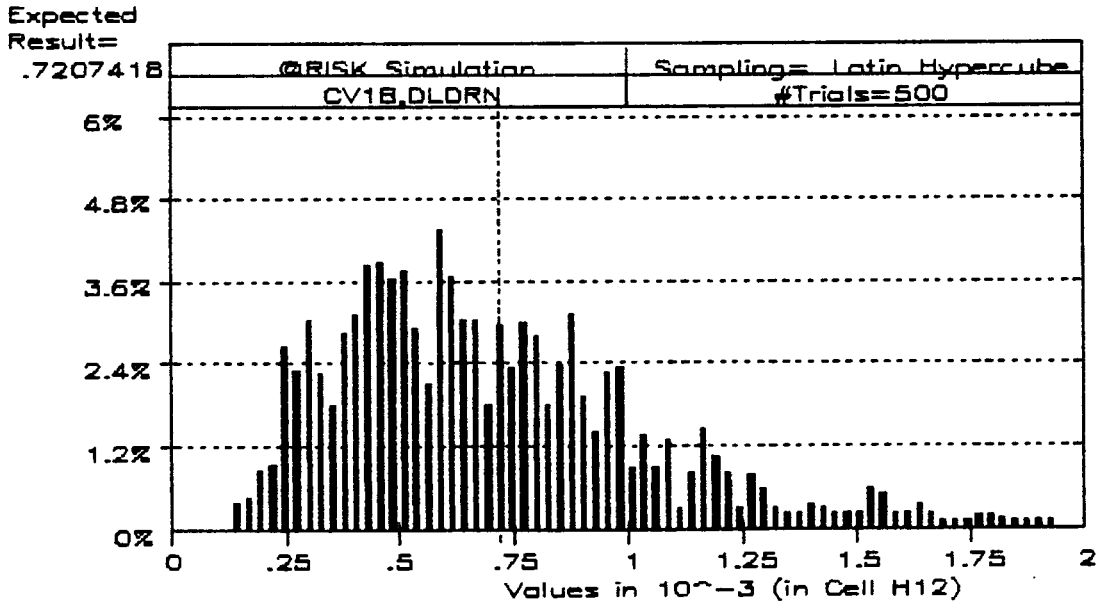
<= 1.1855 = 90%

<= 1.4772 = 95%

<= 2.7511 = 100%

CV1B,DLDRN (in Cell H12)





DIELDRIN, LIFETIME
ZONE 3

IORAL3,DLDRN (in Cell U15)

@RISK Risk Analysis 15-Aug-1992

==========

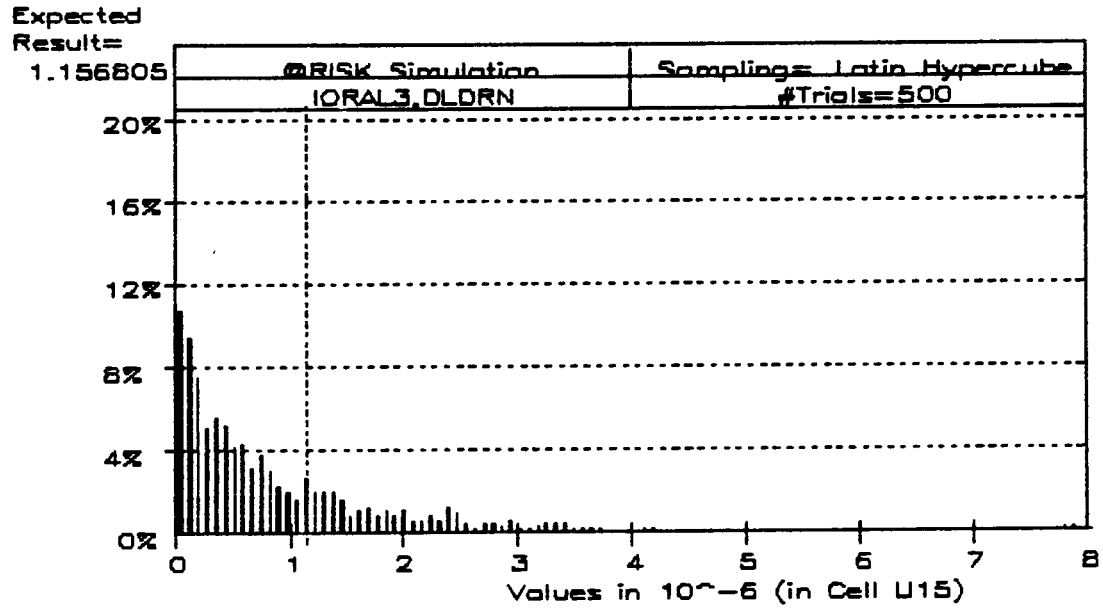
Expected/Mean Result = 1.156805E-06
Maximum Result = 1.567903E-05
Minimum Result = 1.471576E-09
Range of Possible Results = 1.567756E-05
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.671675E-06
Skewness = 3.613553
Kurtosis = 21.4227
Variance = 2.794497E-12
Simulations Executed = 1
Iterations = 500

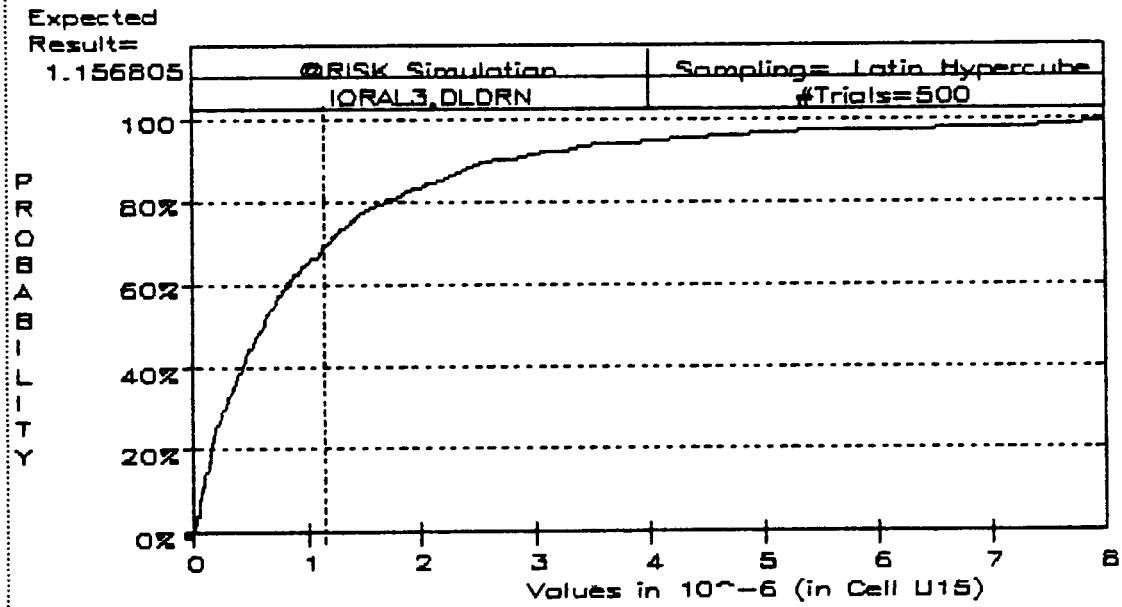
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-5)

==========

<= .0001 = 0%
<= .0042 = 5%
<= .0073 = 10%
<= .0122 = 15%
<= .0156 = 20%
<= .0196 = 25%
<= .0262 = 30%
<= .0351 = 35%
<= .0425 = 40%
<= .0514 = 45%
<= .061 = 50%
<= .08 = 55%
<= .0823 = 60%
<= .0973 = 65%
<= .1176 = 70%
<= .1378 = 75%
<= .1695 = 80%
<= .2101 = 85%
<= .27 = 90%
<= .4086 = 95%
<= 1.5679 = 100%

IORAL3,DLDRN (in Cell U15)





IGW3,DLDRN (in Cell N15)

@RISK Risk Analysis 15-Aug-1992

==========

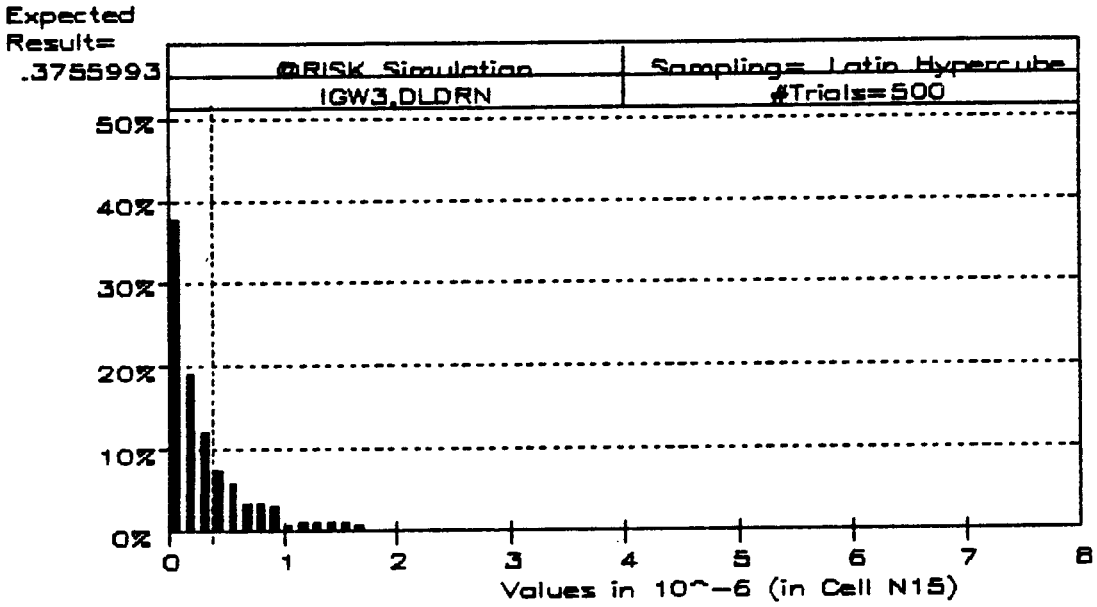
Expected/Mean Result = 3.755993E-07
Maximum Result = 4.924696E-06
Minimum Result = -5.87544E-09
Range of Possible Results = 4.930571E-06
Probability of Positive Result = 99.8%
Probability of Negative Result = .2%
Standard Deviation = 5.432219E-07
Skewness = 3.736746
Kurtosis = 22.74726
Variance = 2.9509E-13
Simulations Executed = 1
Iterations = 500

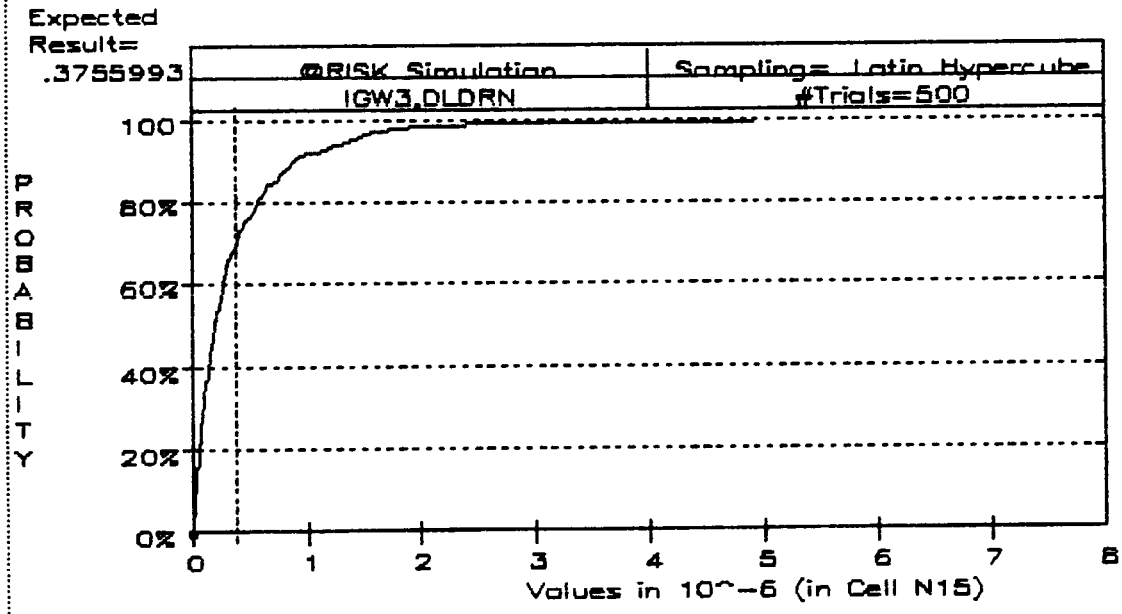
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-6)

==========

<=-.0059 = 0%
<= .0136 = 5%
<= .0259 = 10%
<= .0374 = 15%
<= .0543 = 20%
<= .0685 = 25%
<= .0877 = 30%
<= .1104 = 35%
<= .1299 = 40%
<= .1598 = 45%
<= .1934 = 50%
<= .2281 = 55%
<= .2595 = 60%
<= .3074 = 65%
<= .3878 = 70%
<= .4519 = 75%
<= .5706 = 80%
<= .696 = 85%
<= .8829 = 90%
<= 1.357 = 95%
<= 4.9247 = 100%

IGW3,DLDRN (in Cell N15)





IV3,DLDRN (in Cell P15)

@RISK Risk Analysis 15-Aug-1992

==========

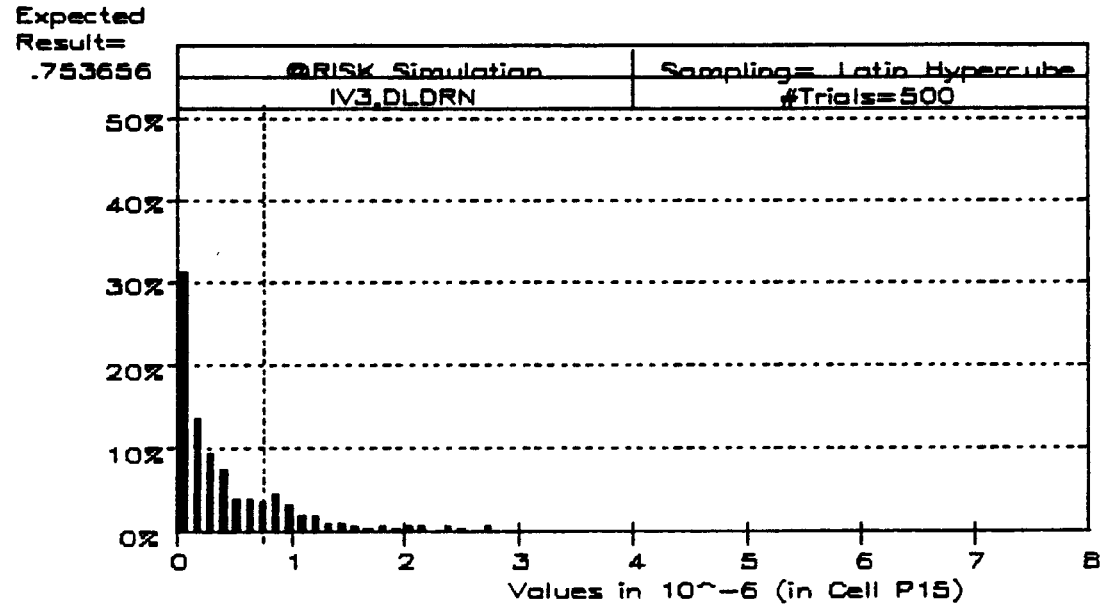
Expected/Mean Result = 7.53656E-07
Maximum Result = 1.157898E-05
Minimum Result = 1.083303E-10
Range of Possible Results = 1.157888E-05
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.295535E-06
Skewness = 3.875666
Kurtosis = 22.73319
Variance = 1.678411E-12
Simulations Executed = 1
Iterations = 500

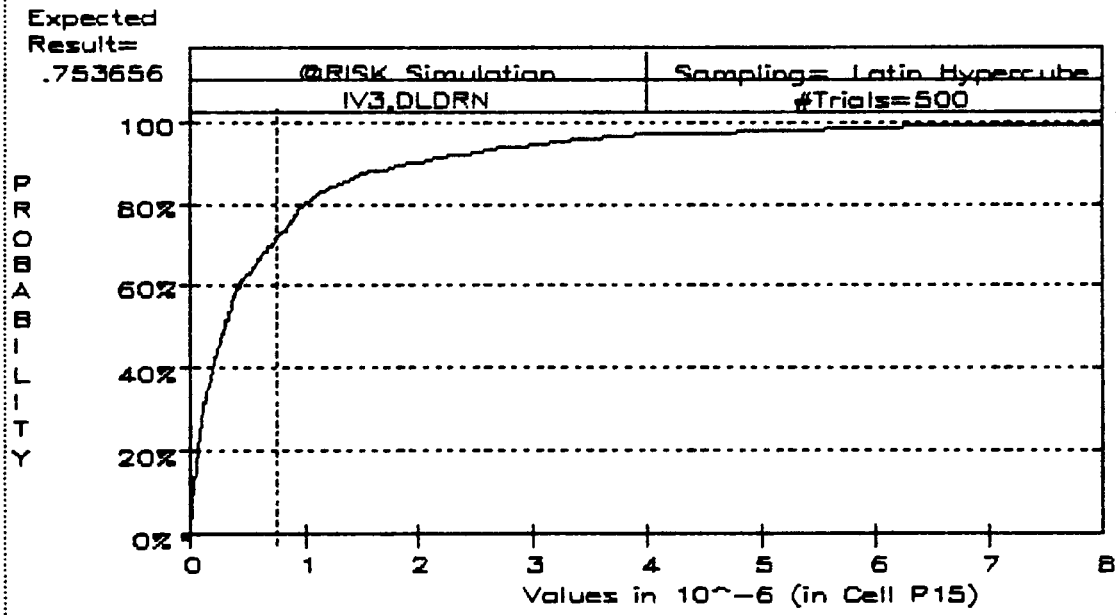
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-5)

==========

<= .00001 = 0%
<= .0011 = 5%
<= .0026 = 10%
<= .0041 = 15%
<= .0063 = 20%
<= .0085 = 25%
<= .0112 = 30%
<= .0142 = 35%
<= .03 = 40%
<= .0238 = 45%
<= .0306 = 50%
<= .0364 = 55%
<= .0428 = 60%
<= .0548 = 65%
<= .0712 = 70%
<= .0862 = 75%
<= .099 = 80%
<= .1252 = 85%
<= .1964 = 90%
<= .3078 = 95%
<= 1.1579 = 100%

IV3,DLDRN (in Cell P15)





CGW3,ALD+DLD (in Cell D17)

@RISK Risk Analysis 15-Aug-1992

==========

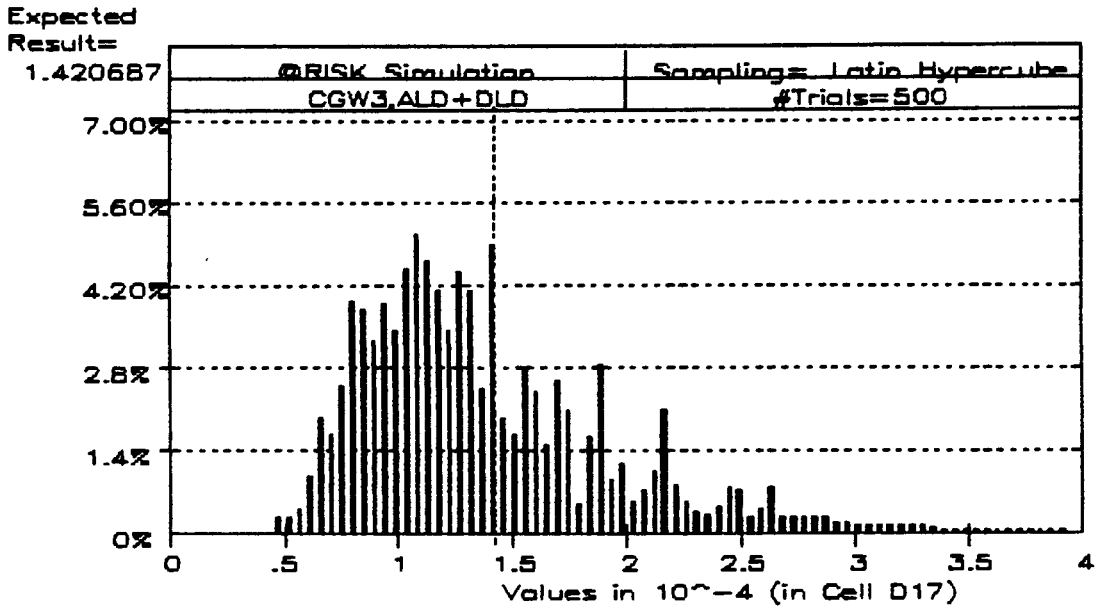
Expected/Mean Result = 1.420687E-04
Maximum Result = 5.157802E-04
Minimum Result = 4.453032E-05
Range of Possible Results = 4.712499E-04
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 6.326209E-05
Skewness = 1.742006
Kurtosis = 7.686744
Variance = 4.002092E-09
Simulations Executed = 1
Iterations = 500

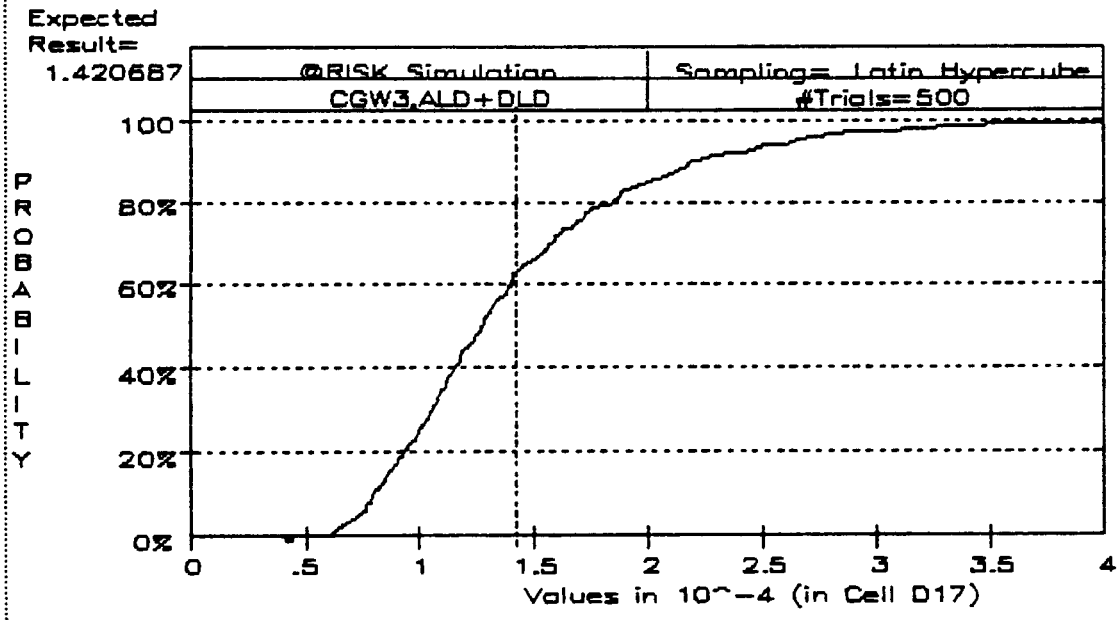
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-4)

==========

<= .4453 = 0%
<= .7136 = 5%
<= .7902 = 10%
<= .8575 = 15%
<= .9237 = 20%
<= .9968 = 25%
<= 1.0489 = 30%
<= 1.0986 = 35%
<= 1.1512 = 40%
<= 1.2072 = 45%
<= 1.2715 = 50%
<= 1.3283 = 55%
<= 1.3968 = 60%
<= 1.4529 = 65%
<= 1.5748 = 70%
<= 1.6846 = 75%
<= 1.8435 = 80%
<= 1.9712 = 85%
<= 2.1896 = 90%
<= 2.6372 = 95%
<= 5.1578 = 100%

CGW3,ALD+DLD (in Cell D17)





CS3,ALD+DLD (in Cell D26)

@RISK Risk Analysis 23-Sep-1992

==========

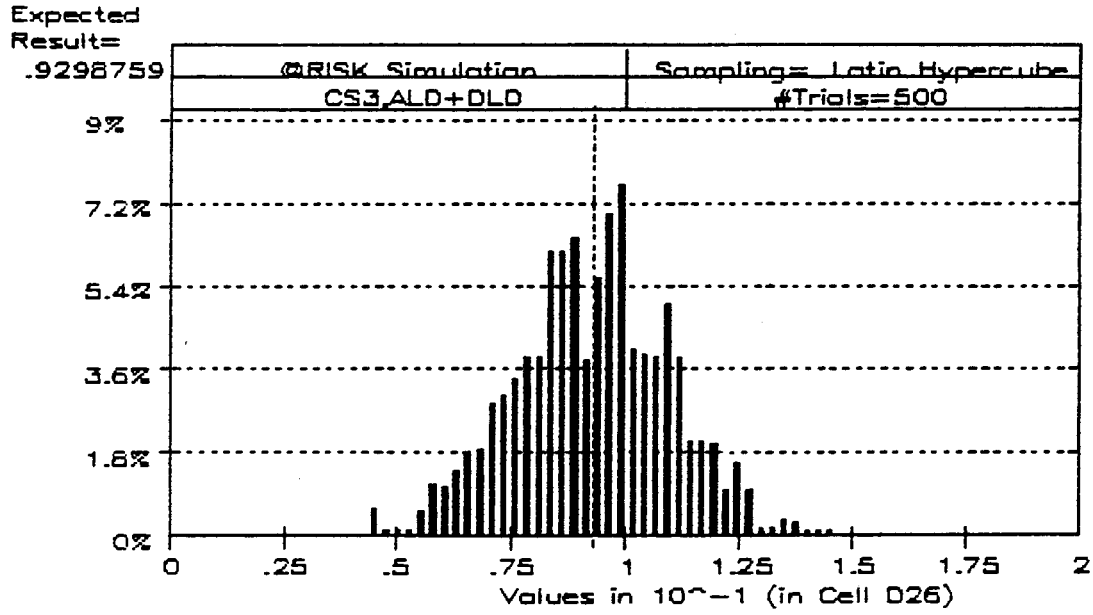
Expected/Mean Result = 9.298758E-02
Maximum Result = .146615
Minimum Result = 4.368081E-02
Range of Possible Results = .1029342
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.725843E-02
Skewness = .0375252
Kurtosis = 2.93105
Variance = 2.978535E-04
Simulations Executed = 1
Iterations = 500

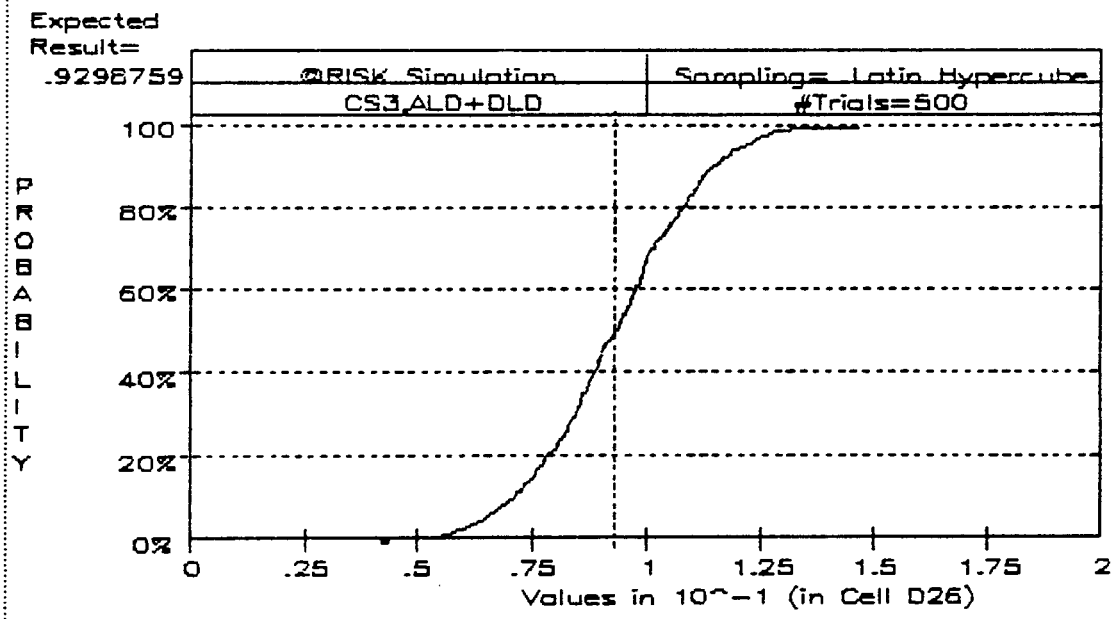
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-1)

==========

<= .4368 = 0%
<= .6403 = 5%
<= .7106 = 10%
<= .7495 = 15%
<= .7791 = 20%
<= .8198 = 25%
<= .8423 = 30%
<= .8602 = 35%
<= .8828 = 40%
<= .9005 = 45%
<= .9341 = 50%
<= .9569 = 55%
<= .9754 = 60%
<= .9918 = 65%
<= 1.0146 = 70%
<= 1.05 = 75%
<= 1.0801 = 80%
<= 1.1057 = 85%
<= 1.1484 = 90%
<= 1.2115 = 95%
<= 1.4662 = 100%

CS3,ALD+DLD (in Cell D26)





CGW3,DLDRN (in Cell F17)

@RISK Risk Analysis 15-Aug-1992

==========

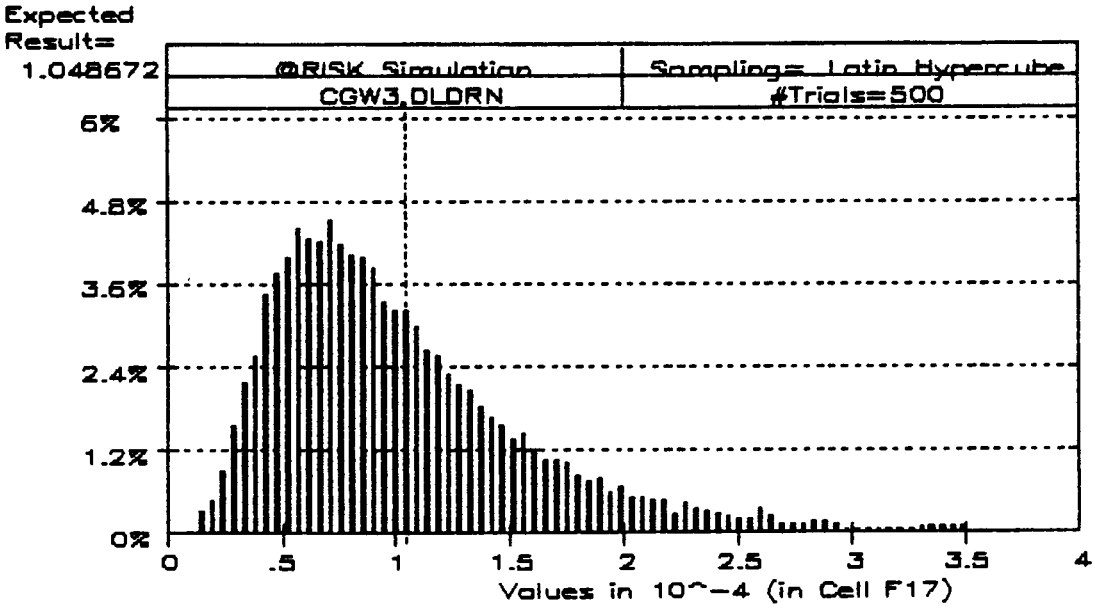
Expected/Mean Result = 1.048672E-04
Maximum Result = 4.835349E-04
Minimum Result = 1.23566E-05
Range of Possible Results = 4.711783E-04
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 6.306713E-05
Skewness = 1.796621
Kurtosis = 7.9976
Variance = 3.977464E-09
Simulations Executed = 1
Iterations = 500

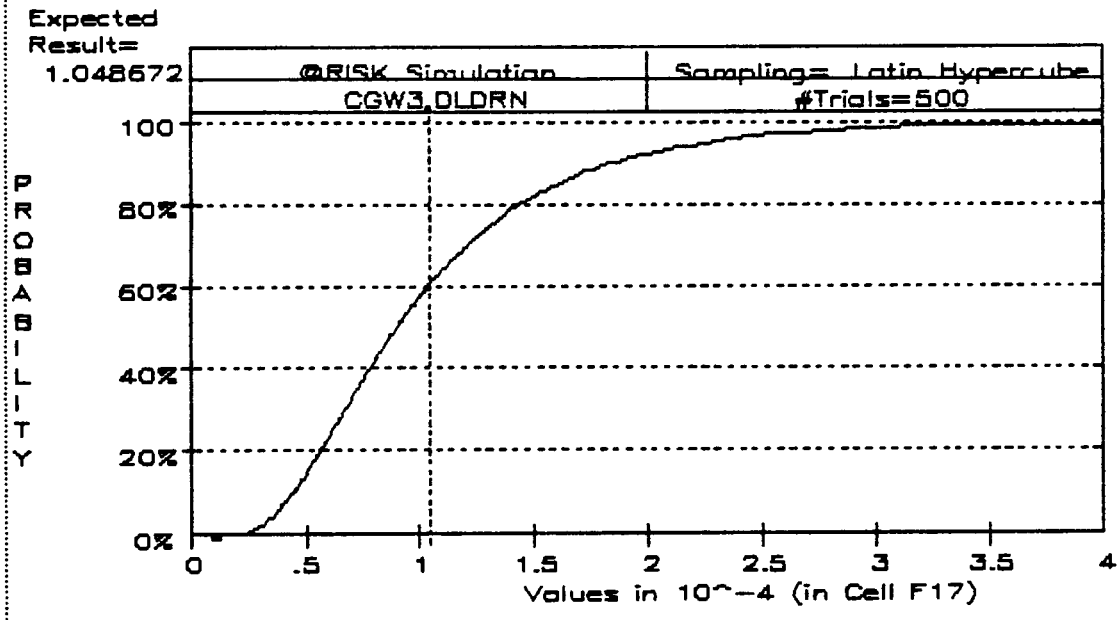
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-4)

==========

<= .1236 = 0%
<= .3542 = 5%
<= .4353 = 10%
<= .4987 = 15%
<= .5576 = 20%
<= .6124 = 25%
<= .6672 = 30%
<= .7217 = 35%
<= .7763 = 40%
<= .8344 = 45%
<= .8952 = 50%
<= .9608 = 55%
<= 1.0308 = 60%
<= 1.1108 = 65%
<= 1.2012 = 70%
<= 1.307 = 75%
<= 1.4346 = 80%
<= 1.5991 = 85%
<= 1.8321 = 90%
<= 2.2579 = 95%
<= 4.8353 = 100%

CGW3,DLDRN (in Cell F17)





CV3,DLDRN (in Cell H15)

@RISK Risk Analysis 15-Aug-1992

==========

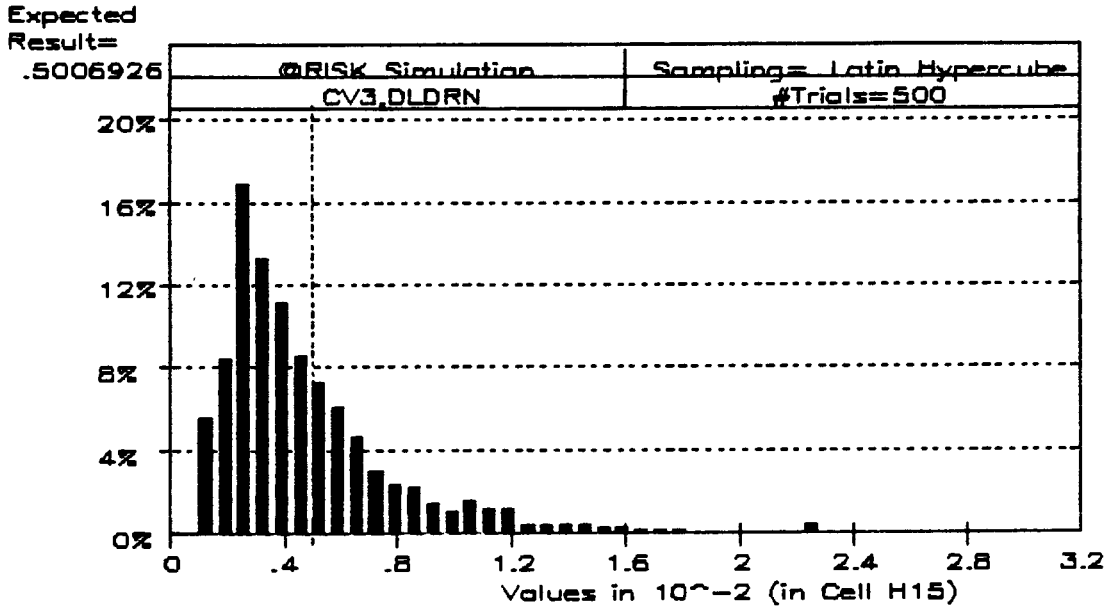
Expected/Mean Result = 5.006926E-03
Maximum Result = 2.753284E-02
Minimum Result = 8.832281E-04
Range of Possible Results = 2.664961E-02
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 3.731635E-03
Skewness = 2.498269
Kurtosis = 11.41958
Variance = 1.39251E-05
Simulations Executed = 1
Iterations = 500

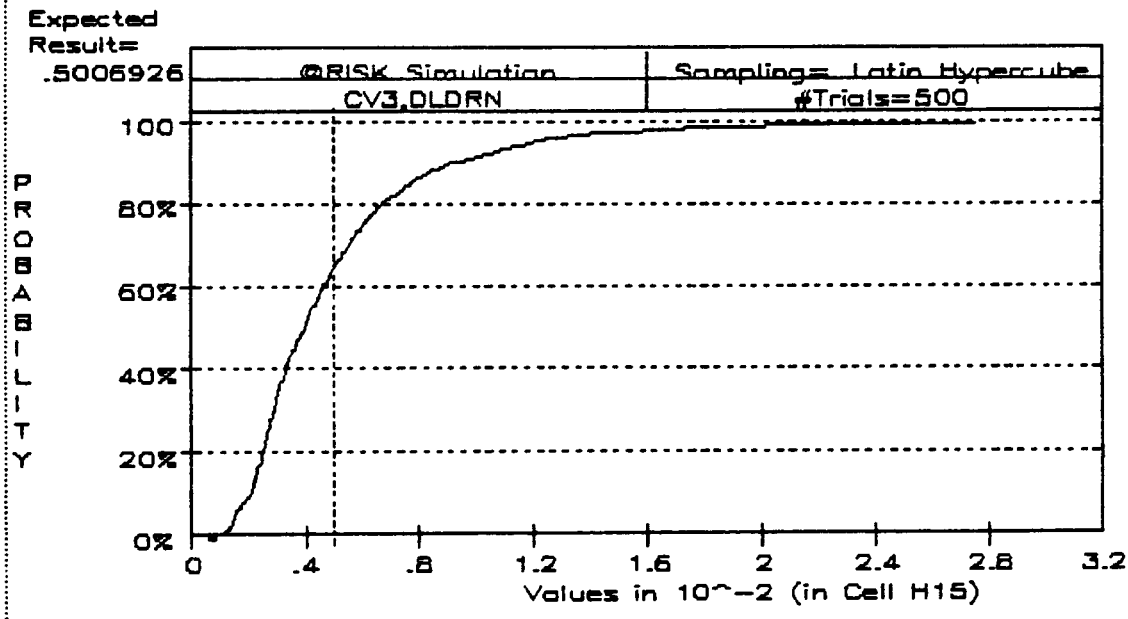
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-2)

==========

<= .0883 = 0%
<= .1522 = 5%
<= .2009 = 10%
<= .2256 = 15%
<= .2463 = 20%
<= .2665 = 25%
<= .286 = 30%
<= .3059 = 35%
<= .3298 = 40%
<= .3614 = 45%
<= .3934 = 50%
<= .421 = 55%
<= .4586 = 60%
<= .5021 = 65%
<= .5481 = 70%
<= .5986 = 75%
<= .6654 = 80%
<= .7674 = 85%
<= .9157 = 90%
<= 1.1982 = 95%
<= 2.7533 = 100%

CV3,DLDRN (in Cell H15)





EXPOSURE FACTOR VARIABILITY ANALYSIS ALL EXPOSURE CONCENTRATIONS AT EXPECTED RESULT CHLOROFORM (LIFETIME) ZONE 2 DIELDRIN (LIFETIME) ZONE 3

Note: Concentrations at Expected Result, Exposure Factor Variability

IORAL2,CHCL3 (in Cell U14)

@RISK Risk Analysis 27-Aug-1992

==========

Expected/Mean Result = 7.977681E-05
Maximum Result = 4.642596E-04
Minimum Result = 1.409439E-08
Range of Possible Results = 4.642455E-04
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 8.244636E-05
Skewness = 1.861427
Kurtosis = 6.941244
Variance = 6.797403E-09
Simulations Executed = 1
Iterations = 500

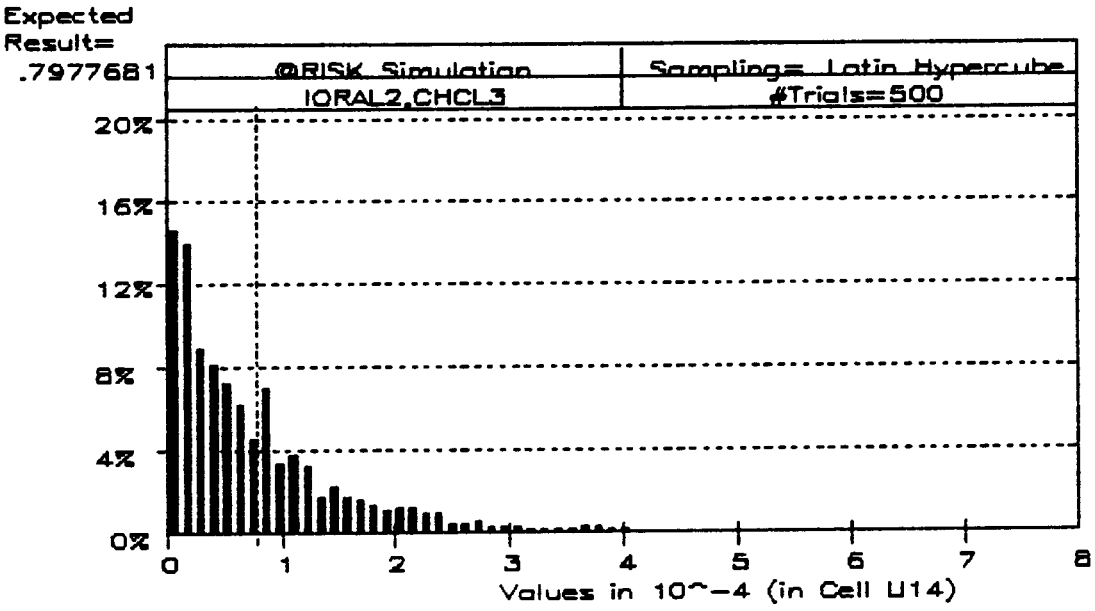
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-4)

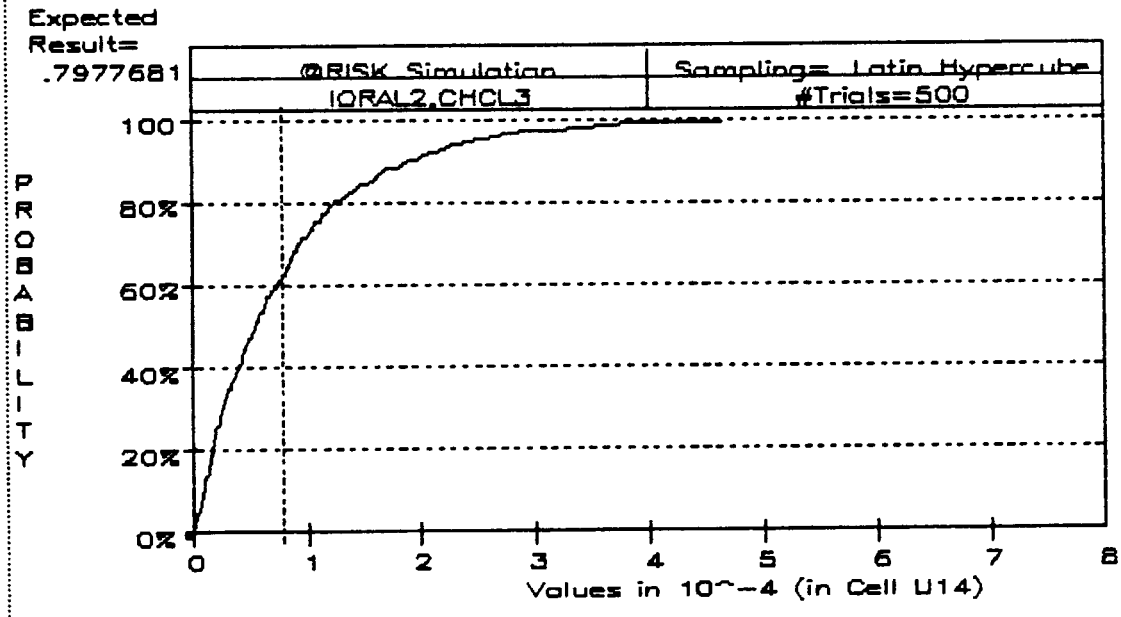
==========

<= .0001 = 0%
<= .0374 = 5%
<= .0844 = 10%
<= .1273 = 15%
<= .1606 = 20%
<= .201 = 25%
<= .2492 = 30%
<= .3141 = 35%
<= .3945 = 40%
<= .4561 = 45%
<= .5354 = 50%
<= .622 = 55%
<= .7309 = 60%
<= .8369 = 65%
<= .9141 = 70%
<= 1.0669 = 75%
<= 1.2308 = 80%
<= 1.5104 = 85%
<= 1.9045 = 90%
<= 2.3989 = 95%
<= 4.6426 = 100%

Note: Concentrations at Expected Result, Exposure Factor Variability

IORAL2,CHCL3 (in Cell U14)





Note: Concentrations at Expected Result, Exposure Factor Variability

IINH2,CHCL3 (in Cell T14)

@RISK Risk Analysis 27-Aug-1992

==========

Expected/Mean Result = 4.729717E-05
Maximum Result = 7.033471E-04
Minimum Result = 1.931023E-08
Range of Possible Results = 7.033278E-04
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 8.85496E-05
Skewness = 4.177528
Kurtosis = 24.09675
Variance = 7.841033E-09
Simulations Executed = 1
Iterations = 500

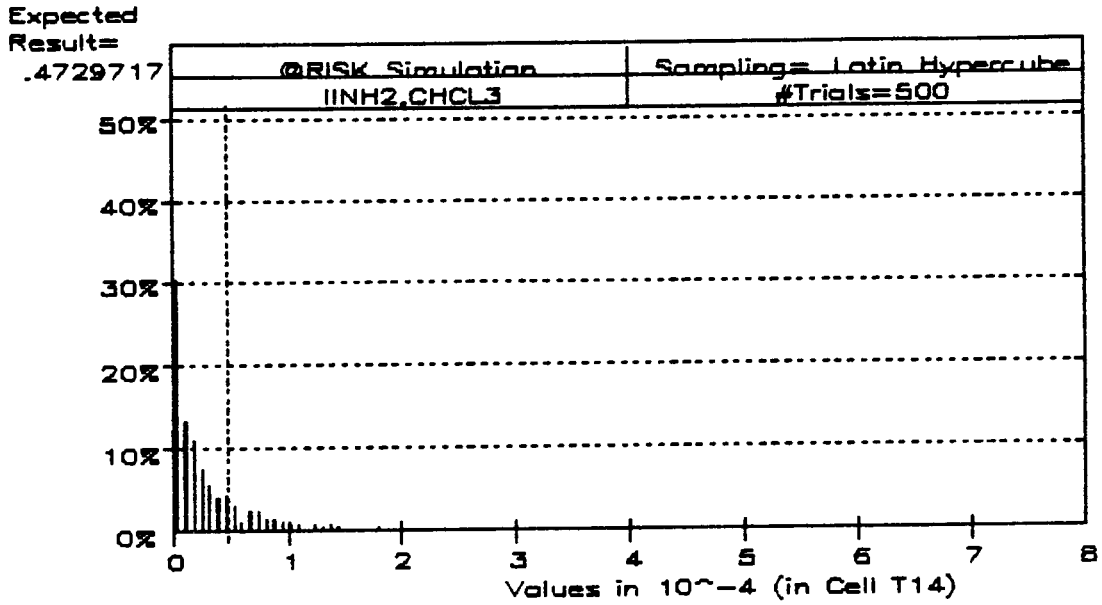
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-4)

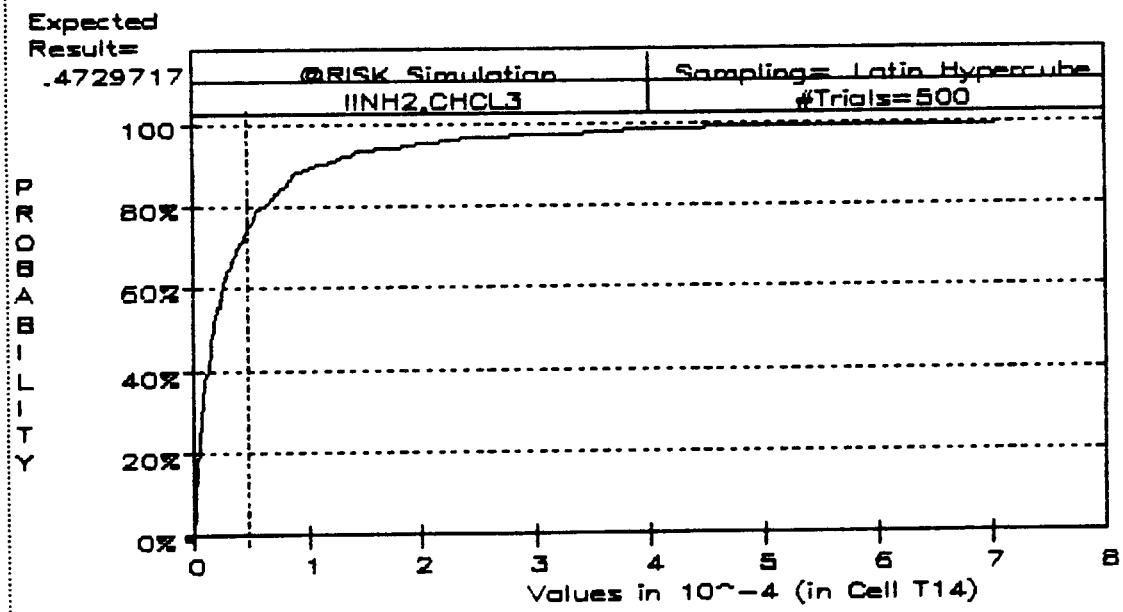
==========

<= .0002 = 0%
<= .0103 = 5%
<= .0191 = 10%
<= .0303 = 15%
<= .0418 = 20%
<= .0548 = 25%
<= .0697 = 30%
<= .0884 = 35%
<= .1221 = 40%
<= .1448 = 45%
<= .1751 = 50%
<= .2132 = 55%
<= .252 = 60%
<= .3195 = 65%
<= .3936 = 70%
<= .4719 = 75%
<= .6308 = 80%
<= .7731 = 85%
> <= 1.093 = 90%
<= 1.847 = 95%
<= 7.0335 = 100%

Note: Concentrations at Expected Result, Exposure Factor Variability

IINH2,CHCL3 (in Cell T14)





Note: Concentrations at Expected Result, Exposure Factor Variability

IORAL3,DLDRN (in Cell U15)

@RISK Risk Analysis 27-Aug-1992

==========

Expected/Mean Result = 1.768594E-06
Maximum Result = 1.62246E-05
Minimum Result = 8.411772E-10
Range of Possible Results = 1.622376E-05
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 2.08616E-06
Skewness = 2.66636
Kurtosis = 12.88454
Variance = 4.352064E-12
Simulations Executed = 1
Iterations = 500

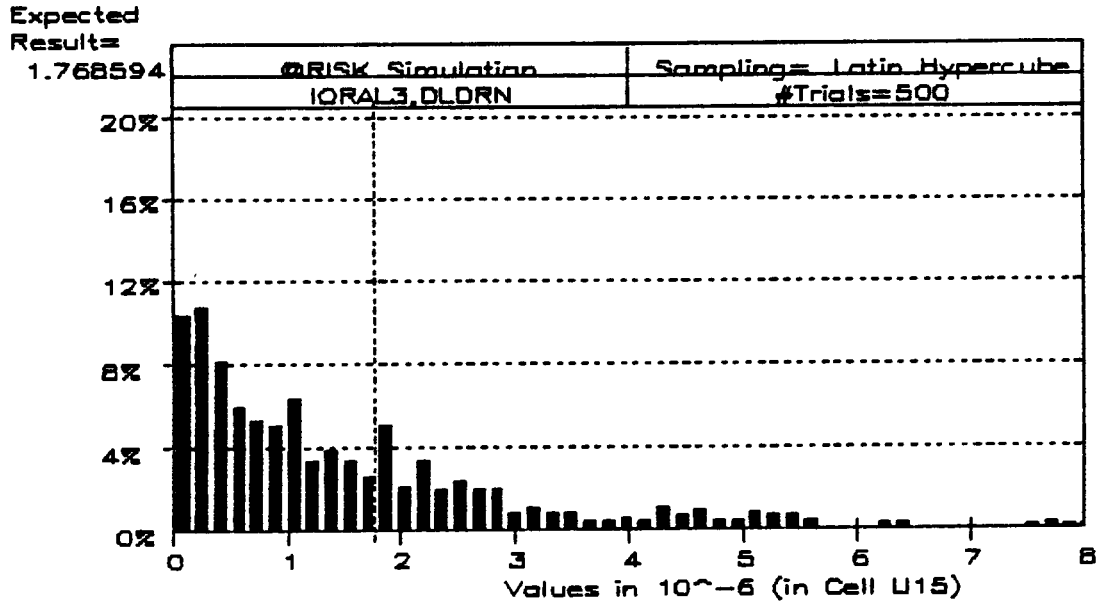
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-5)

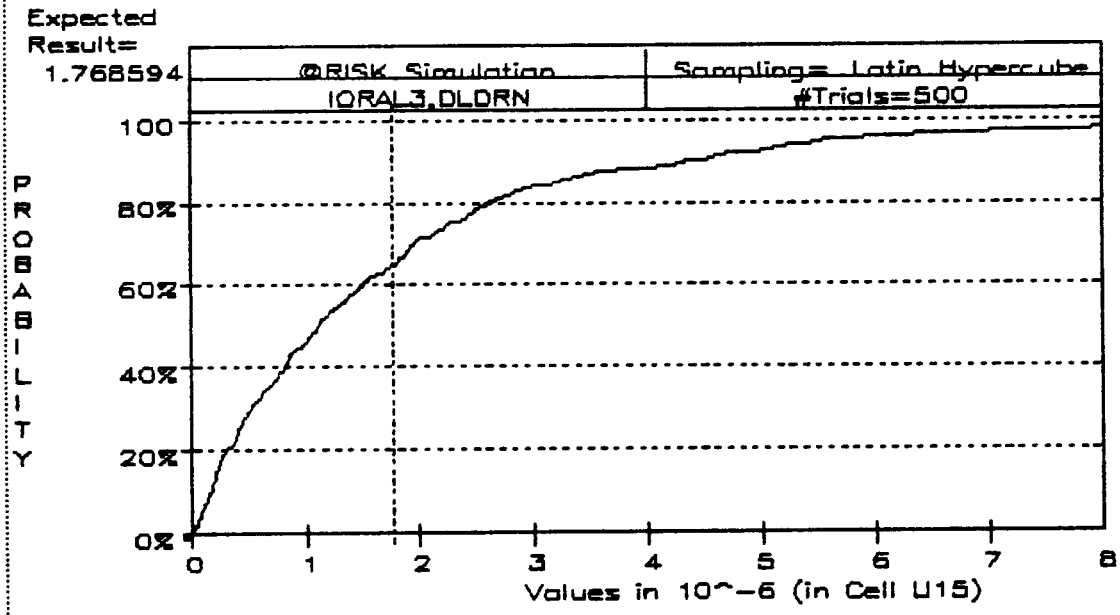
==========

<= .00008 = 0%
<= .0075 = 5%
<= .0154 = 10%
<= .022 = 15%
<= .0296 = 20%
<= .0411 = 25%
<= .0504 = 30%
<= .0654 = 35%
<= .0804 = 40%
<= .0973 = 45%
<= .1099 = 50%
<= .1299 = 55%
<= .1499 = 60%
<= .1787 = 65%
<= .1947 = 70%
<= .2242 = 75%
<= .2611 = 80%
<= .315 = 85%
<= .4336 = 90%
<= .5511 = 95%
<= 1.6225 = 100%

Note: Concentrations at Expected Result, Exposure Factor Variability

IORAL3,DLDRN (in Cell U15)





ARSENIC, LIFETIME
ZONE 4

IORAL4,AS (in Cell U16)

@RISK Risk Analysis 15-Aug-1992

==========

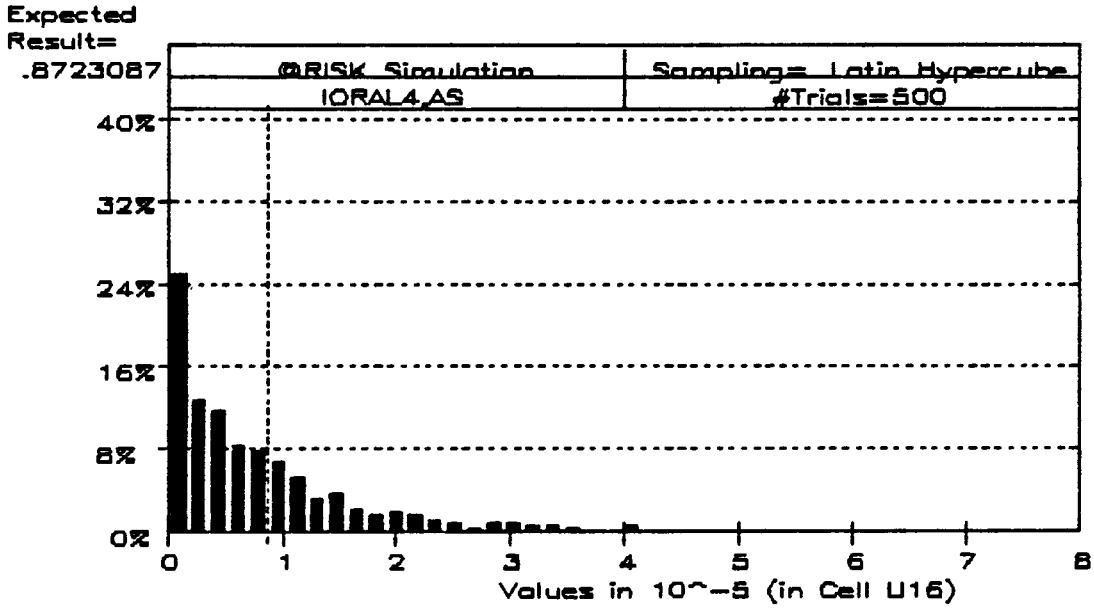
Expected/Mean Result = 8.723086E-06
Maximum Result = 6.914823E-05
Minimum Result = 4.855341E-09
Range of Possible Results = 6.914337E-05
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.023759E-05
Skewness = 2.453925
Kurtosis = 10.93427
Variance = 1.048083E-10
Simulations Executed = 1
Iterations = 500

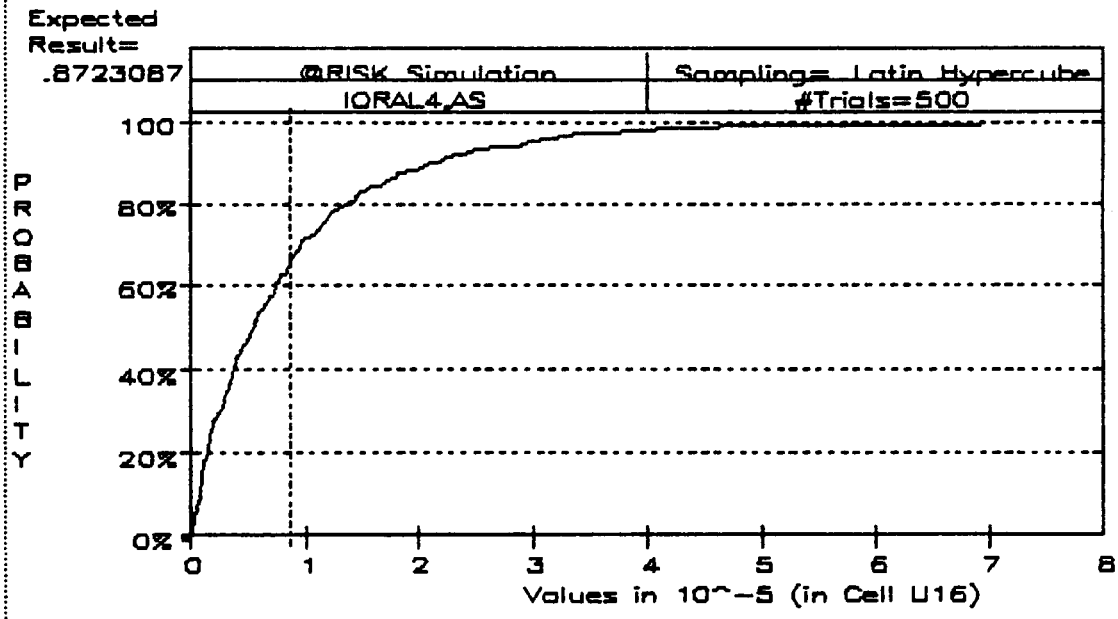
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-5)

==========

<= .0005 = 0%
<= .0323 = 5%
<= .0777 = 10%
<= .0991 = 15%
<= .1382 = 20%
<= .1726 = 25%
<= .2382 = 30%
<= .3113 = 35%
<= .3694 = 40%
<= .4413 = 45%
<= .5373 = 50%
<= .6368 = 55%
<= .7437 = 60%
<= .8578 = 65%
<= .9583 = 70%
<= 1.1486 = 75%
<= 1.3555 = 80%
<= 1.6676 = 85%
<= 2.0867 = 90%
<= 2.9207 = 95%
<= 6.9148 = 100%

IORAL4,AS (in Cell U16)





IGW4,AS (in Cell N16)

@RISK Risk Analysis 15-Aug-1992

==========

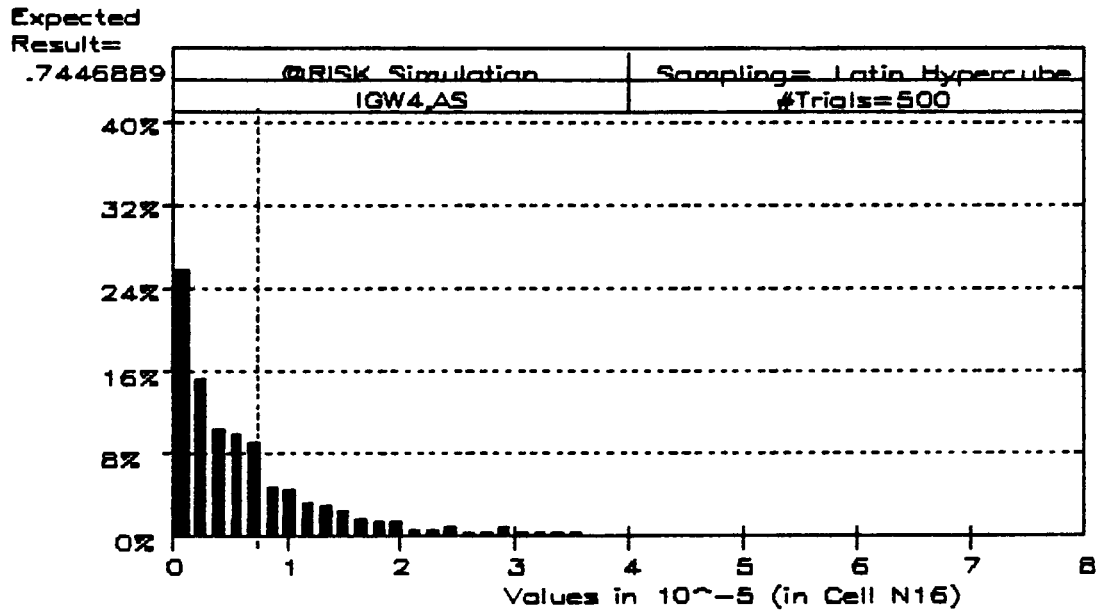
Expected/Mean Result = 7.446889E-06
Maximum Result = 6.275647E-05
Minimum Result = 4.822466E-09
Range of Possible Results = 6.275164E-05
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 9.146112E-06
Skewness = 2.639194
Kurtosis = 11.91961
Variance = 8.365137E-11
Simulations Executed = 1
Iterations = 500

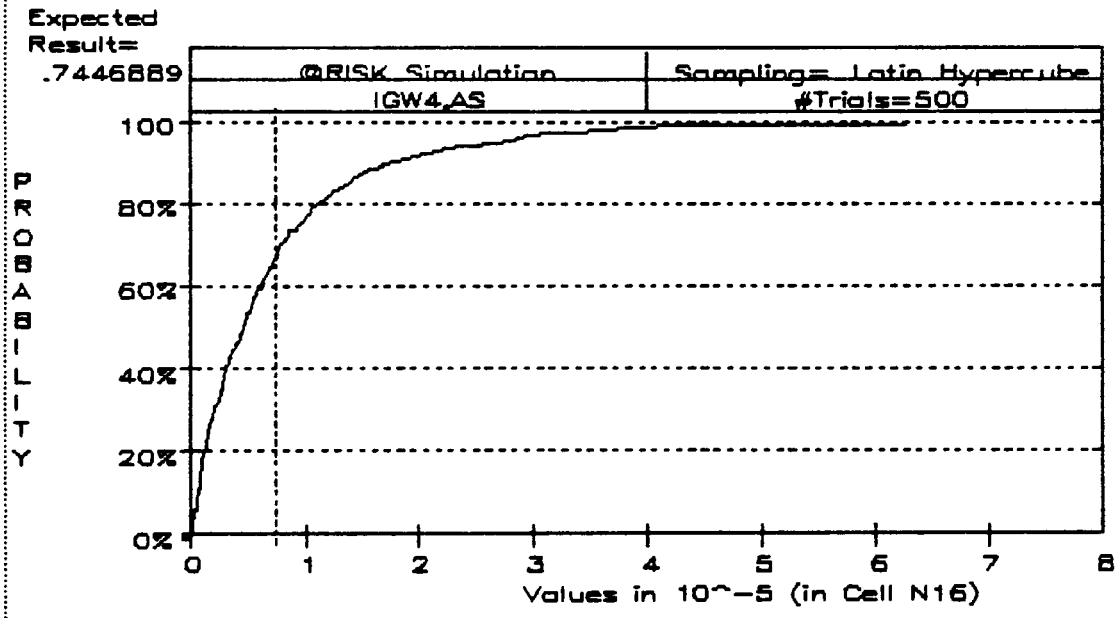
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-5)

==========

<= .0005 = 0%
<= .0289 = 5%
<= .0604 = 10%
<= .0873 = 15%
<= .1175 = 20%
<= .1516 = 25%
<= .2076 = 30%
<= .2707 = 35%
<= .3072 = 40%
<= .3843 = 45%
<= .4535 = 50%
<= .5268 = 55%
<= .6032 = 60%
<= .7014 = 65%
<= .7753 = 70%
<= .9316 = 75%
<= 1.1094 = 80%
<= 1.3703 = 85%
<= 1.8034 = 90%
<= 2.6484 = 95%
<= 6.2756 = 100%

IGW4,AS (in Cell N16)





CGW4,AS (in Cell F18)

@RISK Risk Analysis 15-Aug-1992

==========

Expected/Mean Result = 2.020673E-03

Maximum Result = 3.682617E-03

Minimum Result = 7.039265E-04

Ranmc of Possible Results = 2.978691E-03

Probability of Positive Result = 100%

Probability of Negative Result = 0%

Standard Deviation = 4.223227E-04

Skewness = 5.654126E-02

Kurtosis = 3.198761

Variance = 1.783565E-07

Simulations Executed = 1

Iterations = 500

Percentile Probabilities:

(Chance of Result <= Shown Value)

(Values in 10^-3)

==========

<= .7039 = 0%

<= 1.3211 = 5%

<= 1.4786 = 10%

<= 1.5823 = 15%

<= 1.6637 = 20%

<= 1.7352 = 25%

<= 1.7992 = 30%

<= 1.8581 = 35%

<= 1.9133 = 40%

<= 1.9658 = 45%

<= 2.0195 = 50%

<= 2.0725 = 55%

<= 2.1263 = 60%

<= 2.1805 = 65%

<= 2.2392 = 70%

<= 2.3023 = 75%

<= 2.3734 = 80%

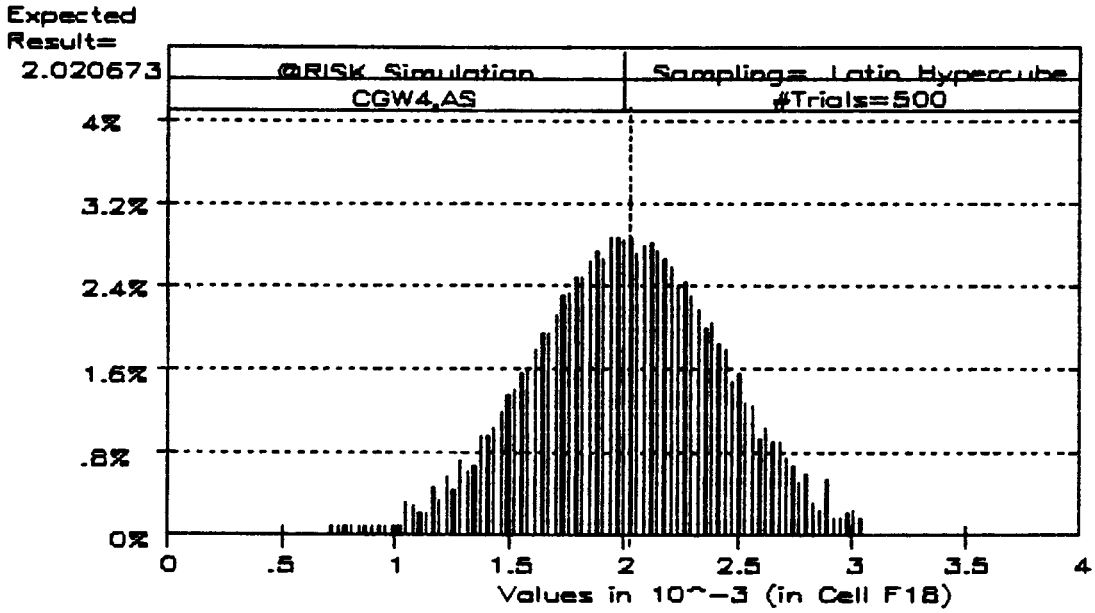
<= 2.4523 = 85%

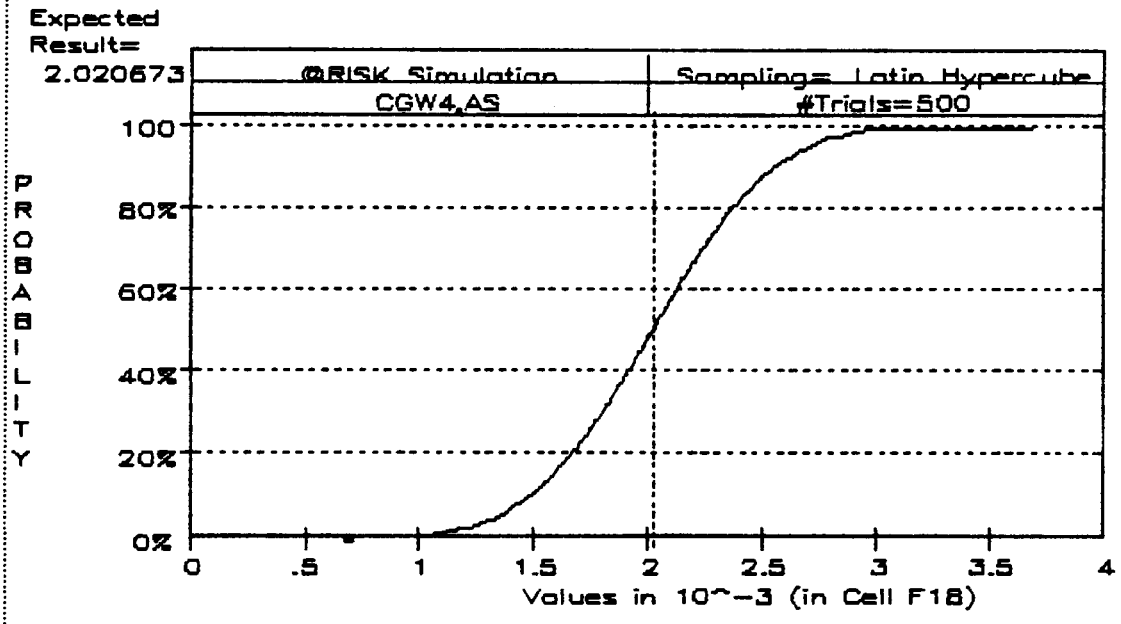
<= 2.5545 = 90%

<= 2.7057 = 95%

<= 3.6826 = 100%

CGW4,AS (in Cell F18)





CV4,AS (in Cell H16)

@RISK Risk Analysis 15-Aug-1992

==========

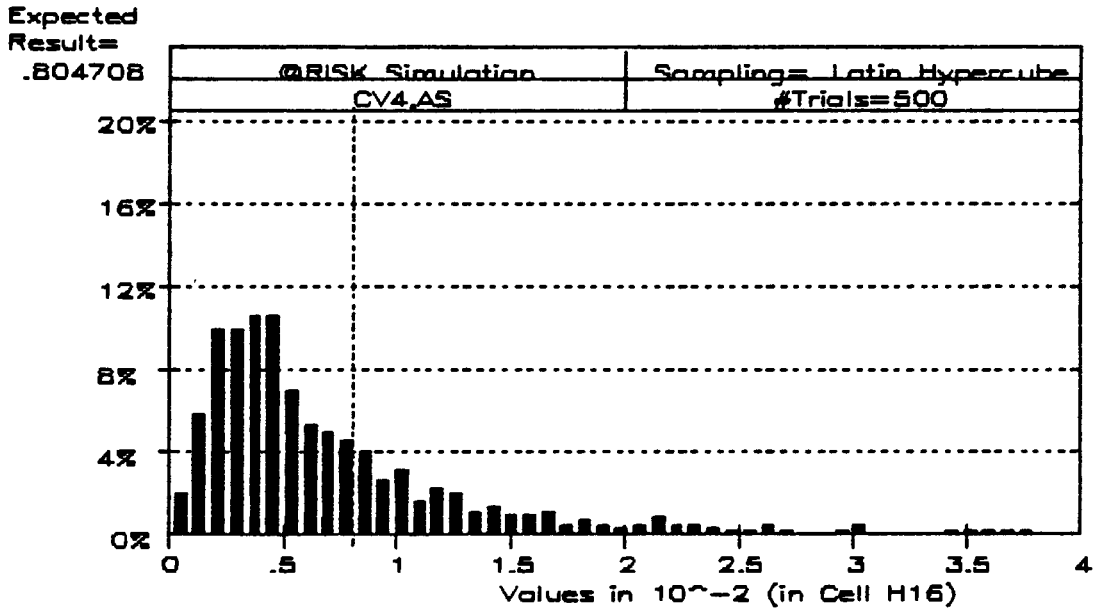
Expected/Mean Result = 8.04708E-03
Maximum Result = .161246
Minimum Result = 1.114812E-04
Range of Possible Results = .1611345
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = .0107165
Skewness = 7.45112
Kurtosis = 91.59088
Variance = 1.148435E-04
Simulations Executed = 1
Iterations = 500

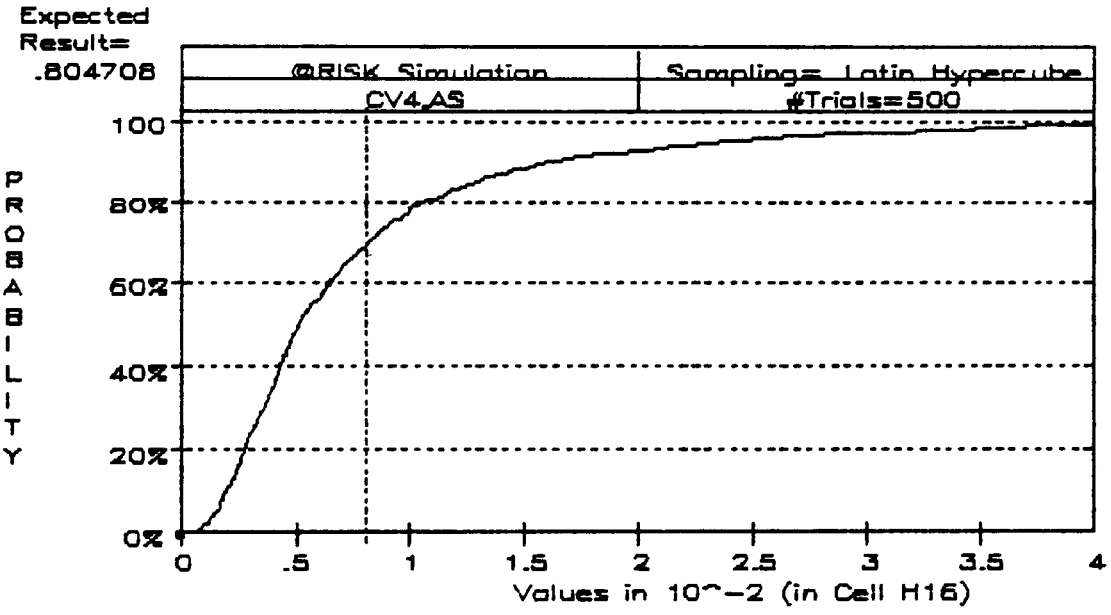
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-1)

==========

<= .0011 = 0%
<= .0136 = 5%
<= .0192 = 10%
<= .024 = 15%
<= .0269 = 20%
<= .0305 = 25%
<= .0352 = 30%
<= .0394 = 35%
<= .0424 = 40%
<= .0467 = 45%
<= .0504 = 50%
<= .0564 = 55%
<= .0639 = 60%
<= .0716 = 65%
<= .09 = 70%
<= .0911 = 75%
<= .1055 = 80%
<= .1269 = 85%
<= .1616 = 90%
<= .2302 = 95%
<= 1.6125 = 100%

CV4,AS (in Cell H16)





CSW4,AS (in Cell D23)

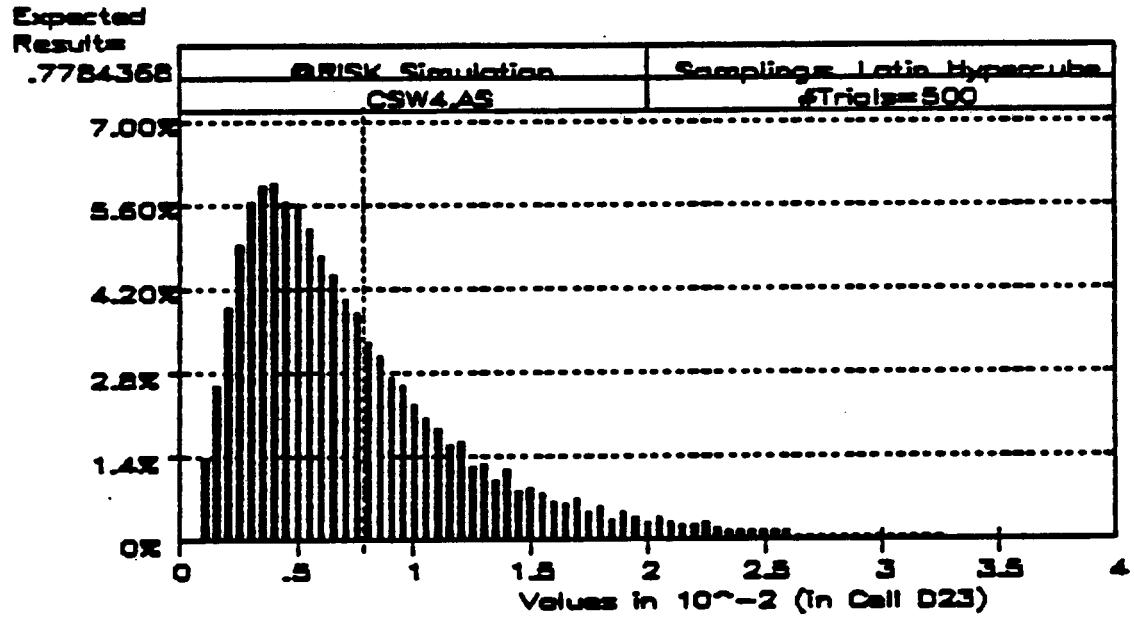
@RISK Risk Analysis 21-Jul-1991

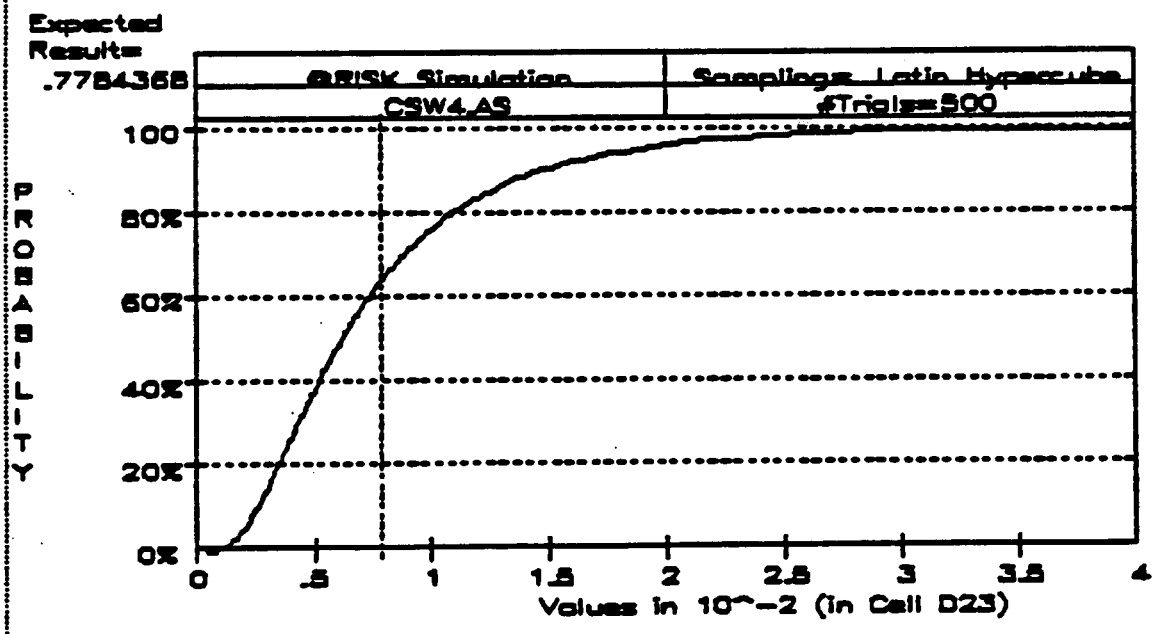
Expected/Mean Result = 7.784368E-03
Maximum Result = 5.053511E-02
Minimum Result = 8.249069E-04
Range of Possible Results = .0497102
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 5.952083E-03
Skewness = 2.427492
Kurtosis = 12.46923
Variance = 3.542729E-05
Simulations Executed = 1
Iterations = 500

Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-2)

<= .0825 = 0%
<= .1972 = 5%
<= .2552 = 10%
<= .3024 = 15%
<= .3449 = 20%
<= .3877 = 25%
<= .4293 = 30%
<= .4725 = 35%
<= .5173 = 40%
<= .564 = 45%
<= .6151 = 50%
<= .6699 = 55%
<= .7324 = 60%
<= .7997 = 65%
<= .8801 = 70%
<= .975 = 75%
<= 1.0935 = 80%
<= 1.248 = 85%
<= 1.478 = 90%
<= 1.8911 = 95%
<= 5.0535 = 100%

CSW4,AS (in Cell D23)





DIELDRIN, LIFETIME
ZONE 6

IORAL6,DLDRN (in Cell U18)

@RISK Risk Analysis 15-Aug-1992

==========

Expected/Mean Result = 2.816432E-07

Maximum Result = 2.100168E-06

Minimum Result = 5.166072E-10

Range of Possible Results = 2.099651E-06

Probability of Positive Result = 100%

Probability of Negative Result = 0%

Standard Deviation = 3.22079E-07

Skewness = 2.179635

Kurtosis = 8.711363

Variance = 1.037349E-13

Simulations Executed = 1

Iterations = 500

Percentile Probabilities:

(Chance of Result <= Shown Value)

(Values in 10^-6)

==========

<= .0005 = 0%

<= .0122 = 5%

<= .0268 = 10%

<= .0356 = 15%

<= .0483 = 20%

<= .0627 = 25%

<= .09 = 30%

<= .1064 = 35%

<= .129 = 40%

<= .1476 = 45%

<= .1678 = 50%

<= .19 = 55%

<= .2256 = 60%

<= .2655 = 65%

<= .3101 = 70%

<= .3715 = 75%

<= .4616 = 80%

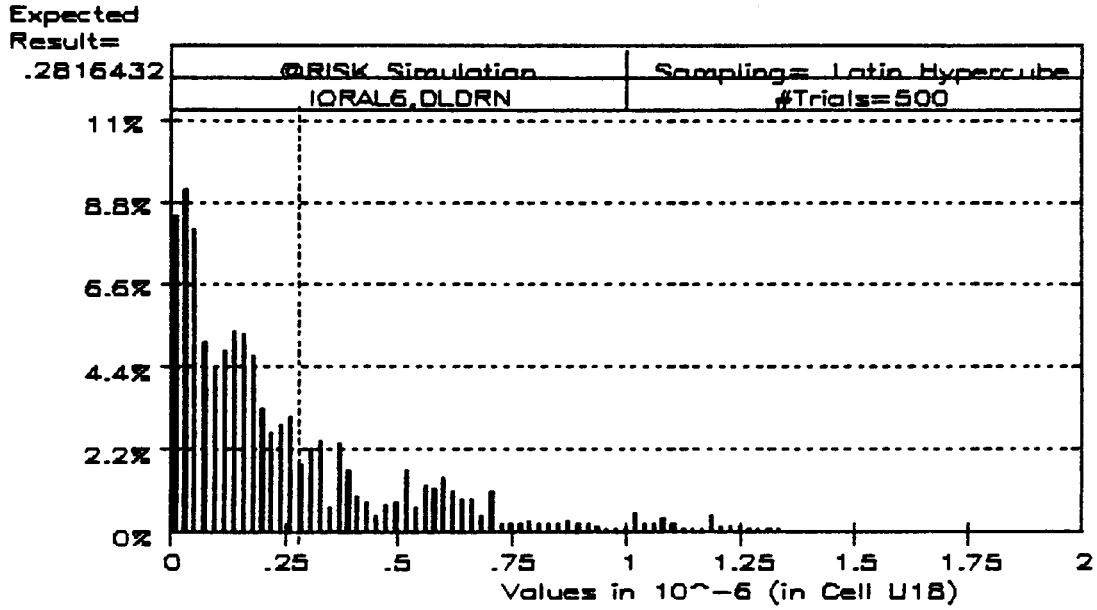
<= .5668 = 85%

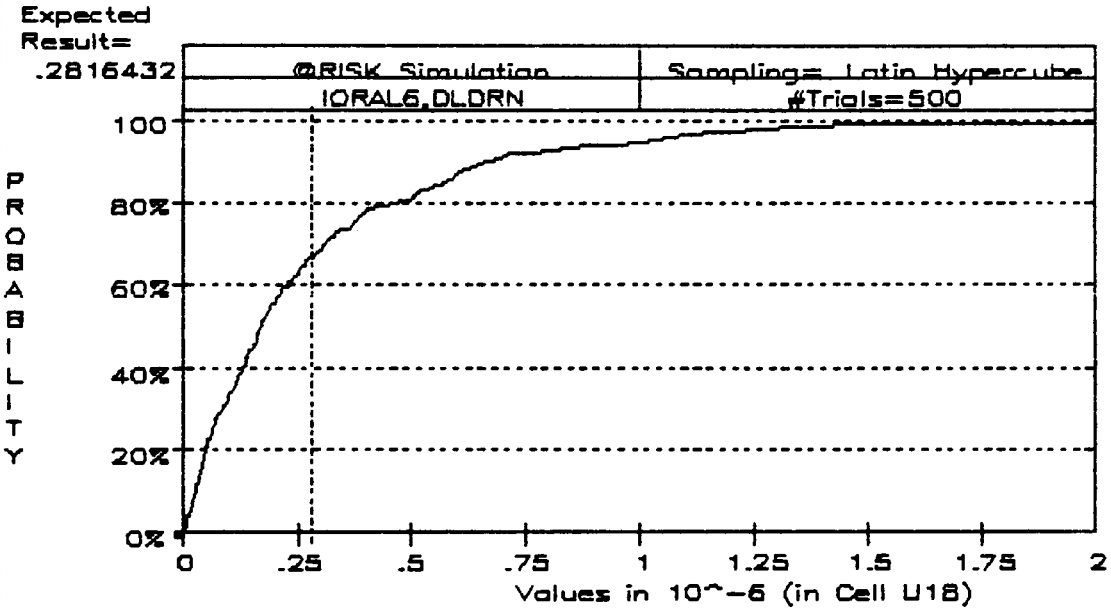
<= .6661 = 90%

<= 1.0102 = 95%

<= 2.1002 = 100%

IORAL6,DLDRN (in Cell U18)





IGW6,DLDRN (in Cell N18)

@RISK Risk Analysis 15-Aug-1992

==========

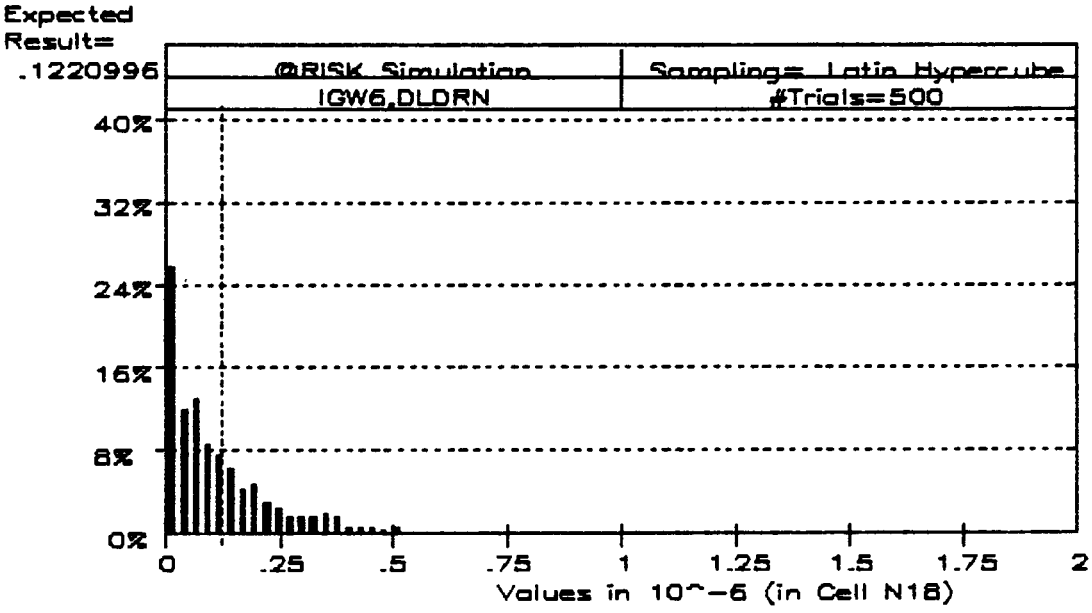
Expected/Mean Result = 1.220996E-07
Maximum Result = 1.03418E-06
Minimum Result = 2.573306E-10
Range of Possible Results = 1.033922E-06
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.348427E-07
Skewness = 2.179644
Kurtosis = 9.861394
Variance = 1.818254E-14
Simulations Executed = 1
Iterations = 500

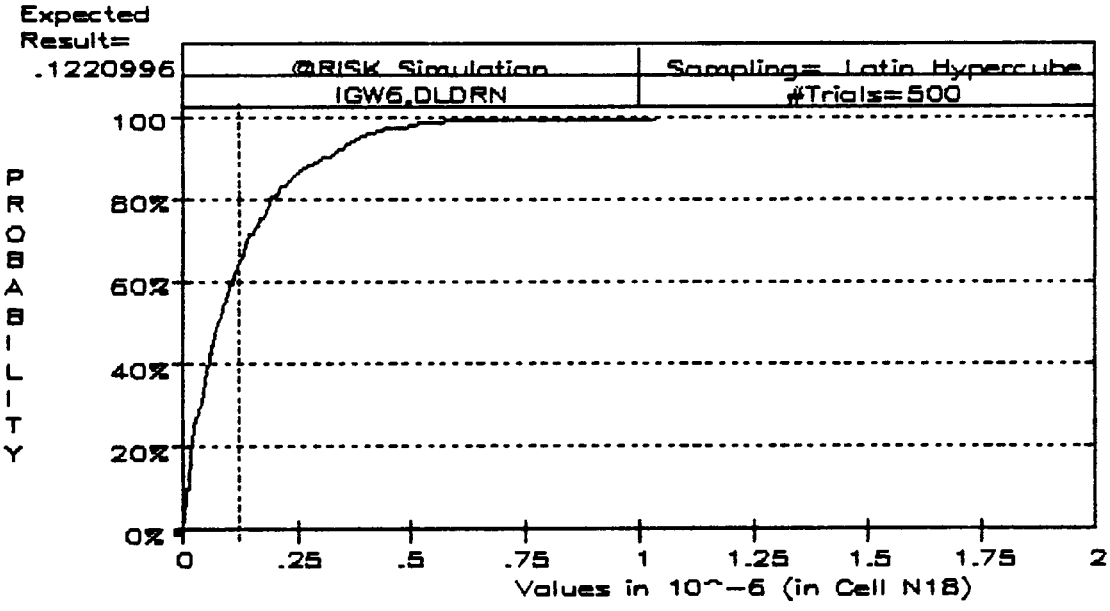
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-6)

==========

<= .0003 = 0%
<= .0052 = 5%
<= .0098 = 10%
<= .0141 = 15%
<= .0182 = 20%
<= .0249 = 25%
<= .0373 = 30%
<= .0476 = 35%
<= .0554 = 40%
<= .0639 = 45%
<= .0768 = 50%
<= .0923 = 55%
<= .1054 = 60%
<= .1234 = 65%
<= .139 = 70%
<= .1701 = 75%
<= .1937 = 80%
<= .2353 = 85%
<= .3059 = 90%
<= .3769 = 95%
<= 1.0342 = 100%

IGW6,DLDRN (in Cell N18)





IV6,DLDRN (in Cell P18)

@RISK Risk Analysis 15-Aug-1992

==========

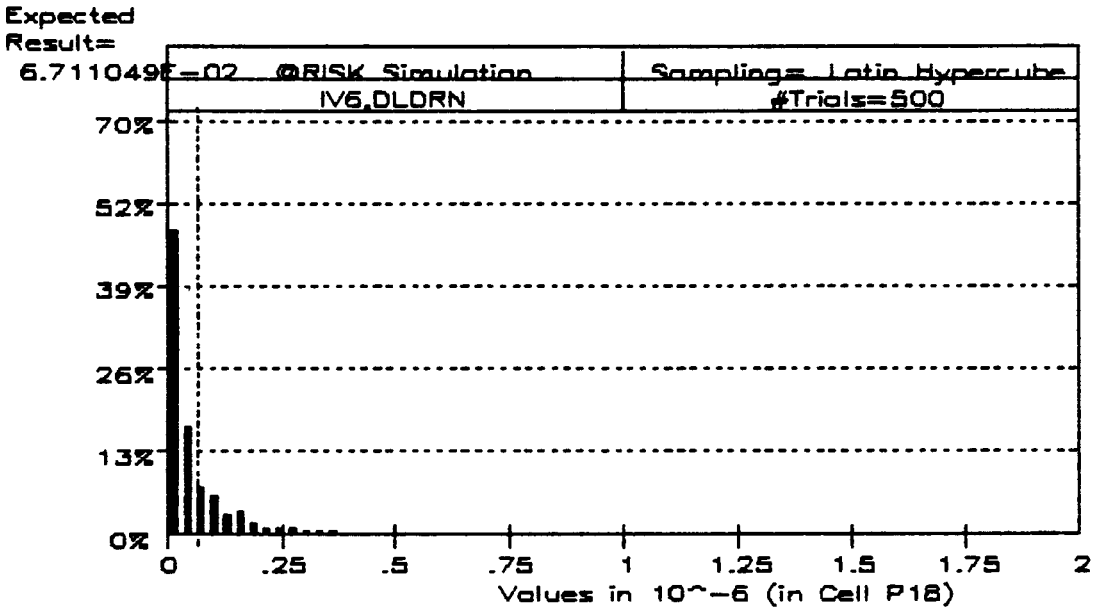
Expected/Mean Result = 6.711048E-08
Maximum Result = 1.150681E-06
Minimum Result = 1.956927E-12
Range of Possible Results = 1.150679E-06
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 1.128892E-07
Skewness = 4.675387
Kurtosis = 35.14173
Variance = 1.274398E-14
Simulations Executed = 1
Iterations = 500

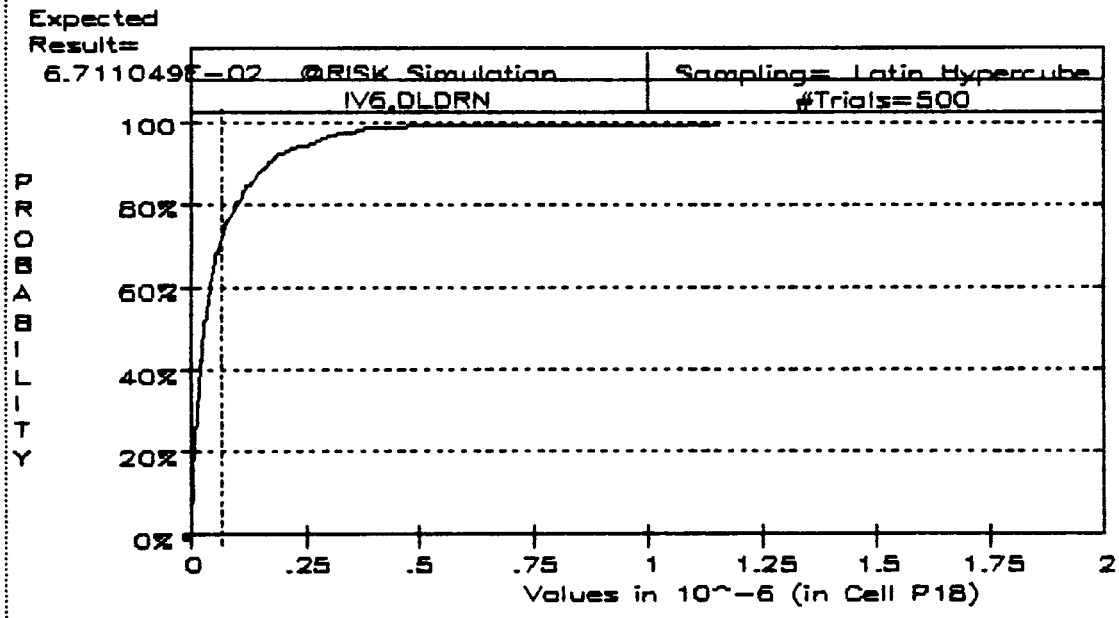
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-6)

==========

<= .000001= 0%
<= .002 = 5%
<= .0028 = 10%
<= .0047 = 15%
<= .0067 = 20%
<= .0094 = 25%
<= .0121 = 30%
<= .0159 = 35%
<= .0201 = 40%
<= .0244 = 45%
<= .0282 = 50%
<= .0337 = 55%
<= .0406 = 60%
<= .0495 = 65%
<= .0597 = 70%
<= .075 = 75%
<= .0985 = 80%
<= .1266 = 85%
<= .169 = 90%
<= .2667 = 95%
<= 1.1507 = 100%

IV6,DLDRN (in Cell P18)





CGW6,ALD+DLD (in Cell D20)

@RISK Risk Analysis 15-Aug-1992

==========

Expected/Mean Result = 6.039856E-05

Maximum Result = 7.109248E-05

Minimum Result = 4.745682E-05

Range of Possible Results = 2.363566E-05

Probability of Positive Result = 100%

Probability of Negative Result = 0%

Standard Deviation = 3.602719E-06

Skewness = 2.887245E-02

Kurtosis = 3.094393

Variance = 1.297958E-11

Simulations Executed = 1

Iterations = 500

Percentile Probabilities:

(Chance of Result <= Shown Value)

(Values in 10^-5)

==========

<= 4.7457 = 0%

<= 5.4661 = 5%

<= 5.5746 = 10%

<= 5.6828 = 15%

<= 5.7276 = 20%

<= 5.7955 = 25%

<= 5.8545 = 30%

<= 5.892 = 35%

<= 5.949 = 40%

<= 5.9772 = 45%

<= 6.0292 = 50%

<= 6.0931 = 55%

<= 6.1233 = 60%

<= 6.1795 = 65%

<= 6.2388 = 70%

<= 6.2831 = 75%

<= 6.3315 = 80%

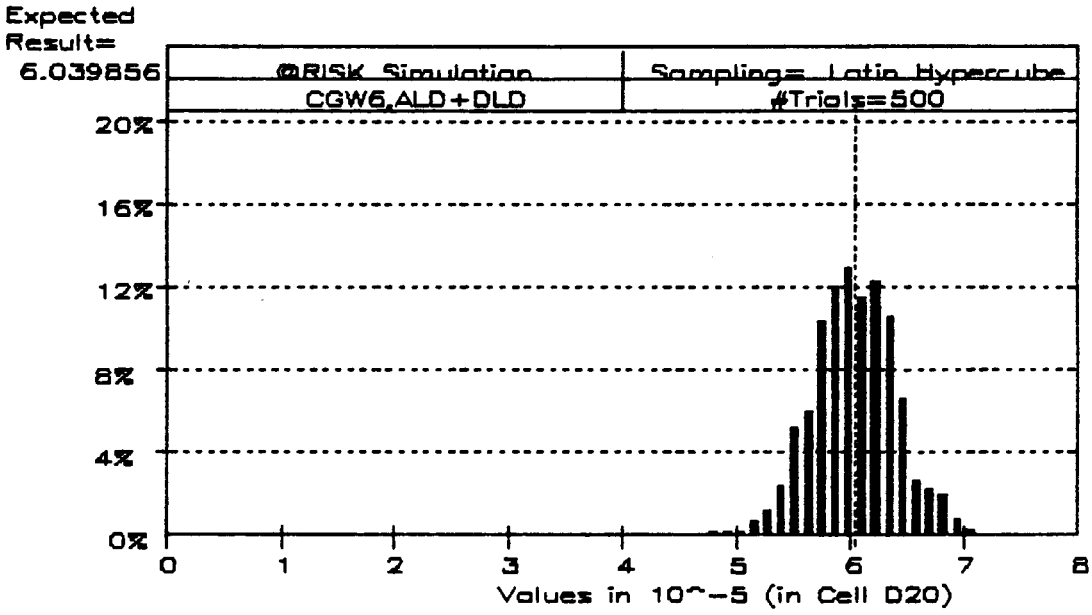
<= 6.3934 = 85%

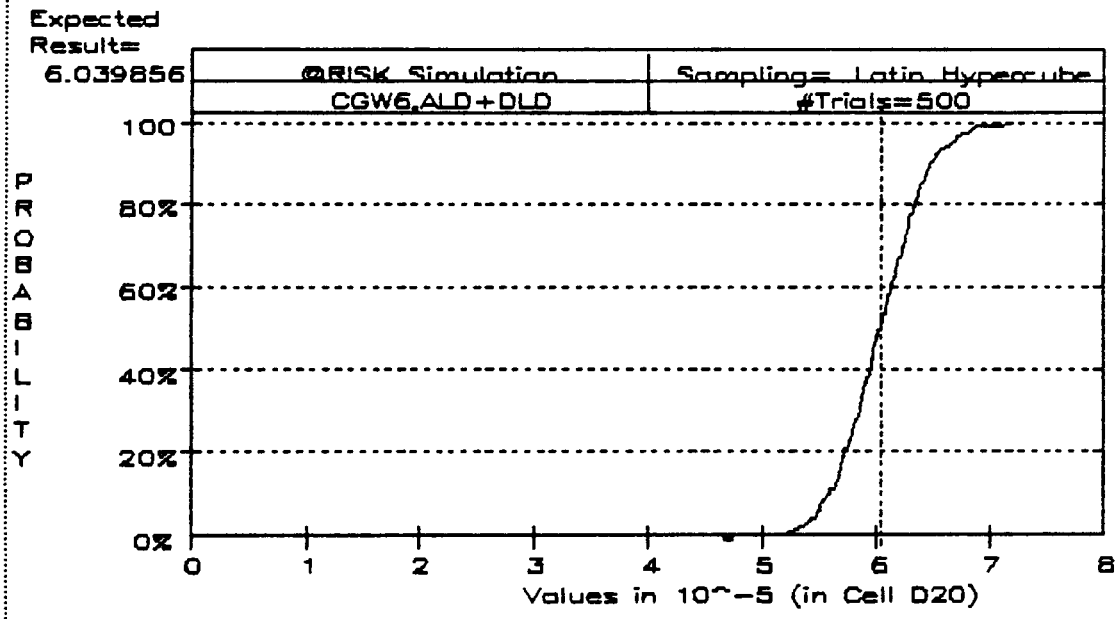
<= 6.4847 = 90%

<= 6.6496 = 95%

<= 7.1092 = 100%

CGW6,ALD+DLD (in Cell D20)





CGW6,DLDRN (in Cell F20)

@RISK Risk Analysis 15-Aug-1992

==========

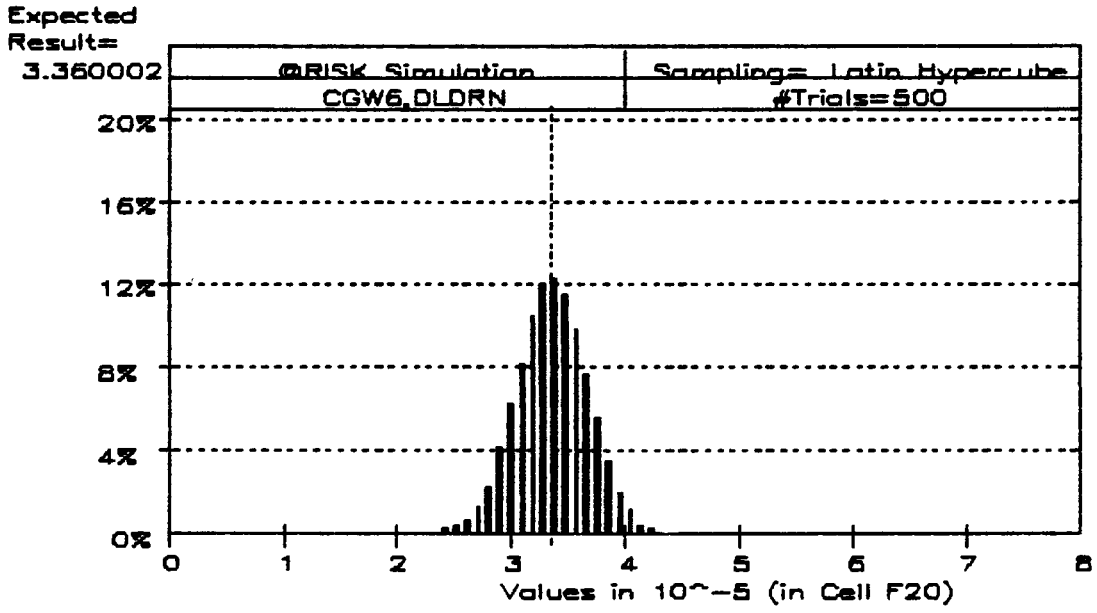
Expected/Mean Result = 3.360002E-05
Maximum Result = 4.280552E-05
Minimum Result = 2.372678E-05
Range of Possible Results = 1.907875E-05
Probability of Positive Result = 100%
Probability of Negative Result = 0%
Standard Deviation = 3.095902E-06
Skewness = -5.035483E-03
Kurtosis = 2.95235
Variance = 9.584607E-12
Simulations Executed = 1
Iterations = 500

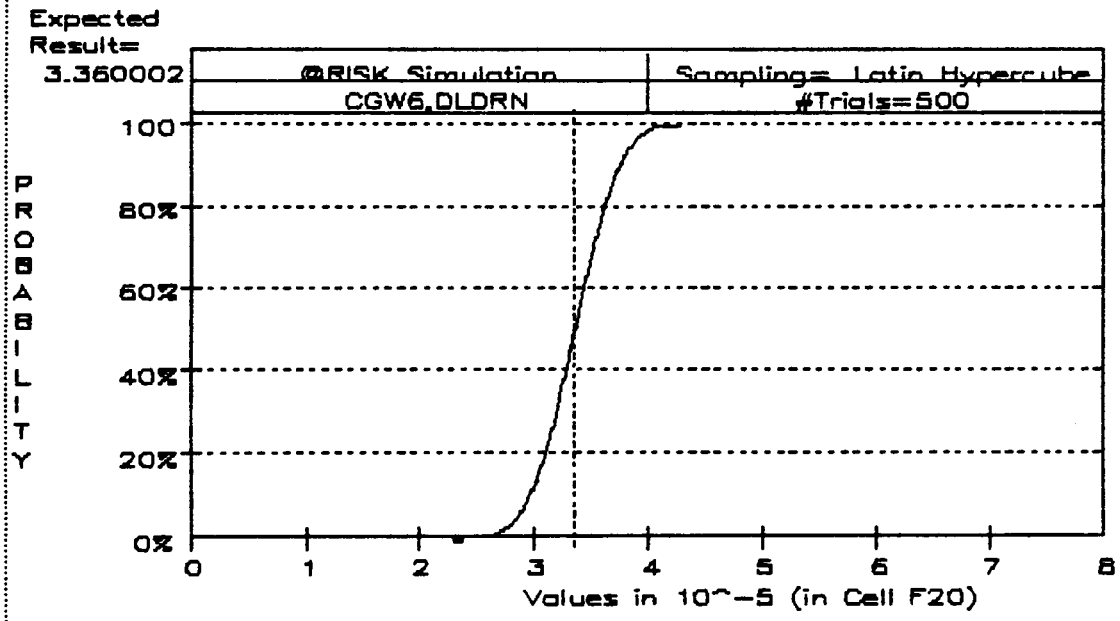
Percentile Probabilities:
(Chance of Result <= Shown Value)
(Values in 10^-5)

==========

<= 2.3727 = 0%
<= 2.8484 = 5%
<= 2.9619 = 10%
<= 3.0363 = 15%
<= 3.0987 = 20%
<= 3.1494 = 25%
<= 3.1961 = 30%
<= 3.2403 = 35%
<= 3.2806 = 40%
<= 3.3202 = 45%
<= 3.3595 = 50%
<= 3.3982 = 55%
<= 3.4372 = 60%
<= 3.4793 = 65%
<= 3.521 = 70%
<= 3.5686 = 75%
<= 3.6191 = 80%
<= 3.6788 = 85%
<= 3.755 = 90%
<= 3.8687 = 95%
<= 4.2806 = 100%

CGW6,DLDRN (in Cell F20)





CV6,DLDRN (in Cell H18)

@RISK Risk Analysis 15-Aug-1992

==========

Expected/Mean Result = 4.667585E-04

Maximum Result = 2.134374E-03

Minimum Result = 4.694644E-05

Range of Possible Results = 2.087427E-03

Probability of Positive Result = 100%

Probability of Negative Result = 0%

Standard Deviation = 3.081423E-04

Skewness = 1.911877

Kurtosis = 8.219741

Variance = 9.495167E-08

Simulations Executed = 1

Iterations = 500

Percentile Probabilities:

(Chance of Result <= Shown Value)

(Values in 10^-3)

==========

<= .0469 = 0%

<= .1358 = 5%

<= .1768 = 10%

<= .2125 = 15%

<= .2322 = 20%

<= .2535 = 25%

<= .2754 = 30%

<= .3028 = 35%

<= .3313 = 40%

<= .3639 = 45%

<= .3958 = 50%

<= .4259 = 55%

<= .4515 = 60%

<= .4979 = 65%

<= .5491 = 70%

<= .5946 = 75%

<= .6398 = 80%

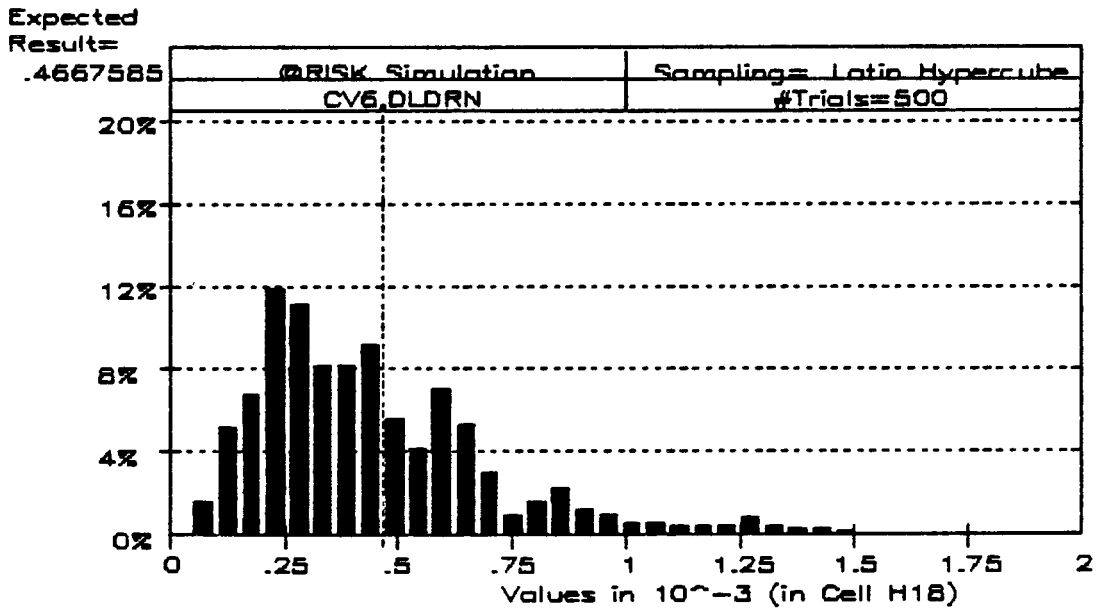
<= .6993 = 85%

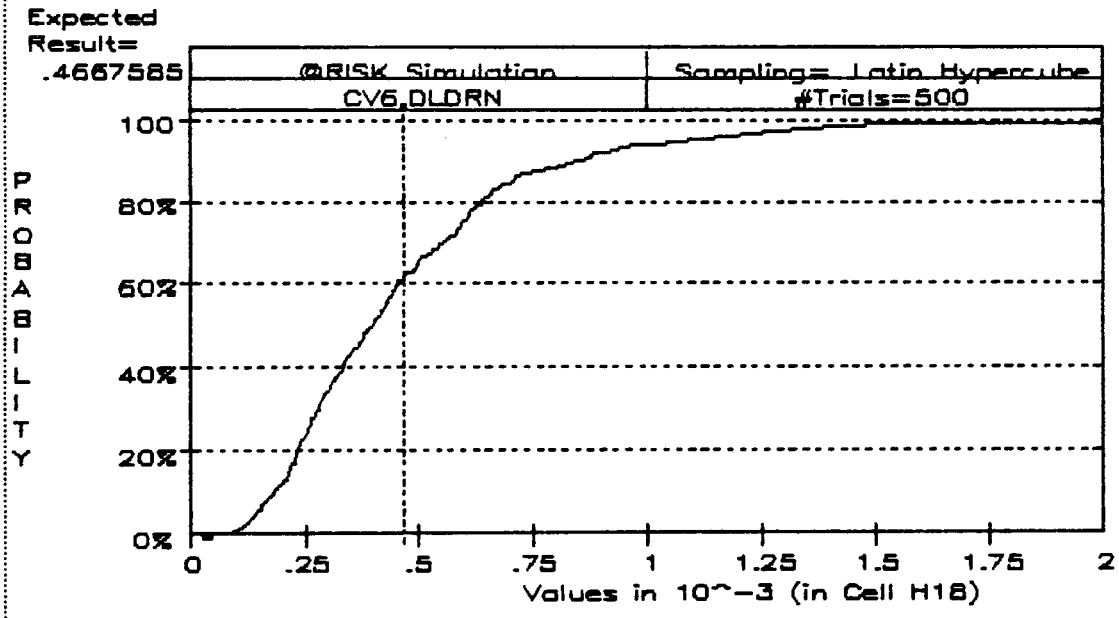
<= .8441 = 90%

<= 1.0587 = 95%

<= 2.1344 = 100%

CV6,DLDRN (in Cell H18)





Appendix F

TOXICOLOGICAL PROFILES OF CHEMICALS OF CONCERN

Appendix F
TABLE OF CONTENTS

Appendix F
TABLE OF CONTENTS
(Continued)

The purpose of this section is to summarize the toxicological information employed in developing the toxicity values used in the risk characterization and in the evaluation of the remedial alternatives for each COC. The toxicity profile for each COC includes a short description of the major fate and transport parameters as well as the toxic effects and the concentrations at which adverse effects are expected to occur in both human and nonhuman receptors. Each toxicity profile consists of three sections. The introductory section provides a brief synopsis of physicochemical and environmental data, including fate and transport information. The second section provides information regarding the toxicity of the contaminant to human receptors, experimental animals, and any human toxicity values that are available. The third section provides toxicity information for nonhuman receptors, concentrating on vegetation, aquatic organisms, and terrestrial organisms, with emphasis on livestock and terrestrial wildlife.

ALDRIN/DIELDRIN

Although aldrin and dieldrin are two distinct compounds, aldrin degrades to its persistent epoxide, dieldrin, in the environment. Photolysis occurs in aqueous solutions and on plant surfaces; most of the conversion is to the epoxide and dieldrin, and less than 5 percent degrades to photodieldrin (Rosenblatt and others, 1975). Hydrolysis of dieldrin is slow; the half-life is approximately four years (Ebasco, 1990).

K_{oc} values for dieldrin range between 1700 and 35,600, and for aldrin they range from 28,200 to 96,000 (Ebasco, 1990). These values indicate that both aldrin and dieldrin will substantially sorb to soils and sediments, resulting in little environmental mobility, and to dissolved organic material, which would enhance mobility (Ebasco, 1990). Additionally, once in soil, aldrin is converted to dieldrin by oxidation, a process that may be enhanced by microorganisms (Rosenblatt and others, 1975). The half-life for the conversion appears to be approximately one year. Dieldrin has a half-life of about seven years in soil (Rosenblatt and others, 1975). Aldrin is reported to evaporate from aquatic environments and from soil if not sorbed (Ebasco, 1990).

Health Effects

During the past 30 to 40 years, a considerable body of information has accumulated on the toxicity of aldrin and dieldrin derived from studies of laboratory animals, domestic animals, and humans under both laboratory and field conditions (Shell, 1990). The oral chronic reference dose (RfD) values for aldrin and dieldrin are 3×10^{-5} and 5×10^{-5} milligrams per kilograms per day (mg/kg/day), respectively (IRIS, 1991). The interim oral subchronic RfD values for aldrin and dieldrin are the same as the chronic values (HEAST, 1991). No inhalation RfDs are available for either compound.

The RfD for aldrin was derived from a study in which rats were fed dietary levels of 0.5 to 150 mg/kg dieldrin for a two-year period (IRIS, 1991). Liver lesions characteristic of chlorinated pesticide poisoning were observed at all dose levels. EPA (IRIS, 1991) states that liver effects were observed at slightly higher doses in several other subchronic-to-chronic rat and dog studies. Based on this, the lowest exposure level of 0.5 mg/kg-feed, which is an approximate daily intake of 0.025 mg/kg/day, was considered the lowest-observed-adverse-effect level (LOAEL).

The dieldrin RfD was derived from a study exposing rats to dieldrin dietary levels of 0.1, 1.0, and 10 mg/kg-feed for two years (IRIS, 1991); these were approximately equal to 0.005, 0.05, and 0.5 mg/kg/day. The animals exposed to the highest dose became irritable, exhibiting tremors and occasional convulsions. Hepatic lesions considered characteristic of organochlorine pesticide (OCP) poisoning were first observed in female rats exposed to the 1.0 mg/kg-feed diet; no effects were reported in the rats receiving a dietary level of 0.1 mg/kg-feed. From these data, the no-observed-adverse-effect level (NOAEL) was established as 0.1 mg/kg-feed level, which is about 0.005 mg/kg/day. Similarly, the LOAEL was set at 1.0 mg/kg-feed, which is approximately 0.05 mg/kg/day.

In humans, following either oral or inhalation exposure, symptoms may occur as a result of a cumulative intoxication, as a culmination of regularly repeated smaller doses, or as an acute convulsive intoxication following an insignificant overdose superimposed on an accumulative intoxication. Available animal and human evidence indicates that the central nervous system (CNS) is the main target organ for acute toxic effects of aldrin and dieldrin (Shell, 1990). Acute

effects on other organ systems, notably liver and kidney, are rarely reported (ATSDR, 1987). Increased liver weights and histological changes in liver cells have been observed in chronic studies involving mice or rats (ATSDR, 1987).

Both compounds were designated by EPA (IRIS, 1991) as B2 (probable human) carcinogens. The carcinogenic classification of B2 indicates that the human carcinogenicity data are inadequate, and animal studies show adequate evidence of carcinogenicity. Two studies cited by EPA (IRIS, 1991) failed to evidence any statistically significant increases in cancers among pesticide manufacturing workers exposed to aldrin and dieldrin. For aldrin, two bioassay studies evidenced significant increases in the occurrence of benign hepatomas or hepatocellular carcinomas in mice when exposed to dietary levels of either 10 mg/kg-feed or 4 and 8 mg/kg-feed (male) and 3 and 6 mg/kg-feed (female) (IRIS, 1991). From these studies, EPA derived an oral slope factor (SF) for aldrin of 17 $(mg/kg/day)^{-1}$. This same value was used as the inhalation SF.

The carcinogenicity of dieldrin was established in several mouse bioassay studies reported by EPA (IRIS, 1991). Depending on the doses, effects ranged from benign liver tumors to hepatocarcinomas and pulmonary metastases. A dietary level of 0.1 mg/kg-feed was the lowest reported effect level in mice (IRIS, 1991). Carcinogenicity has not been confirmed in rats; either the results were insignificant, or the tests were flawed. An oral SF of 16 $(mg/kg/day)^{-1}$ has been calculated from the mouse bioassays; this same value was used as the inhalation SF (IRIS, 1991).

The significance of the liver tumors in mice is widely debated, particularly where there is no other tumor response and where no conclusive genotoxicity can be demonstrated (Shell, 1990). The World Health Organization (WHO, 1989) adds that the available information on aldrin and dieldrin, including human studies, supports the view that for practical purposes, these chemicals make little or no contribution to the incidence of cancer in humans. Epidemiology data gathered from human studies of occupationally exposed individuals have shown that, although many of these individuals had high exposure to aldrin/dieldrin and have been observed for over 25 years, no increase in the incidence of liver cancer among them has been observed (Shell, 1990). WHO

also recommends that research on the carcinogenic mechanics of aldrin/dieldrin should be focused on explaining why the hepatic reaction in the mouse is different from that of other species (WHO, 1989).

No human epidemiological, clinical reproductive, or developmental toxicity data were identified in the reviewed databases (Reprotext, 1991; TERIS, 1991; Shepard, 1991).When pregnant sows were administered oral doses as high as 15 mg/kg/day in the last month of gestation, no fetal changes were reported, but the compound was detected in the fetal tissues (Shepard, 1991); this dose far exceeds the rat LOAEL of 0.05 mg/kg/day. No teratogenic effects were reported in mice exposed to oral doses of 4.0 mg/kg/day (Shepard, 1991).

As part of a study involving several of the chlorinated cyclodiene pesticides, hamsters and mice were given single oral doses of approximately one-half the respective LD_{50} doses on gestational days seven, eight, or nine in the hamster and on day nine in the mouse. A significant number of defects was produced in both species on all the days treated (Shepard, 1991). The resulting malformations in both species were open eye, webbed feet, and cleft palate.

The significance of these findings is questionable because studies in many of the species tested have shown that aldrin/dieldrin are not teratogenic at doses that do not cause overt maternal toxicity and that some of the studies were not designed to conform to current EPA and Organization for Economic Cooperation and Development (OECD) guidelines or standard practices (Shell, 1990).

EPA (IRIS, 1991) reports that aldrin causes chromosomal aberrations in mouse, rat, and human cells and unscheduled DNA synthesis in rat and human cells. Aldrin does not cause reverse mutations or mitotic gene conversion. Similarly, EPA (IRIS, 1991) reports that dieldrin causes chromosomal aberrations in mouse and human cells, forward mutation in Chinese hamster cells, and unscheduled DNA synthesis in rat and human cells. Dieldrin gave negative results in terms of reverse, back, or forward mutations, or in gene conversion assays. However, dieldrin was reported as mutagenic in *Salmonella typhimurium* with or without metabolic activation (IRIS, 1991). Studies reporting an adverse effect of aldrin/dieldrin have been questioned because of

inadequate experimental design, technical problems on the use of high (cytotoxic) doses, and that all in vivo studies have been negative (Shell, 1990).

Toxicity to Nonhuman Receptors

Used as insecticides, neither compound has any herbicidal or fungicidal properties (Osweiler and others, 1985). Dieldrin has been shown to be absorbed through the roots and, to a lesser degree, from foliar surfaces. As no phytotoxicity was reported at soil concentrations as high as 20 mg/kg (Khan and others, 1984), this soil concentration of dieldrin represents the no-observed-effect level (NOEL) and may be considered an acceptable soil level for plants and crops. There is insufficient information from which to derive either a soil or water concentration of aldrin that is protective of vegetation.

Although both compounds are acutely toxic to freshwater animal species at low concentrations, aquatic plants are more resistant. The lowest concentration of dieldrin toxic to aquatic plants is a value of 100 micrograms per liter (μg/l) reported for a 10-day exposure period (EPA, 1980a). Some aquatic invertebrates appear sensitive to dieldrin; 0.2 μg/l was reported as the 30-day LC_{50} (EPA, 1980a). Fish bioassays indicate that the two chemicals have similar toxicities, with LC_{50} values ranging from 1 to 46 μg/l for different species. Rainbow trout are the most sensitive fish species tested in both chronic and acute exposures, evidencing toxic effects in an early life stage study at 0.22 μg/l and reported 96-hour LC_{50} values ranging from 1.1 to 9.9 μg/l (EPA, 1980a). Final acute values (i.e., the concentrations of material protecting 95 percent of the exposed organisms) determined by EPA (1980a) for freshwater species were 2.5 μg/l for dieldrin and 3.0 μg/l for aldrin. The lowest chronic value identified was 0.2 μg/l of dieldrin for freshwater organisms. No chronic values were found for aldrin, but as it is readily converted to dieldrin in the body, the toxicity is considered to be comparable to dieldrin (EPA, 1980a). EPA (1986c) has developed ambient water quality criteria (AWQC) values for these compounds. For dieldrin, the chronic AWQC is 0.0019 μg/l for a 24-hour average, and the acute AWQC is 2.5 μg/l, which should never be exceeded. No chronic AWQC is available for aldrin; the acute AWQC is 3.0 μg/l, which should never be exceeded.

In terrestrial mammals, notably livestock and wildlife, both compounds have the same effects reported for humans and experimental animals, acting primarily as CNS stimulants (Hatch, 1977). Reported toxicity values for livestock indicate that calves are the most sensitive animal. Radeleff (1970) reported minimum oral toxic doses of 5 and 10 mg/kg-bw and maximum nontoxic oral doses of 2.5 and 5 mg/kg/day for aldrin and dieldrin, respectively, for one- to two-week old calves. A minimum toxic dose of 15 mg/kg/day of aldrin for the sheep and 25 mg/kg-bw of aldrin and dieldrin was reported for adult cattle, sheep, and horses, and the dieldrin value for swine was reported to be 50 mg/kg-bw. The acute LD_{50} values of 45 to 50 mg/kg-bw reported for the rabbit indicate that mammals appear less sensitive than birds. In voles, the reported 30-day LD_{50} for aldrin was reported to range from 43 to 129 mg/kg-bw; no value was provided for dieldrin (ESE, 1989).

The symptoms in birds are similar to those observed in other species; that is, changes in behavior and in hepatic cells. Negherbon (1959) reported LD_{50} values for aldrin and dieldrin of 20 to 30 mg/kg-bw for three- to six-week old chicks, LD_{50} values for aldrin and dieldrin reported by Negherbon (1959) for other bird species ranged from 9 mg/kg-bw for partridges to 381 mg/kg-bw for mallard ducks. An LD_{50} value of 6.9 mg/kg-bw was reported for the sharp-tailed grouse (ESE, 1989). For long-term exposure, decreased serotonin, dopamine, and norepinephrine levels were observed in mallard ducks as dietary levels of dieldrin increased from 4 to 30 mg/kg-feed, and increases in hepatic enzymes and liver protein, RNA, and DNA were also observed as dietary levels increased (ESE, 1989). Assuming that a duck eats at a rate of 0.1 kg-feed/kg/day (ESE, 1989), the 4 mg/kg-feed is equivalent to a dose of 0.4 mg/kg/day. In addition, increases in the ratio of brain and liver weight to body weight and behavioral changes, as evidenced by decreased pecking and increased avoidance reaction, were observed as dietary levels increased. Depletion of neurotransmitters was observed in other bird species fed dietary levels of 2 and 16 mg/kg-feed (ESE, 1989). Brain serotonin levels were affected when hens were orally dosed at 10 mg/kg-bw (ESE, 1989). Chickens exposed to dietary dieldrin levels of 10 and 20 mg/kg-feed died before controls during periods of starvation; the 10-mg/kg-feed diet is

equivalent to a dose of 0.52 mg/kg/day (ESE, 1989). Breeding birds on long photoperiods were more susceptible to dieldrin toxicosis than nonbreeding birds (ESE, 1989). Based on available data, the lowest toxic tissue concentration for dieldrin is 0.125 mg/kg in mallard duck brain tissue. As described in the Onpost Biota remedial investigation (RI) (ESE, 1989), this value was used by the Onpost RI to derive a maximum allowable tissue concentration (MATC) of 10 mg/kg. The MATC derived for the Offpost ecological assessment is 1.1 mg/kg on the basis of an American kestrel feeding study (Wiemeyer and others, 1986).

ARSENIC

Arsenic is a metalloid found in the environment as a constituent of either organic or inorganic compounds, with the inorganic forms generally more toxic. It exists in a number of valence states (-3, 0, +3, +5). The form of the arsenic (inorganic versus organic) can change as it moves among media. Similarly, the valence state can change as it is influenced by many factors, including pH and electrical potential (EPA, 1984b).

Chemical speciation plays a major role in the distribution and mobility of arsenic because four different oxidation states are found in the natural environment. Fixation in sediments is pH-dependent (Wauchope and McDowell, 1984); although adsorbed arsenic can be released under anaerobic conditions (Clement and Faust, 1981). Microorganisms can convert As^{+5} to the toxic arsine gas in soil and water (Braman and Foreback, 1973), and volatilization of arsine is a significant release pathway only under extreme reducing conditions (EPA, 1984b). In soils, arsenate ions are readily fixed by many soil components, such as calcium and clay. When combined with some oxides, such as iron or aluminum, the arsenate may be liberated under reducing conditions. Arsenic displays great persistence in soil but is more mobile in water. In both cases, aerobic or anaerobic conditions influence the extent of mobility.

Health Effects

Both form and valence govern the degree of toxicity associated with the form of arsenic being considered. The organic forms, such as monosodium methanearsenate, disodium methanearsenate, and cacodylic acid, are generally less toxic than the inorganic forms.

Furthermore, the pentavalent (+5) form, arsenate, is less toxic than the arsenite, or trivalent (+3) form.

EPA indicates that inorganic arsenic is currently undergoing review by an EPA work group and that RfDs are pending (IRIS, 1991). EPA provides an interim chronic oral RfD of 0.001 mg/kg/day, with the caveat that it is currently under review (HEAST, 1991). The interim subchronic oral RfD is also set equal to 0.001 mg/kg/day (HEAST, 1991). No inhalation RfDs are available.

The oral RfDs are based on the hyperkeratosis and hyperpigmentation observed in the Tseng study of 37 Taiwanese cities (EPA, 1988a), most of which were in areas where arsenic was endemic in the drinking water supply. A correlation existed between the incidence of skin cancer, hyperkeratosis, and hyperpigmentation and the level of exposure to arsenic. Tseng also reported a positive correlation between the presence of a peripheral circulatory disease (Blackfoot disease) and the concentration and duration of intake (EPA, 1988a). The etiology of Blackfoot disease, as described by Tseng, is not fully understood because the water associated with the disease also contained bacteria and ergot alkaloids (Shell, 1990). Blackfoot may be related to a fluorescent arsenic-containing substance present in water where Blackfoot is endemic and others have reported that Blackfoot disease increased when arsenic exposure in drinking water was decreased (ATSDR,1989i).

Following subchronic human oral exposure to approximately 2.5 mg/day as arsenic(+3) or 10.4 mg/day as arsenic sulfides, several organ systems were affected (EPA, 1984b). The major effects involved skin changes, sensimotor polyneuropathy, chronic headache, gastroenteritis, and mild iron deficiency (EPA, 1984b). Similar neurological effects were observed in individuals who consumed about 3 mg arsenic/day in contaminated soy sauce for two to three weeks (EPA, 1984b). Following chronic oral exposure, reported effects included injury to the hematopoietic, renal, and nervous systems. Chronic inhalation of arsenic results in toxicological endpoints similar to those observed following oral exposure.

EPA designated arsenic as a group A (known human) carcinogen by both the inhalation and oral routes. The inhalation carcinogenicity of arsenic is based on numerous studies of smelter

workers, pesticide applicators, and pesticide manufacturing personnel (IRIS, 1991). From these data, an inhalation SF of 50 $(mg/kg/day)^{-1}$ has been determined. In evaluating the oral carcinogenicity of arsenic, two key factors were considered: the potential nutritional essentiality of arsenic and the type of skin cancer associated with exposure to arsenic. In terms of nutritional essentiality, studies in farm animals (chickens and goats) have indicated that arsenic is an essential nutrient. Arsenic-deficient diets led to adverse growth and reproductive effects. Evidence, however, is inconclusive among humans. Regarding the type of skin cancer associated with arsenic carcinogenicity, the most common cancer is a basal cell carcinoma, which generally does not metastasize and has little potential for causing death (EPA, 1988a). EPA has rescinded the oral cancer SF for arsenic, citing that it is currently under review by an EPA work group. In the interim, EPA has proposed an oral unit risk of 5×10^{-5} $(\mu g/l)^{-1}$ (EPA, 1988a); this states that the risk is 5×10^{-5} for a 70-kg adult who drinks 2 l/day of water containing 1 $\mu g/l$ arsenic for a 70-year lifetime. The equivalent oral SF is 1.75 $(mg/kg/day)^{-1}$. Although a number of limitations (the primary basis for the derivation of the slope factor) are associated with the Tseng study, thus casting some doubt on the precise quantitative value calculated, the conclusion that arsenic ingestion does increase the risk of skin cancer remains unchallenged (ATSDR, 1989i).

Evidence suggests arsenic can have reproductive effects in humans. Increased miscarriages and birth defects were reported in employees and women living near a metal smelter in Sweden and Finland, but exposures were mixed with other metals and toxic gases (Reprotext, 1991; Shepard, 1991). Clinical experience indicates that arsenic is not of particular danger as incidences of arsenic poisoning of pregnant women ended in normal offspring (Reprotext, 1991). In addition, organic arsenicals have been used during pregnancy to treat congenital syphilis in the fetus with apparently no ill effect on the unborn (Reprotext, 1991). It was at one time suggested that occupational exposure to arsenic caused testicular injury, but this has not been substantiated in subsequent studies (Reprotext, 1991).

There have been many studies on reproductive effects of arsenic and its compounds in laboratory animals. Generally, the maximum activity for inducing birth defects in animals was at doses that were equally toxic to the mothers (Reprotext, 1991). While the trivalent (+3) form was

more active than the pentavalent (+5), the route of exposure was important; both were less active when exposure was oral rather than when injected (Reprotext, 1991).

Mice injected with a single dose of 45 mg/kg arsenate (+5) during gestation on days 6 through 11 produced fetuses with exencephaly, agnathia, anophthalmos, and a few cleft palates. Skeletal defects were also present. In preliminary experiments with sodium arsenite (+3), the same spectrum of defects was produced in mice exposed to 10 mg/kg pentavalent arsenic (Shepard, 1991). In oral studies, mice administered doses up to 40 mg/kg/day for three consecutive days demonstrated decreased fetal weights, and a single dose of 40 to 45 mg/kg-bw given on any gestation day between days 8 and 15 produced adverse effects in developing mice (EPA, 1984b). Mouse diets containing up to 100 mg trivalent arsenic/kg diet (approximately 5 mg/kg/day) fed throughout pregnancy had no effect on the offspring (EPA, 1984b). Four-day-old chick embryos administered 0.20 mg of sodium ortho arsenate (+5) evidenced stunting, mild micromelia, impaired feather growth, and swelling of the abdomen as 18-day-old chicks (Shepard, 1991). Hamsters treated with 15 to 25 mg/kg of disodium arsenate (+5) on gestational day eight produced fetuses with a high incidence of anencephaly (Shepard, 1991). In a later study, the rate of neural tube defects from pentavalent arsenic in hamsters could not be decreased by constant infusions of folic acid (Shepard, 1991). In rats, post-implantation losses increased following exposure to 0.0025 mg/kg over seven months (Reprotext, 1991).

Potassium arsenate (+5) was not teratogenic in ewes at the comparatively low dose of 0.5 mg/kg (Reprotext, 1991). There was no effect on fertility in a multigeneration study in which mice were provided a diet containing from 0.025 to 215 mg/kg potassium arsenate (Reprotext, 1991).

Toxicity to Nonhuman Receptors

There is no evidence that arsenic is an essential nutrient in vegetation, but small amounts of arsenic can stimulate growth (Adriano, 1986). In soil, arsenic may displace phosphate ions, thereby increasing growth; conversely, the application of phosphate to arsenic-containing soil may release arsenic, leading to crop toxicity. The form of arsenic in soil influences the uptake. Trivalent arsenic (+3) is not readily translocated because it is highly toxic to cell membranes once absorbed. Arsenic trioxide (As^{+3}) can be absorbed by the roots but not translocated within the plant. Pentavalent arsenic (+5) is less toxic and, therefore, more readily translocated (Speer, 1973). In the organic form (i.e., monosodium methanearsenate [MSMA], disodium methanearsenate [DSMA], cacodylic acid), arsenic is readily taken up and translocated to shoots and reproductive tissue (Adriano, 1986). Soil temperature and plant genotype were identified as important factors in the rate of uptake from contaminated soils (Merry and others, 1986). Symptoms of phytotoxicity include the wilting of new-cycle leaves followed by cessation of growth, discoloration, and necrosis of leaf tips (Liebig, 1965). Adriano (1986) reports that crops evidence varying levels of tolerance to arsenic in soil. Members of the bean family, rice, and most legumes are sensitive to arsenic in most forms. The most sensitive plant was spinach, for which a soil concentration of 19 mg/kg was reported to lead to a 50-percent reduction in growth (Woolson and others, 1973). An uncertainty factor of 10 may be applied to a soil value of 19 mg/kg to provide a soil TRV of 1.9 mg/kg for plants and crops.

In aquatic systems, arsenic exists naturally in living aquatic organisms, but little is known concerning the mechanisms of toxicity to the organisms. Two possible modes of toxicity are enzyme inhibition through reaction of trivalent arsenic(+3) with the sulfhydryl groups of proteins and the uncoupling of oxidative phosphorylation by pentavalent arsenic (+5) (EPA, 1985a). In evaluating the toxicity of arsenic to aquatic systems, 95- to 100-percent mortality within two weeks was reported in several species of algae and a submerged macrophyte (*Potamogeton sp.*) exposed to 2320 µg/l sodium arsenite (+3) (ESE, 1989). A 50-percent growth reduction was observed in the alga, *Selenastrum capricornatum*, after a four-day exposure to 31,200 µg/l of

sodium arsenite (ESE, 1989). There is a wide range of toxicity to pentavalent arsenic, with decreased algal growth reported at levels of sodium arsenate from 48 to 202,000 μg/l (EPA, 1985a).

Invertebrates evidenced a wide range of acute toxicity values, with trivalent arsenic values ranging from 812 μg/l for a cladoceran to 97,000 μg/l for a midge; pentavalent arsenic values ranged from 850 to 49,600 μg/l for cladocerans (EPA, 1986). Acute toxicity values for freshwater fish ranged from 13,340 to 41,760 μg/l. Rainbow trout are the most sensitive with a reported LC_{50} of 10,800 μg/l for trivalent arsenic. Decreased survival and growth were reported in bluegill chronically exposed to 4000 μg/l sodium arsenite (+5) in water, and behavioral changes were reported in goldfish (*Carassius auratus*) exposed to 100 μg/l of arsenic in water for 48 hours (ESE, 1989).

Ambient water quality criteria are available for arsenic. Total recoverable arsenic (+3) should not exceed either a four-day average concentration of 190 μg/l (chronic exposure) or a one-hour average of 360 μg/l (acute exposure) more than once every three years (EPA, 1986). EPA (1986b) states that data are insufficient for deriving AWQC for pentavalent arsenic, but indicates that aquatic plants are the most sensitive with toxicity reported at 48 μg/l, and 850 μg/l is reported as the LOEC for the invertebrates with an acute-chronic ratio of 28. Dividing the LOEC by the ratio provides a value of 30 μg/l, which is below the aquatic plant LOEC.

Organic arsenicals are not as toxic to plants and animals as the inorganic forms. The former are used as feed additives in livestock, primarily swine, to improve feed efficiency (Osweiler and others, 1985). Absorption of the organic forms is poor, and excretion through the kidneys is rapid; 90 percent of a single 10-mg/kg dose to goats and sheep is excreted within 120 hours (Shariatpanahi and Anderson, 1984). In livestock, as in aquatic organisms, arsenic reacts with sulfhydryl groups, thereby inhibiting any sulfhydryl enzyme systems, many of which are essential to proper health (Klaassen, 1985). As with plants, by substituting for phosphorus, arsenic uncouples oxidative phosphorylation; thereby substituting labile arsenylated oxidation products for stable phosphorylated intermediates (Riviere and others, 1981; Klaassen, 1985). Chronic toxicosis

from phenylarsonic compounds involves peripheral nerve degeneration, which leads to ataxia and may progress to quadriplegia (Ledet and others, 1973). There is inadequate evidence of cancer in animals. A NOEL for inorganic trivalent arsenic of 720 mg/day following a two-year exposure was reported for the horse (Radeleff, 1970); for a 550-kg horse, this is equivalent to 1.3 mg/kg/day. Osweiler and others (1985) report that the lethal oral dose in most species of animals appears to be from 1 to 25 mg/kg-bw as sodium arsenite (+3), whereas the trivalent form as arsenic trioxide is three to ten times less toxic. For cattle, a value of 1 g/day, which is equivalent to 1.3 mg/kg/day for the dairy cow, is reported as the oral lethal dose for sodium arsenite (+3) (Hatch, 1977). In wild rabbits, a toxic dose of 10.5 mg/kg-bw arsenic was reported for copper acetoarsenite; however, the copper may play a role in the reported toxicity. Higher doses were reported for other arsenic compounds (ESE, 1989). White-tailed deer evidenced toxicity at a total dose of 923 mg sodium arsenite (ESE, 1989). For mice, Gough and others (1979) report a 96-hour LD_{50} of 11.2 mg/kg-feed, which is equivalent to 1.6 mg/kg/day.

On a mg/kg/day basis, chickens are more tolerant of arsenic than other livestock, showing no ill effects at intake levels of organic arsenicals that were toxic to sheep and cattle (Palmer, 1972). For chickens, the lowest oral lethal dose of trivalent arsenic as arsenic trioxide and sodium arsenite reported is 50 and 10 mg, respectively (Hatch, 1977); these are equivalent to doses of 15 and 2.3 mg/kg/day, respectively. In ducklings, dietary levels of 600 ppm sodium arsenilate for four weeks led to a selenium-vitamin E deficiency. This represents a subchronic LOAEL; assuming that a duckling eats 0.1 kg-feed/kg/day (ESE, 1989), this is equivalent to an arsenic intake of 18.9 mg/kg/day. The safe level of organic arsenic in the diet of young turkeys ranges from 5 to more than 3200 ppm for various organic arsenicals (ESE, 1989). In considering the potential toxicity to avian predators, the bioaccumulation factor must be considered because the primary exposure for animals at the top of the food chain is through the ingestion of contaminated animals. Based on data describing tissue concentrations of cowbirds following exposure to known food concentrations, a bioaccumulation factor of 0.08 was calculated (ESE, 1989). The cowbird data were also used to derive a MATC for the Biota RI, which represents the highest observed

tissue level at which no effects were observed. For the cowbird, the MATC is 0.074 mg/kg. There appears to be only a small margin of safety as toxicity may occur at a tissue level of 2 mg/kg (ESE, 1989).

ATRAZINE

Atrazine has been the most heavily used herbicide for both nonselective and selective weed control in the United States over the past 30 years (EPA, 1988b). With a solubility of 70 mg/l and a K_{oc} value of 149 (Ebasco, 1990), atrazine is reported as moderately to highly mobile in the environment dependent upon the soil type (EPA, 1988b). Because atrazine has a low vapor pressure (3×10^{-7} mm Hg at 20°C), vaporization is a minor transport pathway from waters and soil. Although stable in neutral pH waters, atrazine destabilizes as the water becomes either acidic or alkaline (Ebasco, 1990). Atrazine is persistent in soil, with a reported half-life of three to six months in sandy or clay loam soils (Ebasco, 1990).

Under aerobic conditions, atrazine degrades in soil by photolysis and microbial degradation processes, with degradation products of mobile dealkylated metabolites, immobile hydroxy-atrazine, and bound residues (EPA, 1988b); however, atrazine was reported as stable in ground-water following 15 months in the dark at 10° to 25°C (EPA, 1988b). Atrazine dissipated as a result of leaching and dilution under aquatic field conditions (EPA, 1988b).

Health Effects

EPA has withdrawn the chronic oral RfD pending review (IRIS, 1991). A value of 0.005 mg/kg/day is reported as both the interim chronic and subchronic oral RfD (HEAST, 1991). No inhalation RfDs are available.

The oral RfDs are derived from two studies: a feeding study using dogs and a two-generational reproduction rat study. Following a two-year exposure to dietary levels of 15, 150, and 1000 mg/kg, the LOEL was established at 150 mg/kg (4.97 mg/kg/day) based on cardiac effects in female dogs (IRIS, 1991). The NOEL is, therefore, 15 mg/kg-feed (0.48 mg/kg/day). In the reproduction study, based on the observation of decreased growth in the offspring of the second

generation, the reproductive NOEL and LOEL values were 10 and 50 mg/kg-feed (0.5 and 2.5 mg/kg/day), respectively. The parental NOEL and LOEL were 50 and 500 mg/kg-feed (2.5 and 25 mg/kg/day), respectively (IRIS, 1991).

A severe contact dermatitis was reported following an acute dermal exposure (EPA, 1988b). Although other chemicals may also have been involved, atrazine is a skin irritant in animal studies. In other studies, rats gavaged at 3000 mg/kg-bw evidenced lung, liver, kidney, and splenial damage as well as cardiac dilation, cerebral edema, and necropsy. The reported dose is approximately twice the reported rat LD_{50} of 1869 mg/kg (EPA, 1988b).

A second dog chronic feeding study indicated that increased heart and liver weights resulted from exposure to 150 mg/kg-feed, determined in this case to represent 3.5 mg/kg/day. Because 3.5 mg/kg/day was identified as the LOAEL, 15 mg/kg-feed (0.35 mg/kg/day) was established as the NOEL (EPA, 1988b). In an oncogenicity study, rats evidenced decreased weight gains at a feed level of 500 mg/kg-feed, equivalent to 25 mg/kg/day; this level represents an LOAEL, and 70 mg/kg-feed (3.5 mg/kg/day) represented NOEL. In this study, mammary gland tumors in females were observed at above 3.5 mg/kg/day (EPA, 1988b).

EPA recently classified atrazine as a class C (possible) carcinogen by both the oral and inhalation routes. No inhalation slope factor is available, but EPA published (HEAST, 1991) an oral slope factor of 0.22 $(mg/kg/day)^{-1}$. This classification and slope factor is based on a two-year dietary study in which rats exposed to atrazine developed mammary gland adenomas, fibroadenomas, adenocarcinomas, and sarcomas.

Mutagenicity was reported in lymphocyte cells collected from agricultural workers exposed to herbicides, including atrazine. The data regarding the mutagenicity of atrazine are mixed. Chromosomal aberrations as well as dominant and sex-linked recessive lethal mutations have been reported, and other studies were either negative or equivocal in their results (EPA, 1988b). Regarding reproductive effects, in addition to the LOAEL of 50 mg/kg-feed (2.5 mg/kg/day) reported for the RfD calculation, a NOAEL of 100 mg/kg-feed (5 mg/kg/day) was determined

from a rat study; however, first-generation parental feeding patterns changed in the course of the study.

Developmental effects, evidenced as retarded skeletal development and decreased fetal weights, were observed in rats at 70 mg/kg/day and at 500 mg/kg-bw; dose-related runting was seen at 10 mg/kg/day (IRIS, 1991). When female rats were gavaged at levels up to 100 mg/kg/day during organogenesis, the only observed adverse effect was fetal osseous retardation but only at maternally toxic levels (Shepard, 1991). No teratogenicity was reported in any of the studies.

Toxicity to Nonhuman Receptors

Atrazine is toxic to grassy weeds and annual broadleaf weeds, causing inhibited photosynthesis (ESE, 1989). Crop growth in a field treated with atrazine at 3 pounds per acre (lb/acre) of active ingredient was 40 percent of that observed in a control field. Oat plants exposed to a nutrient solution containing 10^{-5} molar atrazine died within seven days; pea plants died within 21 days when exposed to the same concentration (ESE, 1989). In a 10^{-6} M solution, limited phytotoxicity was observed in pea plants, which exhibited stunted growth and were slightly chlorotic (ESE, 1989). Assuming that the effect of the 10^{-6} M solution is equivalent to a 25 percent reduction in growth, applying an uncertainty factor of 5 provides a TRV of 2×10^{-7} molar, which is equivalent to 0.022 mg/l (22 μg/l).

Limited toxicity information is available regarding aquatic systems. A 21-day EC_{50} value (concentration at which an effect is seen in 50 percent of the exposed population) of 410 μg/l was reported for algal growth reduction in natural water, and 854 μg/l was reported as the 96-hour EC_{50} for inhibition of photosynthesis (ESE, 1989). Applying an uncertainty factor of 10 to the chronic EC_{50}, a TRV of 41 μg/l may be calculated.

In sheep and dairy cattle, oral doses of 250 mg/kg-bw were lethal, causing adrenal gland damage and congestion of lungs, liver, and kidney (ESE, 1989). Other toxic effects included muscular spasms, stilted gait, and anorexia (ESE, 1989). LOAEL was reported as 5 and 25 mg/kg/day in sheep and cows, respectively, following the administration of 10 doses. NOEL for cows was 10 mg/kg/day, and no NOEL was available for sheep (ESE, 1989). For avian

wildlife, LD_{50} values >2000 mg/kg are reported for the mallard duck and the pheasant; the value of 2000 is considered the LD_{50} (Hudson and others, 1984). Signs of intoxication are weakness, hyperexcitability, ataxia, and tremors. Weight loss was recorded for the mallard ducks.

BENZENE

Benzene is used primarily as a constituent of motor fuels, as an industrial solvent, as a solvent in the extraction of oils from seeds and nuts, and as a starting material for a wide range of aromatic compounds.

With a reported solubility of 1780 mg/l at 20°C (USAF, 1989), benzene is soluble in water and, therefore, expected to leach from soil. Although direct oxidation in water is unlikely, photo-oxidation involving reaction with hydroxyl radicals may occur quickly once in the atmosphere, based on the reported half-life of 2.4 to 24 hours (EPA, 1979). Hydrolysis is unlikely in an aqueous environment (EPA, 1979). Because of its high volatility, the half-life of benzene in water is about five hours (Mackay and Leinonen, 1975), and the half-life in soil is reported to be less than one month, depending on the soil type (Cogley and others, 1975). In soil, benzene is oxidatively degraded by microorganisms, especially bacteria (Chapman, 1972; Tabak and others, 1981; Korte and Klein, 1982). Although degradation can occur anaerobically, the rate is greatly reduced (Wilson and others, 1986).

Health Effects

The chronic oral RfD is under review by the EPA (IRIS, 1991). No interim chronic or subchronic RfDs for either the oral or the inhalation route are available from EPA (HEAST, 1991).

Most studies of benzene toxicity have concentrated on the inhalation pathway because the primary exposure route for human receptors is through occupational inhalation. The only chronic oral study reported was a carcinogenic bioassay; no symptoms other than carcinomas were reported. No other chronic oral data for human or animal exposure were identified in the available literature. Following subchronic oral exposure, rats subjected to intakes of

10 mg/kg-bw or higher for a 187-day period demonstrated hemopoietic system effects, notably leukopenia (Wolf and others, 1956). Based on these data, an oral NOEL for the rat was set at 1 mg/kg-bw.

Following subchronic inhalation exposures, leukopenia was the health effect most cited (EPA, 1984c). Other reported effects included growth suppression, increased organ weights, and unspecified changes to kidney, bone marrow, spleen, and testes. A subchronic NOEL of 31 ppm for leukopenia was established based on a study by Deichmann and others (1963). Chronic inhalation exposure to rats resulted in lymphocytopenia, anemia, and bone marrow hypoplasia (Snyder and others, 1978, 1980). From these studies, an inhalation LOAEL of 100 ppm may be deduced for the mouse.

EPA lists benzene as a class A (known human) carcinogen (IRIS, 1991). The cancer SF is 0.029 $(mg/kg/day)^{-1}$ for both inhalation and oral routes of exposure. This classification is based on a higher incidence of human nonlymphocytic leukemias following occupational exposure, increased neoplasia in rats and mice following exposure through inhalation and gavage, and additional supporting data.

The carcinogenic effects of benzene exposure among 28,500 Turkish workers employed in the shoe industry were compiled and reported by Aksoy and others (1974), with a follow-up study completed a few years later (Aksoy, 1980). Following approximately 10 years of exposure with peak concentrations reported to be between 210 and 650 ppm, the incidence of leukemia or pre-leukemia was 13 per 100,000, versus 6 per 100,000 in the general population. An additional eight leukemia cases, as well as evidence suggestive of increases in other malignancies, were reported in the follow-up study.

No data regarding human teratogenicity are available (TERIS, 1991). The teratogenicity of benzene has been well studied in mice, rats, and rabbits (TERIS, 1991). Fetotoxicity and delayed ossification have consistently been demonstrated at doses that are maternally toxic and many times greater than the maximum permissible level of human exposure in the air. There is no convincing evidence of an increased frequency of malformations even at such high exposure levels.

Several studies have demonstrated an increased frequency of acquired chromosomal abnormalities in the white blood cells of people who have suffered benzene toxicity or have been exposed occupationally for many years to high levels (in excess of the current maximum permissible level of exposure) (TERIS, 1991). In one study, an increased frequency of acquired lymphocyte cytogenetic abnormalities was observed in a group of 14 children whose mothers had been chronically exposed to benzene and other organic solvents (TERIS, 1991).

Although no RfD is provided, one may be estimated based on available information. EPA (IRIS, 1991) provides a 10-day health advisory level of 0.235 mg/l for a 10-kg child who drinks 1 l/day of water; this is equivalent to a RfD of 0.02 mg/kg/day, which is assumed to be protective for chronic exposures. The water concentration was derived from the inhalation study by Deichmann and others (1963) described previously.

Toxicity to Nonhuman Receptors

No information was found concerning the toxicity of benzene to vegetation; therefore, there is insufficient information from which to derive either soil or water TRVs for vegetation.

For aquatic organisms, DeGraeve and others (1982) determined a 96-hour LC_{50} of 5.3 mg/l for the rainbow trout using a flow-through bioassay system. Tests involving aquatic invertebrates were inconclusive, but no adverse effects were observed at levels as high as 98 mg/l (EPA, 1980b). Amphibians were found to be even more tolerant of benzene. The lowest LC_{50} for amphibians was 190 mg/l reported for the clawed toad (*Xenopus laevis*) (Slooff and Baerselman, 1980). EPA has determined that the data are insufficient to establish any criteria for aquatic organisms, but 5.3 mg/l may be considered an acute LOEC. Applying an uncertainty factor of 100 to the acute LOEC provides a water TRV of 0.053 mg/l (53 μg/l) for aquatic organisms.

In livestock, benzene-induced bone marrow depression, leading to a leukopenia characterized by a greater decrease in lymphocytes than in granulocytes, a reversal of the effect in humans (Andrews and Snyder, 1986). The noncarcinogenic effects are primarily hematopoietic, but unspecified histopathologic effects were reported in kidneys and testes (Wolf and others, 1956). Prolonged or frequent dermal contact may lead to blistering; erythema; and a dry, scaly dermatitis

(Gerarde, 1960). No information was found regarding benzene toxicity in fowl or in terrestrial wildlife.

CARBON TETRACHLORIDE

Once widely used as an industrial solvent and dry cleaning agent, carbon tetrachloride (tetrachloromethane) has been banned for these purposes. Although it is used primarily in the synthesis of chlorofluoromethanes and as a grain fumigant, the reduction in the manufacture of chlorofluoromethanes intimates that there will be a concomitant decrease in the use of carbon tetrachloride for manufacturing purposes.

Carbon tetrachloride is moderately soluble (780 to 930 mg/l) (Ebasco, 1990). Because of its high vapor pressure (150 torr at 20°C), it will rapidly volatilize from surface waters. Carbon tetrachloride does not undergo rapid hydrolysis under normal environmental conditions, nor is it expected to be subjected to microbial degradation except in treatment systems where the microbes have been acclimatized to the compound (USAF, 1989).

Health Effects

EPA provides a chronic oral RfD of 0.0007 mg/kg/day (IRIS, 1991) and an interim subchronic oral RfD of 0.007 mg/kg/day (HEAST, 1991). No inhalation RfD is provided for either chronic or subchronic exposure.

The oral RfDs are based on a study in which liver lesions were observed in rats gavaged for 12 weeks at 10 and 33 mg/kg/day (IRIS, 1991); the 10 mg/kg/day (converted to 7.1 mg/kg/day because exposure occurred only five days per week) was determined to be the LOAEL. The lowest dose of 1 mg/kg/day (converted to 0.71 mg/kg/day) was determined to represent the NOEL.

Minimal oral chronic or subchronic human exposure data are available, but reports of acute toxicity as a result of accidental, medicinal, or suicidal ingestion exist. The major pathological effects are liver and kidney damage, with death often attributable to acute renal or hepatic failure (Shell, 1990). Complete recovery of renal function from a mild case may take from 100 to

200 days with oliguria reported as the major effect; however, in a more serious poisoning, anuria may occur, leading to hypertension, acidosis, and terminal uremia if renal function is not restored (Goodman and Gilman, 1985). Concurrent CNS symptoms include dizziness, headache, confusion, and delirium (Shell, 1990). EPA (1984d) presents oral data for a carcinogenicity bioassay study involving hamsters, in which a gavage dose of 12.26 mg/week for 30 weeks resulted in a 50 percent mortality rate. Following subchronic inhalation exposure, weight gain was depressed at 1 ppm for 90 days, representing a LOAEL. At higher doses, liver damage and increased mortality were reported. Chronic human inhalation exposure led to optic nerve damage and degeneration of the myelin sheath of the sciatic nerve. No liver or kidney damage was reported. Chronic animal exposure to atmospheric levels as low as 5 ppm resulted in hepatomegaly.

Isolated reports of liver cancer in humans have been made following exposure to carbon tetrachloride; however, no epidemiological support is available, rendering the human data inadequate (EPA, 1984d). There are sufficient animal data to support the EPA (IRIS, 1991) classification of this compound as a group B2 (probable human) carcinogen. The SF is determined from the results of several studies. Liver cell carcinomas were the major cancer reported in several species, with investigators theorizing that the necrotizing action on the liver was an important factor in carcinogenicity. The oral SF provided by EPA (IRIS, 1991) is 0.13 $(mg/kg/day)^{-1}$; this same value is used as the inhalation SF.

No reproductive data have been identified in the available literature. Evidence from numerous animal studies indicates that embryotoxicity and fetotoxicity occur at levels that are also maternotoxic (Reprotext, 1991). No teratogenic effects have been reported at levels known to be feto- or maternotoxic. Reproductively, carbon tetrachloride has been reported to prolong the estrous cycle and cause testicular atrophy and a diminished sperm count in rats (Reprotext, 1991). In rabbits, the only effect reported is limited degeneration of embryonic discs following the in vivo exposure of blastocysts to 1.01 ml/kg (Shepard, 1991).

Hepatic abnormalities were reported at birth in rats exposed in utero, and male infertility was observed in rats injected with high doses (EPA, 1984d). Available information suggests that

carbon tetrachloride is not mutagenic, and there were insufficient data to establish genotoxicity. EPA (IRIS, 1991) reports that no chromosomal or chromatic aberrations were seen in cells exposed to low concentrations, and in vivo unscheduled DNA synthesis assays were negative. Mitotic recombination and gene conversion were reported but only at concentrations that reduced cell viability to 10 percent. EPA (IRIS, 1991) indicates that the possibility remains that carbon tetrachloride may be metabolized to more reactive intermediate compounds that could be mutagenic.

Toxicity to Nonhuman Receptors

No information was available concerning the effects of carbon tetrachloride to vegetation; therefore, there is insufficient information from which to derive a vegetation TRV for either soil or water.

In aquatic systems, levels as low as 35 mg/l were found acutely toxic to fish in bioassays; however, because the tests were static and because carbon tetrachloride is a very volatile compound, the toxicity of carbon tetrachloride may have been underestimated (Shell, 1990). Based on the results of exposing newly hatched fish, the LC_{50} at four days posthatching was 1970 μg/l for rainbow trout and 1640 μg/l for the Leopard frog (Shell, 1990). Although it has been estimated that concentrations as low as 30 μg/l would adversely affect sensitive aquatic species, the lack of adequate data suggests that the LC_{50} value reported for the Leopard frog is more appropriate for deriving an acceptable water concentration. Therefore, applying an uncertainty factor of 100 to the reported LC_{50} value of 1640 μg/l, a water TRV of 0.016 mg/l (16 μg/l) is calculated.

In domestic animals and humans, carbon tetrachloride was used as a trematodicide in the early 1920s. Acute toxicity was associated with CNS effects. Delayed toxicity effects are related to hepatic and, to a lesser extent, renal damage (Roberson, 1977). Although effects were reported in swine exposed to levels of 320 mg/kg-bw, cattle were the most sensitive as an exposure level of 20 mg/kg-bw was reported to be acutely toxic; this represents an acute LOAEL.

CHLORDANE

Chlordane, an OCP, was initially used in the United States for field crop protection and later to control structural pests in the home (primarily termites) until it was banned in 1988. Resistant to chemical and biological degradation, chlordane is persistent in the environment (Ebasco, 1990). With reported K_{oc} values ranging from 9500 to 140,000 and solubility values as low as 0.056 mg/l (Ebasco, 1990), chlordane is virtually insoluble in water and immobile in soil. In surface water systems, chlordane readily binds to organic material and, therefore, may reside in sediments preferentially to the water column. Chlordane binds tightly to soil particles and persists for years in soil. Typically more than 99 percent of applied chlordane deposits are found in surficial and near-surface soils, even after the application of several liters of water to test soil columns over an 80-day period (USAF, 1989).

Chlordane is reported to undergo photosensitized isomerization. The cis- isomer is more susceptible to photolysis than the trans- isomer; the extent to which photosensitized isomerization occurs in aquatic environments is unknown (EPA, 1979). Although biotransformation is possible, it is believed to be very slow. However, heptachlor-acclimated fungi, such as *Aspergillus niger*, can use chlordane as a substrate but not as a sole carbon source (EPA, 1979). Atmospheric transport of chlordane may result from reintrainment of contaminated dust, and surface water runoff from contaminated areas represents another potentially significant transport mechanism.

Health Effects

EPA lists a chronic oral RfD of 6×10^{-5} mg/kg/day for chlordane (IRIS, 1991); the same value is listed for the interim subchronic oral RfD (HEAST, 1991). To date, EPA has not published an inhalation RfD. The RfD values are based on a study in which female rats developed liver lesions (hypertrophy) at a dietary level of 5 mg/kg but no effects at a dietary level of 1 mg/kg. These values represent a LOEL and a NOEL, respectively, and are equivalent to a daily intake of 0.273 and 0.055 mg/kg/day.

Rats exposed subchronically through diet to chlordane at 1.2 mg/kg/day for five months evidenced no histopathological damage to the major organs (EPA, 1984e). Rats exposed to

19.5 mg/kg/day for 90 days evidenced decreases in DNA and RNA content. In a third study, female rats exposed to a dietary level of 10 mg/l (0.5 mg/kg/day) had increased liver weights; hepatic damage was observed at 160 mg/kg (8 mg/kg/day). In mice, significantly increased liver weights were observed in females at dietary levels of 5 mg/kg and in males at 25 mg/kg after 18 months of exposure (ESE, 1989); these values, which represent LOELs, are equivalent to 0.6 and 3 mg/kg/day, respectively.

No subchronic or chronic inhalation studies on chlordane were reported by EPA (1984e). Mice exposed for up to four days to air saturated with impure chlordane (up to 40-percent unrelated compounds) died within 14 days (USAF, 1989). When mice were exposed for 14 days to a purer grade, no adverse effects were observed until the addition of hexachlorocyclopentadiene, which is believed to have been the "impure" toxicant in the aforementioned four-day study (USAF, 1989).

Chlordane has been designated a group B2 (probable human) carcinogen, indicating that human data are inadequate but sufficient animal data exist. EPA (IRIS, 1991) states that available human data include individual case reports of CNS effects and neuroblastomas in children exposed either pre- or postnatally. Three occupational studies observed either negative or marginally statistically significant relationships between chlordane exposure and bladder cancer. Concerns on the inadequacies of these studies reduce the value of the resulting conclusions. EPA lists an oral SF of 1.3 $(mg/kg/day)^{-1}$ (IRIS, 1991); the value for the oral SF is also used as the inhalation SF. The oral SF was based on four mouse studies. In the primary study (IRIS, 1991), a significant increase in liver nodular hyperplasias was observed in male and female mice at dietary levels of 25 and 50 mg/kg following an 18-month exposure. An increase in hepatocellular carcinomas was also observed in both sexes of mice exposed for 80 weeks to TWA concentrations of 29.9 or 56.2 mg/kg for the males and 30.1 or 63.8 mg/kg for the females (IRIS, 1991).

No epidemiological studies of congenital anomalies among infants born to women exposed to chlordane during pregnancy have been reported. Two children prenatally exposed to chlordane developed neuroblastoma, but no cause-and-effect relationship was established (TERIS, 1991).

No effect on neonatal weight or viability was observed among the offspring of mice treated during pregnancy with 50 mg/kg/day of chlordane (TERIS, 1991). No teratogenic effects were observed among the offspring of rats exposed to chlordane levels as high as 80 mg/kg/day despite the occurrence of substantial maternal toxicity at the highest dose (TERIS, 1991). When female rats were provided diets containing up to 300 mg/kg for up to 48 weeks, no teratogenic or other reproductive effects were observed (EPA, 1984e). In a six-generation study, a dietary level of 50 mg/kg was identified as the LOAEL, and the NOEL was identified as 25 mg/kg-feed (USAF, 1989). Behavioral alterations have been observed among the offspring of mice exposed up to 2.5 mg/kg/day during pregnancy (TERIS, 1991). A cell-mediated immune response was reported in the progeny of mice exposed to a chlordane level of 8.0 mg/kg/day throughout pregnancy (Shepard, 1991).

As reported by EPA (IRIS, 1991), gene mutation assays indicate that chlordane is not mutagenic in bacteria. Positive results were reported, however, in lung and lymphoma cells as well as in plant assays. Although chlordane is a genotoxicant in yeast, human fibroblasts, and fish, it failed to induce unscheduled DNA synthesis in bacteria, rodent hepatocytes, or human lymphoid cells.

Toxicity to Nonhuman Receptors

No information concerning the toxicity of chlordane to vegetation was found in the reviewed literature. Therefore, insufficient information exists from which to derive either soil or water TRVs for chlordane.

In aquatic systems, little information on the effects of chlordane on aquatic plants was found. In a study involving freshwater algae, a concentration of 0.1 μg/l stimulated growth (ESE, 1989). For higher animals, vertebrate and invertebrate species appear to be sensitive to chlordane. In invertebrates, the lowest reported 96-hour LC_{50} value was 20 μg/l for the *Pteronarcys sp.* (ESE, 1989). The chronic value for *Daphnia magna* is 16 μg/l, and chironomid larvae exposed for 25 days to 1.7 μg/l evidenced increased mortality (ESE, 1989). In fish, the lowest acute LC_{50} was 3 μg/l for the carp (*Cyprinus carpio*). The chronic value for bluegills is 1.6 μg/l, and reduced

embryo viability was observed in brook trout (*Salvenilus fontinalis*) exposed to 0.32 μg/l for 13 months (ESE, 1989). AWQC are available for chlordane. The acute and chronic criteria are 2.4 and 0.0043 μg/l for acute and chronic exposure, respectively.

Terrestrial livestock and wildlife experience the same toxic effects described for rats and mice. Acute symptoms include CNS effects, e.g., tremors and convulsions (Hatch, 1977). As with other OCPs, symptoms also include stumbling while walking, jumping imaginary objects, abnormal posturing, and continued chewing actions (Osweiler and others, 1985). Young animals are the most sensitive to chlordane. The minimum toxic dose observed in calves was 25 mg/kg-bw, and the maximum NOEL was 10 mg/kg-bw; 90 and 75 mg/kg-bw were the minimum toxic and maximum NOEL, respectively, reported for cattle (Osweiler and others, 1985).

In birds, starlings experienced death at dietary levels of 150 mg/kg (ESE, 1989). Assuming that, in terms of percentage of body weight, starlings eat at levels similar to chicken (0.175 kg feed/kg/day), this is equivalent to a chlordane consumption rate of 26 mg/kg/day (ESE, 1989). Hudson and others (1984) reported a value of 1250 mg/kg as the LD_{50} for the mallard duck.

CHLORIDE

Widely distributed throughout the environment, chloride represents approximately 0.05 percent of the lithosphere [National Research Council of Canada (NRCC), 1977]. Although it does not exist in nature in the elemental form as chlorine, it can exist as a free anion (Cl^-), especially in aquatic environments. However, the chloride ion is usually in loose association with other naturally occurring elements or pollutants in the environment, forming organic and inorganic compounds. The most common forms are sodium, potassium, and calcium salts [World Health Organization (WHO), 1984].

The primary source of the chloride ion in the environment is the ocean. Extremely soluble in water, it is present in most water systems. Because it is so soluble in water, chloride is highly mobile in soil, moving downward with the leaching action of rainwater and upward with the water to the surface where it may be entrained as dust and then reach the atmosphere (Thompson

and Troeh, 1973). Because it is highly mobile and nonreactive, chloride is eventually transported to closed basins such as seas or to the oceans (WHO, 1984).

Health Effects

EPA has not yet established the chloride ion chronic or subchronic RfDs for oral or inhalation exposure (IRIS, 1991; HEAST, 1991). Chloride has not been evaluated as a potential carcinogen and therefore currently has no carcinogenic classification. No information was found in the available literature concerning the mutagenicity, teratogenicity, or fetotoxicity of the compound.

The chloride ion is the most abundant anion in the human body and significantly influences the osmotic activity of extracellular fluid and maintenance of electrolyte balance. Chloride levels in drinking water are generally considered to be nontoxic, causing only organoleptic effects at concentrations exceeding 250 mg/l. High concentrations of chloride (up to 1000 mg/l) are known to cause no ill effects in humans living in hot, dry environments. A region study in the Soviet Union revealed an apparent correlation between high chloride levels in drinking water and cholelithiasis and cholecystitis (Popov, 1960).

There are no reports of carcinogenic or mutagenic effects resulting from chloride exposure in either humans or experimental animals. Sodium chloride has been shown to cause teratogenic effects in mice: following exposure to levels between 1900 and 2500 mg/kg-bw of sodium chloride on either day 10 or 11 of gestation, offspring evidenced shortness of forelimb and foot, malformed wrist and ankle joints, and malformations of the fingers and toes (Nishimura and Miyamoto, 1969).

EPA has established a secondary MCL of 250 mg/l (250,000 μg/l) on the basis of organoleptic considerations (50 FR 47142). This is equivalent to 7.1 mg/kg/day, assuming that a 70-kg individual drinks 2 l/day of water.

Toxicity to Nonhuman Receptors

Considered a micronutrient under all but the most stringent test conditions (Thompson and Troeh, 1973), chloride is so ubiquitous in nature that deficiencies do not exist. Plants absorb far more chloride than required; it is believed to serve in part as a balancing ion in the plant. Excess chloride in plant tissue results in more watery plants because of increased water entering the cell to compensate for the osmotic imbalance. This is especially true in potatoes, which become mushy in texture, and in tobacco, which becomes wet and therefore of a poor burning quality (Thompson and Troeh, 1973). No discussion of concentrations considered toxic in soil was presented in the reviewed literature; therefore, no soil TRV can be derived. Grapefruit trees irrigated with water containing 300 mg/l salt (183 mg/l chloride) evidenced no toxicity, but toxic effects were observed in plants exposed to water containing 1300 mg/l salt (790 mg/l chloride) (Gough and others, 1979). The value of 183 mg/l may be considered the vegetation TRV for the chloride ion.

The toxicity of chloride to aquatic organisms depends on the cation associated with the chloride anion. For example, potassium, calcium, and magnesium chlorides are generally more toxic than sodium chloride. Only the sodium data, however, are sufficient for deriving a water quality criterion (EPA, 1988c). Invertebrates are more sensitive to the chloride ion than vertebrates: the LC_{50} for midge is 1434 mg/l, and the LC_{50} is 3336 mg/l for rainbow trout (EPA, 1988c). With a chronic toxicity value of 372 mg/l, *Daphnia magna* is more sensitive to chronic chloride ion exposure than the fathead minnow, for which a chronic toxicity value of 433 mg/l was reported. Based on these values, freshwater criteria for chloride when associated with sodium were established by EPA (1988c) at 860 mg/l as a one-hour average (acute) and 230 mg/l as the four-day average (chronic), neither of which should be exceeded more than once every three years on the average.

CHLOROBENZENE

Chlorobenzene, also referred to as monochlorobenzene, is most commonly used as a solvent and as a raw material in chemical manufacturing. It is moderately volatile (vapor pressure is 8.8 torr at 20°C), and soluble in water, with reported solubility values ranging from 300 to

625 mg/l (Ebasco, 1990). With K_{oc} values ranging from 330 to 1930, sorption to soil may be significant. Although the data are not definitive, hydrolysis is not expected to occur at a rate competitive with volatilization or degradation in surface water (USAF, 1989). Degradation can occur at a significant rate, particularly if chlorobenzene is exposed to a sludge in which the microbial population has been acclimated to benzene (USAF, 1989).

Health Effects

EPA lists a chronic oral RfD of 0.02 mg/kg/day (IRIS, 1991) and an interim subchronic oral RfD of 0.2 mg/kg/day (HEAST, 1991). EPA also provides interim chronic and subchronic inhalation RfDs of 0.005 and 0.05 mg/kg/day, respectively (HEAST, 1991). Based on a 70-kg individual drinking 2 l/day of water, the chronic RfD is equivalent to 0.175 mg/l (175 μg/l). A secondary MCL of 0.1 mg/l (100 μg/l) has been proposed for chlorobenzene, based on organoleptic considerations. Concentrations that exceed this value may adversely affect water quality.

The chronic oral RfD was derived from a 13-week study in which dogs were given chlorobenzene orally by capsule at doses of 27.25, 54.5, or 272.5 mg/kg/day (IRIS, 1991). The lowest dose, 27.25 mg/kg/day, was identified as the NOAEL, and the next higher dose, 54.5 mg/kg/day, was established as the LOAEL. Effects seen at this dose included slight bile duct proliferation, cytologic alterations, and leukocytic infiltration of the stroma, all in the liver. The results of other studies support these NOAEL and LOAEL values.

No reports of subchronic or chronic oral human exposures are currently available in the literature (EPA, 1984f). No subchronic human inhalation data are available; however, factory workers exposed to unknown levels of chlorobenzene for one to two years experienced numbness and stiffness of the extremities as well as uncontrolled movements of the fingers (EPA, 1984f).

In subchronic oral studies involving laboratory animals (IRIS, 1991), male rats and mice experienced minimal liver effects at 250 mg/kg (converted to 178.6 mg/kg/day based on exposure rates) for 13 weeks. Dogs showed no effects after exposure to 27.3 mg/day for 13 weeks (IRIS, 1991). In developing an LD_{50} value of 3400 mg/kg-bw for rats, the reported toxic effects included liver necrosis and interference with porphyrin metabolism (ESE, 1989). In a 13-week

study, mice receiving dietary doses of chlorobenzene of 42.9 mg/kg/day evidenced hepatic necrosis (ESE, 1989); this value represents an LOAEL. In long-term studies with rats, dietary ingestion at 50 mg/kg/day for between 90 and 93 days led to increased liver and kidney weights, and the results of other studies indicated no effects in rats at 50 mg/kg/day or in either mice or rats at 60 mg/kg/day (ESE, 1989). Therefore, the value of 50 mg/kg/day represents an LOAEL for rats. Although no chronic inhalation data are available for experimental animals, dogs were the most sensitive; subchronic exposure (31 days) to a level of 31.6 mg/kg-bw led to weight loss and moribundity (EPA, 1984f).

Chlorobenzene has been designated a group C (possible human) carcinogen on the basis of preliminary data from a 1983 National Toxicology Program (NTP) study (EPA, 1984f). The observed effect was hepatocellular cancer, manifested as neoplastic nodules in the liver. Chlorobenzene is currently under review by an EPA interagency work group to determine which cancer classification it should receive (IRIS, 1991).

No human epidemiological reproductive or developmental toxicity studies are reported in the literature (Reprotext, 1991; TERIS, 1991; Shepard, 1991). A limited quantity of experimental data are available.

Mutagenicity tests indicate that chlorobenzene affects some, but not all, microorganisms. Negative results were obtained in mutagenicity studies in sex-linked recessive lethality tests and in chromosome aberration tests, and positive evidence of sister chromatic exchange was reported (Ebasco, 1990). When rats and rabbits were exposed to concentrations as high as 590 ppm for six hours daily during organogenesis, a few rabbit fetuses were found with ablepharia and forelimb flexure, but the total malformations were not increased significantly (Reprotext, 1991). No adverse fetal effects were reported in rat progeny.

Toxicity to Nonhuman Receptors

No data were identified describing the toxicity of chlorobenzene to vegetation; it was, therefore, not possible to derive either a soil or water TRV for chlorobenzene.

In the alga, *Selenastrum capricornatum*, a 96-hour EC_{50} was established as 228 µg/l, as evidenced by a reduction in cell number and in chlorophyll a production (EPA, 1980c). The 96-hour EC_{50} for growth inhibition was determined to be 12.5 µg/l, and the NOEL was 6.8 µg/l (ESE, 1989). In a separate study, a concentration of 120 µg/l caused incipient growth inhibition of *Mycrocystis aeruginosa*. Chlorobenzene was toxic to embryonic largemouth bass, with a subchronic LC_{50} of 60 µg/l reported (ESE, 1989). EPA (1980c) reports an acute LOEC of 250 µg/l for chlorinated benzenes. Applying an uncertainty factor of 100 to the EPA-derived acute LOEC value provides a water TRV of 2.5 µg/l. This value is expected to be protective not only of embryonic bass but other aquatic organisms as well.

CHLOROFORM

A byproduct of the drinking water chlorination process, chloroform (trichloromethane) is a common contaminant in potable water supplies. Used for several years as an anesthetic, it is now only used in this capacity in emergencies.

A volatile compound (150 torr at 20°C), chloroform rapidly moves from surface water systems to the atmosphere, where it reacts with hydroxyl radicals, forming phosgene ($COCl_2$) (EPA, 1979). Phosgene is readily hydrolyzed to HCl, CO_2, and chlorine oxide radicals, which are not likely to persist (Ebasco, 1990). USAF (1989) reported the following half lives: 1.2 days in a river, 6.2 days in a pond, and 13 days in a lake; and less than 30 minutes in a stirred aqueous solution.

Chloroform does not hydrolyze significantly, but has been shown to biodegrade anaerobically (USAF, 1989).

Health Effects

EPA lists both a chronic oral RfD and interim subchronic oral RfD of 0.01 mg/kg/day (IRIS, 1991; HEAST, 1991). No inhalation RfDs are provided.

The oral RfDs are based on a study in which dogs were exposed to chloroform at either 15 or 30 mg/kg/day for 7.5 years (IRIS, 1991). Fatty cysts, considered dose-dependent, were

observed at both doses; therefore, LOAEL was determined to be 15 mg/kg/day, which was converted to 12.9 mg/kg/day based on the dosing regimen. Chronic oral exposure in humans adversely affects the CNS as well as the liver, kidneys, and heart (NIOSH, 1977). Adverse effects associated with chronic oral exposure of rats to levels of 60 mg/kg/day and greater include decreased liver weights and serum cholinesterase levels, increased incidence of a noncancerous respiratory disease, and gonadal atrophy (EPA, 1984g). Chloroform readily passes the cell membrane, and effects include CNS disturbances, liver glutathione depletion, and gonadal and bone marrow abnormalities (ESE, 1989). Animals on high-fat or protein-poor diets appear more susceptible to hepatotoxicity, and high-carbohydrate and high-protein diets appear to have a protective effect (ESE, 1989). Liver necrosis and gonad dysfunction were reported in rats at 150 mg/kg/day (Palmer and others, 1979). No effects in humans following subchronic oral exposure at 2.5 mg/kg/day (EPA, 1984f), nor in rats exposed to 30 mg/kg/day, were reported; the latter represents a NOEL for rats (Palmer and others, 1979).

Occupational human inhalation exposure at levels between 22 and 237 ppm is reported to lead to depression, gastrointestinal disturbances, headache, and frequent, scalding urination (EPA, 1984f). Other reported effects include cardiac arrhythmia, ventricular tachycardia, and bradycardia. Death from chloroform overdose is attributed to ventricular fibrillation. In rats, inhalation exposure to as little as 25 ppm produced histopathological changes in the liver and kidney (EPA, 1984f). Similar effects were present in guinea pigs and rabbits, but the data are questionable because results were observed in the lowest and highest doses but not at the middle dose.

Chloroform has been classified as a group B2 (probable human) carcinogen (IRIS, 1991). The oral SF, 0.0061 $(mg/kg/day)^{-1}$, is derived from a drinking water bioassay in which rats exposed to a low dose of 19 mg/kg/day experienced an increased incidence of renal tumors (IRIS, 1991). The inhalation SF of 0.081 $(mg/kg/day)^{-1}$ is derived from a gavage study in which mice were administered chloroform for 78 weeks (IRIS, 1991). Mice exposed to 90 mg/kg/day of chloroform developed kidney tumors. Limited data suggest that human oral exposure to

chloroform may result in increased risk of bladder, colon, and rectal cancer (EPA, 1984f). ATSDR (1989h) states that the human data suggest a possible increased risk of cancer at these locations because chloroform is the predominant trihalomethane in drinking water, the evidence is still too weak to draw a conclusion about the carcinogenic potential of chloroform.

Although chloroform has been described by one reviewer as a possible human teratogen, the frequency of congenital anomalies was no greater than expected among 492 children of laboratory workers occupationally exposed to organic solvents during the first trimester of pregnancy; 128 mothers reported first trimester exposure to chloroform (TERIS, 1991). The only cases where chloroform was suspected of human reproductive effects were two cases of eclamptic toxemia of pregnancy in women working in the same laboratory where chloroform was used (Reprotext, 1991). Eclampsia in pregnancy follows high blood pressure and retention of fluid and is marked by headache; visual disturbances; and, on occasion, by convulsions or coma.

In studies of women occupationally exposed to chloroform and other organic solvents, significantly higher frequencies of acquired chromosomal aberrations were noted in the lymphocytes of the exposed women and their children (TERIS, 1991). This study has not been independently confirmed, and the relevance of acquired somatic chromosomal aberrations to the risk of malformations or any other disease in the offspring is unknown.

In general, chloroform is highly embryotoxic and somewhat teratogenic in animals (Reprotext, 1991). Fetal toxicity generally occurs at exposure levels associated with maternal toxicity (Shepard, 1991).

The frequency of cleft palate increased among offspring of mice exposed chronically during pregnancy to chloroform vapors at concentrations 50 times the NIOSH occupational standard (2 ppm; about 1/100 of the human anesthetic dose) (TERIS, 1991). Anal atresia was observed with increased frequency among the offspring of pregnant rats after similar exposure but not when the exposure was only 15 times the NIOSH occupational standard (TERIS, 1991). In both studies, considerable maternal toxicity occurred. In contrast, the frequency of malformations was no greater than expected among the offspring of rabbits or rats orally dosed with chloroform

during pregnancy at levels as high as 50 mg/kg/day or 400 mg/kg/day, respectively, but there was evidence of maternal toxicity (Reprotext, 1991; TERIS, 1991). Oral doses greater than 100 mg/kg/day in female rabbits were toxic to dam and fetus (ESE, 1989), implying that 100 mg/kg/day represents a LOAEL for the rabbit. In a separate study, teratogenic effects were reported in rats and mice exposed to 30 ppm or higher of chloroform via inhalation on days 6 to 15 of gestation (EPA, 1984f). Following the inhalation of chloroform, rats experienced increased post-implantation deaths, decreased fetal weight gain, reduced conception rate, increased resorptions, and retarded fetal growth (TERIS, 1991). In mice, chloroform impaired pregnancy, increased pre-implantation losses, retarded fetal growth, and caused cleft palates (TERIS, 1991). When male mice were exposed to chloroform through inhalation, structural abnormalities in sperm were reported; this effect was not observed following the intraperitoneal injection of chloroform (Reprotext, 1991).

Toxicity to Nonhuman Receptors

No information regarding the toxicity of chloroform to vegetation was found; however, some general observations may be made regarding potential interactions. With a K_{ow} value of 1.94, chloroform is partially miscible with water, based on a regression analysis (Briggs and others, 1982, 1983). This suggests that chloroform enters the plant and is translocated within the plant structure. Because chloroform is lipophilic, it may pass through the cuticle of the leaf, if in contact for a sufficient length of time. However, the volatility of the compound would limit the contact time.

Toxic concentrations reported in the literature for chloroform in aquatic systems cover a wide range of values. Acute toxicity tests conducted on rainbow trout, bluegill, and a daphnia species revealed median effect concentrations ranging from 28,900 to 115,000 µg/l (EPA, 1980d). Birge and others (1980) reported 96-hour LC_{50} values of 270 to 35,100 µg/l in toads and frogs exposed from egg stage to hatchlings; fish LC_{50} values were reported from 2030 to 75,000 µg/l (Anderson and Lusty, 1980). Chronic (27-day) LC_{50} values of 2030 and 1240 µg/l were reported for rainbow trout larvae at water hardness values of 50 and 200 mg/l, respectively (EPA, 1980d).

The 96-hour LC_{50} value of 270 $\mu g/l$ reported by Birge and others (1980) for toads and frogs may be considered the acute LOAEC. Applying an uncertainty factor of 100 yields a water TRV of 0.0027 mg/l (2.7 $\mu g/l$) for aquatic organisms.

No oral or inhalant toxic levels are provided for farm animals. Only a 2 to 4 percent chloroform concentration, however, in air is necessary to induce anesthesia in an animal in 10 to 12 minutes; this concentration should be lowered to 1.5 percent for the duration of anesthesia (Booth, 1977). Dogs deprived of food for 24 hours and then anesthetized for 1.5 hours experienced central necrosis of one-third to one-half of the liver lobules. No information regarding the effects of chloroform on fowl or on terrestrial wildlife is available in current literature.

CPMS, CPMSO, and $CPMSO_2$

The compounds CPMS, CPMSO, and $CPMSO_2$ are three materials used in or associated with the manufacture of Planavin®, an herbicide manufactured from 1966 to 1975 by Shell Oil Company at its RMA facilities. Only a limited number of studies have been reported concerning these compounds. All reported studies indicate that the compounds are similar in toxicity and in environmental movement; therefore, the three compounds are described together.

The low vapor pressure of CPMS, estimated to be 0.11 torr at 25°C, suggests that limited volatilization from soil may occur; the addition of oxygen, i.e., CPMSO and $CPMSO_2$, lowers the vapor pressure to levels (estimated at 0.0008 and 0.0005 torr at 25°C, respectively) where little or no volatilization occurs (Cogley and Foy, 1978). Although CPMS is relatively insoluble in water (12 mg/l), CPMSO and $CPMSO_2$ evidence solubility at 1050 to 1200 mg/l (USAMBRDL, 1985). With estimated K_{oc} values of 930 to 1345 for CPMS and 25 to 126 for CPMSO and $CPMSO_2$, all three compounds evidence some capacity to sorb to the soil. The combined estimated water solubilities and high organic partitioning indicate that limited environmental mobility exists. Microbial degradation is reported to occur, but neither the extent of degradation nor the identity of any intermediates was reported (Cogley and Foy, 1978). A half-life of one to six months is reported for CPMS, and 6 to 12 months are reported for CPMSO and $CPMSO_2$ (Cogley and Foy, 1978). Following soil incubation for 160 days at 30°C, 61, 84.5 and 82.5 percent of the incubated

compound was reported as remaining in the soil for CPMS, CPMSO, and $CPMSO_2$, respectively (Guenzi and others, 1979).

Health Effects

EPA does not provide any reference doses for these compounds, nor has EPA addressed the potential carcinogenicity of these compounds (IRIS, 1991; HEAST, 1991). No data regarding human toxicity or carcinogenicity are currently available. All three compounds were nonmutagenic under the Ames test (Thake and others, 1979). No other information concerning the mutagenicity, teratogenicity, or fetotoxicity of this compound was located.

Metabolic (Menn and others, 1975; Oehler and Ivie, 1983) and pharmacokinetic data (Thake and others, 1979) indicate that conjugated metabolites are excreted primarily in the urine, predominantly as $CPMSO_2$. Mild skin irritation in rabbits was reported for CPMSO and $CPMSO_2$; reversible eye lesions were reported only for $CPMSO_2$. For mice and rats exposed to the compounds in their feed for 28 days, anorexia and the resultant weight loss were associated with doses greater than 281 ppm for CPMS and CPMSO, and greater than 325 ppm for $CPMSO_2$. Considered LOAELs, these values for mice are equivalent to dose levels of 40.1 mg/kg/day for CPMS and CPMSO and 46.4 mg/kg/day for $CPMSO_2$. For rats, these values are equivalent to dose levels of 14.1 mg/kg/day for CPMS and CPMSO and 16.3 mg/kg/day for $CPMSO_2$. Limited mortality was observed in the highest CPMSO dose group (5200 ppm). Rats exposed to dietary levels as high as 3000 ppm for 91 days exhibited reduced red blood cell counts and serum glutamate-oxymate aminotransferase levels and increased liver and kidney weights (Thake and others, 1979). Compound-related lesions were also observed in the livers.

Subacute (14-day) studies found that doses of 20 mg/kg and higher were lethal to Rhesus monkeys (Thake and others, 1979). Other symptoms were reported, but the cause of the symptoms was not clear because the animals were apparently in generally poor health.

For human protection, an acceptable drinking water concentration was developed based on the subchronic NOEL of 281 ppm, which is equivalent to 19.8 mg/kg/day, found in the rat and mouse. Applying an uncertainty factor of 1000, the acceptable intake level is 0.02 mg/kg/day.

Toxicity to Nonhuman Receptors

In vegetation, the response of test plants to each of the compounds was similar. In a study by Guenzi and others (1979), greater than 90 percent of the sulfide and the sulfoxide incubated in the soil oxidized to sulfone; therefore, the plant response may only have been to the sulfone. Browning of the leaf tips was the main response. As growth continued, the browning moved down the leaf toward the stem. Alfalfa was reported as the most sensitive plant; growth was severely depressed at soil concentrations greater than 5 mg/kg. Other vegetation showed little or no effect at soil concentrations of 25 mg/kg (Guenzi and others, 1979). In vegetation, the lowest soil concentration reported at which growth was reduced by 50 percent was 7 mg/kg for alfalfa. Applying an uncertainty factor of 10 to the alfalfa data provides a soil TRV of 0.70 mg/kg for vegetation.

No data concerning the toxicity of these compounds to aquatic organisms were identified in the available literature. Therefore, water TRVs for aquatic organisms cannot be determined.

No data are reported for nonruminant animals. In cattle, CPMS and $CPMSO_2$ are readily absorbed through the gastrointestinal tract (Oehler and Ivie, 1983). $CPMSO_2$ is not metabolized further but is distributed in tissues and slowly excreted by the kidneys. In cattle, up to 3 percent of the administered dose is excreted into the milk as the sulfone.

DIBROMOCHLOROPROPANE

Dibromochloropropane was used as a soil fumigant and nematocide on a wide variety of crops from 1977 until 1979, when EPA canceled all uses of dibromochloropropane, except in Hawaii, where it was used with pineapples until 1985 (EPA, 1987a).

Dibromochloropropane is persistent and mobile in the soil/groundwater system. The compound is expected to migrate because it is moderately soluble in water (1230 mg/l at 20°C) (EPA, 1987a); is relatively dense at 2.09 g/ml; and has a K_{oc}, which is estimated to range from 130 to 225 (Ebasco, 1990; HSDB, 1991). However, significant quantities of compound are found in the soil one year after application (HSDB, 1991). The major route of removal from surface soil and surface water is by volatilization (EPA, 1987a). The estimated K_{oc} values of 130 to 225

indicate that dibromochloropropane is not strongly bound to soils; however, because decomposition in soil by microbial action and by hydrolysis occurs slowly, dibromochloropropane has been shown to remain in soils for more than two years (EPA, 1987a). In saturated subsurface soils (where soil organic carbon and soil air are negligible), a large fraction of dibromochloropropane is expected to be in the soil-water phase and move with flowing groundwater. Groundwater underlying dibromochloropropane-contaminated soils with low organic content may be vulnerable to contamination (EPA, 1987a).

Health Effects

EPA has not released final or interim reference doses for oral or inhalation exposure (IRIS, 1991; HEAST, 1991). Although no reference doses are available for dibromochloropropane, health-based drinking water advisory levels are provided by EPA (1987a). The 10-day drinking water health advisory level of 0.05 mg/l for a 10-kg child derived from a NOEL of 0.5 mg/kg/day obtained from a 90-day oral rat study, is equivalent to a reference dose of 0.005 mg/kg/day. A 10-day health advisory level of 0.02 mg/l for an adult was developed based on LOEL of 3.9 mg/m^3 that represents the estimated exposure level in chemical production workers that resulted in reduced sperm counts (EPA, 1987a).

No studies of acute human exposure to dibromochloropropane were identified (EPA, 1987b). Acute inhalation exposures of rats to dibromochloropropane resulted in kidney tissue scarring, pulmonary irritation, liver damage, CNS depression, and death (EPA, 1987b). Acute oral exposure of rats to dibromochloropropane resulted in decreased body weight, impaired renal function, lesions in the liver and kidney, and degeneration of the testes and the epididymis (EPA, 1987a).

Chronic occupational exposure of men to dibromochloropropane has resulted in reduced spermatogenesis; however, no chromosomal aberrations were found in workers, nor were any increases in abortions and offspring malformation associated with the presence of dibromochloropropane (EPA, 1987a). Rats exposed for 90 days to dibromochloropropane doses as low as 15 mg/kg/day exhibited increased kidney and liver weights, reduced body weight gain,

ruffled fur, muscular weakness, nodules in the stomach, kidney damage, and increased mortality. A NOEL of 0.5 mg/kg/day was established in this study (EPA, 1987a).

Subchronic inhalation exposure of rats to dibromochloropropane resulted in testicular atrophy and reduced spermatogenesis in male animals. Studies in rats and mice resulted in upper respiratory system and nasal cavity lesions (EPA, 1987a). Chronic inhalation studies with rats and mice resulted in decreased body weight, increased liver weight, histopathologic changes (testes, renal tubules, lung, and nasal cavities), and increased mortality (EPA, 1987a).

EPA has classified dibromochloropropane as a group B2 (probable human) carcinogen for the oral and inhalation routes of exposure (HEAST, 1991). This classification indicates that sufficient evidence exists to show carcinogenicity in animals, but inadequate evidence exists to show carcinogenicity in humans. EPA (HEAST, 1991) derived an oral cancer slope factor of 22 $(mg/kg/day)^{-1}$ from a dietary study in which high-dose (2.0 mg/kg/day) rats exhibited an increased incidence of kidney and stomach tumors. This value is no longer valid. The most current oral slope factor value is 1.4 $mg/kg/day^{-1}$ (EPA, 1988d). In a gavage study, dibromochloropropane produced significantly increased incidences of carcinomas in the forestomach of mice and rats and of mammary cancer in female rats (EPA, 1987a). In an inhalation study, rats evidenced increased incidences of nasal cavity tumors and tumors of the tongue, and mice had increased incidences of nasal cavity tumors and lung tumors (EPA, 1987a).

No epidemiological studies of congenital anomalies among infants born to women exposed to dibromochloropropane during pregnancy have been reported. Occupational exposure of men to high levels of dibromochloropropane has been associated with the development of infertility and oligospermia or azoospermia (TERIS, 1991). The frequency of congenital anomalies does not appear to be unusually high among the children of men with heavy exposure to dibromochloropropane, but a reduced ratio of male to female has been reported among such children (TERIS, 1991).

Dibromochloropropane has been found to interfere negatively with mating reproductive success and embryo development in rats and to act as a mutagenic agent (EPA, 1987a). No

increase in malformations was observed in the progeny of rats provided oral doses of dibromochloropropane as high as 50 mg/kg/day, but fetal weights decreased significantly at that level, with the NOEL reported as 12.5 mg/kg (TERIS, 1991; ESE, 1989). As described earlier, subchronic exposures of male rats to 15 mg/kg/day caused numerous toxic effects, including increased mortality. Adult male rats prenatally exposed to dibromochloropropane at 25 mg/kg/day for two, four, or six days during the critical period of sexual differentiation exhibited significant impairment in development of the interstitial and tubular components of the testis (TERIS, 1991). The males who were treated for either four or six days also displayed aberrant sexual behavior (TERIS, 1991).

Other effects include sister chromatic exchanges and chromosomal aberrations in Chinese hamster cells (HSDB, 1991). Although teratogenic effects have not been reported for dibromochloropropane, the doses administered during gestation led to decreased body weight in females and were fetotoxic and maternotoxic (EPA, 1987a).

Toxicity to Nonhuman Receptors

Dibromochloropropane has been found in root crops and leaf or fruit crops following soil treatment with dibromochloropropane (EPA, 1987a). The rate of absorption by the root depends on species and soil type. In foliage, its presence may be due to translocation and/or foliar absorption of volatile forms of the chemical (Newsome and others, 1977). Plant growth appears to be promoted indirectly by the nematicidal action of dibromochloropropane (Williams and others, 1983). For some plants, such as peanuts and bananas, phytotoxic effects of dibromochloropropane were reported; however, the mechanisms by which dibromochloropropane exerts its effect were not determined (Rodriguez-Kabana and others, 1979; Elliott and Edmunds, 1978). The only study providing an exposure concentration at which toxicity was reported was the Elliott and Edmunds (1978) work with banana plants (*Musa acuminata Colla*), in which significant decreases in dry weight and leaf area were reported in plants exposed to a solution of 320 mg/l. Assuming this to be equivalent to a 25 percent growth reduction, an uncertainty factor of 5 is applied to provide a

water TRV of 64 mg/l (64,000 μg/l) for vegetation. There is insufficient information to derive a soil TRV for vegetation.

The aquatic toxicity of dibromochloropropane was evaluated, based on a study in which a 90 percent mortality rate was observed in a saltwater clam larvae population exposed to 1 mg/l dibromochloropropane for 24 hours (Davis, 1961). This acute study is inappropriate for deriving a chronic water TRV for freshwater organisms.

Exposure of monkeys to dibromochloropropane resulted in severe leukopenia and anemia (Ebasco, 1990; Shell, 1986; Berkowitz and others, 1978; Smith, 1983). Because limited information is available regarding the toxicity of dibromochloropropane to monogastric farm animals (i.e., pigs), rat toxicity data will be presented. Renal, hepatic, and reproductive effects were observed in rats exposed from 40 to 50 mg/kg/day for four or five days (ESE, 1989). An oral chronic NOEL of 0.5 mg/kg/day was established for the rat based on increased kidney weights observed at a chronic exposure to 2 mg/kg/day (ESE, 1989). For functional cecum animals, data indicated that the most sensitive animal species tested is the rabbit, which had an oral NOEL of 0.94 mg/kg/day (Shell, 1986; ESE, 1989). Inhalation exposure of rats to 12 ppm for 70 to 92 days resulted in a mortality rate between 40 and 50 percent (ESE, 1989). The MATC value for dibromochloropropane is the adipose tissue value of 0.17 mg/kg reported in rats exhibiting decreased fetal and maternal weight gain following 10 consecutive daily doses of 25 mg/kg (ESE, 1989). No toxicity information was found regarding terrestrial wildlife.

Toxicological information regarding avian wildlife exposure is also limited. Mallard ducklings and female pheasants have reported LD_{50} values of 66.8 and 156 mg/kg, respectively, which are higher than those observed for the chicken (Ebasco, 1990). Chickens are the most sensitive fowl with a reported oral LD_{50} of 60 mg/kg-bw (Smith, 1983; Berkowitz and others, 1978).

DICYCLOPENTADIENE

Dicyclopentadiene is a raw material used in the manufacture of aldrin and dieldrin. The estimated vapor pressure of 1 torr at 20°C, coupled with the Henry's law constant estimated at

approximately 0.012 atm-m^3/mole, suggests that volatilization from surface water is a primary migration mechanism (Ebasco, 1990). Dicyclopentadiene is relatively insoluble in water (20 mg/l; Cogley and Foy, 1978). Photodegradation is expected to occur in the atmosphere (Ebasco, 1990). The reported K_{oc} values of 806 and 1217 indicate that dicyclopentadiene will sorb to soils, sediments, and other organic materials. Viewed together, these facts indicate that dicyclopentadiene will not be mobile in the natural environment (Ebasco, 1990).

The half-life for dicyclopentadiene in soil was reported to be between six months and one year (Cogley and Foy, 1978). Dicyclopentadiene degrades to more stable forms, with half-lives ranging from one to more than five years (Cogley and Foy, 1978). Photolysis was reported to occur with an estimated half-life of 76 days or more (Spanggord and others, 1979). No studies have been reported that indicate that biodegradation occurs in soil (Ebasco, 1990), and biodegradation in aquatic systems is not expected to be extensive (Spanggord and others, 1979).

Health Effects

EPA has not determined final reference doses for dicyclopentadiene (IRIS, 1991) but does provide interim subchronic and chronic oral reference doses of 0.3 and 0.03 mg/kg/day, respectively (HEAST, 1991). EPA also lists interim subchronic and chronic inhalation reference doses of 6×10^{-4} and 6×10^{-5} mg/kg/day, respectively (HEAST, 1991).

Although no human toxicological data for chronic or subchronic exposures were identified in the available literature, several animal studies were completed. Dicyclopentadiene is toxic to mice and rats via the oral route, but other species appear to be less sensitive. LD_{50} values of 520 and 378 mg/kg-bw were reported for male and female rats, respectively, and values of 190 and 250 mg/kg-bw were reported for male and female mice, respectively (Dacre, 1984). EPA (HEAST, 1991) reports that no adverse effects were observed in a three-generation study of rats fed a diet containing 690 ppm of dicyclopentadiene (32 mg/kg/day for males). Other tests included a 90-day oral test wherein no effects were observed in rats fed dietary levels up to 750 ppm or mice fed up to 273 ppm (Ebasco, 1990); these are equivalent to NOELs of 6 and

33 mg/kg/day, respectively. Dogs did not evidence significant toxicity other than gastrointestinal distress as evidenced by vomiting and soft stool when exposed to dietary levels up to 1000 ppm.

Although no human inhalation data are available, the odor threshold is reported as 0.003 ppm, or approximately 0.016 mg/m^3 (HSDB, 1991). The EPA (HEAST, 1991) reports that rats experienced liver dysfunction when exposed to 1 ppm (5.4 mg/m^3) for 90 days, which is equivalent to 0.61 mg/kg/day. NIOSH (1982) reported an inhalation LC_{LO} in rats exposed for four hours of 500 ppm, and the American Conference of Governmental Industrial Hygienists (ACGIH) (1986) reported a 10-day mortality value of 332 ppm for rats and 762 ppm for mice. Toxic effects associated with this study included eye irritation, loss of coordination, and convulsions before death. ACGIH (1986) reported no dose-related changes in internal organs of dogs exposed through inhalation at concentrations up to 32 ppm.

EPA has not addressed the carcinogenicity of dicyclopentadiene, and therefore no slope factors are available (IRIS, 1991; HEAST, 1991)

No teratologenic effects were reported in pregnant rats administered dietary levels up to 750 ppm during days 6 to 15 of gestation. No effects on fertility indices were observed in rats exposed to dietary levels up to 750 ppm before mating (Ebasco, 1990). No mutagenic effects were reported when the compound was tested using the Ames microbial test or a Salmonella/microsome preincubation assay with or without activation (HSDB, 1991; Ebasco, 1990).

Toxicity to Nonhuman Receptors

When grown in solutions containing dicyclopentadiene at concentrations up to 1000 mg/l, vegetation did not absorb dicyclopentadiene efficiently. Water to plant bioconcentration factors were reported to be less than 0.1 (ESE, 1989). Growth reduction was reported at the highest exposure level of 1000 mg/l, but the reduction percentage was not stated. To be conservative, the uncertainty factor of 10 associated with a growth reduction of 50 percent may be applied to the reported toxic concentration of 1000 mg/l, providing a water TRV of 100 mg/l (100,000 μg/l) for vegetation. No data are available that support derivation of soil TRV for vegetation.

In aquatic systems, dicyclopentadiene LC_{50} values are reported for several species. The 96-hour EC_{50} values for several algal species range from 31 to greater than 1000 mg/l, based on cell number or chlorophyll a reduction (Bentley and others, 1976). In fish, 96-hour values ranged from 15.7 mg/l for channel catfish to 31.1 mg/l for fathead minnows, and in invertebrates, 48-hour values ranged from 10.5 to 120 mg/l (Bentley and others, 1976). Applying an uncertainty factor of 100 to the lowest reported acute LC_{50} value of 10.5 mg/l, a water TRV of 0.105 mg/l (105 μg/l) was calculated for aquatic organisms.

With the mink representing terrestrial animals, the LD_{50} for the mink is reported to be greater than 1000 mg/kg (Aulerich and others, 1979). NIOSH (1982) reported an acute oral LD_{50} of 1200 mg/kg-bw for the cow.

With an oral LD_{50} reported to be greater than 40,000 mg/kg-bw, dicyclopentadiene is not acutely toxic to mallard ducks (Aulerich and others, 1979). In bobwhite quail, the LD_{50} was reported as 1010 mg/kg-bw (Aulerich and others, 1979).

DDE

DDE [1,1-dichloro-2,2-bis(parachlorophenyl)ethene] is a hydrolysis product of DDT and usually found as a result of either the metabolism or degradation of DDT (USAF, 1989). Once metabolized in the body from DDT, DDE undergoes no further biotransformation and is stored indefinitely in adipose tissue (USAF, 1989). Once hydrolyzed in the environment, DDE is resistant to further hydrolysis (USAF, 1989).

DDE is relatively immobile in the soil/groundwater environment because of its low solubility in water (0.04 mg/l at 20°C) and high K_{oc}, estimated at 257,000, indicating that DDE strongly binds to soils (USAF, 1989).

Volatilization of DDE from waterbodies may be an important loss mechanism. It was found to be five times faster than volatilization of DDT from distilled and natural water (USAF, 1989). Volatilization from soil, which is expected to be much slower than from water, has an estimated half-life of 40 days (USAF, 1989). As with DDT, aqueous photolysis of DDE may be an important loss process. The estimated half-life of DDE in aquatic systems at 40°N latitude ranged

from one day in the summer to six days in the winter (USAF, 1989). However, for photolysis to occur, DDE must be exposed to sunlight, which often is not the case for a large fraction of the amount sorbed to soils or deep sediments (USAF, 1989). Biological degradation of DDE in aquatic environments is believed to occur slowly, if at all (USAF, 1989).

Health Effects

EPA does not provide final or interim reference doses for DDE (IRIS, 1991; HEAST, 1991). Because reference doses are available for the more toxic compound, DDT, the chronic oral reference dose for DDT of 0.0005 mg/kg/day (IRIS, 1991) is recommended for DDE until one becomes available for DDE. The chronic oral reference dose for DDT was derived from the results of a 27-week rat feeding study that indicated liver lesions were apparent at a NOEL of 1 ppm (0.05 mg/kg/day) (IRIS, 1991).

In addition to adipose tissue, other areas where DDE tends to concentrate are the bone marrow and lymph nodes. The effects to humans following an acute exposure to DDE expected to be similar to those associated with exposure to DDT are primarily associated with the CNS, including headache, nausea, fatigue, dizziness, uncertain gait, vomiting, and convulsions (Shell, 1990). The therapeutic use of DDE in humans is not reported to result in chronic effects (USAF, 1989). No toxic effects of acute DDE exposure in experimental animals, other than the induction of liver enzymes in rodents, have been reported (USAF, 1989).

Chronic studies with rats revealed that the primary chronic effect of DDE exposure was tissue damage of the liver and isolated instances of tremors, ataxia, and loss of equilibrium (USAF, 1989). With no NOEL identified, 242 mg/kg-feed was the lowest reported toxic dietary level (USAF, 1989); this is equivalent to 12.1 mg/kg/day. Mice exposed to a dietary level of 250 mg/kg for 130 weeks evidenced a reduced lifespan (USAF, 1989); this is equivalent to a dose of 35.7 mg/kg/day. Other effects observed in animals studied include heart tissue damage, hemorrhages, leukocytic infiltration, and fibroblastic reaction (USAF, 1989).

DDE has been classified as a group B2 (probable human) carcinogen for the oral route (IRIS, 1991). This classification indicates that sufficient evidence exists to support carcinogenicity in

animals (based on an increased incidence of liver and thyroid tumors in mice or rats), but there is inadequate evidence of carcinogenicity in humans. The oral cancer slope factor of 0.34 $(mg/kg/day)^{-1}$ was based on several dietary studies with rats and mice (IRIS, 1991). No inhalation slope factor has been published by EPA.

Based on the measured levels in human newborn blood, placenta, and maternal milk, no association was established with birth weight or head circumference (Shepard, 1991). In a followup study of 912 infants, hyperreflexia was found. No other information concerning the human reproductive toxicity of DDE was identified.

DDE was not found to be genotoxic in bacterial systems; however, DDE induces point mutations and chromosomal aberrations in some lines of mammalian cells treated in vitro (USAF, 1989; IRIS, 1991). Reproduction effects include eggshell thinning and decreased production of eggs and milk (ESE, 1989). Chronic dietary exposure of hamsters to DDE led to fetotoxicity and embryotoxicity as well as a fertility reduction in the absence of maternal toxicity (Shell, 1990).

Toxicity to Nonhuman Receptors

No studies on the toxicity of DDE to plants were found in the literature reviewed. Because of the structural analogy and common association with DDT, the phytotoxicity of DDE is probably similar to that of DDT. No soil or water TRVs may be derived for vegetation because of insufficient information.

Similarly, little information was found regarding the toxicity of DDE to aquatic organisms. No AWQC are provided (EPA, 1987b; IRIS, 1991). Although an acute toxicity value of 1050 $\mu g/l$ has been reported for freshwater organisms, no chronic toxicity value is available (Shell, 1990). Applying an uncertainty factor of 100 to the acute toxicity value, a water TRV of 11 $\mu g/l$ may be calculated for aquatic organisms.

Most of the studies with birds, domestic animals, and terrestrial wildlife involved DDT, but some considered DDE specifically. Several dietary LC_{50} values are provided for DDD and DDT; they ranged from 311 to more than 4000 mg/kg-feed, with DDT more toxic by almost an order of magnitude. The observations associated with exposure to DDT are generally applicable to DDE.

For bald eagles, DDE residues correlate well with eggshell thinning and reproductive failure; failure occurred when egg residues exceeded 15 mg/kg on wet weight basis, whereas reproduction was nearly normal at eggshell concentrations less than or equal to 3 mg/kg (ESE, 1989). Mallard ducks fed DDE at the rate of 4 mg/kg/day for up to 96 days laid eggs that were up to 20-percent thinner than controls (ESE, 1989). Japanese quail provided diets containing either 5 or 50 mg/kg DDE evidenced no toxicity but were more sensitive to subsequent exposure to parathion or paraoxon (ESE, 1989); these dietary levels are equivalent to 0.875 or 8.75 mg/kg/day. Levels deemed protective for DDT are assumed to be protective of DDE.

DDT

DDT was one of the most widely used pesticides in the United States from 1946 until 1973, when it was banned. Some tropical countries still use it extensively (USAF, 1989). In mammals, including humans, DDT can be metabolized to a slight extent to DDE, which does not undergo further biotransformation but is stored indefinitely in fat tissue (USAF, 1989). The major detoxification pathway is dechlorination to dichlorodiphenyldichloroethane (DDD). DDD is readily degraded via a water-soluble metabolite, dichlorodiphenyl acetic acid (DDA), which is rapidly excreted into the urine (USAF, 1989).

DDT is expected to be highly immobile in the soil/groundwater environment because it is has a low solubility in water of 0.003 mg/l at 20°C and a high K_{oc}, which with an estimated value ranging from 302,000 to 670,200 indicates that DDT is strongly bound to soils (USAF, 1989). Despite these values, volatilization of DDT from waterbodies is expected to be an important loss mechanism as experimental data suggest the half-life of DDT to be on the order of several hours to several days (EPA, 1979). However, volatilization from soils is expected to be negligible, as indicated by the estimated soil half-life of 3 to 15 years (Ebasco, 1990). Biodegradation of DDT, though expected to be the predominant fate process in soils, occurs slowly under aerobic conditions; photolysis can also contribute to DDT degradation in soils exposed to sunlight (USAF, 1989).

Health Effects

EPA reports a chronic oral reference dose of 0.0005 mg/kg/day (IRIS, 1991). The same value is reported for the interim oral subchronic reference dose (HEAST, 1991). No inhalation reference doses are provided by EPA.

Acute toxicity of DDT manifests itself primarily as adverse effects to the CNS in humans and laboratory animals (USAF, 1989). Single large doses or repeated doses can produce hyper-excitability, tremors, ataxia, induction of liver enzymes, and epileptiform convulsions (USAF, 1989). Animals that survive short-term exposures to DDT recover completely and are symptom free within 18 to 20 hours, and human recovery is either complete or well advanced within 24 hours (USAF, 1989). There are marked species differences in susceptibility to acute poisoning by the oral route, but when it is given by the intravenous route, the dose and time required for poisoning are similar for a variety of species (USAF, 1989). Animal oral LD_{50} values range from 87 mg/kg in rats to 250 mg/kg in rabbits; the human oral LD_{50} value is estimated at 250 mg/kg (USAF, 1989).

Chronic dietary exposure in experimental animals led to various adverse effects to the liver and kidney, which are recognized as the primary target organs. These effects include increased enzyme activity, increased liver and kidney weight, necrosis, hypertrophy, and hyperplasia (Shell, 1990; USAF, 1989).

DDT has been classified as a group B2 (probable human) carcinogen by the oral and inhalation routes (IRIS, 1991). This classification indicates that sufficient evidence exists, based on the observance of tumors in a wide range of rat and mouse studies, to support carcinogenicity in animals, but inadequate evidence of human carcinogenicity exists (IRIS, 1991). Several studies resulted in an increased incidence of tumors (usually liver) in rats and mice fed DDT (IRIS, 1991). The oral cancer slope factor of 0.34 $(mg/kg/day)^{-1}$ was derived from the results of a 27-week rat feeding study in which rats exhibited liver lesions at a LOAEL of 5 mg/kg-feed, which was equivalent to 0.25 mg/kg/day; a NOEL of 1 mg/kg-feed, equivalent to 0.05 mg/kg/day, was also

recognized (IRIS, 1991). The cancer slope value of 0.34 $(mg/kg/day)^{-1}$ is also used as the inhalation slope factor (IRIS, 1991).

There is no evidence of reproductive effects in humans exposed to DDT. When a comparison was made of serum drawn from women having spontaneous abortions versus those with normal pregnancies, no significant difference in DDT levels was observed (Shepard, 1991).

The adverse effects reported following oral maternal exposure to DDT in several species include fetotoxicity, embryotoxicity, and reduced fertility (Shell, 1990; USAF, 1989). A significant increase in the incidence of ringtail, a constriction of the tail followed by amputation, occurred in the offspring of mothers whose diets contained 200 mg/kg DDT (Shepard, 1991). Mice maintained for long periods on diets containing DDT at a level of 7 mg/kg evidenced reduced fertility (Shepard, 1991). Rabbit dams exposed to 50 mg/kg on gestational days seven through nine evidenced premature delivery, increased fetal resorptions, and reduced intrauterine growth, but no congenital defects were produced. Postnatally, rats injected with 1-mg DDT showed persistent estrus (Shepard, 1991).

DDT has been shown to induce chromosomal damages in laboratory animals (Shell, 1990), but in vitro and in vivo tests have shown conflicting results regarding the genotoxicity of DDT (USAF, 1989). There is no evidence that DDT is teratogenic at doses ranging from 1 to 50 mg/kg (USAF, 1989). Exposure to DDT through maternal milk has been found to have lasting effects on mice and rats, including impaired reproductive capacity in mice. Statistically significant alterations in body weight and the testes and prostate of male rats followed preweaning exposure to DDT (USAF, 1989). One of the most significant impacts of DDT exposure is the thinning of the bird egg shell. This has been proven to have led to significant decreases in the survival rates of embryos for a number of bird species, notably amongst birds consuming large numbers of fish. The increased quantities of available DDT through bioaccumulation and biomagnification was the cause of the increased dosages to which these birds were being exposed.

Toxicity to Nonhuman Receptors

No significant data on the toxicity of DDT to plants were found in the reviewed literature. DDT has been found in grain, leafy vegetables, and fruits (ESE, 1989). Data are inadequate for deriving soil or water TRVs for vegetation.

DDT is toxic to aquatic life. Effects on growth, morphology, and photosynthesis were seen in algae at concentrations ranging from 0.3 to 800 μg/l; however, exposure to 100,000 μg/l was reported to have no effect on the alga, *Chlorella pyrenoidosa* (ESE, 1989). Aquatic invertebrates are more sensitive to DDT than fish (ESE, 1989). Toxic effects on fish, which significantly bioaccumulate DDT, include enzyme inhibition and behavioral changes (ESE, 1989) as well as liver tumors (IRIS, 1991). The reported chronic toxicity value of 0.74 μg/l to the fathead minnow is 65 times greater than the acute value of 48 μg/l; toxicity is reported to increase slightly with increased water temperature (ESE, 1989). Sublethal effects, such as enzyme inhibition, occurred in fathead minnows following a 265-day exposure to 0.5 μg/l, and other effects, such as behavioral changes, were reported in other species at concentrations as low as 0.008 μg/l (ESE, 1989). Freshwater AWQC for DDT are 0.001 μg/l for chronic exposure and 1.1 μg/l for acute exposure (EPA, 1986).

Studies with ruminant mammals have indicated that latent toxicosis is possible (i.e., DDT stored in fat tissue could be released at toxic levels into the bloodstream during stress as fat reserves are depleted). DDT is present in fat cells of milk, thereby representing a danger to humans and suckling calves (Clarke and Clarke, 1975; Osweiler and others, 1985); calves are twice as sensitive to DDT as full-grown cattle. Based on a number of studies completed with horses, dogs, and pigs, pigs were found to be the least sensitive, probably due to their large fat compartments. The NOEL reported for the calf is 100 mg/kg-bw; the LOAEL was 250 mg/kg-bw (Osweiler and others, 1985). No significant information regarding the toxicity of DDT to nonavian terrestrial wildlife was found in the reviewed literature.

DDT is toxic to a variety of birds, including mallard ducks, ring-necked pheasants, rock doves, quails (California, Japanese, bobwhite), osprey, and bald eagles (ESE, 1989). Depending on

dose and species, toxic effects include eggshell thinning, CNS effects (tremors), and death (ESE, 1989). Dietary levels of 0.1 to 0.3 percent for domestic fowl reduce sperm production. At 500 mg/kg-feed, eggs did not hatch, and at 700 mg/kg-feed, no eggs were laid (HSDB, 1991). In chickens, dietary levels of 50 mg/kg-feed led to decreased egg production (HSDB, 1991). The LD_{50} for chickens is reported as 300 mg/kg (HSDB, 1991). Dietary LC_{50} levels are reported for several other bird species: 611 mg/kg for the bobwhite quail, 568 mg/kg for the Japanese quail, 311 mg/kg for the pheasant, and 1869 mg/kg for the mallard duck (HSDB, 1991). For the sandhill crane, the LD_{50} is greater than 1200 mg/kg (Hudson and others, 1984). DDT bioaccumulation in earthworms and fish indirectly affects bird populations that feed on them (ESE, 1989; Ebasco, 1990).

DICHLOROBENZENES

The commercial production of 1,3-dichlorobenzene is negligible. It primarily occurs as a contaminant in the production of 1,2- and 1,4-dichlorobenzene (USAF, 1989).

With a reported water solubility of 123 mg/l at 25°C, 1,3-dichlorobenzene may be considered slightly soluble (USAF, 1989). It is not a very volatile compound, with a reported vapor pressure of 1.60 torr at 20°C. In water, between 100 and 300 mg/l of 1,3-dichlorobenzene is estimated to completely volatilize from aerated distilled water in less than four hours (EPA, 1979). Once in the atmosphere, the dichlorobenzenes are reactive toward hydroxyl radicals with a half-life approximating three days; no further information about photooxidation was provided (EPA, 1979).

Some evidence suggests that dichlorobenzenes may be biodegraded by acclimated microbial population but that this biodegradation may not be significant. Because of the low microbial populations expected in the deeper aquifers, microbial degradation is not considered a significant removal mechanism (USAF, 1989).

Health Effects

Following a review of the three dichlorobenzene isomers, EPA stated that the data are inadequate to complete a quantitative assessment of 1,3-dichlorobenzene. Thus, there are no reference doses for oral or inhalation exposure (IRIS, 1991). In comparison, the chronic oral and inhalation reference doses are 0.09 mg/kg/day and 0.04 mg/kg/day for the 1,2-isomer, and the inhalation reference dose is 0.7 mg/kg/day for the 1,4- isomer. No oral reference dose is provided for the 1,4- isomer either.

Few data are available concerning human toxicity. A case of chronic lymphoid leukemia has been tentatively attributed to a 16-year exposure to 1,3-dichlorobenzene, and a second case of chronic lymphoid leukemia and a case of acute myeloblastic leukemia involved exposure to a solvent containing the three isomers; the active carcinogenic agent was not identified in any of the three cases (HSDB, 1991).

Rats dosed at 250 mg/kg once daily for three days exhibited increased enzymatic activity but no increase in cytochrome content (HSDB, 1991). Liver dysfunction was reported in rats dosed by gastric intubation at 900 to 1000 mg/kg/day for nine days (USAF, 1989). Intraperitoneal injection at 192 mg/kg in male rats produced minimal liver necrosis and some glycogen loss (USAF, 1989). Confirmed by in vivo studies, rat liver cell cultures indicated that the order of toxicity of the three isomers was 1,2- > 1,3- >1,4-dichlorobenzene (HSDB, 1991).

The carcinogenicity of this isomer has not been determined; it is currently classified as a group D (not classifiable) carcinogen (IRIS, 1991). The 1,4- isomer has been classified as a group C (possible human) carcinogen with an oral cancer SF of 0.024 $(mg/kg/day)^{-1}$; the 1,2- isomer is currently under evaluation (IRIS, 1991).

No teratogenic effects were reported in rats gavaged at doses up to 200 mg/kg on days 6 through 15 of gestation (USAF, 1989). No mutagenic effects were reported in *Salmonella typhimurium* tester strains exposed with and without activation (HSDB, 1991). Of eight chlorinated benzenes, 1,3-dichlorobenzene demonstrated the greatest increase in clastogenic activity in mouse femoral bone marrow at levels up to 70 percent of the LD_{50} (HSDB, 1991). In sea urchins,

exposure to the 1,3- isomer resulted in an increase in developmental defects and mitotic abnormalities (HSDB, 1991).

Following the guidelines presented in Table 3-1, a NOEL is used to derive a reference dose. Using the NOEL dose of 250 mg/kg/day, uncertainty factors for sensitive human populations, extrapolation from animal to human, and extrapolation from subchronic test to chronic exposure are applied for an uncertainty factor of 1000. Although assumed to be insignificant, a modifying factor of 10 is applied as an effect. This provides a total uncertainty value of 10,000. Based on this uncertainty value, the resulting reference dose is 0.03 mg/kg/day.

1,2-DICHLOROETHANE

The compound 1,2-dichloroethane, which represents the largest volume of chlorinated VOC produced in the United States, is used primarily as a starting material in the manufacture of vinyl chloride and other chlorinated solvents such as tetrachloroethylene, trichloroethylene, 1,1,1-trichloroethane, and 1,1-dichloroethylene (USAF, 1989). Minor applications include use as a cleaning solvent and degreaser, a fumigant for grain, a wetting agent, and a lead-scavenging agent in gasoline, as well as uses in upholstery and paints (USAF, 1989).

The compound 1,2-dichloroethane is expected to be highly mobile in the soil/groundwater system because it is soluble in water (8690 mg/l at 20°C) and has a K_{oc} of 14 l/kg (USAF, 1989). The estimated K_{oc} value of 14 indicates that it will not be strongly bound to soils (USAF, 1989). The compound 1,2-dichloroethane is a chlorinated aliphatic; therefore, it is not rapidly metabolized in the environment, but it can be degraded by acclimated microbial populations (USAF, 1989). Under normal environmental conditions, 1,2-dichloroethane is not expected to undergo rapid hydrolysis (USAF, 1989).

Health Effects

EPA has not derived any oral or inhalation reference doses for 1,2-dichloroethane (IRIS, 1991; HEAST, 1991).

Short-term human inhalation exposure to 1,2-dichloroethane has resulted in headaches; dizziness; nausea; vomiting; abdominal pain; irritation of the mucous membranes; and systemic injury to the liver, kidney, and lungs (USAF, 1989). Several human poisonings by ingestion of 1,2-dichloroethane are reported in the literature. Most of these cases were fatal, with death attributed to respiratory and circulatory failure (USAF, 1989). Dermatitis may result from prolonged skin contact, and, in severe cases, moderate edema and necrosis can develop (USAF, 1989).

Short-term inhalation studies of rats and mice exposed to 1,2-dichloroethane resulted in CNS depression (i.e., inactivity or stupor) and organic and histopathological changes in the liver and kidneys (USAF, 1989). Oral LD_{50} values of 670, 860, and 5700 mg/kg were reported for rats, rabbits, and dogs, respectively (RTECS, 1990). Vapors of 1,2-dichloroethane were shown to cause reversible clouding of the corneas of dogs and foxes but not of other species (USAF, 1989). Although 1,2-dichloroethane is absorbed through the skin, larger doses are required to elicit acute systemic poisoning (i.e., the dermal LD_{50} in rabbits was calculated to be 2800 mg/kg-bw, although this is still less than the oral LD_{50} value of 5700 mg/kg reported for the dog) (USAF, 1989).

Chronic exposures to 1,2-dichloroethane in an occupational environment have been associated with effects similar to those observed for short-term exposures (USAF, 1989). Although fatal cases occur less frequently than from acute exposures, chronic effects can progress unless the exposures are reduced (USAF, 1989).

EPA classified 1,2-dichloroethane as a group B2 (probable human) carcinogen for the oral and inhalation exposure routes (IRIS, 1991). This classification was selected because sufficient evidence exists to show carcinogenicity in animals, but no data concerning the carcinogenicity in humans exist (IRIS, 1991). The oral slope factor of 0.091 $(mg/kg/day)^{-1}$ was determined, based on the increased incidence of tumors in rats and mice following oral gavage of 1,2-dichloroethane (IRIS, 1991). When administered by gavage for 78 weeks, 1,2-dichloroethane produced carcinomas of the forestomach and hemangiosarcomas of the circulatory system (male rats), mammary adenocarcinomas (female rats) lung adenomas, and hepatocellular carcinomas (mice) (IRIS, 1991).

Using route-to-route extrapolation, EPA (IRIS, 1991) has adopted the oral SF for the inhalation route as well.

The compound 1,2-dichloroethane has been found to be genotoxic in the Ames assay and has also induced sex-linked recessive lethal mutations in *Drosophila melanogaster* (USAF, 1989). However, 1,2-dichloroethane administered in drinking water to mice failed to produce dominant lethal mutations at concentrations of 50 mg/kg (USAF, 1989). In testing with human cell lines, 1,2-dichloroethane was identified as a direct-acting mutagen; the observed differential in sensitivity was attributed to varying levels of glutathione S-transferase levels (HSDB, 1991). Unactivated 1,2-dichloroethane was identified as a weak mutagen, but when activated with glutathione, it becomes a powerful mutagen for several life forms, showing both DNA repair mutations and sex chromosome loss and nondisjunction (OHM/TADS, 1991). Some tester strains of *Salmonella typhimurium* evidenced mutagenic activity with and without an activator; however, no transformations were reported in mouse hepatocytes exposed to levels as high as 250 mg/l (HSDB, 1991).

No embryotoxicity, fetotoxicity, or reproductive effects were observed or attributed to 1,2-dichloroethane in chronic inhalation studies with pregnant rats and rabbits; however, maternal toxicity was observed in both species (USAF, 1989). Although parental exposure of rats indicated no adverse effects on the reproductive capacity of the adults or on growth and survival of the offspring (USAF, 1989), a reduction was observed in the size of the litter, the number of live births, fetal weight, and vitality of the pups (OHM/TADS, 1991). Surviving first generation females, when bred, demonstrated prolonged estrus periods and high perinatal mortality (OHM/TADS, 1991).

Although no reference doses are available for 1,2-dichloroethane, health-based drinking water advisory levels are available. For children, a long-term health advisory value of 0.74 mg/l was developed by applying an uncertainty factor of 100 to the NOAEL of 7.4 mg/kg/day derived from a combination of three inhalation studies involving rats, guinea pigs, rabbits, and monkeys that were exposed to concentrations ranging from 100 to 500 ppm. At the higher levels, symptoms

included pulmonary congestion; myocarditis; and fatty degeneration of the liver, kidney, heart, and adrenal gland (IRIS, 1991). A level of 100 ppm was recognized as the NOAEL. Assuming that a 10-kg child drinks 1 l/day of water, the health advisory is equivalent to a reference dose of 0.07 mg/kg/day.

Toxicity to Nonhuman Receptors

Little information is available concerning the toxicity of 1,2-dichloroethane to vegetation. It has been reported to retard the growth and development of plants and to interfere with seedling development. A vapor concentration of 3 milligrams per cubic meter (mg/m^3) was lethal and mutagenic for barley seeds over a 24-hour exposure period (Ehrenberg and others, 1974). In other cases, it has induced morphological and chlorophyll mutations, resulting in necrosis and atrophy of the plant; however, exposure levels were not presented (HSDB, 1991). Because of inadequate data, no soil or water TRVs for vegetation can be determined.

Acute and chronic criteria for the protection of freshwater organisms have not been established for 1,2-dichloroethane. The 24- and 48-hour LC_{50} values for *Daphnia magna* are 250,000 and 220,000 $\mu g/l$, respectively (EPA, 1985b), and the NOEL is reported to be 68,000 $\mu g/l$ (LeBlanc, 1980). The 96-hour LC_{50} values for the bluegill and the fathead minnow are 430,000 and 116,000 $\mu g/l$, respectively, and the seven-day LC_{50} value for the guppy (*Poccilia reticulata*) is 106,000 $\mu g/l$ under static conditions (EPA, 1980e). As a chronic test, a concentration of 29,000 to 59,000 $\mu g/l$ was estimated as the acceptable concentration in a 32-day early life stage test with fathead minnows. EPA (1986b) reports acute and chronic LOEC values of 118,000 and 20,000 $\mu g/l$, respectively. Applying an uncertainty factor of 10 to the chronic LOEC provides a water TRV of 2000 $\mu g/l$ for aquatic organisms.

No information was found regarding the toxicity of 1,2-dichloroethane to ruminant livestock. One study using pigs identified an air concentration of 3000 ppm as the lowest concentration at which a lethal effect was reported (LC_{LO}) following a seven-hour exposure (HSDB, 1991). Chickens provided a diet containing 250 or 500 mg/kg 1,2-dichloroethane

exhibited decreased egg weights at both levels and decreased numbers of eggs and feed intake at the higher level (Alumot and others, 1976; WHO, 1987).

DIMP

DIMP is a byproduct produced during the manufacture of the nerve gas isopropyl methylphosphonofluoridate, also known as GB® or Sarin®. DIMP is expected to be found only at Sarin (GB) production facilities. Currently, RMA is the only location where DIMP is known to occur in the environment (EPA, 1989).

Based on the low vapor pressure of 0.28 torr at 25°C reported for DIMP (Ebasco, 1990), limited volatilization from environmental media is expected to occur. With a reported solubility between 1500 and 32,000 mg/l (Ebasco, 1990) and little hydrolysis of DIMP in water observed at 80°C or higher, a half-life of 530 years at 10°C was estimated (Ebasco, 1989). No photolytic degradation of DIMP in aqueous solution was observed following exposure to light for up to 232 hours (Spanggord and others, 1979). Soil incubation studies indicate a slow loss of DIMP at 25°C and virtually no loss at 10°C, leading to an estimated half-life of two years in soil (Spanggord and others, 1979).

Health Effects

EPA lists a chronic oral RfD of 0.08 mg/kg/day (IRIS, 1991). No interim RfDs for oral or inhalation exposure have been established (HEAST, 1991). The chronic oral reference dose is based on a 90-day dog feeding study in which dogs were provided dietary levels up to 3000 mg/kg-feed, which was estimated to be equivalent to an intake of 75 mg/kg/day. No effect was seen at the highest level; therefore, 75 mg/kg/day was established as the NOAEL (Hart, 1980). No data have been reported on systemic effects in humans. Skin irritation was reported in wildlife officers exposed to DIMP (as well as other contaminants) at RMA, but subsequent testing indicated that DIMP did not elicit any dermal reaction (Ebasco, 1990).

Following 90 days of exposure, no toxicity was evidenced in rats administered dietary levels as high as 3000 ppm, or in mice at dietary levels up to 2100 ppm (Hart, 1976). Acute LD_{50} values

were determined as follows: 1125 and 826 mg/kg for male and female rats, respectively, and 1041 and 1363 mg/kg for male and female mice, respectively.

EPA classifies DIMP as a group D (not classifiable) carcinogen because no data are available from either cancer bioassays or epidemiological studies (IRIS, 1991). Neither pregnant rats exposed up to 3000 ppm nor three successive generations of rats exposed up to 3000 ppm demonstrated any toxic effects (Hart, 1980).

Toxicity to Nonhuman Receptors

Low levels (10 mg/l) of DIMP in nutrient solution led to slightly increased growth of vegetation, but higher concentrations (up to 1000 mg/l) caused stunted growth and some leaf damage. Germination was not affected (O'Donovan and Woodward, 1977). From these data, 20 mg/l was reported as the NOAEL. Some bioaccumulation occurred in tissues of plants commonly used as fodder but not in those parts used for human consumption (O'Donovan and Woodward, 1977). The NOAEL of 20 mg/l (20,000 μg/l) may be used as the water TRV for vegetation. Data are insufficient for deriving a soil TRV for vegetation.

Available data indicate that the acute toxicity of DIMP to a variety of aquatic organisms ranges from 257 to 6322 mg/l (Bentley and others, 1976). The most sensitive species was the bluegill, with a 96-hour LC_{50} of 257 mg/l. An uncertainty factor of 100 was applied to the lowest reported acute value of 257 mg/l to calculate a TRV of 2.6 mg/l (2600 μg/l) for aquatic organisms.

Calves exhibited little effect following exposure to 500 mg/kg-bw of DIMP, but 1000 mg/kg-bw led to ataxia and tympanitis (Cysewski and others, 1981); these values are considered the acute NOEL and LOAEL, respectively. In lactating cattle, DIMP was not detected in the milk or in fat tissue following oral exposure because the compound was readily absorbed, metabolized, and excreted (Ivie, 1980). An acute oral LD_{50} of 503 mg/kg was reported in the mink (Aulerich and others, 1979), and female mink ingesting food containing as little as 50 ppm (11 mg/kg/day) resulted in a 9-percent increase in mortality. Because no other toxic effects were

observed in these animals, evidence is equivocal that the increased mortality is attributable to DIMP present in the feed (IRIS, 1991).

Oral LD_{50} values of 1490 and 1000 mg/kg-bw were reported in mallard ducks and bobwhite quail, respectively. In an eight-day subacute feeding study, mallard ducks receiving a diet of 3200 mg/kg (410 mg/kg/day) exhibited decreased feed consumption; mortality was not observed even at the highest level of 16,000 mg/kg (2060 mg/kg/day) (ESE, 1989). Decreased egg production was reported in ducks provided dietary levels of 10,000 mg/kg for 24 weeks (ESE, 1989). In chronic studies (29 weeks), decreased egg production in quail was observed at dietary levels of 1200 mg/kg. Mortality occurred at 3800 mg/kg-feed (Aulerich and others, 1979). Based on the reduced egg production, the dietary level of 1200 mg/kg may be considered a chronic LOAEL. Assuming that quail consume the same percentage of their body weight as 12-week-old chickens (5 percent), this is equivalent to an intake of 60 mg/kg/day.

DITHIANE

Dithiane (1,4-dithiane), a white crystalline solid at ambient temperature, is an impurity in mustard gas (ESE, 1989). Based on a high water solubility estimated at 3000 mg/l and a K_{ow} estimated at 5.9 (no K_{oc} value is available), dithiane is expected to show a high degree of environmental mobility (Ebasco, 1990). Its vapor pressure of 0.80 torr at 25°C suggests that dithiane volatilizes to some extent. Once released to air, it oxidizes to sulfones and sulfoxides by reaction with atmospheric oxidants (Ebasco, 1990; Berkowitz and others, 1978). Although no experimental information is available, dithiane may degrade in the environment because it contains carbon and sulfur, which are established microbial nutrients.

Health Effects

EPA has not developed reference doses for dithiane, nor has EPA evaluated its carcinogenic potential (IRIS, 1991; HEAST, 1991). No data regarding the toxicity of dithiane to humans was found in the reviewed literature. No information on chronic toxicity, mutagenicity, carcinogenicity, or reproductive toxicity was found for dithiane.

Acute oral LD_{50} values reported for male and female rats were 3680 and 2768 mg/kg, respectively (Mayhew and Muni, 1986). Adverse effects included crusty muzzle and eyes, stained fur, hyperactivity, muscle tremors, emaciation, lethargy, few or no stools, ataxia, squinting, prostration, lacrimation, and irregular breathing (Ebasco, 1990). Subchronic oral studies with rats evidenced liver and kidney weight increases and decreases in overall body weight gains at doses of 105, 210, and 420 mg/kg/day; 105 mg/kg/day was subsequently defined as the LOEL. Deposition of unknown crystals in the turbinates and increased incidences of cytoplasmic eosinophilic granulization of cortical renal cells were also observed (Ebasco, 1990).

Following the guidelines presented in Table 3-1, the LOEL is used to derive a reference dose. Using the LOEL dose of 105 mg/kg/day, uncertainty factors for sensitive human populations, extrapolation from animal to human, extrapolation from subchronic test to chronic exposure, and extrapolation from a LOEL to a NOEL are applied for a total uncertainty factor of 10,000. Using this value, the reference dose is 0.01 mg/kg/day.

Toxicity to Nonhuman Receptors

No data regarding the toxicity of dithiane to vegetation, aquatic systems, domestic animals, or terrestrial livestock were found in the available literature. Because of the lack of data, no soil or water TRVs for nonhuman receptors can be developed for vegetation or aquatic organisms.

ENDRIN

Endrin, an isomer of dieldrin, is a cyclodiene insecticide. Less stable in the environment than either aldrin or dieldrin, it is nevertheless a persistent compound in soils and sediments (Ebasco, 1990). Although the toxicological actions of endrin are similar to those of other cyclodienes, the concentrations at which the toxic effects of endrin are manifested, especially in birds and rodents, are typically an order of magnitude less than those associated with aldrin and dieldrin (ESE, 1989; Ebasco, 1990).

As evidenced by the low vapor pressure (2.0×10^{-7} torr at 25°C), volatilization of endrin is not a major migration pathway from either soil or surface water. The K_{oc} values, which range

from 897 to 66,440, indicate that endrin readily sorbs to soil and sediment. In conjunction with the low solubility values, endrin is not likely to be mobile in the environment. Microbial degradation may occur, and the limited data available indicates that this process depends on soil type (Rosenblatt and others, 1975).

Health Effects

EPA lists a chronic oral reference dose of 0.0003 mg/kg/day (IRIS, 1991) and an interim subchronic reference dose of 0.0005 mg/kg/day (HEAST, 1991). No inhalation reference doses are available. The chronic reference dose is derived from a study in which dogs were fed diets ranging from 0.1 to 4.0 mg/kg endrin for two years (IRIS, 1991). No effects were observed in animals receiving up to 1.0 mg/kg-feed (0.025 mg/kg/day), which was determined to be the NOEL. Dogs receiving dietary levels of 2 or 4 mg/kg experienced occasional convulsions, slightly increased liver weights, and mild histopathological liver effects; 2 mg/kg-feed (0.05 mg/kg/day) was designated as the LOAEL. Alternatively, the interim subchronic reference dose is based on a different study (HEAST, 1991) in which the NOEL was established as 1 mg/kg-feed; in this case, the dogs ingested more, so that the 1 mg/kg-feed was equivalent to an intake value of 0.045 mg/kg/day, which was rounded to 0.05 mg/kg/day.

Little information is available concerning the exposure of humans to endrin. Workers in the agriculture chemical manufacturing industry exposed to aldrin, dieldrin, and endrin over a nine-year period reported several instances of convulsive intoxication but no fatalities or permanent injuries (Murphy, 1980). NAS (1977) reports that approximately 20 percent of the workers also evidenced electroencephalograms that suggested brain stem injury, but the electroencephalograms returned to normal three to six months after exposure ceased. Following the ingestion of endrin-contaminated bread, a large group of people either became unconscious or suffered epileptiform convulsions. All individuals, however, recovered without complications (HSDB, 1991). Acute toxicity is reported to involve CNS aberrations, primarily convulsions similar to those evidenced with chronic exposure. In animals, acute exposure led to behavioral changes, nervous phenomena ranging from hypersensitivity to convulsions, autonomic and

locomotor effects; many instances proved lethal (Osweiler and others, 1985; Clarke and Clarke, 1975; Hatch, 1977). Chronic exposures may lead to similar symptoms and have resulted in adverse effects to the heart, lungs, liver, and kidneys.

EPA lists endrin as a group D (not classifiable) carcinogen (IRIS, 1991). Although several bioassay studies have been completed for endrin, most are inconclusive because of inadequacies in the study. Although inconclusive, the data strongly suggest that cancers were present in exposed animals, especially as similar compounds, notably aldrin and dieldrin, are considered carcinogenic.

No human epidemiological or clinical information is available in the reviewed databases (Reprotext, 1991; TERIS, 1991; Shepard, 1991).

Although little information is available concerning the reproductive toxicity of endrin to experimental animals, endrin exposure did not significantly affect sister chromatic exchange frequencies. In one study, female rats and mice were dosed four times weekly for a month at 0.58 mg/kg (Reprotext, 1991); this value is recognized as the LOAEL. The animals were then allowed to become pregnant after a week or more without treatment. A reduced survival rate was found in both species. Nine mouse fetuses with club foot were found in the treated group of 177; only one was identified in the control group of 303. The dose rate was an order of magnitude greater than the value identified as the dog LOAEL.

Endrin was one of three chlorinated cyclodiene pesticides studied to determine reproductive effects in hamsters and mice. When single oral doses of approximately one-half the respective LD_{50} (dose levels greater than those associated with chronic toxicity), were given on gestational days seven, eight, or nine to the hamster and on day nine to the mouse, both species experienced a significant number of malfunctions regardless of treatment day (Shepard, 1991). The malformations consisted of open eye, webbed feet, and cleft palate. In a separate study, a level of 0.75 mg/kg/day in hamsters resulted in increased fetal deaths and skeletal abnormalities. In rats, oral gavage at 0.15 mg/kg/day on days 7 to 15 of gestation, resulted in offspring behavioral abnormalities, but no toxic effects were observed at 0.075 mg/kg/day. These values exceed the value of 0.05 mg/kg/day identified as the dog LOAEL.

Toxicity to Nonhuman Receptors

Terrestrial plants can absorb, translocate, and metabolize endrin (EPA, 1979b). Exposure to endrin has resulted in a decreased rate of germination and variations in tissue amino acid composition, but exposure levels were not provided (ESE, 1989). Data are insufficient for determining a soil or water TRV for vegetation.

Endrin is highly toxic to aquatic organisms. Freshwater fish are generally more sensitive than invertebrates and aquatic plants. Toxic effects were observed in green algae (*Scenedesmus quadricauda* and *Oedogonium sp.*) at concentrations exceeding 20 mg/l (ESE, 1989). The LOAEL for plants is 475 μg/l based on observations of growth inhibition in an alga, *Anacystis nidularas*. Other algae evidenced growth inhibition at levels from 1000 to 20,000 μg/l (EPA, 1980g). In fish, mean acute values ranged from 0.037 to 14.25 μg/l. Effects in fish included CNS disturbances, decreased enzyme activity (notably in certain dehydrogenases), decreased growth rates and body fat percentages, and increased mortality. EPA (1986b) provides AWQC for the protection of freshwater organisms. The 24-hour (chronic) average criterion is 0.0023 μg/l, and the value not to be exceeded (acute) is 0.18 μg/l.

In terrestrial mammals, the reported effects are the same as those for humans, including CNS effects, liver, kidney, and heart damage. Mice and monkeys were identified as being the most sensitive, and guinea pigs and goats were the least sensitive (ESE, 1989). The LD_{50} for mule deer (*Odocileus hemionus*) ranged from 6.25 to 12.5 mg/kg (Hudson and others, 1984). In food animals, endrin was reported to cause decreased egg production, decreased milk production, reproduction problems including interrupted estrus cycles, and poor growth in young animals (Osweiler and others, 1985). Age and sex can influence the endrin's toxicity to mammals (ESE, 1989). The effects reported for wildlife mammals reflect the same symptoms and target organs.

Among domestic livestock, chickens exhibited the greatest toxic response; lethality was observed at dietary levels of 20 mg/kg-feed, which is equivalent to 1.04 mg/kg/day. Mallard ducks exposed to dietary levels of either 1.0 or 3.0 mg/kg for seven months demonstrated improved reproductive success at the 1.0-mg/kg level but a statistically insignificant decreased

success at the 3.0-mg/kg level (ESE, 1989). In a separate study, mallard ducks exposed to a dietary level up to 3.0 mg/kg experienced no changes in egg production, fertility, or hatchability. A 9.6 percent decrease in embryo survival was observed, however, at the 3.0 mg/kg level (ESE, 1989). Considered a NOEL, this value is equivalent to a dose of 0.3 mg/kg/day. The dermal LD_{50} in ten-month old male mallard ducks is greater than 140 mg/kg following a 24-hour foot exposure to a 97 percent solution of endrin (Hudson and others, 1984). CNS symptoms such as hyperexcitability and ataxia were observed within three hours following exposure. The Biota RI MATC value of 0.83 mg/kg for endrin is derived from a brain tissue value of 0.62 mg/kg reported for the mallard duck, adjusted by 1.34 which represents the ratio of carcass tissue concentration to brain tissue concentration (ESE, 1989).

ETHYLBENZENE

Ethylbenzene is a volatile organic compound used as an intermediate in the production of styrene, as a dilutent in the paint industry, in agricultural sprays for insecticides, and in gasoline blends (USAF, 1989).

Ethylbenzene is expected to be moderately mobile in the soil/groundwater system considering its solubility of 152 mg/l at 20°C, and K_{oc} of 96-1200 l/kg (USAF, 1989). Based on the vapor pressure of 7 torr at 20°C, an important loss mechanism for near-surface contaminated soils is transport of ethylbenzene vapors through the air-filled pores of unsaturated soils, followed by photochemical oxidation (USAF, 1989). Biodegradation is expected to occur to completion, i.e., with CO_2 and H_2O as end products; however, in most soil/groundwater systems, the concentration of microorganisms capable of biodegrading chemicals such as ethylbenzene is very low and drops off sharply with increasing depth (USAF, 1989).

Health Effects

EPA provides a chronic oral RfD of 0.1 mg/kg/day (IRIS, 1991) and lists the interim subchronic oral RfD as 1 mg/kg/day (HEAST, 1991). The inhalation reference concentration for both chronic and subchronic exposure is 1 mg/m^3, assuming that a 70 kg adult inhales 200 m^3 per

day. The equivatest reference dose is 0.29 mg/kg/day. Assuming a 70-kg adult ingests 2 l/day, the equivalent chronic drinking water concentration is 3.5 mg/l (3500 μg/l). A secondary MCL of 0.03 mg/l (30 μg/l) has been proposed for ethylbenzene based on organoleptic considerations.

The oral reference doses were derived from the results of a study in which rats were gavaged at levels ranging from 13.6 to 680 mg/kg/day (IRIS, 1991). A LOAEL of 408 mg/kg/day was established based on histopathological changes observed in livers and kidneys, and the NOEL was 136 mg/kg/day. These values were converted to 97.1 and 291 mg/kg/day for the NOEL and LOAEL, respectively, to adjust a five-day-per-week exposure to seven days. The inhalation reference concentration was calculated using data from a study in which developmental effects were observed in rats and rabbits exposed to 100 ppm (434 mg/m^3) during gestation days 1 to 19 for rats and 1 to 24 for rabbits (HEAST, 1991).

Acute oral and dermal animal studies indicate that ethylbenzene has a low toxicity of 500 and 17,800 mg/kg, respectively (USAF, 1989), based on a reported oral LD_{50} in rats of 3500 mg/kg and dermal LD_{50} values in rabbits. Other acute effects include conjunctival irritation to the eye but no corneal injury in eye tests. Dermal studies have resulted in redness, swelling, superficial necrosis, and blistering (USAF, 1989). Human data indicate that ethylbenzene is primarily an irritant to the skin (redness and inflammation), eyes (irritation and lacrimation), and upper respiratory tract (bronchospasm) (USAF, 1989). Systemic absorption in humans causes CNS depression and alterations of blood counts (USAF, 1989). Aspiration of small amounts causes extensive edema and hemorrhage of lung tissue (USAF, 1989).

Ethylbenzene has been classified as a group D (not classifiable) carcinogen because there is inadequate evidence of carcinogenicity due to a lack of both animal bioassays and human studies (IRIS, 1991). The NTP is currently planning to conduct carcinogenicity bioassays for ethylbenezene (IRIS, 1991).

Some animal studies suggest that ethylbenzene has adverse reproductive effects (Ebasco, 1990; USAF, 1989). Studies with rats exposed to air concentrations of 100 or 1000 ppm indicate that ethylbenzene can have maternal toxic effects, including increases in spleen, liver, and kidney

weights, and fetuses evidenced significant increases in the incidence of extra ribs (USAF, 1989). Inhalation studies with rats have resulted in increases in postimplantation loss and skeletal retardation of fetuses at all exposure levels, with the highest concentration (2400 mg/m^3) resulting in increased incidences of extra ribs, anomalies of the urinary apparatus, malformations of the skeleton, and weight retardation (USAF, 1989). Ethylbenzene is toxic to pregnant rabbits at the 1000-mg/m^3 level, causing either abortion, resorption, or maternal death (USAF, 1989).

No information regarding human epidemiological or clinical data has been identified in the reviewed databases (Reprotext, 1991; TERIS, 1991; Shepard, 1991). Ethylbenzene has been detected in human cord (fetal) blood (Reprotext, 1991) and, therefore, is available to the fetus.

Ethylbenzene is not teratogenic (Reprotext, 1991). Skeletal development, extra ribs, tail misplacement, and decreased weight gain were observed in fetal rats exposed to the high dose of 2400 mg/m^3, which was also toxic to the mothers (Reprotext, 1991). However, doses below 100 ppm, which is the threshold limit value (TLV) (ACGIH, 1990), affected female fertility, were fetotoxic and caused smaller litter size in rats (RTECS, 1991). Other studies with rats exposed to air concentrations of 100 or 1000 ppm indicate that ethylbenzene can have maternal toxic effects, including increases in spleen, liver, and kidney weights, and fetuses were observed to have significant increases in the incidence of extra ribs (USAF, 1989). Inhalation studies with rats have resulted in increases in postimplantation loss and skeletal retardation of fetuses at all exposure levels, with the highest concentration (2400 mg/m^3) resulting in increased incidences of extra ribs, anomalies of the urinary apparatus, malformations of the skeleton, and weight retardation (USAF, 1989).

Ethylbenzene was found to increase the mean number of sister chromatic exchanges in human lymphocytes; however, negative results were found in mutagenicity assays with *Salmonella typhimurium*, *Saccharomyces cerevisiae*, and *Drosophila species* (IRIS, 1991; USAF, 1989). No chromosomal alterations or sister chromatic exchange were found in Chinese hamster ovary cells tested with ethylbenzene (Ebasco, 1989).

Toxicity to Nonhuman Receptors

No information concerning the toxicity of ethylbenzene to plants was found in the reviewed literature; therefore, data are insufficient from which to derive either soil or water TRVs for vegetation.

For freshwater aquatic organisms, LOAEL for acute exposure is 32 mg/l; no chronic values were reported (EPA, 1986). The 96-hour EC_{50} reported for the alga, *Selenastrum capricornatum*, is 438 mg/l based on decreased cell numbers and chlorophyll a production (EPA, 1980f). The LC_{50} values reported for fish are 94.44 mg/l for goldfish, 42.33 to 48.51 mg/l for the fathead minnow, and 97.1 mg/l for the guppy. The LC_{50} values for the bluegill ranged from 32.0 to 155.0 mg/l with a geometric mean of 70.4 mg/l (ESE, 1989). Applying an uncertainty factor of 100 to the reported acute LOAEL results in a TRV of 0.32 mg/l (320 μg/l) for aquatic organisms.

No information on birds, livestock, or terrestrial wildlife was found in the literature reviewed. Information on the latter may be inferred from studies on experimental animals.

FLUORIDE

Like many of the elements, fluorine is not found in nature in the elemental form but rather in the oxidized (-1) state (Adriano, 1986). Thus, it may be that the other components of a specific fluoride compound either contribute to or are responsible for the reported effects. Fluorine occurs mainly in the silicate minerals of the earth's crust and ranks thirteenth among the elements.

Like nitrogen, fluorides pass between the atmosphere, hydrosphere, lithosphere, and biosphere in a continuous cycle (Berkowitz and others, 1978). Airborne inorganic fluorides, which can be carried back to the earth by both wet and dry deposition, are often hydrolyzed rapidly by water vapor to less volatile compounds (Ebasco, 1990). Anhydrous hydrogen fluoride, a common industrial pollutant, yields hydrofluoric acid when combined with water vapor (Berkowitz and others, 1978). Natural fluorides are bound to soil particles; the fraction bound is a function of the clay content, the calcium carbonate content, and the pH (Ebasco, 1990). Many of the fluoride-containing minerals are water soluble to some degree, suggesting that fluoride may be mobile in aqueous environments.

Health Effects

EPA provides a value of 0.06 mg/kg/day for both the chronic oral RfD (IRIS, 1991) and the interim subchronic oral RfD (HEAST, 1991). No inhalation reference doses are provided. The potential for human carcinogenic effects has not yet been evaluated by EPA. Based on an assumed ingestion of 2 l/day of water by a 70-kg individual, the chronic reference dose is equivalent to a water concentration of 2.1 mg/l (2100 μg/l). A secondary MCL of 2 mg/l (2000 μg/l) has been established based on dental fluorosis. An exceedance of this level will affect the public welfare as it may lead to objectionable discoloration or pitting of the teeth that can occur in children during tooth formation in the gum.

The chronic oral RfD is derived from a large number of studies that evaluated the long-term effect of fluoride on children (IRIS, 1991). A drinking water concentration of 1 mg/l led to no discernible evidence of dental mottling. This value was designated as the NOAEL, while 2 mg/l in the drinking water resulted in objectionable dental fluorosis, designated the LOAEL. Assuming that a 17-kg child consumes 1 l/day of water, NOAEL is equivalent to 0.06 mg/kg/day. A more serious concern is the development of a crippling skeletal fluorosis in individuals who consume more than 20 mg/day of fluoride; this is equivalent to 0.29 mg/kg/day. Although no NOEL is known for this human toxicity effect, EPA states that no toxicity is associated with the intake of drinking water containing 4 mg/l fluoride, which has been set as the primary MCL. Because a drinking water concentration of 2 mg/l of fluoride leads to tooth mottling, the 2 mg/l has been established as the secondary MCL (50 FR 47142).

No information concerning either subchronic or chronic inhalation exposure to fluoride was found in the reviewed references. Acute toxicity, which is rare, usually results from accidental ingestion. Ebasco (1990) reported that symptoms include restlessness, stiffness, anorexia, excessive salivation, nausea, vomiting, and abdominal pain. More severe poisoning may lead to convulsions, depression, and possibly death, usually as a result of cardiac failure (Ebasco, 1990). Rats dosed with 50-mg/kg-bw sodium fluoride evidenced excessive urine secretion, resulting in

increased urinary excretion of several essential elements, including phosphate ion, calcium, magnesium, potassium, and sodium (Ebasco, 1990).

No significant increase of congenital anomalies was observed in the children of women exposed to fluoride during their pregnancy (TERIS, 1991). Fluoride at 8 ppm in the drinking water has been shown to have no effect on human reproduction, and levels in the range of 12 to 18 ppm have rarely produced mottled deciduous (baby) teeth (Reprotext, 1991). The only occupational studies regarding fluoride that examined reproductive effects reported an increase in disorders of menstrual function in areas of fluoride exposure among Russian female superphosphate workers (Reprotext, 1991). Gynecological disease, miscarriages, and pathological pregnancies were also reported.

Reproductive effects of fluoride, including retarded growth and impaired reproduction, have been reported in female mice exposed to dietary levels of 100-mg/kg sodium fluoride. At 50 mg/kg, declines in litter production were observed. Increased frequencies of fetal resorption, fetal growth retardation, and skeletal alterations have been observed among the offspring of pregnant mice administered water fluoridated at 20 to 30 times the level of 0.7 mg/l recommended for children and infants (TERIS, 1990). Sodium fluoride at 30 or 60 mg/ was embryotoxic to rats, at 10 to 66 mg/kg for two months resulted in no conceptions in mice, and at 30 mg/kg for one year affected fertility and was embryotoxic in rabbits (Reprotext, 1991). Sodium fluoride affected spermatogenesis in mice at levels of 500 ppm or above in the drinking water and caused destructive changes in the testes of rats at 5 mg/kg when given twice a week for six months (Reprotext, 1991).

Mutagenicity was suggested, but studies were inconclusive due to inconsistencies in experimental protocol (TERIS, 1991; Reprotext, 1991). The fluoride ion has a variety of genetic effects in many test systems. In general, it has not been found to be mutagenic to microorganisms but has caused both chromosome aberrations and sister chromatic exchanges in higher animals both in vivo and in vitro. Although these genetic effects are ambiguous, this may be due to the fluoride ion disrupting cellular metabolism, producing varying effects in different experiments. Also,

because the fluoride ion is chemically reactive, it may react with some component in the culture medium or in the cells to produce some unidentified genetically active substance.

Toxicity to Nonhuman Receptors

Fluoride is always present in plants but is not considered an essential plant nutrient. Availability of fluoride to plants is affected by several factors, including pH, soil type, the amount of clay, and soil levels of calcium and phosphate. The use of phosphate fertilizers that are low in fluoride reduces fluoride toxicity at low pH values, presumably through ion competition, as long as the fluoride soil level does not exceed 180 mg/kg (Gough and others, 1979). No description of fluoride toxicity in plants was provided in the reviewed literature.

A summary of acute toxicity values for fluoride was provided by Ebasco (1990). Rainbow trout demonstrated the greatest sensitivity with 48- to 240-hour LC_{50} values of 2.7 to 4.7 mg/l at 13°C, and the mosquito fish was the least sensitive with a 96-hour LC_{50} value of 925 mg/l. Applying an uncertainty factor of 100 to the rainbow trout 48-hour LC_{50} provides a water TRV of 0.027 mg/l (27 μg/l) for aquatic organisms.

Although fluoride is an essential element in animals, herbivores are more likely to be exposed to unacceptable doses through the consumption of vegetation high in fluoride content. A daily intake of approximately 1.5 mg/kg/day corresponds to a marginal fluoride level that could lead to fluorosis (Suttie and others, 1957a, 1957b). Drinking water levels of 10 mg/l led to decreased wool production, and 20 mg/l caused health problems and severe teeth mottling in sheep (Peirce, 1959). Assuming that a 65-kg sheep ingests 4 l/day of water, this would be equivalent to a dose of 0.6 mg/kg/day. In swine, a dietary level of 150 mg/kg of feed is recommended as the long-term tolerance level (NRC, 1980); this is equivalent to approximately 6 mg/kg/day. Fowl appear more tolerant of fluoride as chickens tolerate feed levels as high as 350 mg/kg for chicks and 530 mg/kg for layers (Allcroft, 1954); these would be approximately equivalent to 45 mg/kg/day and 28 mg/kg/day, respectively. Ducks ingesting dietary sodium fluoride at 4220 mg/kg exhibited decreased growth but no mortality; assuming that a 2.5-kg duck ingests 0.25 kg/day of feed, this is equivalent to approximately 420 mg/kg/day.

HEXACHLOROCYCLOPENTADIENE

Hexachlorocyclopentadiene is used as a chemical intermediate for insecticides and as a flame retardant. With a reported solubility range of 0.805 to 2.1 mg/l, the mean value of 1.6 mg/l is used to estimate bioaccumulation by cattle (Ebasco, 1990). Based on these values, hexachlorocyclopentadiene may be considered moderately soluble. Coupled with a high soil sorption coefficient (K_{oc}) value estimated to range between 4800 and 24,330, hexachlorocyclopentadiene will be strongly bound to soil (Ebasco, 1990); therefore, hexachlorocyclopentadiene is not expected to be mobile in the environment.

Hexachlorocyclopentadiene is soluble in water, with an octanol-water coefficient (K_{ow}) value of 3.99. Once dissolved in water, hexachlorocyclopentadiene will rapidly photolyze (estimated photolytic half-life is 10 minutes). Hydrolysis is slower, with the half-life estimated to be between 3 and 11 days, depending on pH and temperature (Ebasco, 1990).

Although hexachlorocyclopentadiene has a vapor pressure of 0.08 mm Hg at 25°C, it is reported to volatilize rapidly from water (Ebasco, 1990). With atmospheric photolysis likely and hexachlorocyclopentadiene reacting with hydroxyl radicals and ozone, its atmospheric residence time is estimated at five hours (Ebasco, 1990).

Hexachlorocyclopentadiene is metabolized by soil microorganisms, with degradation occurring both aerobically and anaerobically (Shell, 1990).

Health Effects

EPA lists a chronic oral reference dose of 0.007 mg/kg/day (IRIS, 1991) and provides an subchronic oral reference dose of 0.07 mg/kg/day (HEAST, 1991). Chronic and subchronic inhalation reference doses of 2×10^{-5} and 2×10^{-4} mg/kg/day, respectively, are also provided (HEAST, 1991). Based on a 70-kg adult drinking 2 l/day, the oral chronic reference dose is equivalent to 0.245 mg/l (245 μg/l). A secondary MCL of 0.008 mg/l (8 μg/l) has been proposed for hexachlorocyclopentadiene based on organoleptic considerations. The human odor threshold value for hexachlorocyclopentadiene is 1.7 to 3.4 mg/m^3. Concentrations above the secondary

MCL value may adversely affect the appearance or odor of drinking water, thereby affecting the public welfare.

The oral reference doses were derived from a subchronic study in which rats were dosed by gavage to exposures ranging from 10 to 150 mg/kg/day (IRIS, 1991). Based on the presence of stomach lesions, 19 mg/kg/day was identified as the LOAEL, while a dose of 10 mg/kg/day was established as the NOAEL. The inhalation reference doses were derived from an inhalation study in which rats evidenced respiratory tract lesions at exposure concentrations of 0.15 ppm (HEAST, 1991).

Hexachlorocyclopentadiene is considered toxic, causing death if inhaled, swallowed, or absorbed into the skin, at doses of 50 to 500 mg/kg (Shell, 1990). Human exposure is most likely to occur by inhalation during manufacturing processes. It acts as an irritant to the eyes, skin, mucous membranes, and respiratory tract. Overdose may cause necrosis of the brain, heart, adrenals, liver, and kidneys (Shell, 1990).

Mice and rats are susceptible to hexachlorocyclopentadiene given by gavage. At high doses, elevated incidences of stomach lesions, toxic nephrosis, and death were observed. The dose-related kidney injuries suggest that the kidney is a major target organ (IRIS, 1991). The stomach lesions may result from direct exposure (portal effect) to large amounts of hexachlorocyclopentadiene. Similarly, lung damage and skin lesions are observed after inhalation and dermal exposure, respectively (IRIS, 1991).

Rats chronically exposed via inhalation to hexachlorocyclopentadiene showed depressed body weights, degenerative changes to the lungs, kidneys, liver, and death. In rat studies, the lungs were the major site of hexachlorocyclopentadiene toxicity following oral, inhalation, and intravenous exposures (Shell, 1990).

EPA is presently evaluating this chemical for evidence of human carcinogenic potential (IRIS, 1991).

No human epidemiological or clinical data were identified in the reviewed databases (Reprotext, 1991; TERIS, 1991; Shepard, 1991).

Very few experimental animal data are available in these databases. Hexachlorocyclopentadiene was determined not to be teratogenic based on the results of a rat primary culture/DNA repair assay (HSDB, 1991). In studies with rats and mice orally fed with hexachlorocyclopentadiene, no reproductive impairment or teratogenic effects were observed. Similarly, following oral exposure, no fertility impairment, teratogenic, or embryotoxic effects were noted, but maternal toxicity was observed in rabbits (Shell, 1990). In one reported study, pregnant mice and rabbits gavaged at doses up to 75 mg/kg/day during active organogenesis evidenced no teratogenic effects (Shepard, 1991). This level is significantly greater than the 19 mg/kg/day established by EPA as the LOAEL (IRIS, 1991).

Hexachlorocyclopentadiene has not been shown to be mutagenic in a variety of bacterial and mammalian cell cultures. It was found to be toxic to cells but without carcinogenic activity in a malignant transformation assay (Shell, 1990).

Toxicity to Nonhuman Receptors

No information pertaining to the toxicity of hexachlorocyclopentadiene to vegetation was identified. Because of the lack of data, no soil or water concentrations deemed protective of vegetation can be developed.

Based on a summary of aquatic toxicity data (Shell, 1990), the lowest acute toxicity value is 7.0 μg/l, and the lowest reported chronic value is 2.6 μg/l for the fathead minnow. Hexachlorocyclopentadiene has been found to act as an uncoupler of oxidative phosphorylation in the rainbow trout (HSDB, 1991). EPA (1987b) reports an LOEC of 7 μg/l for acute exposure and 5 μg/l for chronic exposure for freshwater organisms. Applying an uncertainty factor of 10 to the EPA chronic value derives an acceptable water concentration of 0.5 μg/l.

Little information was found regarding the toxicity of hexachlorocyclopentadiene to domestic livestock or wildlife. Acute LD_{50} values in the rabbit ranged from 420 to 620 mg/kg. This information is insufficient for developing soil or water concentrations deemed protective of this group of receptors.

ISODRIN

Isodrin, a chlorinated cyclodiene pesticide, is an isomer of aldrin. With low vapor pressure (estimated to be less than 1×10^{-4} mm Hg at 25°C) and low solubility values in water estimated to range from 0.02 to 1.4 mg/l, isodrin is not expected to either volatilize to the atmosphere or leach to groundwater to any appreciable extent (Ebasco, 1990). Sorption of isodrin to soils, sediments, and organic material is expected to occur, thereby rendering it persistent in the environment. Dependent on the type of organisms present and their ability to degrade isodrin, detectable isodrin may be present in soils more than 10 to 15 years after application (Ebasco, 1990). Endrin has been identified as a product of isodrin's biodegradation (Section 2.1).

Health Effects

EPA (IRIS, 1991; HEAST, 1991) has not evaluated isodrin quantitatively. Consequently, no RfDs or SFs are available. No information was found concerning the toxicity of isodrin to humans in the available literature. Furthermore, no information concerning either the carcinogenicity or teratogenicity or the subchronic, chronic, or reproductive toxicity in animals was identified in the available literature. Isodrin was one of 174 compounds tested for mutagenicity by the dominant lethal assay using the mouse (Epstein and others, 1972). No mutagenic effects were observed following the administration of 1.3 or 6.4 mg/kg to male mice before eight weeks of mating activity.

Oral LD_{50} values reported are 7 and 15 mg/kg-bw for female and male rats, respectively, and 8.8 mg/kg-bw for both sexes in mice (Ebasco, 1990). Dividing the LD_{50} by an uncertainty factor of 1×10^{5} has been recommended by Layton and others (1987) to provide an adequate margin of safety when deriving an acceptable human intake from an LD_{50} value determined from an animal study. Applying the uncertainty factor to the lowest reported LD_{50} value of 7.0 mg/kg-bw provides a RfD of 7×10^{-5} mg/kg/day.

Toxicity to Nonhuman Receptors

No information is available concerning the toxicity of isodrin to vegetation; therefore, it not possible to derive either soil or in water TRVs for vegetation.

Reported LC_{50} values for freshwater fish were 2.5, 6.0, 1.5, and 6.0 $\mu g/l$ in bass, bluegill, goldfish, and golden shiners, respectively (Ebasco, 1990). These data indicate that aquatic organisms are much more sensitive than terrestrial mammals to the toxic effects of isodrin. Applying an uncertainty factor of 100 for acute exposure to the lowest LC_{50}, a water TRV of 0.015 $\mu g/l$ may be calculated for aquatic organisms.

Oral LD_{50} values are available for the mouse, rat, and rabbit (Ebasco, 1990; ESE, 1989). The oral LD_{50} values are 8.8, 7, and 6 mg/kg-bw, respectively. No other data pertaining to terrestrial animals were identified.

Few avian data are available. In the chicken, a value of 2.7 mg/kg-bw is reported as the LD_{50} (Ebasco, 1990); this represents the LOAEL.

MALATHION

Malathion has a wide range of applications, including the protection of fruits, vegetables, ornamentals, and stored products (Farm Chemicals Handbook, 1990). Malathion is also employed as a topical pediculicide in medicine (TERIS, 1991). With a solubility of 145 mg/l, it is soluble in water; however, with a K_{oc} value of 1797, malathion will bind to soils, sediments, and dissolved organic material (Ebasco, 1990). These factors indicate that the portion of malathion that solubilizes or that sorbs to the dissolved organic material may be environmentally mobile. Based on the K_{oc} value, any malathion that adsorbs to soil and sediment is likely to persist. With a reported vapor pressure of 4×10^{-5} torr at 30°C (Ebasco, 1990), volatilization is not expected to be an important transport pathway, but volatilization may be enhanced by covaporization with water (Ebasco, 1990). However, with an odor threshold of one ppm (13.5 mg/m^3) and a strong characteristic skunk-like odor (HSDB, 1991), volatilization is an important pathway for detection. Stability of malathion in water is pH-dependent. Malathion hydrolyzed within minutes at a pH of 12, had a half-life of 12 hours at a pH of 9, and essentially no hydrolysis occurred at a pH of 5 to

7 (NAS, 1977). In general, malathion is degraded more rapidly than other organophosphate compounds under similar conditions (Ebasco, 1990).

Health Effects

EPA lists a value of 0.02 mg/kg/day for both the oral chronic RfD (IRIS, 1991) and the interim subchronic oral RfD (HEAST, 1991). No inhalation RfDs are available. The oral RfDs were derived from an acute study in which human males received doses of either 8 mg/day for 32 days, 16 mg/day for 47 days, or 24 mg/day for 56 days. The intermediate dose of 16 mg/day (0.23 mg/kg/day) was found to represent the NOEL. Both plasma and erythrocytic cholinesterase activity were decreased in individuals receiving the high dose of 24 mg/day (0.34 mg/kg/day), which represented the LOAEL (IRIS, 1991).

A member of the organophosphate pesticides, malathion inhibits the enzyme acetylcholinesterase (AChE), whether exposure is subchronic or chronic. Inhibition can be further enhanced when malathion is oxidized to malaoxon in vivo, which is a more potent AChE inhibitor in both the central and the peripheral nervous systems (Ebasco, 1990). Exposure leads to a myriad of symptoms, including headache, blurred vision, constricted pupils, respiratory distress, salivation, sweating, muscular weakness, apnea, tremors, convulsions, and coma. At higher doses, death results from respiratory failure (Ebasco, 1990).

Chronically, no adverse effects were observed in rats fed dosages of 100 mg/kg-feed for two years (NOEL), but weight gain and brain AChE were decreased at 1000 mg/kg-feed (LOAEL) (IRIS, 1991); NOEL dose is 5 mg/kg/day. In other chronic oral studies, AChE levels were decreased at dietary concentrations as low as 500 mg/kg. Subacute studies resulted in no effects at levels near 100 mg/kg, but AChE effects were observed at higher doses near 5000 mg/kg (Ebasco, 1990).

Effects were reported in a dog exposed to an air concentration of 5 ppm for four weeks; no other inhalation studies were described (IRIS, 1991). EPA has not yet evaluated malathion for evidence of human carcinogenic potential (IRIS, 1991).

No human epidemiological or clinical data are available in the reviewed databases (Reprotext, 1991; TERIS, 1991; Shepard, 1991). No biologically consistent increase in the frequency of congenital anomalies was observed in a cohort of 22,465 infants born to women who lived in areas of aerial malathion spraying during the first trimester of pregnancy (TERIS, 1991).

Malathion has been shown to affect brain control of reproductive functions in female rats (Reprotext, 1991). In addition, it has been suggested that malathion may affect pregnancy through microsomal enzyme system inhibition (Reprotext, 1991). In males, malathion appears to concentrate in the male reproductive organs. Malathion exposure induced testicular atrophy in mice and has resulted in both negative and positive effects on male sterility in mice (Reprotext, 1991). In rabbits and monkeys, there was a general tendency for increasing doses of malathion to decrease spermatogenic function (Reprotext, 1991).

When dosed at a level of 240 mg/kg, rats experienced no teratogenic activity, but there was a limited increase in the mortality rate of the neonates born to treated mothers (Shepard, 1991). In a separate study, no teratogenicity was reported in pregnant rats gavaged with 300 mg/kg on gestational days 6 through 15 (Shepard, 1991). In comparison, a feed level of 1000 mg/kg, which is approximately equal to an intake of 50 mg/kg/day, resulted in decreased AChE levels, as described earlier.

In a two-generation rat feeding study, reproductive effects were reported in rats receiving diets containing malathion at 4000 mg/kg-feed (approximately 200 mg/kg/day) (Ebasco, 1990); the reported effect was a decrease in the body weights of the second generation (Reprotext, 1991). At lower doses, malathion was not toxic when given alone but decreased the number of implantation sites and live fetuses when given with carbaryl (Reprotext, 1991).

Mutagenic effects were reported in tests using numerous bacterial and mammalian test systems, including human fetal lung fibroblasts (Ebasco, 1990).

Toxicity of Nonhuman Receptors

Although few data were identified regarding the toxicity of malathion to vegetation, malathion is reported to inhibit the degradation of some herbicides (Frear, 1976). A 15 percent

lower biomass increase was reported when malathion was applied at a rate of 8 ounces per acre (ESE, 1989). Applying a conversion factor of 2 x 10^6 pounds of soil per 6-inch-acre (ESE, 1989), the estimated concentration in the soil was 0.26 mg/kg. Adjusting the uncertainty factor to reflect a 15 percent growth reduction rather than a 25 percent growth reduction, the appropriate uncertainty factor to be applied is 3, leading to a soil TRV of 0.1 mg/kg for vegetation.

In aquatic systems, invertebrates appear to be more sensitive than vertebrates, with a 96-hour LC_{50} value of 1.0 μg/l reported for the invertebrate *Gammarus lacustris* (EPA, 1986c). The lowest fish LC_{50} reported was 50 μg/l for the largemouth bass, which was determined in a static test (EPA, 1986c). The lowest LC_{50} reported for a flow-through test was 110 μg/l for the bluegill (EPA, 1986c). Bluegill and channel catfish were not affected in ponds where water concentrations reached levels as high as 20 μg/l as a result of four semimonthly treatments during May through July, but the aquatic invertebrate population was significantly reduced (ESE, 1989). EPA (1986c) has established a chronic ambient water quality criterion of 0.1 μg/l but has not determined an acute criterion.

In livestock, the species, age, and sex of the animal affect the toxicity of malathion to exposed animals. Malathion is used primarily in dusting bags or backrubbers for the control of horn flies, and cattle may be adversely affected if the concentration of the powder exceeds 2 percent (Hatch, 1977). In calves, sheep, and goats, the minimum toxic dose was reported as an exposure to 1.0 percent (Osweiler and others, 1985). Calves, one-to-two weeks old were identified as more sensitive than full-grown animals; the maximum acute nontoxic dose tested was reported as 10 mg/kg-bw, and the minimum acute toxic dose was reported as 20 mg/kg-bw (Osweiler and others, 1985).

The oral LD_{50} for an adult chicken was 150 to 200 mg/kg (Radeleff, 1970). For avian wildlife, the reported LD_{50} values for the ring-necked pheasant, the horned lark, and the mallard duck are 167, 403, and 1485 mg/kg-bw, respectively (ESE, 1989). Observed effects included ataxia, wingdrop, weakness, falling with wings spread, tenesmus, salivation, dyspnea, tremors, and convulsions (Hudson and others, 1984).

MANGANESE

The twelfth most abundant element on earth, manganese is ubiquitous in nature. Used primarily in the metallurgical industry, manganese is an essential ingredient of steel, where it neutralizes the harmful effects of sulfur; serves as an anti-oxidant; and provides strength, toughness, and hardness. For these reasons, it is also used in the production of alloys of steel, aluminum, and copper (Adriano, 1986). Manganese may exist in the elemental state or in one of 10 valence states ranging from -3 to +7; the most common and therefore the most important environmentally are the +2, +4, and +7 valence states. The valence state influences the toxicity of the element that controls the bioavailability of the element. As with other metals, the valence state can change in the environment as many factors, including pH and electrical potential (Eh), are able to influence which valence state predominates (Adriano, 1986).

With three different oxidation states found in the natural environment, chemical speciation plays a major role in the distribution and mobility of manganese. Adsorption rates can be complicated as manganese forms relatively insoluble oxides in response to pH-Eh conditions (Adriano, 1986). In the +3 and +4 oxidation states, manganese occurs as precipitates in oxidized environments, and the +2 state is found in solution and solid phases under reducing conditions. There is great interaction between manganese and iron, notably affecting the bioavailability of both elements (Adriano, 1986). There are some data indicating the transformation of manganese by soil microorganisms, either by direct action or indirectly by changing the environment, such as a change in pH. The actions may then lead to the gradual accumulation of manganese (and iron) on certain anthropogenic substrates, such as tile lines placed subsurface (Adriano, 1986). Although manganese is not a volatile element, limited quantities reach the atmosphere as either particulate matter or aerosols. When these come into contact with water, a significant fraction solubilizes in minutes; the more acidic the water, the more manganese solubilizes upon contact with the water (HSDB, 1991). In aquatic environments, while a flux exists between the water and sediments, adsorption to the sediments represent the primary removal mechanism; flux rates are seasonal and appear to be temperature-dependent (HSDB, 1991).

Health Effects

EPA has derived a chronic oral RfD for manganese of 0.1 mg/kg/day (IRIS, 1991); the same value is used for the interim subchronic oral RfD (HEAST, 1991). EPA lists a value of 0.0004 mg/m^3 as both the chronic and subchronic inhalation reference concentration (HEAST, 1991). An interim inhalation can be calculated from the inhalation reference concentration by assuming that a 70-kg individual inhales 20 m^3/day, leading to an inhalation reference of 0.0001 mg/kg/day.

The oral value was derived from data available from three primary sources (IRIS, 1991). The first source is a review of several adult diet studies completed by the WHO. Based on manganese balance studies, WHO concluded that intakes of 8 to 9 mg/day were perfectly safe. The second source involved the evaluation of standard diets in several countries. No signs of toxicity were reported in individuals exposed to levels estimated to be as high as 11.5 mg/day. The third source (NRC) indicated that an adult intake of 2 to 5 mg/day was adequate and safe based on a level of 10 mg/day that was considered to be safe. The value of 10 mg/day was selected by EPA to represent the NOAEL; this represents an intake value of 0.14 mg/kg/day based on a 70-kg adult.

Following the estimated intake of 0.8 mg/kg/day manganese from a contaminated drinking water source, symptoms in exposed humans included lethargy, increased muscle tonus, tremors, and mental disturbances (IRIS, 1991). Although most severe cases involved the elderly, children also evidenced greater susceptibility. The prolonged inhalation of manganese dusts, leading to metal fume fever, is well documented as causing psychological and neurological disorders. Chronic effects include apathy, anorexia, and behavioral signs, including uncontrolled laughter, euphoria, impulsiveness, and insomnia (HSDB, 1991). Chronic manganese toxicity is not considered a fatal disease, but the individual may remain permanently disabled unless treated early in the exposure.

Most animal studies have evaluated the inhalation route and have demonstrated an effect on both the brain and the lungs (HSDB, 1991). Oral studies in rodents demonstrated biochemical

changes in the brain; however, rodents do not exhibit the same neurological deficits that are seen in humans, so the relevance of these effects is not clear. Dietary levels up to 100 mg/kg stimulated growth but proved deleterious at 600 mg/kg (HSDB, 1991); the value of 100 mg/kg is considered the NOEL for the rat.

Although primates are the species of choice for modeling human effects, only one limited oral study has been completed using four rhesus monkeys (IRIS, 1991). Muscular weakness and lower limb rigidity occurred after 18 months of exposure to 6.9 mg/kg/day of manganese as $MnCl_2 \cdot 4H_2O$. These symptoms ceased three weeks after exposure but returned five months later in more severe form (HSDB, 1991). Degenerated neurons were reported in the substantia nigra portion of the brain, and demyelination was reported in the spinal column (IRIS, 1991; HSDB, 1991). Damage to the brain and CNS, some similar to that found in the monkeys, was reported in dogs following repeated subcutaneous injections and in rabbits after repeated, large oral doses (HSDB, 1991).

EPA has classified manganese as a group D (not classified) carcinogen (IRIS, 1991). This classification indicates that there are insufficient data to assess the carcinogenicity of manganese. There is no evidence of carcinogenicity in the studies completed involving humans. In a mouse study in which mice were dosed through either subcutaneous or intraperitoneal injection, a larger percentage of lymphosarcomas was reported in the exposed animals, but the study was only reported in abstract form and could not be adequately verified. Increased incidences of tumors were reported following intraperitoneal injection in a mouse lung adenoma study, but the results were not considered significant. No significant differences were observed in mice and rats exposed to manganese powder or manganese dioxide through oral gavage or intramuscular injection. A significant increase in injection site sarcomas was observed in rats exposed by intramuscular injection to manganese acetylacetonate, but these results could not be extrapolated to the pure element (IRIS, 1991).

No epidemiological studies of malformations in infants of women who took manganese during pregnancy have been reported (TERIS, 1991). When men are exposed to levels as high as

900 mg/m^3, incidences of impotence have been reported (Reprotext, 1991). In one epidemiological study, men exposed to manganese at levels between 0.07 and 8.61 mg/m^3 had fewer children than expected (Reprotext, 1991). The current TWA-TLV for manganese of 5 mg/m^3 is within this range of exposure (ACGIH, 1990). Because of the other effects on the CNS, it is not clear if the effect of manganese on the male was a selective or a nonspecific CNS effect.

When manganese was provided to rats at dietary levels as high as 1000 mg/kg, no effect was reported on female fertility, and no teratogenic effects were reported (Reprotext, 1991). When manganese was provided in various forms, no teratogenicity was reported in mice, rats, hamsters, or rabbits; however, high doses may have been embryotoxic (Reprotext, 1991).

Manganese salts have selectively affected male fertility in the mouse, rat, and rabbit; however, this effect is protected by zinc (Reprotext, 1991). When injected intraperitoneally into rats, manganese caused structural damage to the testes; an effect also inhibited by zinc (Reprotext, 1991). When administered orally, manganese lowered testosterone levels in rats (Reprotext, 1991).

Nonhuman Receptors

Manganese is recognized as essential in plants, activating many enzyme systems and being a part of photosynthesis (Adriano, 1986). Because of its essentiality, deficiency leads to detrimental effects, including interveinal chlorosis that can lead, under severe deficiency conditions, to brown speckling and bronzing with abscission of developing leaves. Excess manganese is often associated with strongly acidic soil, which enhances its solubility (Adriano, 1986). Waterlogged soil, as in flood conditions, increases soluble manganese (+2) by the reduction of the +3 and +4 valence states to the +2 state. In general, manganese-affected plants exhibit deformed leaves, chlorotic areas, dead spots, stunted growth, and decreased yield (Adriano, 1986). Because of the different valence states and the high number of extraction techniques, it is difficult to provide soil concentrations that may be regarded as potentially toxic; usually, toxic tissue concentrations are provided. In soil with a pH of 4.8, a concentration of 7.88 mg/kg of ammonium acetate-extractable manganese was toxic to cotton. Naturally acid soil containing from 1.2 to 638 mg/kg manganese led to poor growth of lespedeza and sweet clover (Gough and others, 1979). In sandy Florida soils, levels of

approximately 300 to 400 mg/kg manganese were found to be toxic to some plants (Gough and others, 1979). Toxic manganese (+2) concentrations in water supplied for cultures were reported to range from a low of 1 to 10 mg/l for legumes and 5 mg/l for orange and mandarin seedlings to a high of 150 to 500 mg/l for oats and 550 mg/l for yeast cultures (Gough and others, 1979). In terms of tissue concentrations, most plants appear to tolerate about 200 mg/kg. The lowest reported toxic tissue level is 250 mg/kg in potato foliage and in soybeans, and rice is more tolerant (Adriano, 1986). Applying the 50 percent growth uncertainty factor of 10 to the lowest soil concentration of 1.2 mg/kg reported as toxic, the soil TRV is 0.12 mg/kg. Using the lowest water concentration of 1 mg/l reported as toxic to plants and the 50 percent growth reduction uncertainty factor of 10, a water TRV of 0.1 mg/l (100 μg/l) may be calculated for vegetation.

Manganese ions are seldom found in aquatic systems at levels above 1 mg/l: tolerance levels are reported to range from 1.5 mg/l to 1000 mg/l (EPA, 1986c). When in the permanganate form, concentrations as low as 2.3 mg/l are reported to be lethal within 18 hours, but the permanganate is not stable in the presence of organic matter (EPA, 1986c). As EPA has developed no criteria to protect aquatic organisms from manganese, the lowest reported tolerance level of 1.5 mg/l (1500 μg/l) may be considered the TRV for aquatic organisms.

Manganese is considered one of the least toxic trace elements. Because of poor gut absorption and the ability of the biliary system to rapidly excrete manganese, there is no body tissue accumulation with increased uptake (Phillips, 1977). Under natural dietary conditions, spontaneous lactation tetany has been recorded in cows grazing on pastures with high manganese content and of certain tree foliage that contain more manganese than most herbaceous plants; 15 mg/kg-dry weight was reported as the toxicity limit in pastures (Gough and others, 1979). Assuming 50 percent water for pasture grass and, for dairy cows, a forage ingestion rate of 60.1 kg/day-wet weight and a body weight of 800 kg (Table 3-8), this is equivalent to an intake of 2.2 mg/kg/day. The +6 form is highly toxic but does not occur in nature. The following toxic limits as mg/kg are reported: birds and chicks, 4800; rabbits, 1250 to 6000; rats, >2000; pigs, 500 to 2000; and lambs, 5000 (Gough and others, 1979).

OXATHIANE

Oxathiane (1,4-oxathiane; 1,4-thioxane) is a mustard gas decomposition product. A heterocyclic compound, oxathiane is soluble in water at 20,000 mg/l (Ebasco, 1990), and, with a small K_{ow} value estimated at 0.16 (Ebasco, 1990), oxathiane will not readily sorb to soil and may be mobile in the environment. Based on the vapor pressure of 3.9 torr reported at 20°C, it is volatile, which may represent an important transport pathway, especially from water and near-surface soils.

Health Effects

EPA has not developed RfDs for oxathiane, and the issue of carcinogenicity has not been addressed (IRIS, 1991; HEAST, 1991).

No data on the toxicity of oxathiane to humans were found in the reviewed literature. No data on chronic; subchronic; or reproductive toxicity, mutagenicity, or carcinogenicity of this compound were found in the reviewed literature.

Exposure of rabbits to undiluted oxathiane caused slight skin and moderate eye irritations (Ebasco, 1990). An acute LD_{50} value of 3328 mg/kg was determined for male rats (Ebasco, 1990). Antemortem effects reported were coma, polypnea, lacrimation, dyspnea, lethargy, ataxia, cyanosis, squinted eyes, epistaxis, wheezing, decreased body temperature, piloerection, hunched posture, and alopecia. Necropsy revealed discolored intestines, stomachs, and urinary bladders; gaseous stomachs and intestines; and distended urinary bladders (Ebasco, 1990).

Dividing the LD_{50} by an uncertainty factor of 1×10^5 has been recommended to provide an adequate margin of safety when deriving an acceptable human intake from an animal study (Layton and others, 1987). Using the LD_{50} value of 3328 mg/kg determined for rats provides a RfD of 0.03 mg/kg/day.

Toxicity to Nonhuman Receptors

No data regarding the toxicity of oxathiane to vegetation, aquatic systems, wildlife, or domestic animals was found in the reviewed literature. Because of inadequate data, no soil or water TRVs could be determined for vegetation or aquatic organisms.

SULFATE

Sulfate is a divalent anion, found in almost all natural waters, with concentrations ranging from less than 1 mg/l to several thousand milligrams per liter. A natural component of soil, one of the most important terrestrial sources of sulfate is deposited as sediment, from which magnesium, sodium, and especially calcium sulfate may be leached. Other soil sources of sulfates may be the oxidation of metallic sulfides and pyrites by moist oxygen during weathering processes. In addition, sulfates may be formed during the oxidative decay of organic matter (NAS, 1977). The primary industrial effluents that contribute sulfates to the environment are tanneries, sulfate pulp mills, steel mills, and textile plants. Industry is also a primary source of airborne sulfur oxide contamination, which is a primary environmental contaminant.

Except for the lead, barium, and strontium salts, most sulfate salts are moderately soluble in water, remaining in solution except under anaerobic conditions. Under anaerobic conditions, sulfate ions may be reduced to sulfide. The sulfide ion may be released to the atmosphere as hydrogen sulfide gas precipitated into soils or sediments, or incorporated into living organic matter (McKee and Wolf, 1963).

Health Effects

EPA does not provide RfDs for sulfate (IRIS, 1991; HEAST, 1991). EPA has addressed the sulfate ion in its development of the National Secondary Drinking Water Standards (EPA, 1979c), providing a secondary MCL of 250 mg/l in drinking water; this is simply an aesthetic criterion, an exceedance of which adversely affects water quality and, therefore, the public welfare. WHO (1984) provides a Drinking Water Guideline of 400 mg/l. A proposed rule released by EPA in June 1990 proposes an MCL and MCLG of 400 mg/l, stating that sulfate is being regulated for its

acute short-term effects. EPA is also considering an alternative MCL and MCLG of 500 mg/l. Final rules are proposed for release in March 1992. Assuming that a 70 kg adult drinks 2l/day, the proposed MCLG of 400 mg/l is equivalent to an oral RfD of 11 mg/kg/day. In the proposed rules, EPA classifies the sulfate ion as a group D (not classifiable) carcinogen. No information concerning the potential mutagenicity, teratogenicity, or fetotoxicity of sulfate was identified in the available literature.

As sulfate is poorly absorbed from the gastrointestinal tract (Novikov and Erisman, 1975), it has a pronounced cathartic effect resulting in diarrhea and resultant dehydration. The most sensitive subpopulation are infants as the reported consumption of formula containing 630 to 1150 mg/l sulfate led to diarrhea and gastroenteritis (EPA, 1985b). Sensitive adults may be affected at levels of 400 mg/l for short periods of time, but the human system quickly adapts to higher sulfate levels, thereby minimizing any long-term effects. The general population does not evidence any effect at levels as high as 1000 mg/l (Zoeteman and others, 1980). The effect of sulfate on the taste of water tends to limit the toxic effects of high sulfate levels as the palatability of water is adversely affected when the taste threshold is exceeded. The taste threshold for the most prevalent sulfate salts are 200 to 500 mg/l for sodium sulfate, 250 to 900 mg/l for calcium sulfate, and 400 to 600 mg/l for magnesium sulfate (McKee and Wolf, 1963; Zoeteman and others, 1980).

Toxicity to Nonhuman Receptors

Because sulfur is a vital part of all plant proteins and some hormones, it may be considered an essential nutrient (Thompson and Troeh, 1973). The atmosphere, apart from industrial areas, contains approximately 0.05 ppm Sulfur dioxide, but this may be enough to supply 5 to 10 percent of the average plant needs. Near smelters and other sources of sulfur dioxide, the concentration may increase to one ppm or more. This level is toxic to plant growth, primarily through the wet and dry deposition of acids formed from the reaction of sulfur dioxide and SO_3 with water. The deposition of the sulfate ion in soil often leads to acidification, and the soil will not support vegetation (Gough and others, 1979); therefore, toxicity is associated with acidity, not the ion. In

addition to the effects of the acidic soils, the toxicity of the sulfate ion in the soil may be associated with the balance between sulfur and nitrogen; an N:S ratio greater than 15:1 is detrimental for optimum yield and protein production (Woodhouse and Griffith, 1978). No specific soil concentrations are associated with toxicity because many factors affect the sensitivity of plant roots to the sulfate concentration in soil.

Leaf deposition and subsequent absorption of airborne Sulfur dioxide is another major source of toxicity to plants, with phytotoxicity occurring at air concentrations as low as 10 to 80 ppb (27 to 224 $\mu g/m^3$). Acute injury is first manifested as necrotic areas that extend through the leaf, showing on both sides; younger, fully expanded leaves are the most susceptible. This information is insufficient to derive a water or soil TRV for vegetation.

No information was identified describing the potential toxicity of the sulfate ion to aquatic organisms. Because the water chemistry of sulfate is complex, involving pH, electrical potential (Eh), and temperature, the acidification of aquatic systems is a major potential toxic effect. The available information is insufficient to develop a water TRV for aquatic organisms.

The toxicity of sulfates to terrestrial animals is similar to that associated with human exposure, diarrhea and subsequent dehydration. Cattle provided drinking water with a sulfate concentration of 10,000 mg/l evidenced a reduction in water consumption and suffered an average loss of 10 kg over a 56-day period. They also suffered severe cases of scouring (diarrhea), leading to dehydration (Clarke and Clarke, 1975). McKee and Wolf (1963) reported that cattle exposed to 2100 mg/l of sodium sulfate in their drinking water (110 mg/kg/day) eventually weakened and died. Digesti and Weeth (1973) reported that growing cattle tolerated sulfate levels up to 2500 mg/l (130 mg/kg/day) in drinking water with no ill effects. NAS (1977) indicated that this could be used as a maximum safe concentration. Monogastric animals and fowl were found to be less sensitive to sulfate, evidencing no effects at drinking water concentrations less than 7500 mg/l. Lambs were the most sensitive, being symptomatic at water levels of 3500 mg/l sodium sulfate (2700 mg/ sulfate/l or 270 mg/kg/day). This value may be considered a sub-chronic LOAEL.

Another manifestation of sulfate toxicity is the interference with copper absorption from the gut. Associated primarily with sheep, teratogenicity has been observed as a result of copper deficiency resulting from the inhibition of copper absorption by the sulfate ion excess, although no specific concentrations were provided (Gough and others, 1979).

TETRACHLOROETHENE

Tetrachloroethene (1,1,2,2-Tetrachloroethene) is widely distributed in the environment, as evidenced by its detection in trace amounts in most United States waters and in aquatic organisms, air, food, and human tissue (EPA, 1980g). Tetrachloroethene may be found in most environmental media, with a vapor pressure of 14 torr at 20°C, it is sufficiently volatile to dissipate rapidly from water and surficial and near-surface soils into the air, where it reacts with hydroxyl radicals. Photolytic degradation in surface waters has been demonstrated, and hydrolysis occurs very slowly (USAF, 1989). Based on estimated K_{oc} values ranging from 270 to 660 and a measured K_{oc} value of 360 (datum source unclear), tetrachloroethene is expected to sorb to soils and sediments (USAF, 1989). In deeper soils where there is little oxygen, about 25 percent of the compound is estimated to solubilize into the groundwater and migrate from the area (USAF, 1989). Microbial degradation occurs in groundwater under anaerobic conditions (USAF, 1989).

Health Effects

EPA lists a chronic oral RfD of 0.01 mg/kg/day (IRIS, 1991) and an interim subchronic oral RfD of 0.1 mg/kg/bw (HEAST, 1991). No inhalation RfDs are available.

The oral RfDs are based on a study (IRIS, 1991) in which mice were gavaged with tetrachloroethene in corn oil at doses ranging from 20 to 2000 mg/kg for six weeks. Hepatotoxic effects were first observed at an exposure level of 100 mg/kg/day. This value, converted to 71 mg/kg/day because exposure was for only five days per week, was established as the LOAEL. The next lowest dose was 20 mg/kg/day, which was converted to 14 mg/kg/day, and set as the NOEL. A NOEL of 14 mg/kg/day was also established in a second study (IRIS, 1991) in which rats were dosed with drinking water at 14, 400 or 1400 mg/kg/day.

No data regarding the noncarcinogenic effects in humans following chronic or subchronic oral exposure were found in the available literature. In rats, chronic oral exposure led to toxic nephropathy at time-weighted average intake levels as low as 300 mg/kg/day in mice and 471 mg/kg/day in rats (NCI, 1977). For humans exposed through inhalation, no subchronic data are available, but chronic exposure is reported to lead to respiratory irritation, nausea, sleeplessness, abdominal pain, and constipation (EPA, 1984h). EPA (1984h) reported liver cirrhosis, hepatitis, and nephritis following exposure, but the exposure levels were not provided. In rats exposed subchronically through inhalation, the liver, kidneys, and spleen evidenced pathologic changes at concentrations as low as 230 ppm. No effects were observed at 70 ppm, which may therefore be identified as an NOEL (EPA, 1984h). The only chronic nonhuman inhalation data provided by EPA (1984h) concerned unspecified liver damage reported in rats exposed to 600 ppm for a year.

Tetrachloroethene has been classified by EPA as a group B2 (probable human) carcinogen for both oral and inhalation exposure routes, indicating that sufficient data exist to prove that animals develop cancer following exposure, but insufficient data exist to establish carcinogenicity in humans. EPA (IRIS, 1991) states that final values for the SFs are pending; however, interim SFs are available (HEAST, 1991). The interim oral SF is 0.051 $(mg/kg/day)^{-1}$, and the interim inhalation SF is 0.0018 $(mg/kg/day)^{-1}$. The data on which oral carcinogenicity is based are presented in an NCI study (1977) in which rats and mice were orally exposed to tetrachloroethene through gavage. No data concerning human carcinogenicity following oral exposure are available. The inhalation SF was derived from an NTP inhalation study that used mice and rats (HEAST, 1991). The only available human inhalation data concern dry cleaning workers who were exposed to trichloroethylene and carbon tetrachloride as well as tetrachloroethene. No distinction can be made regarding levels of exposure to the three compounds (EPA, 1984h).

Based on the results of a large Scandinavian study of occupational exposures, tetrachloroethene is one of many solvents implicated in increasing the risk of CNS effects and structural defects in children following maternal exposure during pregnancy. Because the women were

exposed to a number of solvents, it is not possible to attribute these effects to tetrachloroethene alone (Reprotext, 1991).

Tetrachloroethene was described as teratogenic in chickens when injected into eggs, but the exposure levels were not presented (Reprotext, 1991). Tetrachloroethene was not teratogenic in several rodent inhalation studies (Reprotext, 1991). However, some developmental delays and embryotoxicity have been reported at similar levels, including lower weight gains, decreased performance on neuromotor tests, and lower brain levels of acetylcholine and dopamine (Shepard, 1991; HSDB, 1991).

Tetrachloroethene was found to be nonmutagenic in several tests including *Salmonella typhirium* and mouse lymphoma cell tests with or without metabolic activation (Ebasco, 1990). Neither sex-linked recessive lethal mutations nor sister chromatic exchanges were induced (Ebasco, 1990).

Toxicity to Nonhuman Receptors

No data regarding the toxicity of tetrachloroethene to terrestrial vegetation were found in the available literature. Though there are no data regarding terrestrial vegetation, tetrachloroethene may be able to enter plants in a manner similar to that surmised for chloroform. With a K_{ow} of 400, tetrachloroethene is partially miscible with water and is likely to cross into the root and be translocated within the plant. No data regarding its toxicological effects on vegetation are known. Data for determining soil or water TRVs for vegetation are insufficient.

Lay and others (1984) evaluated the effects on an aquatic system that included nine photoplankton species. Heterotrophic, mixotrophic, and autotrophic plankton were represented in the test, but only the autotrophic evidenced any toxic effects. Water concentrations as low as 440 μg/l were lethal to three species; the fourth survived one week. No effects were reported in the other species at levels as high as 1200 μg/l. EPA (1980i) states that the acute and chronic toxicity to freshwater aquatic life occur at 5280 and 840 μg/l, respectively. The rainbow trout is reported to be the most sensitive organism. The bluegill and fathead minnow evidence approximately the same sensitivity as *Daphnia magna*, which is about 13,500 μg/l. As no ambient water

quality criteria have been established, an uncertainty factor of 10 is applied to the chronic LOEC of 840 μg/l to derive a water TRV of 84 μg/l for aquatic organisms.

In the early part of the twentieth century, tetrachloroethene was used as an anthelminthic compound against hookworms in man and animal (Roberson, 1977; Negherbon, 1959). Similar in action to carbon tetrachloride, it is reported to be better tolerated, in general, by most animals (Clarke and Clarke, 1975). Acute symptoms are those associated with CNS toxicity, including dizziness and incoordination with occasional vomiting. Sufficient exposure can result in coma, circulatory collapse, and death. Liver and kidney damage have been reported following exposure to large doses that approached near lethal levels (Klaassen and Plaa, 1966). In farm animals, a study by Schlingman and Gruhzit (1926) was completed when the chemical was first introduced. In calves, a dose of 0.14 mg/kg-bw led to liver damage but no kidney damage. When dosed at 0.25 mg/kg-bw, greater liver damage and minor effects in kidney and spleen were observed. In sheep, a level of 0.36 mg/kg-bw led to minor liver effects. The horse appeared the most sensitive, with liver effects reported at levels as low as 0.11 mg/kg-bw. In swine and chickens, effects were not observed until levels exceeded 1 mg/kg-bw. No information regarding the effects in wildlife was found in the available literature. Thus, the levels presented for the horse may be considered the LOAEL.

TOLUENE

Toluene (methylbenzene) is a VOC used in the production of benzene and benzene derivatives, including benzoic acid, phenol, cresols, and TNT (USAF, 1989).

Toluene is expected to be relatively mobile in the soil/groundwater system as, with a solubility of 515 mg/l at 20°C, it is soluble in water. Coupled with a relatively low K_{oc}, estimated at 259, this indicates that it will not be strongly bound to soils (USAF, 1989). It is volatile and not persistent in surface-water systems. Available data indicate that toluene is biodegradable in the soil/groundwater environment (USAF, 1989). Several species of microorganisms are capable of using toluene as the sole carbon source, especially in adapted mixed cultures; however, in most soil/groundwater systems, such aerobic degradation would be of minimal importance because of

the low concentration of microorganisms (at depth) and the low dissolved oxygen (anaerobic) conditions (USAF, 1989).

Health Effects

EPA lists a chronic oral RfD of 0.2 mg/kg/day (IRIS, 1991) and an interim subchronic oral RfD of 2 mg/kg/day. EPA lists interim inhalation reference concentrations of 2 mg/m^3 for both chronic and subchronic exposure (HEAST, 1991). Assuming that a 70-kg individual inhales 20 m^3/day, the equivalent inhalation dose is 0.6 mg/kg/dy. Based on a 70-kg individual drinking 2 l/day of water, the chronic RfD is equivalent to 7 mg/l (7000 μg/l). A secondary MCL 0.04 mg/l (40 μg/l) has been proposed for toluene based on organoleptic considerations.

The primary study from which the chronic oral RfD is derived was a 13-week gavage study in which rats were dosed at levels of 0; 312; 625; 1250; 2500; or 5000 mg/kg for five days/week for the 13-week period. No signs of biologic significance were observed at or below the 1250-mg/kg dose (IRIS, 1991). Prostration, hypoactivity, ataxia, piloerection, lacrimation, salivation, and body tremors were reported at the higher doses. Liver and kidney weights were significantly increased in the male but not the female at the 625-mg/kg dose. Brain neuronal cell damage was observed at dosages of 1250 mg/kg and above. Based on this study, NOAEL was identified as 312 mg/kg, and LOAEL was identified as 625 mg/kg. Adjusting the value from a five-day/week to a seven-day/week exposure period, NOAEL and LOAEL were identified as 223 mg/kg/day and 446 mg/kg/day, respectively, (IRIS, 1991). Support data include a 13-week gavage study involving mice exposed to the same regimen as the rats. NOAEL for mice was identified as 1250 mg/kg (IRIS, 1991). In an earlier subchronic study, female rats exposed to approximate doses of 0, 84, 253, or 422 mg/kg evidenced no toxic effects, indicating that 422 mg/kg/day is the NOAEL (IRIS, 1991). However, male rats are known to be more sensitive than female rats, and the value is very close to the LOAEL identified previously.

Inhalation appears to be the most frequent and significant route of acute exposure to toluene. Animal experiments indicate that acute inhalation exposure leads primarily to CNS effects, including excitability, instability, incoordination, light narcosis and tremors, effects on

behavior patterns, and hearing loss (USAF, 1989). Other observed toxicological effects following acute inhalation exposures to animals include adverse effects on the kidneys, brain, and lungs (USAF, 1989). Exposure of the eyes to toluene vapors can cause conjunctival irritation and ocular irritation; however, no corneal damage was found (USAF, 1989). Acute inhalation exposure of humans to toluene resulted in CNS effects, such as depression, mild fatigue, weakness, confusion, lacrimation, tingling of the skin, euphoria, headache, dizziness, dilated pupils, convulsions, nausea, cardiac arrhythmias, and asphyxiation (USAF, 1989).

Chronic dietary exposure of rats to toluene has resulted in toxic effects, including relative increases in liver, kidney, and heart weights, necrosis of the brain, and hemorrhage of the urinary bladder (USAF, 1989). Similar effects were observed in animals following inhalation exposure (USAF, 1989). Human chronic inhalation exposures to toluene have resulted in enlarged livers, but no pathological changes were observed (USAF, 1989).

Toluene has been classified as a group D (not classifiable) carcinogen (IRIS, 1991). This classification is based on inadequate evidence of carcinogenicity in animals and humans.

Although several incidences of apparent reproductive effects resulting from human exposure to toluene are reported in the literature, invariably the documentation of exposure is poor or nonexistent. Individual case histories report that children exposed in vivo to toluene evidenced symptoms similar to those of fetal alcohol syndrome, including craniofacial and limb anomalies as well as microcephaly and CNS dysfunctions (TERIS, 1991). As toluene abuse is known to produce neurotoxicity in adults, it has been suggested that the same has occurred in the fetus, and therefore, these anomalies reported in children represent a "toluene embryopathy" (TERIS, 1991). Exposure to toluene, at least in conjunction with xylene, appears to lead to menstrual disturbances and to prolapsed uterus associated with strain (Shepard, 1991). In a case history, a man exposed to 1000 ppm of toluene from paint solvents experienced impotence (Shepard, 1991). It was unclear, however, if this was a secondary effect related to CNS damage.

In general, toluene is not teratogenic in laboratory animals, but has been fetotoxic at doses that were toxic to the mothers (Shepard, 1991; TERIS, 1991). No teratogenic effects were observed when female rats were exposed to air concentrations of 100 or 400 ppm on days 6 to 15

of gestation (HSDB, 1991). In a separate study, the effects reported in rats exposed to 400 ppm were decreased fetal weight and delayed ossification as well as maternotoxicity (Shepard, 1991). Pregnant mice exposed to air concentrations of 200 or 400 ppm on days 7 to 16 of gestation evidenced a significant increase in the number of fetuses with 13 ribs and in the brain lactic dehydrogenase activity at the high dose (HSDB, 1991). Increased cleft palate was reported in mice orally dosed at 1 mg/kg on gestation days 6 to 15, but this level was reported to cause maternotoxicity (TERIS, 1991).

Mutagenicity studies indicated that toluene did not induce specific location mutations in mouse lymphoma cells, in bacterial or yeast tester cells with or without metabolic activation, or in a mouse dominant lethal study (HSDB, 1991). Toluene did not cause sister chromatic exchanges or chromosomal aberrations in human lymphocytes (HSDB, 1991).

Toxicity to Nonhuman Receptors

No data regarding the toxicity of toluene to vegetation were identified in the available literature. Because of inadequate data, no soil or water TRVs may be determined for vegetation.

The 24-hour EC_{50} for an alga, *Chlorella vulgaris*, for reduction of cell numbers is 245,000 µg/l (ESE, 1989). The 96-hour EC_{50} for the alga, *Selenastrum capricornatum*, is 433,000 µg/l for the reduction of cell numbers and chlorophyll a production (ESE, 1989). The reported LOEC for acute exposure of freshwater organisms is 17,500 µg/l; no chronic freshwater value is available (IRIS, 1991). Applying an uncertainty factor of 100 to the acute LOEC provides a water TRV of 175 µg/l for aquatic organisms.

No toxicity studies were found for plants, birds, wild mammals, and domestic animals in the reviewed literature; therefore, TRVs for these receptors are calculated from experimental animal data.

TRICHLOROETHENE

Trichloroethene is widely used as an industrial solvent, particularly in metal degreasing (USAF, 1989). Trichloroethene also used in a variety of miscellaneous applications such as a low-temperature heat exchange fluid; as a fumigant; as a diluent in paints and adhesives; in aerospace

operations, i.e. to flush liquid oxygen; and in textile processing (USAF, 1989). Previously used as an extractant in food processing and as an anesthetic, it is no longer used for these purposes because of possible carcinogenic activity (USAF, 1989).

Trichloroethene is expected to be relatively mobile in the soil/groundwater system as, with a solubility of 1000 mg/l at 20°C, it is soluble in water. Trichloroethene has a low K_{oc} which, with an estimated value of 127, indicates that it will not be strongly bound to soils (USAF, 1989). Based on the vapor pressure of 60 torr at 20°C, transport of trichloroethene vapors through the air-filled pores of unsaturated soils followed by photo-oxidation is an important loss mechanism for near-surface contaminated soils (USAF, 1989). Upon reaching the atmosphere from surface waters and soil surfaces, trichloroethene reacts with hydroxyl radicals to produce hydrochloric acid, carbon monoxide, carbon dioxide, and carboxylic acid (EPA, 1979). Trichloroethene is not readily metabolized in the environment, but it can be degraded by acclimated microbial populations (USAF, 1989). Under normal environmental conditions, trichloroethene is not expected to undergo rapid hydrolysis (USAF, 1989).

Health Effects

EPA (IRIS, 1991; HEAST, 1991) does not provide any RfDs for trichloroethene. A chronic health hazard assessment for noncarcinogenic effects is currently under review by an EPA Work Group; therefore, an oral RfD is listed as pending (IRIS, 1991). In addition, no data are available to develop an inhalation RfD for trichloroethene (IRIS, 1991). Although no EPA RfDs are currently available, a value can be derived from available toxicity data. ATSDR (1988) indicated that death was reported in humans acutely exposed to an air concentration of 15,600 mg/m^3. Assuming that a 70-kg individual inhales 20 m^3/day and applying an uncertainty factor of 1000 and a modifying factor of 10, this provides a RfD of 0.4 mg/kg/day.

Animal studies indicate that trichloroethene is capable of causing kidney and liver damage, neurotoxicity, and dermatological reactions following chronic inhalation exposure to levels greater than 2000 mg/m^3 for six months.

The acute oral toxicity of trichloroethene is low in animals, as indicated by acute oral LD_{50} values that range from 2400 mg/kg for a mouse to 7330 mg/kg for a rabbit (ATSDR, 1988); the acute LD_{50} for the rat is reported as 4920 mg/kg (Ebasco, 1990). Increased organ and body weights and increased protein and ketones in urine were observed in mice exposed to levels between 660 and 790 mg/kg/day (ESE, 1989). EPA (1984i) reported 18 mg/kg/day as the NOEL for trichloroethene. Effects of short-term human exposure include mild eye irritation, nausea, vertigo, headache, and confusion. Unconsciousness and death may occur following exposure to excessive concentrations (ATSDR, 1988). Chronic oral exposure of humans to trichloroethene is characterized by dizziness, nausea, headache, ataxia, decreased appetite, and sleep disturbances (ATSDR, 1988).

EPA has classified trichloroethene as a group B2 (probable human) carcinogen (IRIS, 1991). This classification indicates that sufficient animal carcinogenicity evidence exists (based on an increased incidence of lung and liver tumors following exposure), but there is inadequate evidence of carcinogenicity in humans (IRIS, 1991). The results of several mouse bioassays indicated an increased incidence of liver tumors following oral gavage exposure and an increased incidence of lung tumors following inhalation exposure (EPA, 1984i). EPA (HEAST, 1991) has developed an interim oral SF of 0.011 $(mg/kg/day)^{-1}$ and an interim inhalation SF of 0.017 $(mg/kg/day)^{-1}$. EPA (IRIS, 1991) listed final SF values but withdrew them pending further review by an EPA Work Group.

No epidemiological studies of congenital anomalies in children born to women exposed to trichloroethene during pregnancy have been reported (TERIS, 1991).

Developmental toxicity studies with trichloroethene indicate that trichloroethene is fetotoxic but is neither mutagenic nor teratogenic to rodents following inhalation exposure; a potential intermediate metabolite, chloral hydrate, is mutagenic. No fetotoxicity or teratogenicity was reported in pregnant mice and rats exposed to air levels of 300 ppm for seven hours/day on gestational days 6 through 15 (Shepard, 1991). However, anomalies of skeletal and soft tissues indicative of developmental delay were reported in offspring of pregnant rats exposed to 1800 ppm for six hours/day for two weeks before pregnancy and the first 20 days of gestation

(Shepard, 1991). Other effects related to trichloroethene exposure include delayed ossification of the skeleton, increased resorption and decreased fetal body weights in rats (ATSDR, 1988). Increased sperm abnormalities were reported in mice exposed to 3000 ppm for four hours/day for five days (Shepard, 1991). This latter concentration is 50 percent greater than the reported chronic toxic value.

Toxicity to Nonhuman Receptors

No data regarding the toxicity of trichloroethene to vegetation were identified in the available literature. Because of the lack of data, no soil or water TRVs could be determined for vegetation.

Static tests with *Daphnia magna* resulted in 48-hour EC_{50} values ranging from 41,000 to 100,000 µg/l (EPA, 1980). Tests with *Daphnia pulex* provided values ranging from 39,000 to 51,000 µg/l (EPA, 1980). In flow-through tests with the fathead minnow, the 96-hour LC_{50} was 40,700 µg/l, and the value associated with static tests was 66,800 µg/l; fathead minnows evidenced loss of equilibrium at 21,900 µg/l (ESE, 1989). The 96-hour LC_{50} for bluegill was 44,700 µg/l (ESE, 1989). Acute and chronic criteria for the protection of freshwater organisms have not been established for trichloroethene; however, EPA (1986b) reports LOECs for acute and chronic exposures to trichloroethene of 45,000 and 21,900 µg/l, respectively (EPA, 1986). Applying an uncertainty factor of 10 to the chronic freshwater LOEC provides a water TRV of 2200 µg/l for aquatic organisms.

No data concerning the toxicity of trichloroethene to domestic livestock, terrestrial wildlife, or avian life forms were found in the available literature. TRVs will be derived from laboratory animal data.

XYLENE

Commercial xylene is a mixture of three isomers: ortho-xylene (1,2-dimethylbenzene), meta-xylene (1,3-dimethylbenzene), and para-xylene (1,4-dimethylbenzene) (USAF, 1989). The xylenes are widely found as fuel components and as solvents (USAF, 1989). Because they have

similar chemical and biological properties, the isomers are generally considered as one group-xylene.

Xylene, with a water solubility value of 0.3 mg/l (USAF, 1989), is expected to be only slightly mobile in the soil/groundwater system even though it has a comparatively low K_{oc} of 691 (USAF, 1989). Based on the vapor pressure of 7 to 9 torr for the three isomers, transport of the vapors through the air-filled pores of unsaturated soils to the atmosphere, where they undergo photo-oxidation, is an important loss mechanism for the unbound xylene in the near-surface contaminated soils (USAF, 1989). That portion that reaches the atmosphere from surface waters and soil surfaces reacts with hydroxyl radicals to form carbon dioxide and cresol, and when the products react with reactive peroxyacetylnitrate (PAN), nitrogen may be formed (Ebasco, 1990). Limited data on the biodegradability of xylene in the soil/groundwater environment are available; however, based on data for other structurally similar chemicals, i.e., toluene and benzene, it is expected that xylene would be biodegradable.

Health Effects

EPA lists an interim chronic oral RfD of 2 mg/kg/day and states that the final inhalation RfD is pending (IRIS, 1991). An interim subchronic oral RfD is listed by EPA (HEAST, 1991) as 4 mg/kg/day. A value of 0.3 mg/m^3 is listed as the reference inhalation concentration (HEAST, 1991). Assuming that a 70-kg individual inhales 20 m^3/day, this is equivalent to an inhalation RfD of 0.09 μg/kg/dy. Based on a 70-kg adult ingesting 2 l/day of water, the equivalent chronic drinking water concentration is 70 mg/l (70,000 μg/l). A secondary MCL of 0.02 mg/l (20 μg/l) has been proposed for xylene based on organoleptic considerations. Concentrations that exceed this level may adversely affect water quality and, therefore, affect the public welfare.

The oral RfDs were derived from a 103-week study in which rats were dosed by gavage at 250 or 500 mg/kg/day and mice at 500 and 1000 mg/kg/day (IRIS, 1991). Based on the results of these bioassays, NOAEL was set at 250 mg/kg/day. The inhalation RfDs were developed from a study in which humans were exposed to air concentrations of 20 ppm for 7.5 hours/day for five days. Effects of concern were nose and throat irritation and CNS effects (HEAST, 1991).

Human and animal studies indicate that acute inhalation exposures to elevated concentrations of xylene cause CNS depression with symptoms including dizziness, drowsiness, nausea, vomiting, abdominal pain, loss of appetite, pulmonary edema, and unconsciousness, as well as reversible effects on the liver and kidneys (USAF, 1989). Liquid xylene and high vapor concentrations of xylene are irritating to the eyes, and the vapor may cause transient, reversible damage to the cornea (USAF, 1989). Aspiration of liquid into the lungs may cause chemical pneumonitis, pulmonary edema, and hemorrhage (USAF, 1989).

Chronic exposure to xylene in animals resulted in slight inflammation, congestion, and necrosis of the kidney tubules, a reversible decrease in red and white blood cell count, an increase in platelets, and moderate liver enlargement. Necrosis and nephrosis have also been reported (USAF, 1989). Chronic exposure to humans results in effects similar to acute exposures, but these are more severe and include headache, fatigue, irritability, digestive disorders, and sleep disorders (USAF, 1989).

Xylene has been classified as a group D (not classifiable) carcinogen. This classification indicates that there are no human data, and there is inadequate evidence of carcinogenicity in animals (IRIS, 1991).

The limited number of human birth defects reported following exposure to xylene are inconclusive as no documentation is available, and compounding circumstances were likely (Reprotext, 1991). Other reproductive effects, such as menstrual disturbances, have been reported in humans following exposure to xylene; however, the data are inconclusive as other solvents may have been involved (Reprotext, 1991).

Generally, the mixed isomers have been embryotoxic and fetotoxic at high doses where some maternal toxicity was evident (Reprotext, 1991). Delayed formation of bone and extra ribs have been reported, but these are considered normal variants in these species. Fetal deaths were reported to have increased in mice exposed to air concentrations approaching the LD_{50} dose (Reprotext, 1991). Although a single study indicated that the three isomers were teratogenic in the mouse, para-xylene (1,4-xylene) was the only isomer to cause effects at doses not toxic to the mother (Reprotext, 1991). No maternal or fetal toxicity was reported in mice orally dosed at

1030 mg/kg on gestation days 6 through 15; toxicity was seen at the next highest dose of 2060 mg/kg (ESE, 1989).

Studies with *Salmonella typhimurium* and *E. coli* indicated that technical grade xylenes or mixed xylenes are not mutagenic (USAF, 1989). In *Drosophila* recessive lethal tests, technical grade xylene, but neither ortho- nor meta-xylene, was weakly mutagenic (IRIS, 1991). In vitro tests with human lymphocytes showed that xylene did not cause an increase in the number of sister chromatic exchanges (IRIS, 1991).

Toxicity to Nonhuman Receptors

No data on the toxicity of xylenes to plants were found in the literature reviewed; therefore, no soil or water TRVs could be determined for vegetation.

In aquatic ecosystems, plants exposed to 100 ppm of xylene died within four weeks, but no effects were observed at 5 ppm. Growth of phytoplankton was inhibited at 10 to 100 ppm (ESE, 1989). For rainbow trout and bluegill, 96-hour LC_{50} values are 8.2 and 13.5 mg/l, respectively (ESE, 1989). Xylene causes an increase in membrane permeability, which leads to a loss of fatty substances. Acute toxicity manifests as rapid, violent, and erratic swimming; coughing or backflushing of water around the gills; irritability; equilibrium loss; paralysis; and death (ESE, 1989). As no ambient water quality criteria are available (IRIS, 1991), an uncertainty factor of 100 may be applied to the lowest reported acute LC_{50} value of 8.2 mg/l to provide a water TRV of 0.082 mg/l (82 μg/l) for aquatic organisms.

No data concerning the toxicity of xylenes to birds, livestock animals, or terrestrial wildlife was found in the literature reviewed.

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TOXICOLOGICAL PROFILE FOR ALDRIN/DIELDRIN

PREPARED BY
SHELL OIL COMPANY
OCTOBER 13, 1992 VERSION

DATE: October 13, 1992 Version

ALDRIN/DIELDRIN

SUMMARY The cyclodiene pesticides aldrin and dieldrin are no longer manufactured or used in the U.S. (Hazardous Substances Data Bank, 1990). Both are acutely toxic, with LD_{50} values ranging from 39 to 60 mg/kg in rats. The major site of action is on the central nervous system with symptoms ranging from disorientation to convulsions and muscle twitching etc. Death may be due to anoxemia. Other indices of effects on the liver have been reported in rats and dogs (hypertrophy) and monkeys (enzyme induction), but not in humans. (At least some of these effects may be prevented by antioxidant vitamins.) Aldrin and dieldrin may cause embryotoxicity, but are apparently not teratogenic. Reproductive toxicity has been reported in animals, but usually only at dose levels which also caused maternal toxicity. Neither compound is considered to be genotoxic or mutagenic in a wide variety of in vitro and in vivo assays. Both compounds are associated with liver tumors in mice. There is no consistent pattern of treatment-related tumors, in liver or other tissues, that has been observed in any other species exposed to aldrin/dieldrin. A recently updated epidemiology study in which individual exposures were estimated from blood concentrations, showed a slight negative trend between exposure and death or tumor incidence, contrary to predictions based on mice. There was no evidence of morbidity or long term effects in this population, which has been followed for nearly 40 years. The Acceptable Daily Intake (ADI) of 0.0001 mg/kg/day which was established by WHO and re-affirmed on several occasions, should provide an ample margin of safety to the general public since there is a factor of 100-500 between the intakes of the highest exposed manufacturing workers and the WHO ADI.

CHEMICAL AND PHYSICAL PROPERTIES

CAS Number: Aldrin: 309-00-2
Dieldrin: 60-57-1

Chemical Formula: Aldrin: $C_{12}H_8Cl_6$
Dieldrin: $C_{12}H_8Cl_6O$

IUPAC Name:
Aldrin: 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-exo-1,4-endo-5,8-dimethanonaphthalene.

Dieldrin: 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-endo-1,4-exo-5,8-dimethoanonaphthalene.

Molecular Weights: Aldrin: 365
Dieldrin: 381

Melting Point: Aldrin: 104 C
(Tech. aldrin 49-60 C ref. WHO, 1989)
Dieldrin: 176 C

Solubility in Water: Aldrin: 27 ug/liter at 27 C
(WHO, 1989)
Dieldrin: 186 ug/liter at 20 C
(WHO 1989)

Solubility in Organics: Soluble in most organic solvents

Log Octanol/Water Partition Coefficient (K_{ow}):

Aldrin:
5.66 (Geyer *et al.*, 1984)
7.40 (Briggs, 1981)
5.66 (Kenaga, 1980) Table III
5.30 (U.S. EPA, 1986)

Dieldrin:
4.32 (Davies and Dobbs, 1984)
6.2 (Briggs, 1981)
3.69 (Rao and Davidson, 1983)
5.48 (Kenaga, 1980) Table III
3.5 (U.S. EPA, 1986)

Soil/Water Partition Coefficient (K_{oc}):

Aldrin:

76,000	Versar (1984)
28,200	Briggs (1981)
96,000	U.S. EPA (1986)

Dieldrin:

3,300; 12880	Kadeg *et al.* (1986) Literature Values
7,413	Briggs (1981)
35,600	Kenaga (1980)

Bioconcentration Factor

	Aldrin
1,555	Davies and Dobbs (1984) Eqn C (log k_{ow} = 5.66)
13,640	Davies and Dobbs (1984) Eqn C (log k_{ow} = 7.4)
1,500	Lyman *et al.* (1982)
3,140	Kenaga (1980)
10,800	Kenaga (1980)
3,690	Davies and Dobbs (1984) Eqn B (log k_{ow} = 5.66)
40,345	Davies and Dobbs (1984) Eqn C (log k_{ow} = 7.4)
11,792	Lyman *et al.* (1982) Eqn 5-2 (log k_{ow} = 5.66)
247,742	Lyman *et al.* (1982) Eqn 5-2 (log k_{ow} 7.4)
1,810	Davies and Dobbs (1984) Eqn C (log k_{ow} 6.12)
6,940	Davies and Dobbs (1984) Eqn B (log k_{ow} 6.12)
26,400	Lyman *et al.* (1982) Eqn 5-2 (log k_{ow} = 6.12)

	Dieldrin
5,800,4,420	Kenaga (1980) Table 3 (experimental)
1,489	Davies and Dobbs (1984) Eqn B (log k_{ow} = 5.0)
12,590	Davies and Dobbs (1984) Table 2 (experimental)
292	Davies and Dobbs (1984) Eqn C (log k_{ow} = 4.32)
1,130	Lyman *et al.* (1982) Eqn 5-2 (log k_{ow} = 4.32)
30,339	Lyman *et al.* (1982) Eqn 5-2 (log k_{ow} 6.2)
480	Davies and Dobbs (1984) Eqn A (S = 0.25)
3,700	Lyman *et al.* (1982) Eqn (log k_{ow} = 5.0)

Vapor Pressure: Aldrin: 2.31x10^{-}5mm Hg at 20 C
Aldrin: 6.5 x 10-5mm Hg at 25C (WHO, 1989)
Aldrin: 6 x 10^{-}6mm Hg (U.S. EPA 1986)
Dieldrin: 3.3 x 10-6 mm Hg at 25 C
(WHO, 1989)

Henry's Law Constant:

Aldrin: 2.4 x 10-5 atm=ms/mole (calculated)
1.6 x 10^{-5} atm-m^3/mole (U.S. EPA 1986)

Dieldrin: 1.4 x 10^{-5} atm-m^3/mole (calculated)
4.58 x 10^{-7} atm-m^3/mole (U.S. EPA)

METABOLISM AND TOXICOKINETICS

Summary of Metabolism Data

Extensive data have been published on the metabolism of aldrin and dieldrin, which has been summarized in the WHO Environmental Criteria Document 91 (WHO, 1989). Aldrin is rapidly oxidized to dieldrin in both plants and animals (including humans). Dieldrin is slowly metabolized to more hydrophilic compounds which are excreted via feces and urine. There is no evidence of qualitative differences in metabolites formed in different animal species, including humans, which might explain any differences in species response. The major metabolite of dieldrin in most species is 9-hydroxydieldrin, with lesser amounts of 6,7-*trans*-dihydroxydihydroaldrin, its dicarboxylic acid derivative and the bridged pentachloroketone formed in species-specific ratios.

The major animal metabolites, 9-hydroxy-dieldrin, the pentachloroketone and the 6,7-diol, have also been identified in humans. None of these metabolites have been shown to possess biological activity approaching that of dieldrin itself.

Absorption and Distribution

Aldrin and dieldrin are absorbed into the body from the alimentary tract, through the skin or by inhalation of the vapor or dust. Aldrin is rapidly converted to dieldrin in the body, and exposure to either compound by any route results in an almost immediate elevation of dieldrin levels in the blood. Dieldrin partitions from blood into the fatty tissues and the concentration differences between organs reflect this partitioning. It is detoxified in the liver and excreted. In some species this is mainly via the feces, while in others the urine is an important route. A typical distribution ratio for humans for dieldrin in adipose

tissue/dieldrin in blood is 136 under equilibrium conditions of intake, storage, and elimination (Hunter and Robinson, 1967; Hunter *et al.*, 1969), indicating the extensive partitioning into the fat for this material. Since dieldrin is taken up very rapidly and since the biological half-life of dieldrin is very long (approximately 9 months in humans) the levels in blood are quite stable and representative of total body burden. With continuous exposure to aldrin (or dieldrin) in humans, the rate of elimination gradually increases until a steady state is achieved at about 21 to 24 months.

Steady State Concentrations

When a steady state is reached between intake and excretion, the amount of dieldrin found in specific tissues reflects the total amount absorbed regardless of the route of absorption. The ratio of dieldrin intake (e.g., ppm in food) to the concentration found in various tissues has been determined for several species, including the human. It is possible, therefore, to estimate daily exposures from tissue concentrations and, conversely, the tissue concentrations in different organs at given dietary exposures. NIOSH (1978) summarized some of these data for different species.

Biological Half-Life

Since dieldrin is only slowly metabolized and excreted, it accumulates in the body. Available information leads to the conclusion that with continuous exposure, a plateau is reached for concentrations found in the various body tissues -- an approximation being that 95% of the maximum for a particular intake would be reached in a time interval of three times the excretion half-life. There are data for half-lives of dieldrin in many species, including man. Many of these data were summarized by Moriarty (1975), and are presented in Table 1.

TABLE 1.

Biological Half-Life of Dieldrin in Several Species

Species	Biological half-life (days)
Laboratory rat	5 - 15
Pigeon	47
Steers and heifers	74
Ewes	97
Beagle dogs	126 - 164
Human	266

Correlation of Dieldrin Blood Levels With Exposure and Effects

Symptoms of aldrin/dieldrin intoxication are non-specific, and thus a tissue analysis test is required to confirm that symptoms, signs and clinical course of any particular case are the result of aldrin/dieldrin intoxication. Extensive work, including animal studies, medical surveillance of workers employed in the manufacture or formulation of aldrin/dieldrin, and human volunteer studies, has demonstrated that the adverse effects caused by aldrin/dieldrin are directly related to the concentration of dieldrin in the blood (Brown *et al.*, 1964; Hunter and Robinson, 1967; Hunter *et al.*, 1969; Jager, 1970). Thus, determination of dieldrin levels in blood provides a powerful, convenient and reliable differential diagnostic aid. Further, since dieldrin concentrations have been reported in blood as well as various tissues and organs of both animals and humans, it is possible to extrapolate from one route of exposure to any other route, and to determine rather precisely what the total exposure to aldrin/dieldrin has been, expressed as mg per unit weight of oral exposure. It should also be pointed out that dieldrin blood levels are more reliable, useful and definitive indicators of actual exposure than human diet estimates.

Because of the convenience and early demonstration of the value of blood monitoring, it has been possible to correlate blood levels with specific observed effects following exposure to aldrin/ dieldrin. Jager (1970) showed that no objective clinical or laboratory indications of adverse effect were seen in workers whose blood dieldrin levels were less than 200 ng/ml (0.2 ug/ml). This observation has been confirmed more recently by de Jong (1991). discussion of blood levels with specific effects follows as appropriate in this document.

TOXIC EFFECTS OF ALDRIN/DIELDRIN

There is a considerable body of information on the toxicity of aldrin and dieldrin derived from studies of laboratory animals, domestic animals, and humans under both laboratory and practical conditions. This data base includes reports and papers published thirty to forty years ago, when dieldrin was used for public health purposes and also for the treatment of external parasites in domestic animals such as sheep by dipping. The concentration in the dip bath was a nominal 0.05% dieldrin.

Acute Toxicity

Both aldrin and dieldrin are acutely toxic to animals and humans. The oral LD_{50}s for aldrin and dieldrin in rats are 39-60 mg/kg and 46 mg/kg, respectively (Merck, 1983).

The dermal LD_{50} for both aldrin and dieldrin is approximately 100 mg/kg in organic solvents. Both are less toxic when administered as wettable powders. The available information suggests that there are no major species differences in the acute toxicity of aldrin and dieldrin - most species are within the range of an order of magnitude.

The 1990 Toxicology Profile on aldrin and dieldrin published by ATSDR included graphical summaries representing the available acute, sub-acute and chronic toxicity information which is available on these compounds. This document suggests there is a trend which indicates the difference between the acute no-effect intake and the chronic no-effect intake is about one to two orders of magnitude for many end-points. Thus, the use of an acceptable intake such as the WHO ADI, which is based on chronic data, will represent a daily intake which for short term exposure would contain an even greater safety factor.

Major Target Organs and Systems for Aldrin/Dieldrin

Available animal and human evidence points to the central nervous system (CNS) as the main target organ for acute toxic effects of aldrin/dieldrin. These effects, including hyperexcitability, tremors, convulsions and possibly death from anoxia. While several biochemical changes have been demonstrated after exposure to aldrin or dieldrin in nerve or brain tissue, it is still not certain as whether there is a single biochemical change which can explain the toxic effects. For example, some authors claim that changes in neurotransmitters such as GABA are important. Others claim that the Mg++ ATPases (Bandyopadyay, 1982a) and Ca++ ATPases (Janik and Wolf, 1992) are inhibited.

Liver is also a target organ in many species, responding with hypertrophy and/or enzyme induction in a species-specific manner. Mice appear to be more susceptible than other species with respect to liver lesions. Dieldrin-induced immunosuppression has been observed in mice (e.g. Krzystyniak *et al.* 1989) and several other species (Wassermann *et al.* 1972; Kaminski *et al.* 1982), but this effect has not been noted in humans. In general, liver is the most sensitive target, showing reversible changes (e.g. hepatomegaly, enzyme induction) at levels of exposure that have no detectable effect on the CNS.

There have been several recent papers which describe the effects of antioxidants on the toxicity of dieldrin, endrin and several other organochlorine compounds. With endrin, Numan et al. (1990) and Hassan et al. (1991) showed that it was possible to approximately

double the toxic dose and also protect against histological changes in the livers and kidneys of rats, mice, Guinea Pigs and hamsters. Bandyopadhyay (1982 a,b) showed that pretreatment with vitamin C prevented growth retardation and also histological changes in the livers and kidneys of rats dosed with 5 mg/kg/day dieldrin. These studies are intriguing and the studies are being repeated.

Central Nervous System

Acute or long-term overexposure to aldrin and dieldrin produces effects ranging from apprehension and excitability to involuntary muscle movements and epileptiform convulsions in all mammalian species that have been studied. These effects may be caused by global intensification of synaptic activity, apparently due to inhibition of GABA-nergic transmission (Woolley *et al.*, 1985). It is also possible that the inhibition of Mg++ ATPases and Ca++ ATPases alters the electrolyte mechanisms for homeostasis in nerve cells, including the flux of calcium and potassium (Bandyopadhyay, 1982a; Janik and Wolf, 1992). These actions are not necessarily mutually exclusive.

Some of the studies relating to the CNS have been summarized by Taylor and Calabrese (1979). In humans, exposure to high levels of aldrin/dieldrin produces electroencephalographic (EEG) anomalies (Spiotta, 1951; Hoogendam *et al.*, 1962, 1965; Kazantzis *et al.*, 1964; Jager, 1970; Gupta, 1975). Jager (1970) described the EEG changes as consisting of bilateral peak and dome complexes which did not occur when dieldrin blood levels were below 0.2 ug/ml. The EEG anomalies he described had disappeared within a few weeks or months after exposures were discontinued.

Garrettson and Curley (1969) reported a parallelism between the rate of disappearance of EEG changes and the rate of decrease in dieldrin blood levels in the case of an accidentally poisoned child. Now, blood analysis has supplanted EEG examination as the method of choice for monitoring exposed persons. Based on studies with exposed workers, Brown *et al.* (1964) concluded that a blood dieldrin concentration of 150-200 ug/l is the threshold for CNS effects. This level is supported by other human data reported by Avar and Czegledi-Janko (1970) and Kazantzis *et al.* (1964).

Those who survive acute intoxication recover completely after a short period of residual symptoms and signs (Hoogendam *et al.*, 1962; Jager, 1970; Avar and Czegledi-Janko, 1970). Rare cases have been reported in which some unusual sequelae were alleged to be due to aldrin/dieldrin poisoning, but in each of these cases, the connection to

aldrin/dieldrin was circumstantial, the exposure had not been high, no analyses of dieldrin concentrations in blood or fat were reported and the symptoms reported were different from and not typical of results from animal experiments. Importantly, in humans, even at exposures which caused clinical signs of CNS effect, there were no observed effects on any other organ system.

Liver

There are distinct species differences in liver responses to aldrin/dieldrin, including increased liver-to-body weight ratios, induction of hepatic drug metabolizing enzymes and neoplasia (Wright *et al.* 1972, 1977, 1978).

Enzyme Induction

Animal Studies

The earliest, most sensitive response to aldrin/dieldrin exposure in many species is the proliferation of hepatic smooth endoplasmic reticulum and the induction of several drug metabolizing enzymes, including the microsomal cytochrome P-450-dependent monooxygenases. These inductions may serve to increase or decrease the toxicity of a given xenobiotic, since specific enzymatic activities can either detoxify or bioactivate not only the inducing compound but others which may also be present.

In addition to enzyme induction, mouse liver tissue responds with organ weight and structural changes that are visible under light or electron microscopy. In the Wright *et al.* studies cited above, primates did not show increased liver weights following dieldrin exposure, whereas mice did. Other primate studies (Adamson and Sieber, 1983) highlighted the differences between rodents and primates with regard to hepatic responses to organochlorines. As mentioned above, there is data suggesting that at least some of the effects on the liver can be reversed by feeding antioxidants.

Human Studies

A number of human studies have shown no evidence of measurable alterations in liver structure or function, including enzyme induction, in exposed manufacturing and agricultural workers and volunteers who were examined specifically for this endpoint. Many reports (Hunter *et al.*, 1969; Jager, 1970; Warnick and Carter, 1972; Morgan and Roan, 1974; Ottevanger and van Sittert, 1979; Sandifer *et al.*, 1981; van Sittert and de Jong, 1987) have shown that no liver enzyme induction occurs in humans with blood dieldrin levels at or below 105 ng/ml (0.1 ug/ml).

The most recent account is that of de Jong (1991), who concluded that total exposures of up to a median value of 1260 mg, with a highest personal intake of 941 micrograms per day and a total estimated intake of up to 5758 mg did not have any effect on liver function. The tests included the use of D-Glucaric acid as an indicator of enzyme induction. Using a 10-fold safety factor to extrapolate to the general population, a safe blood dieldrin level of 10 ng/ml (0.01 ug/ml) has been used. It should also be noted that a no observed adverse effect (NOAEL) blood dieldrin level of 20 ng/ml (0.02 ug/ml) has been determined for humans for effects on the central nervous system.

Neoplasia

On the basis of the criteria proposed by the Carcinogen Assessment Group (CAG) of the U.S. EPA for evaluating the overall weight of evidence for carcinogenicity to humans, both aldrin and dieldrin are classified as Group B2 carcinogens (probable human carcinogens) (U.S. EPA, 1989) due to their hepatocarcinogenicity in mice. On the basis of the same data base, IARC classified aldrin and dieldrin in Class 3 - not classifiable as a carcinogen.

Mice

Aldrin/dieldrin have been tested extensively for carcinogenic potential in mice (Davis and Fitzhugh, 1962; Walker *et al.*, 1972; Hunt *et al.*, 1975; Thorpe and Walker, 1973; Epstein, 1975; National Cancer Institute (NCI), 1978; Dix, 1981; Meierhenry *et al.*, 1981; Tennekes *et al.*, 1982). The results of several of these studies are summarized below; the consensus from these data is that aldrin/ dieldrin cause tumors in mouse liver, but no other tissue.

The early studies of aldrin and dieldrin by Davis and Fitzhugh (1962) used only one dose level, 10 ppm, and were not conducted according to current standards, but showed that aldrin and dieldrin caused tumors in mouse livers. The Walker *et al.* studies (1972) were well designed and conducted. They also employed many more mice and additional dose rates than were used, for example in the studies conduct by the NTP. CF1 mice were treated at multiple dose levels (0.1, 1 and 10 ppm) over their lifetimes, and a dose-response relationship for liver tumors established. A smaller number of mice were exposed to dieldrin levels of 1.25, 2.5, 5, 10 and 20 ppm to define the dose-response relationship. Tennekes *et al.* (1982) examined the results of the Walker *et al.* studies and concluded that the dose-response for dieldrin supported the concept that it acted as a promoter rather than an initiator of liver tumors in mice. A reversibility study done by

Walker *et al.* (1972) showed a regression of non-tumorigenic effects (hepatomegaly and cytoplasmic changes) and a reduced incidence of type B tumors after cessation of exposure, although once liver tumors appeared they did not regress. This observation is also consistent with a promotional mechanism of carcinogenesis.

NCI (1978) conducted a bioassay in B6C3F1 mice at 2.5 and 5 ppm dieldrin in the diet for 80 weeks, with an additional observation period of 13 weeks. This study was also well designed and conducted, and confirmed a dose-related increase in hepatocellular carcinomas in males, but not in females.

Other studies on various strains of mice (C3HeB/Fe, C3H, CF1, B6C3F1, and C57BL/6J) confirm that dieldrin causes liver tumors in mice (Thorpe and Walker, 1973; Hunt *et al.*, 1975; Dix, 1981; Meierhenry *et al.*, 1981; Tennekes *et al.*, 1982).

Rats

A number of rat studies involving both aldrin (Borgmann *et al.*, 1952; Treon and Cleveland, 1955; Deichmann *et al.*, 1967, 1970, 1979; NCI, 1978a) and dieldrin (Treon and Cleveland, 1955; Fitzhugh *et al.*, 1964; Deichmann *et al.*, 1970, 1979; NCI, 1977, 1978a, 1978b; Walker *et al.*, 1969) have been done. In general, liver changes typical of chlorinated hydrocarbon insecticide rodent liver (CHIRL) were seen, including enlarged centrilobular hepatocytes with somewhat increased cytoplasmic oxyphilia and peripheral migration of the basophilic granules. However, no increase in liver tumors was observed in any of the studies.

The NCI studies were considered to be the best designed and conducted; others suffered from excessive dosing, high mortality; short duration and/or inadequate pathologic evaluations. The histopathology for three of the rat studies was reevaluated by Reuber (cited in Epstein, 1975) and Stevenson *et al.* (1976). Reevaluation of the Fitzhugh *et al.* (1964) data showed an inverse dose-response relationship, with 5/18 rats (4/7 females and 1/11 males) fed 100 ppm dieldrin having hepatocellular carcinomas, but only 3/11 rats at 150 ppm (Epstein, 1975). The 100 ppm response was significant at $P<0.03$ for combined males and females, but 150 ppm was not. None of the other studies substantiated this finding, and it is considered to be highly questionable.

Hamsters

In a hamster study, Cabral *et al.* (1979) reported that Syrian hamsters could tolerate dietary exposures of dieldrin up to 180 ppm with no evidence of increased incidence of liver tumors.

Dogs

Hypertrophy of individual liver cells caused liver enlargement in dieldrin-treated dogs, with some evidence of organelle changes similar to those found in the rat (Wright *et al.* 1972, 1977, 1978). Regression of the liver effects following cessation of exposure occurred more slowly than in the rat, possibly due to the longer half-life of dieldrin in the dog. No liver tumors were observed.

Monkeys

The effects of feeding diets containing 0, 0.01, 0.1, 0.5, 1.0, 1.76 or 5 ppm dieldrin (0.0002 - 0.07 mg/kg/day) to male rhesus monkeys for approximately six years has been studied. There was little detectable increase in liver weight or evidence of hypertrophy in the monkey, although the dieldrin tissue concentrations were above those associated with a response in other species (Wright *et al.* 1972, 1977, 1978). As two monkeys at the highest dose level died, this level was reduced.

Although the livers of test monkeys contained higher levels of dieldrin than did those of rodents receiving similar concentrations in the diet, monkey liver response was less marked. There was no evidence of liver enlargement or histological changes, including neoplastic or preneoplastic changes, associated with dieldrin exposure. The liver microsomal monooxygenase system was induced in Rhesus monkeys fed dieldrin at dietary levels of 1.0 ppm and above for 6 years (Wright.,1978). However, the toxicological significance of this induction is unclear.

Genotoxicity

Aldrin and, to a greater extent, dieldrin have been the subjects of many genotoxicity studies, including investigations of gene mutation, chromosome aberrations, and epigenetic mechanisms of carcinogenesis. The majority of studies have given negative results, although a few in vitro cytogenic tests have given positive results at high doses - generally above concentrations compatible with life in vivo. The consensus is that both pesticides are considered to be non-genotoxic. Much of the data has been reviewed by Ashwood-Smith (1981) and by the International Commission for the Protection against

Environmental Mutagens and Carcinogens (Upton et al., 1984). Their analysis described the range of results that has been found. All the in vivo studies have been negative.

Dieldrin was negative in a mouse dominant lethal assay (Epstein *et al.*, 1972) and a mitotic gene conversion assay (Dean *et al.*, 1975). Haworth *et al.* (1983), Glatt *et al.* (1983), Marshall *et al.* (1976) and DeFlora *et al.* (1984) all reported negative results in mutagenicity studies. Majumdar *et al.* (1977) reported positive results, but this study is flawed by their failure to include positive controls and inconsistent results in the solvent controls. Ahmed *et al.* (1977a) also reported positive results, but these workers failed to use S9 fraction and encountered cytotoxicity at the higher doses.

Majumdar *et al.* (1976) conducted an in vitro chromosomal aberration study with human lung cells and found dose-dependent increases in aberrations. However, dose-related cytotoxicity was also observed, making the study results inconclusive.

Probst *et al.* (1981) and Klaunig *et al.* (1984) reported negative results in unscheduled DNA synthesis studies. Ahmed *et al.* (1977b) observed unscheduled DNA synthesis, but their data were qualitative only, and there were critical technical flaws in both study design and performance.

Dieldrin caused inhibition of gap junction intercellular communication in Chinese hamster cells, an effect typical of many tumor promoters (Kurata *et al.*, 1982; Trosko *et al.*, 1987). Klaunig has reported positive results in mice, but showed that the response in rat, monkey and human liver cells was negative (J. Klaunig, in press). Wade *et al.* (1986) used a different technique and different mammalian cell line to investigate the same phenomenon.

Mechanism of Aldrin/Dieldrin Carcinogenicity

Stevenson and Walker (1969) suggested that there might be a relationship between hepatic enzyme induction and liver tumors, a view still regarded as plausible (Newberne, 1986; Diwan, 1986). However, this connection cannot be made indiscriminately, as there are also many enzyme-inducing compounds, including human drugs such as the diazepams and phenobarbital, which cause tumors in mice but not in humans. Upton *et al.* (1984) speculated that free radical formation might be involved in the development of murine liver tumors caused by dieldrin and other non-genotoxic inducers of mouse liver

hyperplasia. There is an increasing body of experimental information which supports this view, although the mechanism has not yet been elucidated (Ruch and Klaunig, 1986).

The available information for mechanisms by which organochlorine pesticides may cause liver tumors was reviewed by Stevenson (1990).

The significance of liver tumors in mice is a highly controversial matter and there is much debate on this point, particularly where there is no other tumor response and where no genotoxicity can be demonstrated. For reasons discussed in greater detail below, use of the mouse liver tumor response as a basis for quantitative risk assessment for aldrin/dieldrin in the human may not be appropriate. This position has been supported over many years by the Joint Medical Panel on Pesticide Residues of WHO, who most recently (1990) have re-affirmed their position, while advocating the development of mechanistic information on individual compounds.

Teratology/Developmental Toxicity

Studies in several species have indicated that aldrin/dieldrin are not teratogenic at doses that do not cause overt maternal toxicity (mice: Ottolenghi *et al.*, 1974, Chernoff *et al.*, 1975, Dix *et al.*, 1978, Costella and Virgo, 1980; rabbits: Dix and Wilson, 1971; rats: Chernoff *et al.*, 1975, Coulston *et al.*, 1980; hamsters: Ottolenghi *et al.*, 1974).

Costella and Virgo (1980) showed that both aldrin and dieldrin were fetotoxic at doses which were also maternally toxic. Ottolenghi *et al.* (1974) exposed pregnant Syrian golden hamsters and CD1 mice to a dose of half the LD_{50} on day 7, 8 or 9 of gestation, and observed reduced fetal weight, increased fetal mortality and increased abnormalities (cleft palate, open eye, webbed feet) in hamsters, and abnormalities in mice. However, the significance of these results is questionable, as the study design does not conform to current U.S. EPA and Organization for Economic Cooperation and Development (OECD) guidelines or standard practice.

Reproductive Toxicity

Animal Studies

Adverse reproductive effects associated with aldrin and dieldrin in animals, primarily decreased litter size and increased postnatal mortality, have only been reported at doses which also produce maternal toxicity.

Mice

Virgo and Bellward (1975, 1977) conducted two studies with Swiss-Vancouver mice. Doses of 2.5, 5, 10, 15, 20 or 25 ppm in the diet were administered in the first study, and 5, 10 and 15 ppm in the second, starting 4 weeks prior to the second mating and continuing until day 28 post partum. In the first study, pre-weaning pup mortality was increased at all dose levels. No gross abnormalities were seen in any pups, and no pups had tremors or convulsions. Significant maternal mortality was seen at 20 and 25 ppm. No major behavioral changes were seen in dams fed 5 or 10 ppm dieldrin other than a delayed time to start nursing, but dams showed hyperactivity at 10 ppm and above. This hyperactivity apparently contributed to the high pup mortality. Decreased fertility was seen at 10 and 15 ppm (but not at higher doses), and decreased litter size at 25 ppm. In the second study, there was a dose-related decrease in pup viability at 48 hours. Litter loss was found to correlate with aldrin/dieldrin-induced maternal hepatomegaly.

No effects were seen on fecundity, gestation period or litter size of Swiss mice fed dieldrin at 5 mg/kg for 20 days prior to mating (Good and Ware, 1969) or at 3 ppm in the diet for 6 generations (Keplinger *et al.*, 1970).

Rats

Treon and Cleveland (1955) fed groups of rats aldrin or dieldrin at levels of 2.5, 12.5 and 25 ppm for three generations. A reduced number of pregnancies at the first mating (but not in subsequent generations) was reported at 12.5 and 25 ppm aldrin and at all three doses of dieldrin. A marked increase in pre-weaning pup mortality was seen at 12.5 and 25 ppm for both compounds. Neither material had any adverse effect on reproductive capacity. The LOAEL was 2.5 ppm; a NOAEL was not established.

Eisenlord (1967) observed no adverse effects in a three-generation study of rats fed doses of 0.01, 1 and 2 ppm dieldrin in the diet. Harr (1970) conducted a two-generation study in Wistar rats, with doses ranging from 0.08 ppm to 40 ppm in the diet; 10 per group were mated at 146 days. There were maternal deaths at 20 and 40 ppm, and no dose-response for fertility or litter size. Preweaning deaths from convulsions or starvation were seen in pups from mothers fed 2.5 ppm or higher, but not from those fed 1.25 ppm or lower. The no-effect level was 1.25 ppm. This study had major flaws in design and conduct and is considered of questionable value.

Coulston (1980) conducted a single generation study in rats administered 4 mg/kg from day 15 of gestation through 20 days post partum. No adverse effects and no malformations were seen.

Dogs

Kitselman (1953) studied dogs fed 0.2, 0.6 and 2.0 mg/kg aldrin or dieldrin for one year. Survival of pups was decreased and histologic examination of the pups revealed hepatic and renal degenerative changes; liver changes were also seen in the mothers. The size of the study was too limited to delineate dose-response relationships, but 0.2 mg/kg was a no-effect level.

Deichmann (1971) dosed beagle dogs with 0.15 or 0.3 mg/kg/day aldrin for 14 months and observed subnormal reproductive performance up to 16 months after dosing was stopped.

Humans

Transplacental transfer of dieldrin from mother to the fetus is known to occur (O'Leary *et al.*, 1970; D'Ercole *et al.*, 1976; Polishuk *et al.*, 1977; Saxena *et al.*, 1980), but no adverse fetal effects have been correlated with its presence. Curley *et al.* (1969) measured the concentration of dieldrin in various tissues of stillborn infants and in the cord blood of normal-term infants. Levels in adipose and major organ tissues of stillborns were in the same range as that reported for the general adult population of the U.S.; dieldrin levels did not correlate with either known or unknown cause of death. Levels in the cord blood of normal-term infants were within the range previously reported for human blood (Dale *et al.*, 1966).

A study carried out in India by Saxena *et al.* (1983) is the only human study suggesting potential reproductive effects of aldrin/dieldrin. However, this study has major analytical, statistical and procedural deficiencies which render the results uninterpretable.

Inhalation Toxicity

Inhalation is generally a much less important route of exposure for aldrin/dieldrin than ingestion, due to the very low vapor pressures of aldrin and dieldrin. As is true for other exposure routes, inhaled aldrin is rapidly converted to dieldrin, which is rapidly distributed throughout the body via the blood. Dieldrin has very low volatility, with a vapor pressure of 3.1×10^{-6} mm Hg at 20 degrees C, and a saturated vapor concentration

of 0.004 ppm (63 ug/m^3). Aldrin is slightly more volatile, with a vapor pressure of 7.5 x 10^{-5} mm Hg at 20 degrees C, and a saturated vapor concentration of 0.099 ppm (1.47 mg/m^3). Based on these concentrations, and the known acute toxicity, it is unlikely that a toxic concentration by inhalation alone could be attained for either compound.

Animal Inhalation Studies

Rats were exposed to air containing 2-3 mg/l dust of technical aldrin or dieldrin for 1 hour and observed for 48 hours to determine Class B Poison Labelling and Packaging requirements of the Bureau of Explosives (Anderson, 1951-1954). Less than 10% mortality occurred with each material.

A study of rats exposed to air containing 1-2 mg/l of formulated products and observed for 48 hours (Anderson, 1951-1954) gave the results shown in Table 2.

TABLE 2.

Rat Mortality Following Inhalation of Aldrin or Dieldrin

Formulation	%Mortality
85% dieldrin wettable powder	10
65% aldrin wettable powder	<50
60% aldrin emulsifiable concentrate	<50

The acute 4-hour LC_{50} for rats exposed to aqueous dilutions of a 48% (w/v) emulsifiable concentrate of aldrin as an aerosol was estimated to be equivalent to 3% (w/v) aldrin aerosol (Macdonald, 1982). Median droplet size was 52 micrometers, and although the rats were exposed "nose only," observed grooming of the face after exposure and the large droplet size suggest that ingestion was a significant contributory factor.

Mice, hamsters and guinea pigs exposed to vaporized aldrin at 0.5 g/1000 cubic feet of air (18 mg/m^3) for 178 days showed no adverse effects (Baker *et al.*, 1959).

Human Inhalation Studies

Human volunteers were exposed to levels of 1.31 and 15.5 ug/m^3 aldrin vapor in air for 60 minutes (Bragt *et al.*, 1984). Medical follow-up showed no adverse effects in any subjects. It was determined that approximately 50% of the inhaled aldrin vapor was absorbed and retained. It has been determined that a concentration of 6-10 ug/m^3 aldrin is a no-observed-effect level of exposure, with resulting dieldrin blood levels still being at or below a no-observed-effect level for the general population. Based on the demonstrated human no-observed-effect blood level of 0.01 ug/ml, assuming 12 cubic meters of air are inhaled per day with 100% retention (very conservative; actual data have shown approximately 50% retention is more realistic (Beyermann and Eckrich, 1973)), exposure to 10 ug/m^3 continuously for 21 to 24 months would be required to attain the blood level of 0.01 ug/ml. This means the daily intake would be 12 m^3 x 10 ug/m^3 = 120 ug, the human no-effect level derived from the volunteer and worker studies, using a safety factor of 10.

Toxicity to Aquatic Organisms

Aquatic Organisms

Aldrin and dieldrin are both acutely toxic to freshwater species at low concentrations. Tests in fish showed that the two chemicals had similar toxicities, with LC_{50} values ranging from 1 to 46 ug/liter for different species. Final acute values (i.e., the concentrations of material protecting 95 percent of the organisms (U.S. EPA, 1980) for freshwater species were determined to be 2.5 ug/liter for dieldrin and 3.0 ug/liter for aldrin. Saltwater species were also quite sensitive to aldrin and dieldrin. The range of LC_{50} values was similar to that for freshwater species: 2 to 100 ug/liter for aldrin and 1 to 34 ug/liter for dieldrin. The saltwater Final Acute Values were 1.3 ug/liter for aldrin and 0.71 ug/liter for dieldrin.

Chronic studies of the effects of dieldrin on freshwater and saltwater species have also been conducted. For freshwater organisms, chronic values as low as 0.2 ug/liter were obtained. The Final Acute-Chronic Ratio was determined to be 8.5, and the calculated Freshwater Final Chronic Value is 0.29 ug/liter. Only one chronic study was done on saltwater species. Therefore, the saltwater Final Chronic Value of 0.084 mg/liter was determined by dividing the Final Acute Value by the Acute-Chronic ratio.

No chronic studies were identified for aldrin, but because its acute toxicity is comparable to that of dieldrin and because it is rapidly converted to dieldrin in animals and in the environment, it likely exhibits chronic toxicity as well.

Wild-Life Toxicology

Both compounds, but especially dieldrin, have been associated with large-scale bird and animal kills in treated areas e.g., as seed dressings. The LD_{50}s of aldrin and dieldrin in several species are listed in Table 3.

TABLE 3.

Orals LD50s of Aldrin and Dieldrin in Wild and Domestic Birds and Mammals*

Species	Oral LD_{50} (mg/kg)	
	Aldrin	Dieldrin
Avian		
Mallard duck	520	381
Pheasant	16.8	79
Bobwhite quail	6.59	—
California quail	—	<9.0
Mammalian		
Mule deer	18.8-37.5	75-150
Goat	—	100-200

*Data from Hudson et al. (1984)

Epidemiology Data

As discussed previously, while the earliest and most sensitive effect of aldrin/dieldrin in many animal species is induction of liver microsomal mixed function oxygenase enzymes (Wright et al., 1972), it has been well documented in studies with long-term exposed humans (volunteers, manufacturing and formulation workers, and agricultural workers) that these changes have not been found in humans (Hunter et al., 1969; Jager, 1970; Warnick and Carter, 1972; Morgan and Roan, 1974; Ottevanger and van Sittert, 1979; Sandifer et al., 1981).

In a recent study of occupationally exposed humans, liver function of aldrin/dieldrin workers showed no changes associated with exposure to these materials, even in those workers with the most extensive exposure (van Sittert and de Jong, 1987, de Jong, 1991). There were 100 exposed workers in the study, with 29 in the group with the highest exposures and 808 non-exposed office workers in the control group. In the group of aldrin/dieldrin workers with longest duration of employment (median: 21.6 yrs; range: 7.1 to 26.6 yrs), the highest personal total aldrin + dieldrin intake (median: 1260 mg; range: 777 to 5758 mg), and the highest personal daily intake (median: 209 ug/person/day; range: 103 to 941 ug/person/day), there were no statistically significant differences in serum levels of alkaline phosphatase, alanine aminotransferase, lactate dehydrogenase, and gamma glutamyl transferase or in urinary levels of glucaric acid compared to the large control group. Serum gamma glutamyl transferase was slightly increased compared to controls, but all results outside the upper reference limit could be explained by the individuals' medical histories. In addition, the four workers with the highest average personal daily intake over their total exposure period (range: 464-941 ug/person/day), with a total absorbed dose of aldrin + dieldrin ranging from 2219 to 5758 mg, showed no abnormalities in any liver function parameter. The authors concluded that "long-term occupational exposures to aldrin and dieldrin, up to 941 ug/person/day and up to a personal total intake of 5758 mg, did not produce detectable liver damage or hepatic enzyme induction."

The workers in the above-described study are also included in an ongoing study of more than 1000 workers exposed to aldrin and/or dieldrin (Jager, 1970; Versteeg and Jager, 1973; van Raalte, 1977; Ribbens, 1985). Although many of these individuals had high exposure and have been observed for more than 25 years, no increase in the incidence of liver cancer among them has been observed. Ribbens(1985) reported that the observed total mortality of a sub-group of 232 men with long-term exposure (mean = 11 years; range 4-27 years) to high concentrations and with long observation times (mean = 24 years; range 4-29 years) was 25, "significantly lower than the expected number of 38" for the study group.

This study has now been updated again (de Jong (1991). It is important to note that this study is superior to its predecessors in two significant respects: (1) the follow-up interval following cessation of exposure is longer; and (2) it incorporates a detailed analysis of the biological monitoring study which permits estimation of personal exposures during the period of exposure, and hence delineation of dose-response relationships. Notably, with

the observation period extended up to 1987 (35 years), no statistically significant increased risk was found for any of the site-specific cancers examined in the exposed groups.

A statistical analysis of these data (Sielken (1990) which was summarized by de Jong (1991) indicated an apparent increased survival rate with increasing lifetime average daily dose, as well as a reduction in the proportion of deaths due to cancer. Sielken and Stevenson (1992) have also compared the mouse and human data and concluded that the available evidence based on the most likely estimates of cancer potency in the two species confirms that the men and mice are not compatible populations with regard to dieldrin carcinogenesis.

An epidemiology study was also conducted on workers from four pesticide plants in the United States (Ditraglia *et al.*, 1981). It was found that deaths to all causes and from cancer were fewer than expected. However, there was a small excess of non-malignant respiratory disease and in certain tumor types. This study has been updated recently (Brown 1992). The cohort was defined white workers employed at least six months prior to December 31, 1964, with follow-up of vital status until December 31, 1987.

Mortality from 'all causes' was significantly lower than expected in plant 3 (RMA, where aldrin and dieldrin were manufactured with several other pesticides). The only disease category that was in excess was diseases of the respiratory system, which was no longer significant if local rates were used for comparison. Five cases of liver cancer were seen. Since these were of several cell types and were in workers with relatively short exposures as defined by working on the plant, it is difficult to ascribe any significance to them at this stage, particularly as there was the potential for exposure to other potentially carcinogenic materials. investigations of these cases are in progress.

Another report (Hayes and Curley, 1968) presented a correlation of exposures and dieldrin levels in plasma, fat and urine from workers at one of these plants (the Rocky Mountain Arsenal). This report concluded that dieldrin levels were more related to total exposure than to either high or low recent exposures, and that there was no relationship between dieldrin levels found and the use of sick leave for the workers.

Discussion of Epidemiological Data

The importance of regular updating for relevant epidemiology studies becomes evident as each additional few years of observation provide increasingly valuable information. For instance, at the time of the U.S. EPA Hearings on dieldrin in 1974, the Shell experience at Pernis was based on an exposure period of about 20 years. Now that experience covers a period of 35 years of detailed follow-up and is continuing. The population described by de Jong had a high initial exposure, in that there were workers who exhibited central nervous effects such as convulsions. It seems reasonable to assume that the continuing study of this population would detect any untoward effect in humans should it occur. Some members of the cohort had blood concentrations that suggested that their daily exposures over a period were at least a hundred-fold higher than the WHO ADI. This indicates that the WHO ADI should be fully protective of the general population.

Although the U.S. EPA previously considered "...that there is no evidence presently available to indicate that any of the termiticides, including aldrin/dieldrin, are carcinogenic in humans" (July 19, 1983, letter from Edwin Johnson, former Director of U.S. EPA Office of Pesticide Programs, to Roger Strelow, who had written to Johnson as counsel for Shell International Chemical Company), its Cancer Assessment Group (CAG) has reclassified aldrin/dieldrin as B2, a probable human carcinogen (sufficient evidence of carcinogenicity in animals, inadequate evidence of carcinogenicity in humans) on the basis of the mouse tumor response (U.S. EPA, 1990 (IRIS)). In this estimation of the human risk of these compounds it differs with the World Health Organization (WHO), the National Toxicology Program (NTP) of the U.S. Department of Health and Human Services, and the International Agency for Research on Cancer (IARC).

IARC classified aldrin/dieldrin in Group 3, "the agent is not classifiable as to its carcinogenicity in humans; agents are placed in this category when they do not fall into any other group," in 1982 and again in 1987 (IARC, 1982, 1987). The IARC Group 3 classification corresponds to an U.S. EPA ranking of Group C ("possible human carcinogen" -- limited evidence in animals and absence of human data) or Group D ("not classified" -- inadequate animal data).

The WHO Expert Committee on Pesticide Residues (Food and Agricultural Organization [FAO]/WHO, 1978) agreed that aldrin and dieldrin did not present carcinogenic hazard to humans, stating: "These new findings again support the view that dieldrin and aldrin are not carcinogens on the basis of the knowledge available to the meeting." This position was

recently reaffirmed in the report of a task group on aldrin/dieldrin by the International Programme on Chemical Safety, which concluded that "all the available information on aldrin and dieldrin taken together, including studies on human beings, supports the view that for practical purposes, these chemicals make very little contribution, if any, to the incidence of cancer in man" (WHO, 1989).

On the basis of the available animal and human data, neither aldrin nor dieldrin are classified as "known" or "reasonably anticipated to be" carcinogens by the NTP (1989).

REGULATIONS AND STANDARDS

Ambient Water Quality Criteria (U.S. EPA, 1980)

Aquatic Life (Freshwater)

Acute Toxicity: Aldrin: 3.0 μg/liter
Dieldrin: 2.5 μg/liter

Chronic toxicity: Aldrin: No available data
Dieldrin: 0.0019 ug/liter

Aquatic Life (Saltwater)

Acute Toxicity: Aldrin: 1.3 μg/liter
Dieldrin: 0.71 μg/liter

Chronic toxicity: Aldrin: No available data
Dieldrin: 0.0019 μg/liter

Due to the presumed carcinogenicity of both aldrin and dieldrin, the ambient water criterion for both compounds is zero. Estimates of the carcinogenicity risks due to ingestion of contaminated water and contaminated organisms are listed in Table 4.

TABLE 4.

Estimated Risks of Carcinogenicity due to Contamination of Water with Aldrin/Dieldrin

Concentration (ng/liter)

Risk	Aldrin	Dieldrin
10^{-4}	7.4	7.1
10^{-5}	0.74	0.71
10^{-6}	0.074	0.071

CAG Potency Slope for oral exposure (U.S. EPA, 1989):

Aldrin: 17 $(mg/kg/day)^{-1}$

Dieldrin: 16 $(mg/kg/day)^{-1}$

ACGIH Threshold Limit Value:

$TWA^{1*} = 0.25\ mg/m^3$

$STEL^{**} = 0.74\ mg/m^3$

OSHA standard (air): $TWA^{*} = 250\ pg/m^3$

[1] Applies to both aldrin and dieldrin

* Time Weighted Average

** Short Term Exposure Level

RANGE OF RISK SPECIFIC DOSE (RSD) VALUES

CAG-Based RSD Values

The Risk Specific Dose (RSD) is defined as that contaminant intake rate (mg/kg/day) that should not induce any adverse effect on human health or pose a risk of cancer occurrence greater than a predetermined risk level.

The U.S. EPA CAG's cancer potency slope derived using the linearized multistage model on mouse liver tumor data was used to determine the RSD values for aldrin/dieldrin used in the Human Health Exposure Assessment for RMA. The slopes are intended to provide a plausible upper bound of the propensity of a carcinogen to produce cancer at low doses. Calculation of a RSD using a cancer potency slope requires selection of an acceptable cancer risk level. A range of risk levels from 10^{-4} to 10^{-6} was considered for all

carcinogens; therefore, ranges of RSD values are presented. Derivation of the CAG RSD values for aldrin/dieldrin are as follows:

$$RSD = \text{Risk Level/Potency Slope (mg/kg/day)}^{-1}$$

For example, in the case of aldrin,

$$RSD = 1 \times 10^{-4}/17$$
$$= 5.9 \times 10^{-6} \text{ mg/kg/day}$$

The range of CAG RSD values for aldrin/dieldrin is presented in Table 5.

TABLE 5.

U.S. EPA CAG RSD Values for Aldrin/Dieldrin at Various Risk Levels RSD (mg/kg/day)

Risk	Aldrin	Dieldrin
10^{-4}	5.9×10^{-6}	6.2×10^{-6}
10^{-5}	5.9×10^{-7}	6.2×10^{-7}
10^{-6}	5.9×10^{-8}	6.2×10^{-8}

Human Data-Based RSD Values

Since the mouse liver tumor response to aldrin/dieldrin is species-specific, probably represents a non-genotoxic promotional response, is considered by many to be non-predictive of the human response, and since considerable data regarding the toxicity and carcinogenicity of aldrin/dieldrin in humans are extant, an approach for determination of a RSD for aldrin/dieldrin is to base it on the available human data. A reference dose based on human data would appear to be more relevant in determining potential human risk than one based on mouse data.

Species Comparisons

The human data available from detailed observations on aldrin/dieldrin manufacturing plant workers indicates that humans are no more (and probably less) sensitive than animals with respect to the effects studied. No evidence of either enzyme induction or CNS effects has been seen in humans at intakes (on a per kg basis) even higher than those which would have produced slight but discernible effects in animals. From the data summarized above, it is possible to estimate the intakes which may be regarded as having no effect on either the CNS or the liver. Other non-cancer effects may be seen; there is

no evidence, however, that other effects occur at lower intakes than those which affect the liver or CNS. The intakes which were considered to have no effect in animals are shown below in Table 5:

TABLE 5.

Dietary No-Effect Levels in Several Animal Species

Species	Dose Level (ppm)	Daily Intake (ug/kg/day)
Rat	0.10	(5)
Dog	(0.15)	5
Monkey	0.1	(5)

(data in brackets are calculated values)

Based on the two-year human volunteer studies and the ongoing monitoring program of Pernis workers cited above, the no-effect blood concentration level for humans was estimated to be 0.1-0.2 ug/ml. Liver function tests, including tests for enzyme induction, were carried out on the Pernis plant population at a time when the blood concentrations of dieldrin had fallen and no effects were seen at or below 0.105 ug/ml. Based on Hunter and colleagues' studies (Hunter and Robinson, 1967; Hunter *et al.*, 1969) relating tissue concentrations to dietary intake in a steady state condition, the blood level of 0.105 ug/ml was estimated to be equivalent to an intake of 1.22 mg/person/day for a 70-kg individual (17.4 ug/kg/day). As this intake is over 3 times higher than the no-effect intakes listed above for the rat, dog and monkey, these results suggest that humans are no more, and possibly less, sensitive to the chronic, non-carcinogenic effects of dieldrin.

Protective Daily Intake Level

The average total daily dieldrin intake (17.4 ug/kg/day) with which this blood level corresponds can therefore be regarded as an approximate no-effect intake level for the human. The 0.1 ug/ml blood level corresponds to a total daily intake of 1.221 mg/person/day (17.4 ug x 70 kg) as calculated from the mathematical relationship derived from the human volunteer study cited above. Applying a safety factor of 10 to allow for individual variation and susceptibility results in a blood level of 0.01 ug/ml, and a corresponding daily intake of 0.12 mg/person/day for a no-effect level, or approximately 0.0017 mg/kg/day.

Human RSD Based on the WHO Acceptable Daily Intake (ADI)

A RSD based on the WHO ADI is 0.0001 mg/kg/day; for a 70-kg person, this corresponds to a daily intake of 0.007 mg/person/day. This intake level is even more conservative than the human data-based number of 0.12 mg/person/day derived above. The WHO ADI is about 20 times lower than the number derived above from human-based data.

CERTAINTY AND UNCERTAINTY IN THE ALDRIN/DIELDRIN TOXICITY AND CARCINOGENICITY DATA

The data base for aldrin/dieldrin toxicity is extensive and varied. However, when considering the risk potential associated with these chemicals, it is important to take into account the strengths and weaknesses of the information used to derive the risk estimates, and the impact these have on the degrees of certainty and/or uncertainty associated with the estimates. Some of these factors are highlighted in the following discussion.

Although animal toxicity data are very important and can be used to elucidate mechanisms of action and indicate areas of concern for human health, they cannot substitute for or supersede actual human data in providing the best possible measure of potential risk to humans, no matter how elegant the study design or appropriate the animal model used. It is self-evident that, when appropriate safety/uncertainty factors are applied, risk assessments based on good quality human data cannot be improved upon by projections based on animal data. Thus developing and using human data is a critically important step in the process of risk assessment, significantly reducing its inherent uncertainty. The U.S. Interagency Staff Group on Carcinogens concurs with this view, stating that "epidemiological investigations comprise one of the major strategies in creating the scientific base necessary for regulatory decision-making... [and] are useful in generating and refining hypotheses about potential cancer risk factors.... This...makes a strong argument for...inclusion of their results in regulatory decision-making, whenever relevant exposure has occurred in human populations" (1986a). "Even if an epidemiology investigation fails to demonstrate an increased incidence of carcinogenicity among exposed study members, upper and lower confidence limits on the risk measure used in the study can indicate a range of probable risk that could be incurred by a similarly composed segment (i.e., in terms of age, race, sex etc.) of the general population" (1986b).

U.S. EPA guidelines too are consistent with this approach. For example, at a recent workshop on cancer risk assessment guidelines (U.S. EPA, 1989), one of the major

conclusions was that, where available, human epidemiology results should be given equal or greater weight than animal data. Further more, in "Guidelines For Carcinogen Risk Assessment," (U.S. EPA, 1986a), the Agency states that "negative results from such [epidemiology] studies cannot prove the absence of carcinogenic action; however, negative results from a well-designed and well-conducted epidemiology study that contains usable exposure data can serve to define the upper limits of risk; these are useful if animal evidence indicates that the agent is potentially carcinogenic in humans."

The human exposure and epidemiology reports for aldrin/dieldrin represent a major strength of the overall data package. As pointed out above, the scope and duration of these studies of workers exposed to high concentrations of aldrin/dieldrin, together with information on individual exposure levels, increase confidence in their findings of no significant increase in frequency of any tumor types in humans.

Certain weaknesses which reduce the predictive value of this human exposure data should not be ignored, however, e.g.: (1) Many of the subjects in the epidemiological studies were simultaneously exposed to other toxicologically significant compounds, making attribution of any pathological findings to a specific chemical difficult. However, as there have been no significant findings to date, this problem has not been encountered. (2) A relatively small number of subjects were included in the epidemiology studies, limiting the statistical power of the data analyses. (3) Exposure levels and durations were variable among the subjects.

The appropriateness of the animal models used in toxicity testing protocols must also be carefully evaluated with respect to their applicability to the human species. The development of liver tumors in mice is a natural phenomenon, increasingly encountered as they age. Certain chemicals are known to promote the natural development of these tumors. The mechanism of this effect is not fully understood at present, and research in this area is currently very active. The relevance of the mouse liver tumor to other species is therefore unclear, controversial, and a significant source of uncertainty in cancer risk assessment. Some, including the U.S. EPA, consider that the occurrence of such tumors in mice must be considered to be predictive of human carcinogenicity; the CAG classification of aldrin/dieldrin as B2 reflects this position. Others, including WHO, IARC and NTP, consider that since the propensity for spontaneous development of liver tumors is a murine peculiarity, tumorigenicity in this species should not form the sole basis for ranking a chemical which is not carcinogenic in other experimental animals (and, most importantly,

humans) as a "probable" human carcinogen. The U.S. EPA itself acknowledges that "There are widely diverging scientific views...about the validity of the mouse liver tumors as an indication of potential carcinogenicity in humans when such tumors occur in strains with high spontaneous background incidence and when they constitute the only tumor response to an agent" (U.S. EPA, 1986a).

The choices of which low-dose extrapolation model to use and of the animal data set to utilize in the model to derive estimates of upper bounds of risk are other substantive matters not currently settled. Different extrapolation models and data sets may lead to large differences in estimates of risk at low doses. The U.S. EPA states that "no single mathematical procedure is recognized as the most appropriate for low-dose extrapolation in carcinogenesis" (U.S. EPA, 1986a), and "an established procedure does not yet exist for making "most likely" or "best" estimates of risk within the range of uncertainty defined by the upper and lower limit estimates" (U.S. EPA, 1986a). The latter statement applies also to the linearized multistage model currently espoused by the Agency.

In view of the myriad uncertainties of interspecific extrapolation, the designated "upper-limit risk" should be accompanied, where appropriate, with explicit acknowledgment that the agent may not be a human carcinogen at all, and that there may be zero risk of cancer to humans due to exposure. Moreover, it should be made clear that there is currently no way to decide whether the upper-bound value for risk is more or less likely to be the true risk than the lower-bound value (zero). In the case of aldrin/dieldrin, it should be concluded that the true carcinogenic risk is as likely to be zero as to be any positive value whatsoever, whether 10^{-9}, 10^{-6} or 10^{-3}.

Models of carcinogenic risk are continually evolving. Models such as those of Moolgavkar and Venzon (1979), Moolgavkar and Knudson (1981), Sielken (1987) and Thorsland (1987) can incorporate information on cell turnover, providing estimates of risk which more satisfactorily fit the data. By taking alterations in cell dynamics into account, these models tend to reduce uncertainty in the extrapolation process, particularly in cases where there may be major qualitative and/or quantitative species differences (as in the case of aldrin/dieldrin).

In conclusion, it is clear that the mouse liver tumor issue is of critical importance in understanding the rationale of U.S. EPA's CAG classification -- a point which the Agency itself acknowledges. The assumption that murine neoplasia predicts human tumors is a

subject of intense scientific controversy at present; reference doses based on a different interpretation of the aldrin/dieldrin database have therefore been included in this document. In the case of aldrin/dieldrin, where data are available for exposed humans, the lack of an increase in human liver tumors should be taken into account. It is therefore important to provide the foregoing perspective to enable informed decision making about potential significant exposure levels associated with various adverse health effects of these compounds.

It will be noted that there are several potential estimates of human intakes which might be considered acceptable and that there is a wide range - many orders of magnitude - between them. One of the most conservative estimates is that of EPA, employing a default value of an upper bound estimate of a 10-6 life-time risk. This does not take into account the uncertainty expressed in the classification of aldrin and dieldrin as a B2 carcinogen based on the mouse data. The least conservative estimate of an acceptable daily intake is based on a no-effect intake determined on a worker population which has been subjected to a considerable amount of medical surveillance over a nearly forty year period. A safety factor of ten may then be applied to represent potential differences between individuals. A human volunteer study conducted over two years reinforces the safety of intakes in a similar range. These estimates of acceptable daily intakes which are based on human non-cancer endpoints are also consistent with the epidemiological data which does not indicate that aldrin or dieldrin represent a carcinogenic hazard for man.

The Acceptable Daily Intake established by WHO, which was identical to the figure used by the U.S. FDA prior to the existence of EPA, represents a value that reflects the weight of evidence and is consistent with both the animal and human data other than that derived from the mouse liver. The uniqueness of the latter response and the recent demonstration that it is not consistent with the human experience confirms that the WHO ADI is fully protective for a life-time's exposure to aldrin and dieldrin.

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Appendix G

ESTIMATED REASONABLE MAXIMUM EXPOSURE RISKS AND HAZARD INDICES

Zone 1A; Lifetime Resident

ANALYTE (Weight of Evidence)		PATHWAY											GRAND TOTAL
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	TOTAL	Groundwater	TOTAL	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	TOTAL	
Aldrin	(B2)	1.1E-08	1.1E-08					5.8E-06		5.7E-08		5.9E-06	5.9E-06
Arsenic, total	(A)					9.3E-08		4.4E-05	1.1E-07		9.7E-07	4.5E-05	4.5E-05
Atrazine	(C)					2.1E-08		7.5E-06	5.2E-09		3.4E-07	7.8E-06	7.8E-06
Benzene	(A)			2.1E-07	2.1E-07	2.2E-10		2.1E-07	5.0E-11		6.1E-09	2.1E-07	4.2E-07
Chloroform	(B2)			6.5E-07	6.5E-07	1.1E-11		4.9E-08	2.6E-12		1.3E-09	5.0E-08	7.0E-07
DDE, p,p'-	(B2)	1.3E-09	1.3E-09			4.0E-07		1.2E-07	1.4E-07	8.1E-09	1.6E-07	8.3E-07	8.3E-07
DDT, p,p'-	(B2)	2.5E-09	2.5E-09					1.5E-07		1.6E-08		1.6E-07	1.6E-07
Dieldrin	(B2)	8.7E-08	8.7E-08			1.3E-05	9.8E-06	6.4E-06	4.6E-06	4.5E-07	1.3E-05	4.7E-05	4.7E-05
Tetrachloroethene	(B2)			1.5E-08	1.5E-08	1.2E-09		4.2E-07	2.9E-10		1.9E-08	4.4E-07	4.5E-07
TOTAL		1.0E-07	1.0E-07	8.7E-07	8.7E-07	1.4E-05	9.8E-06	6.5E-05	4.9E-06	5.3E-07	1.4E-05	1.1E-04	1.1E-04

Zone 1B; Lifetime Resident

ANALYTE (Weight of Evidence)		PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	TOTAL	Groundwater	TOTAL	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	TOTAL	GRAND TOTAL
Aldrin	(B2)	1.1E-08	1.1E-08					5.8E-06		5.7E-08		5.9E-06	5.9E-06
Arsenic, total	(A)					5.8E-07		4.4E-05	6.9E-07		6.1E-06	5.1E-05	5.1E-05
Atrazine	(C)					1.3E-07		7.5E-06	3.3E-08		2.1E-06	9.8E-06	9.8E-06
Benzene	(A)			2.1E-07	2.1E-07	1.4E-09		2.1E-07	3.1E-10		3.8E-08	2.5E-07	4.6E-07
Chloroform	(B2)			6.5E-07	6.5E-07	7.1E-11		4.9E-08	1.6E-11		8.2E-09	5.7E-08	7.1E-07
DDE, p,p'-	(B2)	1.3E-09	1.3E-09			4.7E-07		1.2E-07	1.6E-07	8.1E-09	2.0E-07	9.6E-07	9.6E-07
DDT, p,p'-	(B2)	2.5E-09	2.5E-09					1.5E-07		1.6E-08		1.6E-07	1.6E-07
Dieldrin	(B2)	8.7E-08	8.7E-08			1.8E-05	9.8E-06	6.4E-06	6.0E-06	4.5E-07	1.8E-05	5.8E-05	5.8E-05
Tetrachloroethene	(B2)			1.5E-08	1.5E-08	7.4E-09		4.2E-07	1.8E-09		1.2E-07	5.5E-07	5.6E-07
TOTAL		1.0E-07	1.0E-07	8.7E-07	8.7E-07	1.9E-05	9.8E-06	6.5E-05	6.9E-06	5.3E-07	2.6E-05	1.3E-04	1.3E-04

Zone 1C; Lifetime Resident

ANALYTE (Weight of Evidence)		PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	TOTAL	Groundwater	TOTAL	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	TOTAL	GRAND TOTAL
Aldrin	(B2)	1.1E-08	1.1E-08					5.8E-06		5.7E-08		5.9E-06	5.9E-06
Arsenic, total	(A)					9.3E-08		4.4E-05	1.1E-07		9.7E-07	4.5E-05	4.5E-05
Atrazine	(C)					2.1E-08		7.5E-06	5.2E-09		3.4E-07	7.8E-06	7.8E-06
Benzene	(A)			2.1E-07	2.1E-07	2.2E-10		2.1E-07	5.0E-11		6.1E-09	2.1E-07	4.2E-07
Chloroform	(B2)			6.5E-07	6.5E-07	1.1E-11		4.9E-08	2.6E-12		1.3E-09	5.0E-08	7.0E-07
DDE, p,p'-	(B2)	1.3E-09	1.3E-09			4.0E-07		1.2E-07	1.4E-07	8.1E-09	1.6E-07	8.3E-07	8.3E-07
DDT, p,p'-	(B2)	2.5E-09	2.5E-09					1.5E-07		1.6E-08		1.6E-07	1.6E-07
Dieldrin	(B2)	8.7E-08	8.7E-08			1.3E-05	9.8E-06	6.4E-06	4.6E-06	4.5E-07	1.3E-05	4.7E-05	4.7E-05
Tetrachloroethene	(B2)			1.5E-08	1.5E-08	1.2E-09		4.2E-07	2.9E-10		1.9E-08	4.4E-07	4.5E-07
TOTAL		1.0E-07	1.0E-07	8.7E-07	8.7E-07	1.4E-05	9.8E-06	6.5E-05	4.9E-06	5.3E-07	1.4E-05	1.1E-04	1.1E-04

Zone 2; Lifetime Resident

ANALYTE (Weight of Evidence)		PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	TOTAL	Groundwater	TOTAL	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	TOTAL	GRAND TOTAL
Aldrin	(B2)	1.1E-08	1.1E-08					8.9E-06		5.7E-08		8.9E-06	9.0E-06
Arsenic, total	(A)					4.4E-07		3.4E-05	5.2E-07		4.6E-06	3.9E-05	3.9E-05
Atrazine	(C)					2.4E-07		1.4E-05	6.0E-08		4.0E-06	1.8E-05	1.8E-05
Benzene	(A)			2.2E-07	2.2E-07	1.4E-09		2.2E-07	3.3E-10		3.9E-08	2.6E-07	4.8E-07
Carbon tetrachloride	(B2)			4.7E-07	4.7E-07	2.2E-08		1.2E-06	5.6E-09		3.5E-07	1.5E-06	2.0E-06
Chlordane, total	(B2)					3.8E-08		2.7E-06	8.2E-09		5.4E-07	3.3E-06	3.3E-06
Chloroform	(B2)			6.4E-05	6.4E-05	7.0E-09		4.8E-06	1.6E-09		8.1E-07	5.7E-06	7.0E-05
DDE, p,p'-	(B2)	1.3E-09	1.3E-09			4.7E-07		1.1E-07	1.6E-07	8.1E-09	2.0E-07	9.5E-07	9.5E-07
DDT, p,p'-	(B2)	2.5E-09	2.5E-09					1.3E-07		1.6E-08		1.5E-07	1.5E-07
Dibromochloropropane	(B2)			1.2E-08	1.2E-08	1.1E-08		7.2E-06	2.4E-09		1.1E-06	8.4E-06	8.4E-06
Dichlorobenzenes, total	(C)					1.1E-07		1.4E-06	3.1E-08		1.1E-06	2.7E-06	2.7E-06
Dichloroethane, 1,2-	(B2)			8.2E-07	8.2E-07	2.5E-09		8.2E-07	5.5E-10		1.2E-07	9.4E-07	1.8E-06
Dieldrin	(B2)	8.7E-08	8.7E-08			2.0E-05	9.8E-06	6.5E-06	6.4E-06	4.5E-07	1.9E-05	6.2E-05	6.2E-05
Tetrachloroethene	(B2)			2.1E-07	2.1E-07	1.1E-07		6.1E-06	2.7E-08		1.8E-06	8.0E-06	8.2E-06
Trichloroethene	(B2)			1.3E-07	1.3E-07	1.7E-09		8.3E-08	4.6E-10		2.8E-08	1.1E-07	2.4E-07
TOTAL		1.0E-07	1.0E-07	6.6E-05	6.6E-05	2.1E-05	9.8E-06	8.7E-05	7.2E-06	5.3E-07	3.4E-05	1.6E-04	2.3E-04

Zone 3; Lifetime Resident

ANALYTE (Weight of Evidence)		PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sedi-ment	Soil	Surface Water	TOTAL	Ground-water	TOTAL	Ground-water	Sedi-ment	Soil	Vege-tables	TOTAL	GRAND TOTAL
Aldrin	(B2)	1.0E-08	7.3E-08		8.3E-08			1.0E-05	5.3E-08	3.8E-07		1.0E-05	1.1E-05
Arsenic, total	(A)			2.1E-07	2.1E-07						5.0E-06	5.0E-06	5.2E-06
Atrazine	(C)							3.4E-05			8.7E-06	4.2E-05	4.2E-05
Benzene	(A)					2.5E-07	2.5E-07	2.5E-07			4.2E-08	3.0E-07	5.5E-07
Chlordane, total	(B2)		2.0E-08	1.6E-09	2.1E-08			2.9E-06		1.0E-07	1.3E-06	4.4E-06	4.4E-06
Chloroform	(B2)					4.8E-06	4.8E-06	3.6E-07			5.4E-08	4.1E-07	5.2E-06
DDE, p,p'-	(B2)	7.4E-12	2.0E-09	2.1E-10	2.2E-09			8.6E-07	4.8E-11	1.3E-08	5.3E-07	1.4E-06	1.4E-06
DDT, p,p'-	(B2)	1.2E-10	5.3E-09	1.1E-10	5.5E-09			4.3E-07	8.1E-10	3.4E-08		4.6E-07	4.7E-07
Dibromochloropropane	(B2)	5.8E-09			5.8E-09	3.9E-09	3.9E-09	2.3E-06	4.4E-08		3.2E-07	2.7E-06	2.7E-06
Dichloroethane, 1,2-	(B2)					9.8E-07	9.8E-07	9.8E-07			1.3E-07	1.1E-06	2.1E-06
Dieldrin	(B2)	1.2E-07	5.6E-07	2.8E-07	9.6E-07			4.0E-05	6.1E-07	2.9E-06	1.2E-04	1.6E-04	1.7E-04
Tetrachloroethene	(B2)					4.4E-07	4.4E-07	1.2E-05			3.3E-06	1.6E-05	1.6E-05
Trichloroethene	(B2)					1.0E-07	1.0E-07	6.6E-08			2.0E-08	8.6E-08	1.9E-07
TOTAL		1.3E-07	6.6E-07	5.0E-07	1.3E-06	6.5E-06	6.5E-06	1.0E-04	7.1E-07	3.4E-06	1.4E-04	2.5E-04	2.6E-04

Zone 4; Lifetime Resident

ANALYTE (Weight of Evidence)		PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sedi-ment	Soil	Surface Water	TOTAL	Ground-water	TOTAL	Ground-water	Sedi-ment	Soil	Vege-tables	TOTAL	GRAND TOTAL
Aldrin	(B2)	1.0E-08	1.1E-08		2.1E-08			2.3E-05	5.3E-08	5.7E-08		2.3E-05	2.3E-05
Arsenic, total	(A)			2.1E-07	2.1E-07			5.7E-05			1.2E-05	6.9E-05	6.9E-05
Atrazine	(C)							1.9E-05			4.9E-06	2.4E-05	2.4E-05
Benzene	(A)					3.2E-07	3.2E-07	3.2E-07			5.2E-08	3.7E-07	6.8E-07
Chlordane, total	(B2)			1.6E-09	1.6E-09			8.2E-06			1.5E-06	9.8E-06	9.8E-06
Chloroform	(B2)					1.4E-06	1.4E-06	1.1E-07			1.6E-08	1.2E-07	1.6E-06
DDE, p,p'-	(B2)	7.4E-12	1.3E-09	2.1E-10	1.5E-09			3.4E-07	4.8E-11	8.1E-09	2.9E-07	6.4E-07	6.4E-07
DDT, p,p'-	(B2)	1.2E-10	2.5E-09	1.1E-10	2.7E-09			4.0E-07	8.1E-10	1.6E-08		4.2E-07	4.2E-07
Dibromochloropropane	(B2)	5.8E-09			5.8E-09	4.3E-09	4.3E-09	2.5E-06	4.4E-08		3.6E-07	2.9E-06	2.9E-06
Dichlorobenzenes, total	(C)							8.3E-07			5.7E-07	1.4E-06	1.4E-06
Dichloroethane, 1,2-	(B2)					7.8E-06	7.8E-06	7.8E-06			1.0E-06	8.8E-06	1.7E-05
Dieldrin	(B2)	1.2E-07	8.7E-08	2.8E-07	4.9E-07			1.0E-05	6.1E-07	4.5E-07	5.0E-05	6.1E-05	6.2E-05
Tetrachloroethene	(B2)					1.3E-07	1.3E-07	3.6E-06			9.6E-07	4.6E-06	4.7E-06
Trichloroethene	(B2)					5.4E-07	5.4E-07	3.5E-07			1.1E-07	4.5E-07	9.9E-07
TOTAL		1.3E-07	1.0E-07	5.0E-07	7.3E-07	1.0E-05	1.0E-05	1.3E-04	7.1E-07	5.3E-07	7.2E-05	2.1E-04	2.2E-04

Carcinogenic risks
Zone 5; Adult Commercial/Industrial; Chronic RME

ANALYTE (Weight of Evidence)		PATHWAY							
		Dermal		Inhalation		Oral			
		MEDIUM		MEDIUM		MEDIUM			
		Soil	Total	GW	Total	GW	Soil	Total	Grand Total
Aldrin	(B2)	7.0E-09	7.0E-09			2.3E-06	5.6E-09	2.3E-06	2.3E-06
Arsenic	(A)					1.6E-05		1.6E-05	1.6E-05
Chloroform	(B2)			3.4E-06	3.4E-06	2.6E-07		2.6E-07	3.7E-06
Dibromochloropropane	(B2)			8.4E-10	8.4E-10	4.9E-07		4.9E-07	4.9E-07
DDE, p,p'-	(B2)	1.0E-09	1.0E-09				8.0E-10	8.0E-10	1.8E-09
DDT, p,p'-	(B2)	2.0E-09	2.0E-09				1.6E-09	1.6E-09	3.6E-09
Dieldrin	(B2)	5.7E-08	5.7E-08			4.0E-06	4.5E-08	4.0E-06	4.1E-06
Tetrachloroethene	(B2)			4.7E-09	4.7E-09	1.3E-07		1.3E-07	1.4E-07
TOTAL		6.7E-08	6.7E-08	3.4E-06	3.4E-06	2.4E-05	5.3E-08	2.4E-05	2.7E-05

Zone 6; Lifetime Resident

ANALYTE (Weight of Evidence)		PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	TOTAL	Groundwater	TOTAL	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	TOTAL	GRAND TOTAL
Aldrin	(B2)	1.1E-08	1.1E-08					5.9E-06		5.7E-08		6.0E-06	6.0E-06
Atrazine	(C)					3.2E-08		1.1E-05	8.0E-09		5.2E-07	1.2E-05	1.2E-05
Chloroform	(B2)			3.2E-06	3.2E-06	5.5E-11		2.4E-07	1.2E-11		6.4E-09	2.5E-07	3.4E-06
DDE, p,p'-	(B2)	1.3E-09	1.3E-09			3.9E-07			1.4E-07	8.1E-09	1.6E-07	6.9E-07	6.9E-07
DDT, p,p'-	(B2)	2.5E-09	2.5E-09							1.6E-08		1.6E-08	1.9E-08
Dieldrin	(B2)	8.7E-08	8.7E-08			1.3E-05	9.8E-06	7.3E-06	4.6E-06	4.5E-07	1.3E-05	4.8E-05	4.8E-05
Tetrachloroethene	(B2)			3.5E-08	3.5E-08	2.8E-09		1.0E-06	7.1E-10		4.7E-08	1.0E-06	1.1E-06
Trichloroethene	(B2)			8.1E-07	8.1E-07	1.8E-09		5.2E-07	4.6E-10		2.8E-08	5.5E-07	1.4E-06
TOTAL		1.0E-07	1.0E-07	4.0E-06	4.0E-06	1.4E-05	9.8E-06	2.6E-05	4.8E-06	5.3E-07	1.4E-05	6.9E-05	7.3E-05

Zone 1A; Adult Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			8.4E-04	8.4E-04	2.4E-07		8.4E-04	2.0E-07		2.4E-05	8.6E-04	1.7E-03
	TOTAL			8.4E-04	8.4E-04	2.4E-07		8.4E-04	2.0E-07		2.4E-05	8.6E-04	1.7E-03
Cardiovascular	Atrazine					1.2E-05		1.6E-02	1.1E-05		7.2E-04	1.6E-02	1.6E-02
	TOTAL					1.2E-05		1.6E-02	1.1E-05		7.2E-04	1.6E-02	1.6E-02
CNS	DIMP					5.7E-07		2.2E-02	5.9E-07		1.8E-03	2.4E-02	2.4E-02
	Xylenes, total			2.4E-04	2.4E-04	1.9E-08		1.0E-05	1.8E-08		7.9E-07	1.1E-05	2.5E-04
	TOTAL			2.4E-04	2.4E-04	5.9E-07		2.2E-02	6.1E-07		1.8E-03	2.4E-02	2.4E-02
Gastrointestinal	Hexachlorocyclopentadiene					5.8E-07		1.1E-04	5.9E-07		3.1E-05	1.5E-04	1.5E-04
	TOTAL					5.8E-07		1.1E-04	5.9E-07		3.1E-05	1.5E-04	1.5E-04
Hepatic	Aldrin	5.0E-05	5.0E-05					2.7E-02		8.6E-05		2.7E-02	2.7E-02
	Benzene			8.4E-04	8.4E-04	2.4E-07		8.4E-04	2.0E-07		2.4E-05	8.6E-04	1.7E-03
	Chlorobenzene			5.6E-03	5.6E-03	1.2E-06		1.4E-03	1.1E-06		7.0E-05	1.5E-03	7.0E-03
	Chloroform			1.9E-03	1.9E-03	1.2E-07		1.9E-03	9.8E-08		5.0E-05	1.9E-03	3.8E-03
	DDE, p,p'-	1.7E-05	1.7E-05			1.5E-03		1.6E-03	1.9E-03	3.7E-05	2.3E-03	7.3E-03	7.4E-03
	DDT, p,p'-	3.4E-05	3.4E-05					2.0E-03		7.3E-05		2.1E-03	2.1E-03
	Dieldrin	2.5E-04	2.5E-04			1.1E-02	2.9E-02	1.9E-02	1.3E-02	4.3E-04	3.7E-02	1.1E-01	1.1E-01
	Endrin	1.0E-05	1.0E-05			1.7E-04		3.0E-03	1.5E-04	1.7E-05	2.0E-03	5.3E-03	5.3E-03
	Isodrin							1.1E-02				1.1E-02	1.1E-02
	Tetrachloroethene			1.9E-03	1.9E-03	1.5E-06		1.9E-03	1.3E-06		8.9E-05	2.0E-03	3.9E-03
	TOTAL	3.7E-04	3.7E-04	1.0E-02	1.0E-02	1.3E-02	2.9E-02	6.9E-02	1.6E-02	6.5E-04	4.2E-02	1.7E-01	1.8E-01
Renal	Chlorobenzene			5.6E-03	5.6E-03	1.2E-06		1.4E-03	1.1E-06		7.0E-05	1.5E-03	7.0E-03
	TOTAL			5.6E-03	5.6E-03	1.2E-06		1.4E-03	1.1E-06		7.0E-05	1.5E-03	7.0E-03
Respiratory	Xylenes, total			2.4E-04	2.4E-04								2.4E-04
	TOTAL			2.4E-04	2.4E-04								2.4E-04

(CONTINUED)

Zone 1A; Adult Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Skin	Arsenic, total					1.2E-04		2.0E-01	4.9E-04		4.3E-03	2.0E-01	2.0E-01
	TOTAL					1.2E-04		2.0E-01	4.9E-04		4.3E-03	2.0E-01	2.0E-01

Zone 1A; Child Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			1.3E-03	1.3E-03	1.8E-06		1.3E-03	6.2E-07		4.0E-05	1.3E-03	2.6E-03
	TOTAL			1.3E-03	1.3E-03	1.8E-06		1.3E-03	6.2E-07		4.0E-05	1.3E-03	2.6E-03
Cardiovascular	Atrazine					8.9E-05		2.4E-02	3.3E-05		1.2E-03	2.5E-02	2.5E-02
	TOTAL					8.9E-05		2.4E-02	3.3E-05		1.2E-03	2.5E-02	2.5E-02
CNS	DIMP					4.2E-06		3.3E-02	1.8E-06		3.0E-03	3.6E-02	3.6E-02
	Xylenes, total			3.6E-04	3.6E-04	1.4E-07		1.6E-05	5.5E-08		1.3E-06	1.7E-05	3.8E-04
	TOTAL			3.6E-04	3.6E-04	4.3E-06		3.3E-02	1.9E-06		3.0E-03	3.6E-02	3.6E-02
Gastrointestinal	Hexachlorocyclopentadiene					4.2E-06		1.7E-04	1.8E-06		5.0E-05	2.3E-04	2.3E-04
	TOTAL					4.2E-06		1.7E-04	1.8E-06		5.0E-05	2.3E-04	2.3E-04
Hepatic	Aldrin	1.0E-04	1.0E-04					4.0E-02		5.5E-04		4.1E-02	4.1E-02
	Benzene			1.3E-03	1.3E-03	1.8E-06		1.3E-03	6.2E-07		4.0E-05	1.3E-03	2.6E-03
	Chlorobenzene			8.5E-03	8.5E-03	9.0E-06		2.1E-03	3.5E-06		1.1E-04	2.2E-03	1.1E-02
	Chloroform			2.8E-03	2.8E-03	8.9E-07		2.8E-03	3.0E-07		8.2E-05	2.9E-03	5.8E-03
	DDE, p,p'-	3.5E-05	3.5E-05			1.1E-02		2.4E-03	5.9E-03	2.3E-04	3.7E-03	2.3E-02	2.3E-02
	DDT, p,p'-	7.0E-05	7.0E-05					3.0E-03		4.7E-04		3.5E-03	3.6E-03
	Dieldrin	5.2E-04	5.2E-04			7.9E-02	7.9E-02	2.8E-02	4.1E-02	2.8E-03	6.0E-02	2.9E-01	2.9E-01
	Endrin	2.1E-05	2.1E-05			1.2E-03		4.5E-03	4.5E-04	1.1E-04	3.3E-03	9.6E-03	9.6E-03
	Isodrin							1.6E-02				1.6E-02	1.6E-02
	Tetrachloroethene			2.9E-03	2.9E-03	1.1E-05		2.9E-03	4.1E-06		1.4E-04	3.1E-03	5.9E-03
	TOTAL	7.5E-04	7.5E-04	1.5E-02	1.5E-02	9.2E-02	7.9E-02	1.0E-01	4.8E-02	4.1E-03	6.8E-02	3.9E-01	4.1E-01
Renal	Chlorobenzene			8.5E-03	8.5E-03	9.0E-06		2.1E-03	3.5E-06		1.1E-04	2.2E-03	1.1E-02
	TOTAL			8.5E-03	8.5E-03	9.0E-06		2.1E-03	3.5E-06		1.1E-04	2.2E-03	1.1E-02
Respiratory	Xylenes, total			3.6E-04	3.6E-04								3.6E-04
	TOTAL			3.6E-04	3.6E-04								3.6E-04

(CONTINUED)

Zone 1A; Child Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Skin	Arsenic, total					8.4E-04		3.0E-01	1.5E-03		7.0E-03	3.1E-01	3.1E-01
	TOTAL					8.4E-04		3.0E-01	1.5E-03		7.0E-03	3.1E-01	3.1E-01

Zone 1B; Adult Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			8.4E-04	8.4E-04	1.5E-06		8.4E-04	1.3E-06		1.5E-04	9.9E-04	1.8E-03
	TOTAL			8.4E-04	8.4E-04	1.5E-06		8.4E-04	1.3E-06		1.5E-04	9.9E-04	1.8E-03
Cardiovascular	Atrazine					7.6E-05		1.6E-02	6.8E-05		4.5E-03	2.0E-02	2.0E-02
	TOTAL					7.6E-05		1.6E-02	6.8E-05		4.5E-03	2.0E-02	2.0E-02
CNS	DIMP					1.3E-06		2.2E-02	1.4E-06		4.3E-03	2.6E-02	2.6E-02
	Xylenes, total			2.4E-04	2.4E-04	1.2E-07		1.0E-05	1.1E-07		4.9E-06	1.5E-05	2.6E-04
	TOTAL			2.4E-04	2.4E-04	1.5E-06		2.2E-02	1.5E-06		4.3E-03	2.6E-02	2.6E-02
Gastrointestinal	Hexachlorocyclopentadiene					3.6E-06		1.1E-04	3.7E-06		1.9E-04	3.1E-04	3.1E-04
	TOTAL					3.6E-06		1.1E-04	3.7E-06		1.9E-04	3.1E-04	3.1E-04
Hepatic	Aldrin	5.0E-05	5.0E-05					2.7E-02		8.6E-05		2.7E-02	2.7E-02
	Benzene			8.4E-04	8.4E-04	1.5E-06		8.4E-04	1.3E-06		1.5E-04	9.9E-04	1.8E-03
	Chlorobenzene			5.6E-03	5.6E-03	7.7E-06		1.4E-03	7.1E-06		4.4E-04	1.8E-03	7.4E-03
	Chloroform			1.9E-03	1.9E-03	7.6E-07		1.9E-03	6.1E-07		3.1E-04	2.2E-03	4.1E-03
	DDE, p,p'-	1.7E-05	1.7E-05			1.8E-03		1.6E-03	2.2E-03	3.7E-05	2.8E-03	8.4E-03	8.4E-03
	DDT, p,p'-	3.4E-05	3.4E-05					2.0E-03		7.3E-05		2.1E-03	2.1E-03
	Dieldrin	2.5E-04	2.5E-04			1.5E-02	2.9E-02	1.9E-02	1.7E-02	4.3E-04	5.1E-02	1.3E-01	1.3E-01
	Endrin	1.0E-05	1.0E-05			3.8E-04		3.0E-03	3.2E-04	1.7E-05	4.8E-03	8.5E-03	8.5E-03
	Isodrin							1.1E-02				1.1E-02	1.1E-02
	Tetrachloroethene			1.9E-03	1.9E-03	9.5E-06		1.9E-03	8.4E-06		5.6E-04	2.5E-03	4.4E-03
	TOTAL	3.7E-04	3.7E-04	1.0E-02	1.0E-02	1.7E-02	2.9E-02	6.9E-02	2.0E-02	6.5E-04	6.1E-02	2.0E-01	2.1E-01
Renal	Chlorobenzene			5.6E-03	5.6E-03	7.7E-06		1.4E-03	7.1E-06		4.4E-04	1.8E-03	7.4E-03
	TOTAL			5.6E-03	5.6E-03	7.7E-06		1.4E-03	7.1E-06		4.4E-04	1.8E-03	7.4E-03
Respiratory	Xylenes, total			2.4E-04	2.4E-04								2.4E-04
	TOTAL			2.4E-04	2.4E-04								2.4E-04

(CONTINUED)

Zone 1B; Adult Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Skin	Arsenic, total					7.2E-04		2.0E-01	3.1E-03		2.7E-02	2.3E-01	2.3E-01
	TOTAL					7.2E-04		2.0E-01	3.1E-03		2.7E-02	2.3E-01	2.3E-01

Zone 1B; Child Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			1.3E-03	1.3E-03	1.1E-05		1.3E-03	3.9E-06		2.5E-04	1.5E-03	2.8E-03
	TOTAL			1.3E-03	1.3E-03	1.1E-05		1.3E-03	3.9E-06		2.5E-04	1.5E-03	2.8E-03
Cardiovascular	Atrazine					5.5E-04		2.4E-02	2.1E-04		7.3E-03	3.2E-02	3.2E-02
	TOTAL					5.5E-04		2.4E-02	2.1E-04		7.3E-03	3.2E-02	3.2E-02
CNS	DIMP					9.8E-06		3.3E-02	4.2E-06		7.0E-03	4.0E-02	4.0E-02
	Xylenes, total			3.6E-04	3.6E-04	8.6E-07		1.6E-05	3.4E-07		8.0E-06	2.5E-05	3.9E-04
	TOTAL			3.6E-04	3.6E-04	1.1E-05		3.3E-02	4.6E-06		7.0E-03	4.0E-02	4.0E-02
Gastrointestinal	Hexachlorocyclopentadiene					2.6E-05		1.7E-04	1.1E-05		3.1E-04	5.2E-04	5.2E-04
	TOTAL					2.6E-05		1.7E-04	1.1E-05		3.1E-04	5.2E-04	5.2E-04
Hepatic	Aldrin	1.0E-04	1.0E-04					4.0E-02		5.5E-04		4.1E-02	4.1E-02
	Benzene			1.3E-03	1.3E-03	1.1E-05		1.3E-03	3.9E-06		2.5E-04	1.5E-03	2.8E-03
	Chlorobenzene			8.5E-03	8.5E-03	5.6E-05		2.1E-03	2.2E-05		7.1E-04	2.9E-03	1.1E-02
	Chloroform			2.8E-03	2.8E-03	5.5E-06		2.8E-03	1.9E-06		5.1E-04	3.4E-03	6.2E-03
	DDE, p,p'-	3.5E-05	3.5E-05			1.3E-02		2.4E-03	6.7E-03	2.3E-04	4.6E-03	2.7E-02	2.7E-02
	DDT, p,p'-	7.0E-05	7.0E-05					3.0E-03		4.7E-04		3.5E-03	3.6E-03
	Dieldrin	5.2E-04	5.2E-04			1.1E-01	7.9E-02	2.8E-02	5.3E-02	2.8E-03	8.4E-02	3.6E-01	3.6E-01
	Endrin	2.1E-05	2.1E-05			2.8E-03		4.5E-03	9.7E-04	1.1E-04	7.8E-03	1.6E-02	1.6E-02
	Isodrin							1.6E-02				1.6E-02	1.6E-02
	Tetrachloroethene			2.9E-03	2.9E-03	6.9E-05		2.9E-03	2.6E-05		9.0E-04	3.9E-03	6.8E-03
	TOTAL	7.5E-04	7.5E-04	1.5E-02	1.5E-02	1.2E-01	7.9E-02	1.0E-01	6.1E-02	4.1E-03	9.8E-02	4.7E-01	4.9E-01
Renal	Chlorobenzene			8.5E-03	8.5E-03	5.6E-05		2.1E-03	2.2E-05		7.1E-04	2.9E-03	1.1E-02
	TOTAL			8.5E-03	8.5E-03	5.6E-05		2.1E-03	2.2E-05		7.1E-04	2.9E-03	1.1E-02
Respiratory	Xylenes, total			3.6E-04	3.6E-04								3.6E-04
	TOTAL			3.6E-04	3.6E-04								3.6E-04

(CONTINUED)

Zone 18; Child Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Skin	Arsenic, total					5.3E-03		3.0E-01	9.4E-03		4.4E-02	3.6E-01	3.6E-01
	TOTAL					5.3E-03		3.0E-01	9.4E-03		4.4E-02	3.6E-01	3.6E-01

Zone 1C; Adult Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							Grand Total
		MEDIUM		MEDIUM		MEDIUM						Total	
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables		
Blood	Benzene			8.4E-04	8.4E-04	2.4E-07		8.4E-04	2.0E-07		2.4E-05	8.6E-04	1.7E-03
	TOTAL			8.4E-04	8.4E-04	2.4E-07		8.4E-04	2.0E-07		2.4E-05	8.6E-04	1.7E-03
Cardiovascular	Atrazine					1.2E-05		1.6E-02	1.1E-05		7.2E-04	1.6E-02	1.6E-02
	TOTAL					1.2E-05		1.6E-02	1.1E-05		7.2E-04	1.6E-02	1.6E-02
CNS	DIMP					2.1E-07		2.2E-02	2.2E-07		6.9E-04	2.2E-02	2.2E-02
	Xylenes, total			2.4E-04	2.4E-04	1.9E-08		1.0E-05	1.8E-08		7.9E-07	1.1E-05	2.5E-04
	TOTAL			2.4E-04	2.4E-04	2.3E-07		2.2E-02	2.4E-07		6.9E-04	2.2E-02	2.3E-02
Gastrointestinal	Hexachlorocyclopentadiene					5.8E-07		1.1E-04	5.9E-07		3.1E-05	1.5E-04	1.5E-04
	TOTAL					5.8E-07		1.1E-04	5.9E-07		3.1E-05	1.5E-04	1.5E-04
Hepatic	Aldrin	5.0E-05	5.0E-05					2.7E-02		8.6E-05		2.7E-02	2.7E-02
	Benzene			8.4E-04	8.4E-04	2.4E-07		8.4E-04	2.0E-07		2.4E-05	8.6E-04	1.7E-03
	Chlorobenzene			5.6E-03	5.6E-03	1.2E-06		1.4E-03	1.1E-06		7.0E-05	1.5E-03	7.0E-03
	Chloroform			1.9E-03	1.9E-03	1.2E-07		1.9E-03	9.8E-08		5.0E-05	1.9E-03	3.8E-03
	DDE, p,p'-	1.7E-05	1.7E-05			1.5E-03		1.6E-03	1.9E-03	3.7E-05	2.3E-03	7.3E-03	7.4E-03
	DDT, p,p'-	3.4E-05	3.4E-05					2.0E-03		7.3E-05		2.1E-03	2.1E-03
	Dieldrin	2.5E-04	2.5E-04			1.1E-02	2.9E-02	1.9E-02	1.3E-02	4.3E-04	3.7E-02	1.1E-01	1.1E-01
	Endrin	1.0E-05	1.0E-05			1.7E-04		3.0E-03	1.5E-04	1.7E-05	2.0E-03	5.3E-03	5.3E-03
	Isodrin							1.1E-02				1.1E-02	1.1E-02
	Tetrachloroethene			1.9E-03	1.9E-03	1.5E-06		1.9E-03	1.3E-06		8.9E-05	2.0E-03	3.9E-03
	TOTAL	3.7E-04	3.7E-04	1.0E-02	1.0E-02	1.3E-02	2.9E-02	6.9E-02	1.6E-02	6.5E-04	4.2E-02	1.7E-01	1.8E-01
Renal	Chlorobenzene			5.6E-03	5.6E-03	1.2E-06		1.4E-03	1.1E-06		7.0E-05	1.5E-03	7.0E-03
	TOTAL			5.6E-03	5.6E-03	1.2E-06		1.4E-03	1.1E-06		7.0E-05	1.5E-03	7.0E-03
Respiratory	Xylenes, total			2.4E-04	2.4E-04								2.4E-04
	TOTAL			2.4E-04	2.4E-04								2.4E-04

(CONTINUED)

Zone 1C; Adult Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Skin	Arsenic, total					1.2E-04		2.0E-01	4.9E-04		4.3E-03	2.0E-01	2.0E-01
	TOTAL					1.2E-04		2.0E-01	4.9E-04		4.3E-03	2.0E-01	2.0E-01

Zone 1C; Child Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			1.3E-03	1.3E-03	1.8E-06		1.3E-03	6.2E-07		4.0E-05	1.3E-03	2.6E-03
	TOTAL			1.3E-03	1.3E-03	1.8E-06		1.3E-03	6.2E-07		4.0E-05	1.3E-03	2.6E-03
Cardiovascular	Atrazine					8.9E-05		2.4E-02	3.3E-05		1.2E-03	2.5E-02	2.5E-02
	TOTAL					8.9E-05		2.4E-02	3.3E-05		1.2E-03	2.5E-02	2.5E-02
CNS	DIMP					1.6E-06		3.3E-02	6.8E-07		1.1E-03	3.4E-02	3.4E-02
	Xylenes, total			3.6E-04	3.6E-04	1.4E-07		1.6E-05	5.5E-08		1.3E-06	1.7E-05	3.8E-04
	TOTAL			3.6E-04	3.6E-04	1.7E-06		3.3E-02	7.3E-07		1.1E-03	3.4E-02	3.4E-02
Gastrointestinal	Hexachlorocyclopentadiene					4.2E-06		1.7E-04	1.8E-06		5.0E-05	2.3E-04	2.3E-04
	TOTAL					4.2E-06		1.7E-04	1.8E-06		5.0E-05	2.3E-04	2.3E-04
Hepatic	Aldrin	1.0E-04	1.0E-04					4.0E-02		5.5E-04		4.1E-02	4.1E-02
	Benzene			1.3E-03	1.3E-03	1.8E-06		1.3E-03	6.2E-07		4.0E-05	1.3E-03	2.6E-03
	Chlorobenzene			8.5E-03	8.5E-03	9.0E-06		2.1E-03	3.5E-06		1.1E-04	2.2E-03	1.1E-02
	Chloroform			2.8E-03	2.8E-03	8.9E-07		2.8E-03	3.0E-07		8.2E-05	2.9E-03	5.8E-03
	DDE, p,p'-	3.5E-05	3.5E-05			1.1E-02		2.4E-03	5.9E-03	2.3E-04	3.7E-03	2.3E-02	2.3E-02
	DDT, p,p'-	7.0E-05	7.0E-05					3.0E-03		4.7E-04		3.5E-03	3.6E-03
	Dieldrin	5.2E-04	5.2E-04			7.9E-02	7.9E-02	2.8E-02	4.1E-02	2.8E-03	6.0E-02	2.9E-01	2.9E-01
	Endrin	2.1E-05	2.1E-05			1.2E-03		4.5E-03	4.5E-04	1.1E-04	3.3E-03	9.6E-03	9.6E-03
	Isodrin							1.6E-02				1.6E-02	1.6E-02
	Tetrachloroethene			2.9E-03	2.9E-03	1.1E-05		2.9E-03	4.1E-06		1.4E-04	3.1E-03	5.9E-03
	TOTAL	7.5E-04	7.5E-04	1.5E-02	1.5E-02	9.2E-02	7.9E-02	1.0E-01	4.8E-02	4.1E-03	6.8E-02	3.9E-01	4.1E-01
Renal	Chlorobenzene			8.5E-03	8.5E-03	9.0E-06		2.1E-03	3.5E-06		1.1E-04	2.2E-03	1.1E-02
	TOTAL			8.5E-03	8.5E-03	9.0E-06		2.1E-03	3.5E-06		1.1E-04	2.2E-03	1.1E-02
Respiratory	Xylenes, total			3.6E-04	3.6E-04								3.6E-04
	TOTAL			3.6E-04	3.6E-04								3.6E-04

(CONTINUED)

Zone 1C; Child Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Skin	Arsenic, total					8.4E-04		3.0E-01	1.5E-03		7.0E-03	3.1E-01	3.1E-01
	TOTAL					8.4E-04		3.0E-01	1.5E-03		7.0E-03	3.1E-01	3.1E-01

Zone 2; Adult Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			8.7E-04	8.7E-04	1.6E-06		8.7E-04	1.3E-06		1.6E-04	1.0E-03	1.9E-03
	TOTAL			8.7E-04	8.7E-04	1.6E-06		8.7E-04	1.3E-06		1.6E-04	1.0E-03	1.9E-03
Cardiovascular	Atrazine					1.4E-04		2.9E-02	1.3E-04		8.3E-03	3.8E-02	3.8E-02
	Dichloroethane, 1,2-					2.6E-07		3.0E-04	2.0E-07		4.3E-05	3.4E-04	3.4E-04
	TOTAL					1.4E-04		2.9E-02	1.3E-04		8.4E-03	3.8E-02	3.8E-02
CNS	DIMP					1.5E-05		2.4E-01	1.6E-05		4.8E-02	2.9E-01	2.9E-01
	Malathion					1.9E-06		3.5E-04	1.7E-06		1.1E-04	4.6E-04	4.6E-04
	Manganese					7.9E-03		4.3E-01	1.9E-03		1.1E-01	5.5E-01	5.5E-01
	TOTAL					7.9E-03		6.8E-01	1.9E-03		1.6E-01	8.4E-01	8.4E-01
Gastrointestinal	Hexachlorocyclopentadiene					4.1E-06		1.3E-04	4.2E-06		2.2E-04	3.5E-04	3.5E-04
	TOTAL					4.1E-06		1.3E-04	4.2E-06		2.2E-04	3.5E-04	3.5E-04
Hepatic	Aldrin	5.0E-05	5.0E-05					4.1E-02		8.6E-05		4.1E-02	4.1E-02
	Benzene			8.7E-04	8.7E-04	1.6E-06		8.7E-04	1.3E-06		1.6E-04	1.0E-03	1.9E-03
	Carbon tetrachloride			1.6E-04	1.6E-04	1.6E-04		3.0E-02	1.4E-04		9.0E-03	3.9E-02	3.9E-02
	Chlordane, total					3.2E-04		8.1E-02	2.4E-04		1.6E-02	9.8E-02	9.8E-02
	Chlorobenzene			9.8E-03	9.8E-03	1.4E-05		2.4E-03	1.2E-05		7.6E-04	3.2E-03	1.3E-02
	Chloroform			1.8E-01	1.8E-01	7.5E-05		1.8E-01	6.0E-05		3.1E-02	2.2E-01	4.0E-01
	Chlorophenylmethyl sulfone, p-					1.9E-06		6.0E-03	1.4E-06		7.7E-04	6.7E-03	6.7E-03
	Chlorophenylmethyl sulfoxide, p-					6.4E-06		2.0E-02	4.8E-06		2.6E-03	2.2E-02	2.2E-02
	DDE, p,p'-	1.7E-05	1.7E-05			1.8E-03		1.6E-03	2.2E-03	3.7E-05	2.8E-03	8.3E-03	8.3E-03
	DDT, p,p'-	3.4E-05	3.4E-05					1.8E-03		7.3E-05		1.9E-03	1.9E-03
	Dibromochloropropane			2.1E-01	2.1E-01	1.0E-06		2.4E-03	8.1E-07		3.8E-04	2.8E-03	2.1E-01
	Dichlorobenzenes, total			3.5E-03	3.5E-03	3.4E-05		1.6E-03	3.3E-05		1.2E-03	2.8E-03	6.3E-03

(CONTINUED)

Zone 2; Adult Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Hepatic	Dicyclopentadiene					2.0E-05		3.3E-03	1.9E-05		1.9E-03	5.2E-03	5.2E-03
	Dieldrin	2.5E-04	2.5E-04			1.6E-02	2.9E-02	1.9E-02	1.9E-02	4.3E-04	5.6E-02	1.4E-01	1.4E-01
	Endrin	1.0E-05	1.0E-05			4.3E-04		3.4E-03	3.6E-04	1.7E-05	5.4E-03	9.6E-03	9.6E-03
	Isodrin							1.4E-02				1.4E-02	1.4E-02
	Tetrachloroethene			2.8E-02	2.8E-02	1.4E-04		2.8E-02	1.2E-04		8.1E-03	3.6E-02	6.4E-02
	Trichloroethene			4.4E-05	4.4E-05	2.6E-07		4.4E-05	2.4E-07		1.5E-05	5.9E-05	1.0E-04
	TOTAL	3.7E-04	3.7E-04	4.4E-01	4.4E-01	1.9E-02	2.9E-02	4.4E-01	2.2E-02	6.5E-04	1.4E-01	6.5E-01	1.1E+00
Renal	Chlorobenzene			9.8E-03	9.8E-03	1.4E-05		2.4E-03	1.2E-05		7.6E-04	3.2E-03	1.3E-02
	Dibromochloropropane			2.1E-01	2.1E-01	1.0E-06		2.4E-03	8.1E-07		3.8E-04	2.8E-03	2.1E-01
	TOTAL			2.2E-01	2.2E-01	1.5E-05		4.9E-03	1.3E-05		1.1E-03	6.0E-03	2.3E-01
Respiratory	Dichloroethane, 1,2-			2.3E-04	2.3E-04								2.3E-04
	TOTAL			2.3E-04	2.3E-04								2.3E-04
Skin	Arsenic, total					5.5E-04		1.5E-01	2.3E-03		2.0E-02	1.7E-01	1.7E-01
	TOTAL					5.5E-04		1.5E-01	2.3E-03		2.0E-02	1.7E-01	1.7E-01

Zone 2; Child Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Blood	Benzene			1.3E-03	1.3E-03	1.2E-05		1.3E-03	4.0E-06		2.6E-04	1.6E-03	2.9E-03
	TOTAL			1.3E-03	1.3E-03	1.2E-05		1.3E-03	4.0E-06		2.6E-04	1.6E-03	2.9E-03
Cardiovascular	Atrazine					1.0E-03		4.4E-02	3.9E-04		1.4E-02	5.9E-02	5.9E-02
	Dichloroethane, 1,2-					1.9E-06		4.5E-04	6.1E-07		6.9E-05	5.3E-04	5.3E-04
	TOTAL					1.0E-03		4.5E-02	3.9E-04		1.4E-02	6.0E-02	6.0E-02
CNS	DIMP					1.1E-04		3.7E-01	4.8E-05		7.9E-02	4.5E-01	4.5E-01
	Malathion					1.4E-05		5.3E-04	5.1E-06		1.8E-04	7.3E-04	7.3E-04
	Manganese					5.8E-02		6.6E-01	5.7E-03		1.8E-01	9.0E-01	9.0E-01
	TOTAL					5.8E-02		1.0E+00	5.8E-03		2.6E-01	1.3E+00	1.3E+00
Gastrointestinal	Hexachlorocyclopentadiene					3.0E-05		2.0E-04	1.3E-05		3.5E-04	5.9E-04	5.9E-04
	TOTAL					3.0E-05		2.0E-04	1.3E-05		3.5E-04	5.9E-04	5.9E-04
Hepatic	Aldrin	1.0E-04	1.0E-04					6.2E-02		5.5E-04		6.2E-02	6.2E-02
	Benzene			1.3E-03	1.3E-03	1.2E-05		1.3E-03	4.0E-06		2.6E-04	1.6E-03	2.9E-03
	Carbon tetrachloride			2.4E-04	2.4E-04	1.2E-03		4.5E-02	4.4E-04		1.5E-02	6.1E-02	6.2E-02
	Chlordane, total					2.3E-03		1.2E-01	7.5E-04		2.6E-02	1.5E-01	1.5E-01
	Chlorobenzene			1.5E-02	1.5E-02	9.8E-05		3.7E-03	3.8E-05		1.2E-03	5.1E-03	2.0E-02
	Chloroform			2.8E-01	2.8E-01	5.5E-04		2.8E-01	1.8E-04		5.0E-02	3.3E-01	6.1E-01
	Chlorophenylmethyl sulfone, p-					1.4E-05		9.0E-03	4.4E-06		1.3E-03	1.0E-02	1.0E-02
	Chlorophenylmethyl sulfoxide, p-					4.7E-05		3.0E-02	1.5E-05		4.3E-03	3.4E-02	3.4E-02
	DDE, p,p'-	3.5E-05	3.5E-05			1.3E-02		2.4E-03	6.6E-03	2.3E-04	4.5E-03	2.7E-02	2.7E-02
	DDT, p,p'-	7.0E-05	7.0E-05					2.8E-03		4.7E-04		3.2E-03	3.3E-03
	Dibromochloropropane			3.2E-01	3.2E-01	7.6E-06		3.7E-03	2.5E-06		6.1E-04	4.3E-03	3.2E-01
	Dichlorobenzenes, total			5.3E-03	5.3E-03	2.5E-04		2.4E-03	1.0E-04		1.9E-03	4.7E-03	1.0E-02

(CONTINUED)

Zone 2; Child Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Hepatic	Dicyclopentadiene					1.4E-04		5.0E-03	5.8E-05		3.0E-03	8.3E-03	8.3E-03
	Dieldrin	5.2E-04	5.2E-04			1.2E-01	7.9E-02	2.9E-02	5.7E-02	2.8E-03	9.0E-02	3.7E-01	3.8E-01
	Endrin	2.1E-05	2.1E-05			3.2E-03		5.1E-03	1.1E-03	1.1E-04	8.8E-03	1.8E-02	1.8E-02
	Isodrin							2.1E-02				2.1E-02	2.1E-02
	Tetrachloroethene			4.2E-02	4.2E-02	1.0E-03		4.2E-02	3.7E-04		1.3E-02	5.7E-02	9.9E-02
	Trichloroethene			6.7E-05	6.7E-05	1.9E-06		6.7E-05	7.4E-07		2.4E-05	9.4E-05	1.6E-04
	TOTAL	7.5E-04	7.5E-04	6.6E-01	6.6E-01	1.4E-01	7.9E-02	6.7E-01	6.7E-02	4.1E-03	2.2E-01	1.2E+00	1.8E+00
Renal	Chlorobenzene			1.5E-02	1.5E-02	9.8E-05		3.7E-03	3.8E-05		1.2E-03	5.1E-03	2.0E-02
	Dibromochloropropane			3.2E-01	3.2E-01	7.6E-06		3.7E-03	2.5E-06		6.1E-04	4.3E-03	3.2E-01
	TOTAL			3.4E-01	3.4E-01	1.1E-04		7.4E-03	4.0E-05		1.9E-03	9.4E-03	3.4E-01
Respiratory	Dichloroethane, 1,2-			3.5E-04	3.5E-04								3.5E-04
	TOTAL			3.5E-04	3.5E-04								3.5E-04
Skin	Arsenic, total					4.0E-03		2.3E-01	7.1E-03		3.3E-02	2.7E-01	2.7E-01
	TOTAL					4.0E-03		2.3E-01	7.1E-03		3.3E-02	2.7E-01	2.7E-01

Zone 3; Adult Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Blood	Benzene					1.0E-03	1.0E-03	1.0E-03			1.7E-04	1.2E-03	2.2E-03
	Toluene							1.7E-04			4.4E-05	2.2E-04	2.2E-04
	TOTAL					1.0E-03	1.0E-03	1.2E-03			2.1E-04	1.4E-03	2.4E-03
Cardiovascular	Atrazine							7.1E-02			1.8E-02	8.9E-02	8.9E-02
	Dichloroethane, 1,2-							3.6E-04			4.6E-05	4.1E-04	4.1E-04
	TOTAL							7.1E-02			1.8E-02	9.0E-02	9.0E-02
CNS	DIMP			4.6E-05	4.6E-05			2.0E-01			3.8E-02	2.4E-01	2.4E-01
	Dithiane, 1,4-							1.8E-04			1.9E-05	2.0E-04	2.0E-04
	Malathion							5.2E-04			1.5E-04	6.7E-04	6.7E-04
	Oxathiane, 1,4-							1.2E-04			1.1E-05	1.3E-04	1.3E-04
	Toluene					3.1E-04	3.1E-04						3.1E-04
	TOTAL			4.6E-05	4.6E-05	3.1E-04	3.1E-04	2.0E-01			3.8E-02	2.4E-01	2.4E-01
Ocular	Toluene					3.1E-04	3.1E-04						3.1E-04
	TOTAL					3.1E-04	3.1E-04						3.1E-04
Gastrointestinal	Hexachlorocyclopentadiene							1.7E-04			2.6E-04	4.3E-04	4.3E-04
	TOTAL							1.7E-04			2.6E-04	4.3E-04	4.3E-04
Hepatic	Aldrin	4.7E-05	3.3E-04		3.8E-04			4.6E-02	8.0E-05	5.7E-04		4.6E-02	4.7E-02
	Benzene					1.0E-03	1.0E-03	1.0E-03			1.7E-04	1.2E-03	2.2E-03
	Chlordane, total		5.9E-04	4.8E-05	6.4E-04			8.7E-02		1.0E-03	4.0E-02	1.3E-01	1.3E-01
	Chlorobenzene					9.7E-03	9.7E-03	2.4E-03			6.8E-04	3.1E-03	1.3E-02
	Chloroform					1.4E-02	1.4E-02	1.4E-02			2.1E-03	1.6E-02	3.0E-02
	Chlorophenylmethyl sulfone, p-							9.1E-03			1.1E-03	1.0E-02	1.0E-02
	Chlorophenylmethyl sulfoxide, p-							1.4E-02			1.7E-03	1.6E-02	1.6E-02
	DDE, p,p'-	1.0E-07	2.8E-05	2.8E-06	3.1E-05			1.2E-02	2.2E-07	6.0E-05	7.3E-03	1.9E-02	1.9E-02

(CONTINUED)

Zone 3; Adult Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Hepatic	DDT, p,p'-	1.7E-06	7.2E-05	1.5E-06	7.5E-05			5.9E-03	3.7E-06	1.5E-04		6.0E-03	6.1E-03
	Dibromochloropropane	1.9E-06			1.9E-06	6.7E-02	6.7E-02	7.6E-04	4.8E-06		1.1E-04	8.8E-04	6.8E-02
	Dicyclopentadiene			5.3E-06	5.3E-06			1.5E-01			7.5E-02	2.2E-01	2.2E-01
	Dieldrin	3.4E-04	1.6E-03	8.2E-04	2.8E-03			1.2E-01	5.9E-04	2.8E-03	3.5E-01	4.7E-01	4.8E-01
	Dithiane, 1,4-							1.8E-04			1.9E-05	2.0E-04	2.0E-04
	Endrin	1.6E-06	7.6E-05		7.8E-05			6.6E-02	2.7E-06	1.3E-04	4.9E-02	1.2E-01	1.2E-01
	Isodrin							1.8E-02				1.8E-02	1.8E-02
	Tetrachloroethene					5.7E-02	5.7E-02	5.7E-02			1.5E-02	7.2E-02	1.3E-01
	Trichloroethene					3.5E-05	3.5E-05	3.5E-05			1.1E-05	4.5E-05	8.0E-05
	TOTAL	3.9E-04	2.7E-03	8.8E-04	4.0E-03	1.5E-01	1.5E-01	6.0E-01	6.8E-04	4.7E-03	5.5E-01	1.1E+00	1.3E+00
Renal	Chlorobenzene					9.7E-03	9.7E-03	2.4E-03			6.8E-04	3.1E-03	1.3E-02
	Dibromochloropropane	1.9E-06			1.9E-06	6.7E-02	6.7E-02	7.6E-04	4.8E-06		1.1E-04	8.8E-04	6.8E-02
	TOTAL	1.9E-06			1.9E-06	7.7E-02	7.7E-02	3.2E-03	4.8E-06		7.9E-04	4.0E-03	8.1E-02
Respiratory	Dichloroethane, 1,2-					2.8E-04	2.8E-04						2.8E-04
	Toluene					3.1E-04	3.1E-04						3.1E-04
	TOTAL					5.8E-04	5.8E-04						5.8E-04
Skin	Arsenic, total			9.4E-04	9.4E-04						2.2E-02	2.2E-02	2.3E-02
	TOTAL			9.4E-04	9.4E-04						2.2E-02	2.2E-02	2.3E-02

Zone 3; Child Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Blood	Benzene					1.6E-03	1.6E-03	1.6E-03			2.7E-04	1.8E-03	3.4E-03
	Toluene							2.7E-04			7.1E-05	3.4E-04	3.4E-04
	TOTAL					1.6E-03	1.6E-03	1.8E-03			3.4E-04	2.2E-03	3.7E-03
Cardiovascular	Atrazine							1.1E-01			3.0E-02	1.4E-01	1.4E-01
	Dichloroethane, 1,2-							5.5E-04			7.5E-05	6.2E-04	6.2E-04
	TOTAL							1.1E-01			3.0E-02	1.4E-01	1.4E-01
CNS	DIMP			9.3E-05	9.3E-05			3.1E-01			6.1E-02	3.7E-01	3.7E-01
	Dithiane, 1,4-							2.7E-04			3.1E-05	3.0E-04	3.0E-04
	Malathion							7.9E-04			2.4E-04	1.0E-03	1.0E-03
	Oxathiane, 1,4-							1.8E-04			1.8E-05	2.0E-04	2.0E-04
	Toluene					4.7E-04	4.7E-04						4.7E-04
	TOTAL			9.3E-05	9.3E-05	4.7E-04	4.7E-04	3.1E-01			6.1E-02	3.7E-01	3.7E-01
Ocular	Toluene					4.7E-04	4.7E-04						4.7E-04
	TOTAL					4.7E-04	4.7E-04						4.7E-04
Gastrointestinal	Hexachlorocyclopentadiene							2.6E-04			4.2E-04	6.8E-04	6.8E-04
	TOTAL							2.6E-04			4.2E-04	6.8E-04	6.8E-04
Hepatic	Aldrin	9.6E-05	6.8E-04		7.8E-04			6.9E-02	5.1E-04	3.6E-03		7.4E-02	7.4E-02
	Benzene					1.6E-03	1.6E-03	1.6E-03			2.7E-04	1.8E-03	3.4E-03
	Chlordane, total		1.2E-03	9.9E-05	1.3E-03			1.3E-01		6.5E-03	6.4E-02	2.0E-01	2.0E-01
	Chlorobenzene					1.5E-02	1.5E-02	3.7E-03			1.1E-03	4.8E-03	2.0E-02
	Chloroform					2.1E-02	2.1E-02	2.1E-02			3.4E-03	2.4E-02	4.5E-02
	Chlorophenylmethyl sulfone, p-							1.4E-02			1.7E-03	1.6E-02	1.6E-02
	Chlorophenylmethyl sulfoxide, p-							2.2E-02			2.7E-03	2.4E-02	2.4E-02
	DDE, p,p'-	2.1E-07	5.7E-05	5.8E-06	6.3E-05			1.8E-02	1.4E-06	3.8E-04	1.2E-02	3.0E-02	3.0E-02

(CONTINUED)

Zone 3; Child Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Hepatic	DDT, p,p'-	3.5E-06	1.5E-04	3.0E-06	1.5E-04			8.9E-03	2.3E-05	9.8E-04		9.9E-03	1.0E-02
	Dibromochloropropane	4.0E-06			4.0E-06	1.0E-01	1.0E-01	1.2E-03	3.1E-05		1.7E-04	1.4E-03	1.0E-01
	Dicyclopentadiene			1.1E-05	1.1E-05			2.3E-01			1.2E-01	3.5E-01	3.5E-01
	Dieldrin	7.0E-04	3.3E-03	1.7E-03	5.7E-03			1.8E-01	3.7E-03	1.8E-02	5.7E-01	7.7E-01	7.8E-01
	Dithiane, 1,4-							2.7E-04			3.1E-05	3.0E-04	3.0E-04
	Endrin	3.2E-06	1.6E-04		1.6E-04			1.0E-01	1.7E-05	8.3E-04	8.0E-02	1.8E-01	1.8E-01
	Isodrin							2.8E-02				2.8E-02	2.8E-02
	Tetrachloroethene					8.6E-02	8.6E-02	8.6E-02			2.4E-02	1.1E-01	2.0E-01
	Trichloroethene					5.3E-05	5.3E-05	5.3E-05			1.7E-05	7.0E-05	1.2E-04
	TOTAL	8.1E-04	5.6E-03	1.8E-03	8.2E-03	2.2E-01	2.2E-01	9.1E-01	4.3E-03	3.0E-02	8.9E-01	1.8E+00	2.1E+00
Renal	Chlorobenzene					1.5E-02	1.5E-02	3.7E-03			1.1E-03	4.8E-03	2.0E-02
	Dibromochloropropane	4.0E-06			4.0E-06	1.0E-01	1.0E-01	1.2E-03	3.1E-05		1.7E-04	1.4E-03	1.0E-01
	TOTAL	4.0E-06			4.0E-06	1.2E-01	1.2E-01	4.8E-03	3.1E-05		1.3E-03	6.2E-03	1.2E-01
Respiratory	Dichloroethane, 1,2-					4.2E-04	4.2E-04						4.2E-04
	Toluene					4.7E-04	4.7E-04						4.7E-04
	TOTAL					8.9E-04	8.9E-04						8.9E-04
Skin	Arsenic, total			1.9E-03	1.9E-03						3.6E-02	3.6E-02	3.8E-02
	TOTAL			1.9E-03	1.9E-03						3.6E-02	3.6E-02	3.8E-02

Zone 4; Adult Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sediment	Soil	Surface Water	Total	Groundwater	Total	Groundwater	Sediment	Soil	Vegetables	Total	Grand Total
Blood	Benzene					1.3E-03	1.3E-03	1.3E-03			2.1E-04	1.5E-03	2.7E-03
	Toluene							1.6E-04			4.0E-05	2.0E-04	2.0E-04
	TOTAL					1.3E-03	1.3E-03	1.4E-03			2.5E-04	1.7E-03	2.9E-03
Cardiovascular	Atrazine							4.0E-02			1.0E-02	5.1E-02	5.1E-02
	Dichloroethane, 1,2-							2.9E-03			3.7E-04	3.2E-03	3.2E-03
	TOTAL							4.3E-02			1.1E-02	5.4E-02	5.4E-02
CNS	DIMP			4.6E-05	4.6E-05			1.7E+00			3.0E-01	2.0E+00	2.0E+00
	Dithiane, 1,4-							3.9E-04			4.1E-05	4.3E-04	4.3E-04
	Malathion							4.3E-04			1.2E-04	5.5E-04	5.5E-04
	Manganese							3.4E-01			7.8E-02	4.2E-01	4.2E-01
	Oxathiane, 1,4-							2.0E-04			1.8E-05	2.2E-04	2.2E-04
	Toluene					2.8E-04	2.8E-04						2.8E-04
	Xylenes, total					3.5E-04	3.5E-04	1.5E-05			6.5E-06	2.2E-05	3.7E-04
	TOTAL			4.6E-05	4.6E-05	6.4E-04	6.4E-04	2.0E+00			3.8E-01	2.4E+00	2.4E+00
Ocular	Toluene					2.8E-04	2.8E-04						2.8E-04
	TOTAL					2.8E-04	2.8E-04						2.8E-04
Gastrointestinal	Hexachlorocyclopentadiene							1.7E-04			2.5E-04	4.2E-04	4.2E-04
	TOTAL							1.7E-04			2.5E-04	4.2E-04	4.2E-04
Hepatic	Aldrin	4.7E-05	5.0E-05		9.7E-05			1.1E-01	8.0E-05	8.6E-05		1.1E-01	1.1E-01
	Benzene					1.3E-03	1.3E-03	1.3E-03			2.1E-04	1.5E-03	2.7E-03
	Chlordane, total			4.8E-05	4.8E-05			2.5E-01			4.6E-02	2.9E-01	2.9E-01
	Chlorobenzene					2.5E-02	2.5E-02	6.2E-03			1.7E-03	7.9E-03	3.3E-02
	Chloroform					4.1E-03	4.1E-03	4.1E-03			6.2E-04	4.8E-03	8.9E-03
	Chlorophenylmethyl sulfone, p-							7.0E-03			8.1E-04	7.8E-03	7.8E-03

(CONTINUED)

Zone 4; Adult Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sedi-ment	Soil	Surface Water	Total	Ground-water	Total	Ground-water	Sedi-ment	Soil	Vege-tables	Total	Grand Total
Hepatic	Chlorophenylmethyl sulfoxide, p-							1.1E-02			1.2E-03	1.2E-02	1.2E-02
	DDE, p,p'-	1.0E-07	1.7E-05	2.8E-06	2.0E-05			4.6E-03	2.2E-07	3.7E-05	4.0E-03	8.6E-03	8.7E-03
	DDT, p,p'-	1.7E-06	3.4E-05	1.5E-06	3.7E-05			5.5E-03	3.7E-06	7.3E-05		5.6E-03	5.6E-03
	Dibromochloropropane	1.9E-06			1.9E-06	7.4E-02	7.4E-02	8.4E-04	4.8E-06		1.2E-04	9.6E-04	7.5E-02
	Dichlorobenzenes, total					2.0E-03	2.0E-03	8.9E-04			6.2E-04	1.5E-03	3.5E-03
	Dicyclopentadiene			5.3E-06	5.3E-06			6.1E-02			3.1E-02	9.2E-02	9.2E-02
	Dieldrin	3.4E-04	2.5E-04	8.2E-04	1.4E-03			3.0E-02	5.9E-04	4.3E-04	1.5E-01	1.8E-01	1.8E-01
	Dithiane, 1,4-							3.9E-04			4.1E-05	4.3E-04	4.3E-04
	Endrin	1.6E-06	1.0E-05		1.2E-05			5.3E-03	2.7E-06	1.7E-05	7.1E-03	1.2E-02	1.2E-02
	Ethylbenzene					5.5E-05	5.5E-05	1.6E-04			6.8E-05	2.2E-04	2.8E-04
	Isodrin							2.2E-02				2.2E-02	2.2E-02
	Tetrachloroethene					1.7E-02	1.7E-02	1.7E-02			4.4E-03	2.1E-02	3.8E-02
	Trichloroethene					1.8E-04	1.8E-04	1.8E-04			5.6E-05	2.4E-04	4.3E-04
	TOTAL	3.9E-04	3.7E-04	8.8E-04	1.6E-03	1.2E-01	1.2E-01	5.3E-01	6.8E-04	6.5E-04	2.4E-01	7.7E-01	9.0E-01
Renal	Chlorobenzene					2.5E-02	2.5E-02	6.2E-03			1.7E-03	7.9E-03	3.3E-02
	Dibromochloropropane	1.9E-06			1.9E-06	7.4E-02	7.4E-02	8.4E-04	4.8E-06		1.2E-04	9.6E-04	7.5E-02
	Ethylbenzene					5.5E-05	5.5E-05	1.6E-04			6.8E-05	2.2E-04	2.8E-04
	TOTAL	1.9E-06			1.9E-06	9.8E-02	9.8E-02	7.2E-03	4.8E-06		1.9E-03	9.1E-03	1.1E-01
Respiratory	Dichloroethane, 1,2-					2.2E-03	2.2E-03						2.2E-03
	Toluene					2.8E-04	2.8E-04						2.8E-04
	Xylenes, total					3.5E-04	3.5E-04						3.5E-04
	TOTAL					2.8E-03	2.8E-03						2.8E-03
Skin	Arsenic, total			9.4E-04	9.4E-04			2.5E-01			5.3E-02	3.1E-01	3.1E-01
	TOTAL			9.4E-04	9.4E-04			2.5E-01			5.3E-02	3.1E-01	3.1E-01

Zone 4; Child Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sedi-ment	Soil	Surface Water	Total	Ground-water	Total	Ground-water	Sedi-ment	Soil	Vege-tables	Total	Grand Total
Blood	Benzene					1.9E-03	1.9E-03	1.9E-03			3.4E-04	2.3E-03	4.2E-03
	Toluene							2.4E-04			6.5E-05	3.1E-04	3.1E-04
	TOTAL					1.9E-03	1.9E-03	2.2E-03			4.0E-04	2.6E-03	4.5E-03
Cardiovascular	Atrazine							6.1E-02			1.7E-02	7.8E-02	7.8E-02
	Dichloroethane, 1,2-							4.3E-03			6.0E-04	4.9E-03	4.9E-03
	TOTAL							6.6E-02			1.7E-02	8.3E-02	8.3E-02
CNS	DIMP			9.3E-05	9.3E-05			2.6E+00			4.9E-01	3.1E+00	3.1E+00
	Dithiane, 1,4-							5.8E-04			6.6E-05	6.5E-04	6.5E-04
	Malathion							6.5E-04			2.0E-04	8.5E-04	8.5E-04
	Manganese							5.2E-01			1.3E-01	6.5E-01	6.5E-01
	Oxathiane, 1,4-							3.1E-04			3.0E-05	3.4E-04	3.4E-04
	Toluene					4.3E-04	4.3E-04						4.3E-04
	Xylenes, total					5.3E-04	5.3E-04	2.3E-05			1.1E-05	3.4E-05	5.7E-04
	TOTAL			9.3E-05	9.3E-05	9.6E-04	9.6E-04	3.1E+00			6.2E-01	3.7E+00	3.7E+00
Ocular	Toluene					4.3E-04	4.3E-04						4.3E-04
	TOTAL					4.3E-04	4.3E-04						4.3E-04
Gastrointestinal	Hexachlorocyclopenta-diene							2.5E-04			4.1E-04	6.6E-04	6.6E-04
	TOTAL							2.5E-04			4.1E-04	6.6E-04	6.6E-04
Hepatic	Aldrin	9.6E-05	1.0E-04		2.0E-04			1.6E-01	5.1E-04	5.5E-04		1.6E-01	1.6E-01
	Benzene					1.9E-03	1.9E-03	1.9E-03			3.4E-04	2.3E-03	4.2E-03
	Chlordane, total			9.9E-05	9.9E-05			3.7E-01			7.5E-02	4.5E-01	4.5E-01
	Chlorobenzene					3.7E-02	3.7E-02	9.4E-03			2.8E-03	1.2E-02	5.0E-02
	Chloroform					6.3E-03	6.3E-03	6.3E-03			1.0E-03	7.3E-03	1.4E-02
	Chlorophenylmethyl sulfone, p-							1.1E-02			1.3E-03	1.2E-02	1.2E-02

(CONTINUED)

Zone 4; Child Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal				Inhalation		Oral					
		MEDIUM				MEDIUM		MEDIUM					
		Sedi-ment	Soil	Surface Water	Total	Ground-water	Total	Ground-water	Sedi-ment	Soil	Vege-tables	Total	Grand Total
Hepatic	Chlorophenylmethyl sulfoxide, p-							1.6E-02			2.0E-03	1.8E-02	1.8E-02
	DDE, p,p'-	2.1E-07	3.5E-05	5.8E-06	4.1E-05			7.0E-03	1.4E-06	2.3E-04	6.4E-03	1.4E-02	1.4E-02
	DDT, p,p'-	3.5E-06	7.0E-05	3.0E-06	7.6E-05			8.3E-03	2.3E-05	4.7E-04		8.8E-03	8.9E-03
	Dibromochloropropane	4.0E-06			4.0E-06	1.1E-01	1.1E-01	1.3E-03	3.1E-05		1.9E-04	1.5E-03	1.1E-01
	Dichlorobenzenes, total					3.1E-03	3.1E-03	1.4E-03			1.0E-03	2.4E-03	5.4E-03
	Dicyclopentadiene			1.1E-05	1.1E-05			9.2E-02			5.0E-02	1.4E-01	1.4E-01
	Dieldrin	7.0E-04	5.2E-04	1.7E-03	2.9E-03			4.6E-02	3.7E-03	2.8E-03	2.4E-01	2.9E-01	2.9E-01
	Dithiane, 1,4-							5.8E-04			6.6E-05	6.5E-04	6.5E-04
	Endrin	3.2E-06	2.1E-05		2.4E-05			8.0E-03	1.7E-05	1.1E-04	1.2E-02	2.0E-02	2.0E-02
	Ethylbenzene					8.3E-05	8.3E-05	2.4E-04			1.1E-04	3.5E-04	4.3E-04
	Isodrin							3.4E-02				3.4E-02	3.4E-02
	Tetrachloroethene					2.5E-02	2.5E-02	2.5E-02			7.1E-03	3.2E-02	5.8E-02
	Trichloroethene					2.8E-04	2.8E-04	2.8E-04			9.1E-05	3.7E-04	6.5E-04
	TOTAL	8.1E-04	7.5E-04	1.8E-03	3.4E-03	1.9E-01	1.9E-01	8.0E-01	4.3E-03	4.1E-03	4.0E-01	1.2E+00	1.4E+00
Renal	Chlorobenzene					3.7E-02	3.7E-02	9.4E-03			2.8E-03	1.2E-02	5.0E-02
	Dibromochloropropane	4.0E-06			4.0E-06	1.1E-01	1.1E-01	1.3E-03	3.1E-05		1.9E-04	1.5E-03	1.1E-01
	Ethylbenzene					8.3E-05	8.3E-05	2.4E-04			1.1E-04	3.5E-04	4.3E-04
	TOTAL	4.0E-06			4.0E-06	1.5E-01	1.5E-01	1.1E-02	3.1E-05		3.1E-03	1.4E-02	1.6E-01
Respiratory	Dichloroethane, 1,2-					3.3E-03	3.3E-03						3.3E-03
	Toluene					4.3E-04	4.3E-04						4.3E-04
	Xylenes, total					5.3E-04	5.3E-04						5.3E-04
	TOTAL					4.3E-03	4.3E-03						4.3E-03
Skin	Arsenic, total			1.9E-03	1.9E-03			3.9E-01			8.7E-02	4.7E-01	4.7E-01
	TOTAL			1.9E-03	1.9E-03			3.9E-01			8.7E-02	4.7E-01	4.7E-01

Noncarcinogenic Hazard Indices
Zone 5; Adult Commercial/Industrial; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY							
		Dermal		Inhalation		Oral			
		MEDIUM		MEDIUM		MEDIUM			
		Soil	Total	GW	Total	GW	Soil	Total	Grand Total
CNS	DIMP					9.4E-04		9.4E-04	9.4E-04
	Manganese					6.6E-02		6.6E-02	6.6E-02
	TOTAL					6.6E-02		6.6E-02	6.6E-02
Gastrointestinal	Hexachlorocyclo-pentadiene					4.9E-05		4.9E-05	4.9E-05
	TOTAL					4.9E-05		4.9E-05	4.9E-05
Hepatic	Aldrin	3.8E-05	3.8E-05			1.3E-02	3.1E-05	1.3E-02	1.3E-02
	Dibromochloropropane			1.7E-02	1.7E-02	2.0E-04		2.0E-04	1.7E-02
	Chlorobenzene			2.1E-03	2.1E-03	5.3E-04		5.3E-04	2.7E-03
	Chloroform			1.2E-02	1.2E-02	1.2E-02		1.2E-02	2.3E-02
	DDE, p,p'-	1.6E-05	1.6E-05				1.3E-05	1.3E-05	3.0E-05
	DDT, p,p'-	3.3E-05	3.3E-05				2.6E-05	2.6E-05	5.9E-05
	Dieldrin	2.0E-04	2.0E-04			1.4E-02	1.6E-04	1.4E-02	1.4E-02
	Endrin	7.7E-06	7.7E-06				6.2E-06	6.2E-06	1.4E-05
	Tetrachloroethene			7.3E-04	7.3E-04	7.3E-04		7.3E-04	1.5E-03
	TOTAL	2.9E-04	2.9E-04	3.2E-02	3.2E-02	4.0E-02	2.4E-04	4.0E-02	7.2E-02
Renal	Chlorobenzene			2.1E-03	2.1E-03	5.3E-04		5.3E-04	2.7E-03
	Dibromochloropropane			1.7E-02	1.7E-02	2.0E-04		2.0E-04	1.7E-02
	TOTAL			1.9E-02	1.9E-02	7.3E-04		7.3E-04	2.0E-02
Skin	Arsenic, total					8.7E-02		8.7E-02	8.7E-02
	TOTAL					8.7E-02		8.7E-02	8.7E-02

Zone 6; Adult Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY											
		Dermal		Inhalation		Oral							
		MEDIUM		MEDIUM		MEDIUM							
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Cardiovascular	Atrazine					1.9E-05		2.4E-02	1.7E-05		1.1E-03	2.5E-02	2.5E-02
	TOTAL					1.9E-05		2.4E-02	1.7E-05		1.1E-03	2.5E-02	2.5E-02
CNS	DIMP					1.6E-08		1.6E-03	1.6E-08		5.1E-05	1.6E-03	1.6E-03
	TOTAL					1.6E-08		1.6E-03	1.6E-08		5.1E-05	1.6E-03	1.6E-03
Hepatic	Aldrin	5.0E-05	5.0E-05					2.7E-02		8.6E-05		2.7E-02	2.7E-02
	Chlorobenzene			7.0E-03	7.0E-03	1.5E-06		1.7E-03	1.4E-06		8.7E-05	1.8E-03	8.8E-03
	Chloroform			9.1E-03	9.1E-03	5.9E-07		9.1E-03	4.8E-07		2.5E-04	9.4E-03	1.9E-02
	DDE, p,p'-	1.7E-05	1.7E-05			1.5E-03			1.9E-03	3.7E-05	2.1E-03	5.5E-03	5.6E-03
	DDT, p,p'-	3.4E-05	3.4E-05							7.3E-05		7.3E-05	1.1E-04
	Dieldrin	2.5E-04	2.5E-04			1.1E-02	2.9E-02	2.1E-02	1.4E-02	4.3E-04	3.7E-02	1.1E-01	1.1E-01
	Endrin	1.0E-05	1.0E-05			1.5E-04			1.4E-04	1.7E-05	1.9E-03	2.2E-03	2.2E-03
	Isodrin							1.6E-02				1.6E-02	1.6E-02
	Tetrachloroethene			4.6E-03	4.6E-03	3.7E-06		4.6E-03	3.2E-06		2.1E-04	4.8E-03	9.4E-03
	Trichloroethene			2.8E-04	2.8E-04	2.6E-07		2.8E-04	2.4E-07		1.5E-05	2.9E-04	5.7E-04
	TOTAL	3.7E-04	3.7E-04	2.1E-02	2.1E-02	1.3E-02	2.9E-02	8.0E-02	1.6E-02	6.5E-04	4.2E-02	1.8E-01	2.0E-01
Renal	Chlorobenzene			7.0E-03	7.0E-03	1.5E-06		1.7E-03	1.4E-06		8.7E-05	1.8E-03	8.8E-03
	TOTAL			7.0E-03	7.0E-03	1.5E-06		1.7E-03	1.4E-06		8.7E-05	1.8E-03	8.8E-03

RMA ARES 8: NONCARCINOGENIC HAZARD INDICES FOR RME EXPOSURES

Zone 6; Child Resident; Chronic RME

TARGET SYSTEM	ANALYTE	PATHWAY												
		Dermal		Inhalation		Oral								
		MEDIUM		MEDIUM		MEDIUM								
		Soil	Total	Groundwater	Total	Dairy Products	Eggs	Groundwater	Meat	Soil	Vegetables	Total	Grand Total
Cardiovascular	Atrazine					1.4E-04		3.6E-02	5.1E-05		1.8E-03	3.8E-02	3.8E-02
	TOTAL					1.4E-04		3.6E-02	5.1E-05		1.8E-03	3.8E-02	3.8E-02
CNS	DIMP					1.2E-07		2.4E-03	5.0E-08		8.2E-05	2.5E-03	2.5E-03
	TOTAL					1.2E-07		2.4E-03	5.0E-08		8.2E-05	2.5E-03	2.5E-03
Hepatic	Aldrin	1.0E-04	1.0E-04					4.1E-02		5.5E-04		4.2E-02	4.2E-02
	Chlorobenzene			1.1E-02	1.1E-02	1.1E-05		2.6E-03	4.3E-06		1.4E-04	2.8E-03	1.3E-02
	Chloroform			1.4E-02	1.4E-02	4.3E-06		1.4E-02	1.5E-06		4.0E-04	1.4E-02	2.8E-02
	DDE, p,p'-	3.5E-05	3.5E-05			1.1E-02			5.7E-03	2.3E-04	3.5E-03	2.0E-02	2.0E-02
	DDT, p,p'-	7.0E-05	7.0E-05							4.7E-04		4.7E-04	5.4E-04
	Dieldrin	5.2E-04	5.2E-04			8.0E-02	7.9E-02	3.2E-02	4.1E-02	2.8E-03	6.1E-02	3.0E-01	3.0E-01
	Endrin	2.1E-05	2.1E-05			1.1E-03			4.1E-04	1.1E-04	3.0E-03	4.7E-03	4.7E-03
	Isodrin							2.4E-02				2.4E-02	2.4E-02
	Tetrachloroethene			6.9E-03	6.9E-03	2.7E-05		6.9E-03	9.9E-06		3.5E-04	7.3E-03	1.4E-02
	Trichloroethene			4.2E-04	4.2E-04	1.9E-06		4.2E-04	7.4E-07		2.4E-05	4.5E-04	8.7E-04
	TOTAL	7.5E-04	7.5E-04	3.2E-02	3.2E-02	9.2E-02	7.9E-02	1.2E-01	4.8E-02	4.1E-03	6.8E-02	4.1E-01	4.4E-01
Renal	Chlorobenzene			1.1E-02	1.1E-02	1.1E-05		2.6E-03	4.3E-06		1.4E-04	2.8E-03	1.3E-02
	TOTAL			1.1E-02	1.1E-02	1.1E-05		2.6E-03	4.3E-06		1.4E-04	2.8E-03	1.3E-02

Appendix H

SUPPORTING INFORMATION FOR THE ECOLOGICAL ASSESSMENT

Appendix H1

ANIMAL SPECIES OF POSSIBLE OCCURRENCE IN RMA OFFPOST AREA

Table H1-1: Species of Possible Occurrence in RMA Offpost Area
(Page 1 of 6)

Family	Genus	Species	Common Name	Status[1]	Habitat[2]	Offpost
Reptiles						
Chelydridae	*Chelydra*	*serpentina*	Snapping turtle	b	RpL, Ms, OW-St/Ri, OW-L/R	
Colubridae	*Coluber*	*constrictor flaviventris*	Eastern yellowbelly racer	B	SgP, MXP, TgP, RpL, Ag, U	
Colubridae	*Heterodon*	*nasicus*	Western hognose snake	B	SgP, TgP, RpL, Ag, sd	
Colubridae	*Lampropeltis*	*trangulum*	Milk snake	B	SgP, TgP, RpL, Ag, sd	
Colubridae	*Masticophis*	*flagellum*	Coachwhip	B	SgP, TgP, RpL, cl	
Colubridae	*Nerodia*	*sipedon*	Northern water snake	B	RpL, Ms, OW-St/Ri, OW-L/R	
Colubridae	*Pituophis*	*melanoleucus*	Bullsnake	B	SgP, MXP, TgP, RpL, Ag, U, sd	x
Colubridae	*Thamnophis*	*elegans*	Western terrestrial garter	B	RpL, Ms, In	
Colubridae	*Thamnophis*	*radix*	Plains garter snake	B	RpL, Ms, In, SgP, TgP, U	
Colubridae	*Thamnophis*	*sirtalis*	Red-sided garter snake	B	RpL, Ms, In	
Colubridae	*Tropidoclonion*	*lineatum*	Lined snake	B	SgP, U, Rpl	
Emydidae	*Chrysemys*	*picta*	Western painted turtle	B	RpL, Ms, OW-St/Ri, OW-L/R	
Emydidae	*Terrapene*	*ornata*	Western box turtle	B	SgP, sd, TgP, RpL	
Iguanidae	*Holbrookia*	*maculata maculata*	Northern earless lizard	B	SgP, MXP, TgP, Ag, sd	
Iguanidae	*Phrynosoma*	*douglassi*	Short-horned lizard	B	SgP, TgP, SgSD, cl	
Iguanidae	*Sceloporus*	*undulatus erythrochlus*	Eastern fence lizard	B	SgP, RpL, cl	
Iguanidae	*Sceloporus*	*undulatus garmani*	Northern fence lizard	B	SgP, TgP, sd	
Scincidae	*Eumeces*	*multivirgatus*	Many-lined skink	B	SgP, TgP, Ag, U, sd	
Scincidae	*Eumeces*	*obsoletus*	Great Plains skink	B	SgP, TgP, Ag, U, sd	
Telidae	*Cnemidophorus*	*sexlineatus*	Six-lined racerunner	B	SgP, sd, TgP, RpL	

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Table H1-1: Species of Possible Occurrence in RMA Offpost Area
(Page 2 of 6)

Family	Genus	Species	Common Name	Status[1]	Habitat[2]	Offpost
Reptile (continued)						
Trionychidae	*Trionyx*	*spiniferus*	Spiny soft-shelled turtle	b	RpL, OW-St/Ri, OW-L/R, Ms, In	
Viperidae	*Crotalus*	*viridis*	Prairie rattlesnake	B	SgP, TgP, cI	
Amphibians						
Ambystomatidae	*Ambystoma*	*tigrinum*	Tiger salamander	B	Ms, In, all other types	
Bufonidae	*Bufo*	*cognatus*	Great Plains toad	B	In, SgP, MXP, TgP, RpL, Ag, U	
Bufonidae	*Bufo*	*woodhouse*	Woodhouse's toad	B	SgP, SgSD, MXP, TgP, RpL, Ag	
Hylidae	*Pseudacris*	*triseriata*	Chorus frog	B	Ms, In, RpL, Ag	
Pelobatidae	*Scaphiopus*	*hombifrons*	Plains spadefoot	B	In, SgP, sd, TgP	
Ranidae	*Rana*	*catesbiana*	Bullfrog	B	Ms, In, RpL	
Birds						
Emberizidae	*Wilsonia*	*pusilla*	Wilson's warbler	M	Ag, U	
Emberizidae	*Xanthocephalus*	*xanthocephalus*	Yellow-headed blackbird	B	Ms, Ag, RpL, U	
Emberizidae	*Zonotrichla*	*leucophrys*	White-crowned sparrow	W	U, Ag	
Falconidae	*Falco*	*columbarius*	Merlin	W	GL, RpL, Ms, Ag, U	
Falconidae	*Falco*	*mexicanus*	Prairie falcon	R	GL, Ag, Cr, SgP	
Falconidae	*Falco*	*peregrinus*	Peregine falcon	M	GL, Ms	
Falconidae	*Falco*	*sparverius*	American kestrel	R	Ag, RpL, SgP, U, GL	
Fringillidae	*Carduelis*	*flammea*	Common redpoll	W	GL	
Fringillidae	*Carduelis*	*pinus*	Pine siskin	W	RpL, U	
Fringillidae	*Carduelis*	*psaltria*	Lesser goldfinch	B	RpL	
Fringillidae	*Carduelis*	*tristis*	American goldfinch	R	RpL, Ag, U	
Fringillidae	*Carpodacus*	*mexicanus*	House finch	R	U, RpL, Ag	
Fringillidae	*Leucosticte*	*arctoa*	Rosy finch	W	U, SgP	

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Table H1-1: Species of Possible Occurrence in RMA Offpost Area
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Family	Genus	Species	Common Name	Status[1]	Habitat[2]	Offpost
Birds (continued)						
Hirundinidae	*Hirundo*	*pyrrhonota*	Cliff swallow	B	Ag, Aq	
Hirundinidae	*Hirundo*	*rustica*	Barn swallow	B	Ag, Aq	
Hirundinidae	*Riparia*	*riparia*	Bank swallow	B	Ag, Aq	
Hirundinidae	*Stelgidopteryx*	*serripennis*	Northern rough-winged swallow	B	Ag, Aq	
Hirundinidae	*Tachycineta*	*bicolor*	Tree swallow	B	Aq	
Hirundinidae	*Tachycineta*	*thalassina*	Violet-green swallow	M	RpL, Aq	
Laniidae	*Lanius*	*excubitor*	Northern shrike	W	Ag, RpL, U, GL	
Laniidae	*Lanius*	*ludovicianus*	Loggerhead shrike	B	SgP, RpL, GL, Ag	
Laridae	*Chlidonias*	*niger*	Black tern	B	Ms, L	
Laridae	*Larus*	*argentatus*	Herring gull	W	L, U (dumps)	
Laridae	*Larus*	*californicus*	California gull	N	L, Ri, Cr, U (dumps)	
Laridae	*Larus*	*delawarensis*	Ring-billed gull	N	L, Ri, Cr, U (dumps)	
Laridae	*Larus*	*philadelphia*	Bonaparte's gull	M	L, Ms	
Laridae	*Larus*	*pipixcan*	Franklin's gull	M	Cr, Ag, GL	
Laridae	*Sterna*	*forsteri*	Forster's term	B	L, Ms	
Laridae	*Sterna*	*hirundo*	Common tern	B	L, Ms	
Mimidae	*Dumetella*	*carolinensis*	Gray catbird	B	RpL	
Mimidae	*Mimus*	*polyglottos*	Northern mockingbird	R	Ag, RpL	
Mimidae	*Toxostoma*	*rufum*	Brown thrasher	B	RpL, Ag, U	
Motacillidae	*Anthus*	*spinoletta*	Water pipit	M	Ag, SgP, Ag	
Muscicapidae	*Catharus*	*ustulatus*	Swainson's thrush	B	RpL, U, Ag	
Muscicapidae	*Myadestes*	*townsendii*	Townsend's solitaire	B	RpL, U, Ag	
Muscicapidae	*Sialia*	*currucoides*	Mountain bluebird			
Muscicapidae	*Sialia*	*mexicana*	Western bluebird	B	GL, U, Ag, RpL	
Muscicapidae	*Sialia*	*sialis*	Eastern bluebird	M	RpL, Ag	
Muscicapidae	*Turdus*	*migratorius*	American robin	R	Ag, U, RpL	x
Paridae	*Parus*	*atricapillus*	Black-capped chickadee	R	RpL, U, Ag	
Paridae	*Parus*	*gambeli*	Mountain chickadee	W	U, RpL	
Passeridae	*Passer*	*domesticus*	House sparrow	R,I	Ag, U	x

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Table H1-1: Species of Possible Occurrence in RMA Offpost Area
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Family	Genus	Species	Common Name	Status[1]	Habitat[2]	Offpost
Birds (continued)						
Pelecanidae	*Pelecanus*	*erythrorhynchose*	American white pelican	n	Ms, L	x
Phalaropodidae	*Phalaropus*	*lobatus*	Northern phalarope	M	W/OG, Ms, L, U	
Phalaropididae	*Phalaropus*	*tricolor*	Wilson's phalarope	B	W/OG, Ms, Cr	
Phasianidae	*Alectoris*	*chukar*	Chukar	N,I	Cr, Ag	
Phasianidae	*Callipepla*	*squamata*	Scaled quail	b	Ag, RpL	
Phasianidae	*Colinus*	*virginianus*	Northern bobwhite	R	Ag, RpL	
Phasianidae	*Phasianus*	*colchicus*	Ring-necked pheasant	R,I	Ag, Cr, RpL	x
Picidae	*Colaptes*	*auratus*	Northern flicker	R	U	
Picidae	*Melanerpes*	*erythocephalus*	Red-headed woodpecker	B	Ag, RpL, U	
Picidae	*Picoides*	*pubescens*	Downy woodpecker	R	U, RpL	
Picidae	*Picoides*	*villosus*	Hairy woodpecker	R	U	
Podicipedidae	*Aechmophorus*	*occidentalis*	Western grebe	B	L, Ri, Ms	
Podicipedidae	*Podiceps*	*auritus*	Horned grebe	M	Ms, L	
Podicipedidae	*Podiceps*	*nigricollis*	Eared grebe	b	Ms, L	
Podicipedidae	*Podilymbus*	*podiceps*	Pied-billed grebe	R	Ms, L	
Rallidae	*Fulica*	*americana*	American coot	R	Ms, L	
Rallidae	*Porzana*	*carolina*	Sora	B	Ms	
Rallidae	*Rallus*	*limicola*	Virginia rail	R	Ms	
Recurvirostridae	*Himantopus*	*mexicanus*	Black-necked stilt	M	L, Ms, W/OG	
Recurvirostridae	*Recurvirostra*	*americana*	American avocet	B	L, Ms, W/OG	
Scolopacidae	*Bartramia*	*longicauda*	Upland sandpiper	b	TgP, SgP, Cr	
Scolopacidae	*Calidris*	*alba*	Sanderling	M	W/OG, L, S	
Scolopacidae	*Calidris*	*himantopus*	Stilt sandpiper	M	L, Ms, W/OG	
Scolopacidae	*Calidris*	*mauri*	Western sandpiper	M	L, Ms, Cr, W/OG	
Scolopacidae	*Calidris*	*melanotos*	Pectoral sandpiper	M	L, W/OG	
Scolopacidae	*Calidris*	*minutilla*	Least sandpiper	M	L, Ms, W/OG	
Scolopacidae	*Calidris*	*pusilla*	Semipalmated sandpiper	M	L, Ms, W/OG	
Scolopacidae	*Catoptrophorus*	*semipalmatus*	Willet	M	Ms, L, W/OG	
Scolopacidae	*Gallinago*	*gallinago*	Common snipe	R	GL, Ms, W/OG, Ag	
Scolopacidae	*Limnodromus*	*scolopaceus*	Long-billed dowitcher	M	L, Ms, W/OG, Cr	

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Table H1-1: Species of Possible Occurrence in RMA Offpost Area
(Page 5 of 6)

Family	Genus	Species	Common Name	Status[1]	Habitat[2]	Offpost
Birds (continued)						
Scolopacidae	*Limosa*	*fedoa*	Marbled godwit	M	L, W/OG, Ms	
Scolopacidae	*Numenius*	*americanus*	Long-billed curlew	M	SgP, Cr.wheat, Ms, L, W/OG	
Scolopacidae	*Tringa*	*flavipes*	Lesser yellowlegs	M	L, Ri, Ms, W/OG	
Scolopacidae	*Tringa*	*melanoleuca*	Greater yellowlegs	M	Ms, L, Ri, W/OG	
Scolopacidae	*Tringa*	*solitaria*	Solitary sandpiper	M	Aq	
Sittidae	*Certhia*	*americana*	Brown creeper	R	U, RpL	
Solopacidae	*Actitis*	*macularia*	Spotted sandpiper	B	Aq	
Strigidae	*Asio*	*flammeus*	Short-eared owl	R	GL, MS, Ag	
Strigidae	*Asio*	*otus*	Long-eared owl	R	Rpl, Ag	
Strigidae	*Athene*	*cunicularia*	Burrowing owl	B	GL, rodent burrows	
Strigidae	*Bubo*	*virginianus*	Great horned owl	R	Ag, RpL	x
Strigidae	*Otus*	*asio*	Eastern screech owl	R	RpL, Ag, U	
Strigidae	*Otus*	*kennicotti*	Western screen owl	R	RpL, Ag, U	
Sturnidae	*Sturnus*	*vulgaris*	Starling	R,I	Ag, RpL, U	x
Thresliorniithidae	*Plegadis*	*chihi*	White-faced ibis	M	Ms, Aq, Ag	
Troglodytidae	*Cistothorus*	*palustris*	Long-bill marsh wren	R	Ms	
Tyrannidae	*Contopus*	*borealis*	Olive-sided flycatcher	M	Ag	
Tyrannidae	*Empidonax*	*traillii*	Willow flycatcher	M	RpL	
Tyrannidae	*Sayornis*	*saya*	Say's phoebe	B	Ag, GL, U, RpL	
Tyrannidae	*Tyrannus*	*tyrannus*	Eastern kingbird	B	Ag, RpL, U	
Tyrannidae	*Tyrannus*	*verticalis*	Western kingbird	B	Ag, RpL, U	
Tyrannidae	*Tyrannus*	*vociferans*	Cassin's kingbird	b	Ag, RpL	
Tytonidae	*Tyto*	*alba*	Common barn owl	R	Ag, RpL, U, buildings	
Vireonidae	*Vireo*	*gilvus*	Warbling vireo	B	U	
Vireonidae	*Vireo*	*olivaceus*	Red-eyed vireo	B	RpL, Ag, U	
Vireonidae	*Vireo*	*solitarius*	Solitary vireo	B	Ag, U	

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Table H1-1: Species of Possible Occurrence in RMA Offpost Area
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Source: ESE, 1989; Colorado Division of Wildlife, 1982

[1] B (definite breeder), b (likely breeder), E (endangered), G (game), I (introduced), M (migrant), n (nonbreeder), R (resident), W (winter visitor)

[2] GL (grassland); SgP (short-grass prairie); CG (cactus/grassland); Sg/SD (shortgrass/semidesert); MXP (mixed-grass prairie); TgP (tallgrass plains); Ms (marshes, bogs); W/OG (wet open ground); OW-St/Ri, Ri (open water, rivers/streams); OW-L/R, L (lakes, reservoirs); Ag (agricultural areas); Cr (croplands); U (urban); RpL (riparian lowland); In (intermittant ponds/lakes, streams); sd (sand dunes); cl (cliff/dirt bank/exposed bedrock)

RMA = Rocky Mountain Arsenal

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Appendix H2

BIOACCUMULATION FACTORS, BIOMAGNIFICATION FACTORS, AND PREDICTED TISSUE CONCENTRATIONS
- TERRESTRIAL FOOD WEB
- AQUATIC FOOD WEB

The bioaccumulation factors (BAFs) and bioconcentration factors (BCFs) listed in Tables H2-1 and H2-2, respectively, were derived from the open literature by the U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS), and Shell Oil Company (Shell). These organizations derived the factors based on scientific consensus of the available literature. The U.S. Department of the Army (Army) reviewed the factors submitted by the organizations and, after a revision of the insect aldrin/dieldrin BAF, accepted the factors as presented.

The acceptance of the BAF and BCF values for the Offpost OU does not imply that the Offpost procedures and values set precedent for use at other sites or locations.

Table H2-1: Bioaccumulation Factors, Biomagnification Factors, and Predicted Tissue Concentrations for the Terrestrial Food Web
(Page 1 of 2)

Species	Aldrin	DDE	DDT	Dieldrin	Endrin
Bioaccumulation Factors (BAFs)					
Small bird	2	2	2	2	8
Small mammal	3	6	6	3	8
Medium mammal	3	6	6	3	8
Worm	6	3	3	6	29
Insect	2.4	32	32	2.4	29
Plant	0.4	1.4	1.4	0.4	0.06
Great horned owl	19	31	31	19	8
American kestrel	12	31	31	12	8
Bald eagle	19	31	31	19	8
BMFs for each pathway and analyte:					
s>w>sm>o,e	3.42E+02	5.58E+02	5.58E+02	3.42E+02	1.86E+03
s>w>sm>k	2.16E+02	5.58E+02	5.58E+02	2.16E+02	1.86E+03
s>p>i>sm>o,e	5.47E+01	8.33E+03	8.33E+03	5.47E+01	1.11E+02
s>p>i>sm>k	3.46E+01	8.33E+03	8.33E+03	3.46E+01	1.11E+02
s>p>i<ph>o,e	3.65E+01	2.78E+03	2.78E+03	3.65E+01	1.11E+02
s>p>i>ph>k	2.30E+01	2.78E+03	2.78E+03	2.30E+01	1.11E+02
s>p>i>k	1.15E+01	1.39E+03	1.39E+03	1.15E+01	1.39E+01
s>p>pd>o,e	2.28E+01	2.60E+02	2.60E+02	2.28E+01	3.84E+00
s>p>sm>o,e	2.28E+01	2.60E+02	2.60E+02	2.28E+01	3.84E+00
s>p>sm>k	1.44E+01	2.60E+02	2.60E+02	1.44E+01	3.84E+00
Total BMF for each Target Organism for Food Chains and Soil:					
American kestrel	1.30E+01	1.61E+03	1.61E+03	1.30E+01	2.36E+01
Great horned owl	3.78E+01	2.92E+03	2.92E+03	3.78E+01	7.87E+01
Bald eagle	1.91E+01	2.68E+02	2.68E+02	1.91E+01	5.17E+00
Prairie dog	1.30E+00	7.87E+00	7.87E+00	1.30E+00	1.06E+00

	%Kestrel	%Owl	Eagle
		1.98E-02	1.49E-04
	2.76E-03		
		3.19E-01	2.40E-03
	4.46E-02		
		3.96E-02	1.37E-02
	1.22E-02		
	8.60E-01		
		2.20E-01	8.05E-01
		3.13E-01	2.35E-03
	4.37E-02		

Table H2-1: Bioaccumulation Factors, Biomagnification Factors, and Predicted Tissue Concentrations for the Terrestrial Food Web
(Page 2 of 2)

Species	Aldrin	DDE	DDT	Dieldrin	Endrin
Deer mouse	2.53E+00	1.31E+02	1.31E+02	2.53E+00	1.39E+01
Pheasant	1.64E+00	6.51E+01	6.51E+01	1.64E+00	1.06E+01
Insect	9.60E-01	4.48E+01	4.48E+01	9.60E-01	1.74E+00
Worm	6.00E+00	3.00E+00	3.00E+00	6.00E+00	2.90E+01
Plant	4.00E-01	1.40E+00	1.40E+00	4.00E-01	6.00E-02
Predicted tissue concentrations (mg/kg) based on above BMFs and Geometric Means of zone 3 soil data.					
American kestrel	0.01	1.33	3.60	0.11	0.04
Great horned owl	0.01	0.72	1.66	0.10	0.04
Bald eagle	0.00	0.00	0.00	0.00	0.00
Prairie dog	0.01	0.03	0.07	0.06	0.01
Deer mouse	0.01	0.54	1.24	0.11	0.12
Pheasant	0.01	0.27	0.62	0.07	0.09
Insect	0.00	0.18	0.43	0.04	0.01
Worm	0.03	0.01	0.03	0.26	0.25
Plant	0.00	0.01	0.01	0.02	0.00

e = bald eagle
w = earthworm
i = grasshopper (insect)
k = American kestrel
sm = deer mouse (small mammal)
o = great horned owl
pd = prairie dog
ph = pheasant
p = plant
s = soil

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Table H2-2: Bioconcentration Factors, Biomagnification Factors, and Predicted Tissue Concentration for the Aquatic Food Web
(Page 1 of 2)

Species	Aldrin	Arsenic	DDE	DDT	Dieldrin	Endrin
Bioconcentration Factors						
Small fish	16716	15	70094	70094	16716	4180
Invertebrates	8787	15	9029	9029	8787	4180
Algae	133	422	1811	1811	133	96
k2[1]						
Small fish	0.093	0.67	0.007	0.007	0.093	0.15
Mallard duck	0.006	0.018	0.019	0.038	0.013	0.063
Great blue heron	0.012	0.27	0.004	0.004	0.012	0.06
Bald eagle	0.012	0.27	0.004	0.004	0.012	0.06
Alpha[1]						
Small fish	0.9	0.8	0.787	0.787	0.9	0.85
Mallard duck	0.9	0.8	0.9	0.9	0.9	0.9
Great blue heron	0.9	0.8	0.9	0.9	0.9	0.9
Bald eagle	0.9	0.8	0.9	0.9	0.9	0.9
Feeding Rate		Fraction of prey in diet				
Small fish	0.015	Algae > Small fish			0.02	
		Sediment > Small fish			0.15	
Great blue heron	0.089	Small fish > Heron			0.37	
		Invert > Heron			0.16	
		Sediment > Heron			0.04	
Mallard duck	0.076	Algae > Mallard			0.84	
		Invert > Mallard			0.1	
		Sediment > Mallard			0.04	
Bald eagle	0.089	Mallard > Eagle			0.029	
		Sediment > Eagle			0.03	
Food Term						
Small fish	2.90E-03	3.58E-04	3.37E-02	3.37E-02	2.90E-03	1.70E-03
	2.18E-02	2.69E-03	2.53E-01	2.53E-01	2.18E-02	1.28E-02
Great blue heron	2.47E+00	9.76E-02	7.41E+00	7.41E+00	2.47E+00	4.94E-01
	1.07E+00	4.22E-02	3.20E+00	3.20E+00	1.07E+00	2.14E-01
	2.67E-01	1.05E-02	8.01E-01	8.01E-01	2.67E-01	5.34E-02
Mallard duck	9.58E+00	2.84E+00	3.02E+00	1.51E+00	4.42E+00	9.12E-01
	1.14E+00	3.38E-01	3.60E-01	1.80E-01	5.26E-01	1.09E-01
	2.28E-01	9.01E-03	6.84E-01	6.84E-01	2.28E-01	4.56E-02
Bald eagle	1.94E-01	7.65E-03	5.81E-01	5.81E-01	1.94E-01	3.87E-02
	2.00E-01	7.91E-03	6.01E-01	6.01E-01	2.00E-01	4.01E-02

Table H2-2: Bioconcentration Factors, Biomagnification Factors, and Predicted Tissue Concentration for the Aquatic Food Web
(Page 2 of 2)

Species	Aldrin	Arsenic	DDE	DDT	Dieldrin	Endrin
Pathway Specific BAFs						
sw>a>sf>gbh	4.13E+04	1.48E+00	5.20E+05	5.20E+05	4.13E+04	2.06E+03
sw>in>gbh	9.38E+03	6.33E-01	2.89E+04	2.89E+04	9.38E+03	8.93E+02
sw>a>md	1.27E+03	1.20E+03	5.48E+03	2.74E+03	5.88E+02	8.76E+01
sw>in>md	1.00E+04	5.07E+00	3.25E+03	1.63E+03	4.62E+03	4.54E+02
sw>a>md>be	2.47E+02	9.16E+00	3.18E+03	1.59E+03	1.14E+02	3.39E+00
sw>in>md>be	1.94E+03	3.87E-02	1.89E+03	9.44E+02	8.95E+02	1.76E+01
s>md	2.28E-01	9.01E-03	6.84E-01	6.84E-01	2.28E-01	4.56E-02
s>gbh	2.67E-01	1.05E-02	8.01E-01	8.01E-01	2.67E-01	5.34E-02
s>be	2.00E-01	7.91E-03	6.01E-01	6.01E-01	2.00E-01	4.01E-02
s>sf	2.18E-02	2.69E-03	2.53E-01	2.53E-01	2.18E-02	1.28E-02
Total BMF for Each Indicator Species						
Bald eagle	2.19E+03	9.20E+00	5.07E+03	2.53E+03	1.01E+03	2.10E+01
Great blue heron	5.07E+04	2.11E+00	5.49E+05	5.49E+05	5.07E+04	2.96E+03
Small fish	1.67E+04	1.52E+01	7.02E+04	7.02E+04	1.67E+04	4.18E+03
Mallard duck	1.13E+04	1.20E+03	8.73E+03	4.36E+03	5.21E+03	5.41E+02
Predicted Tissue Concentrations (mg/kg) in Aquatic Species From First Creek Water						
Bald eagle	0.0	0.0	0.0	0.0	0.0	0.0
Great blue heron	0.0	0.0	1.1	1.1	0.2	0.0
Small fish	0.0	0.1	3.5	3.5	2.0	0.0
Mallard duck	0.0	4.2	0.4	0.2	0.6	0.0
Algae	0.0	1.5	0.1	0.1	0.0	0.0
Invertebrates	0.0	0.1	0.5	0.5	1.1	0.0
Predicted Tissue Concentrations (mg/kg) in Aquatic Species From First Creek Sediment						
Bald eagle	0.000	0.000	0.000	0.000	0.000	0.000
Great blue heron	0.000	0.000	0.000	0.000	0.000	0.000
Small fish	0.000	0.000	0.001	0.001	0.000	0.000
Mallard duck	0.004	0.000	0.002	0.003	0.004	0.000

[1] ERC Model Post Calibration Input Parameters, Ebasco (1992). See Appendix H.

sw = surface water
in = invertebrate
a = algae
md = mallard duck
sf = small fish
be = bald eagle
gbh = great blue heron
s = sediment

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Appendix H3

EXPOSURE POINT CONCENTRATIONS OF CHEMICALS IN SURFACE WATER AND PREDICTED CHEMICAL INTAKE FOR AVIAN SPECIES

Table H3-1: Exposure Point Concentrations of Chemicals in Surface Water and Predicted Chemical Intake for Avian Species[1]

Chemical	Exposure Point Concentrations (µg/l)	Avian Intake (µg/kg-bw/day)
Arsenic	3.5	0.87
Chlordane	0.18	0.045
DDE	0.05	0.01
DDT	0.05	0.01
DIMP	11.9	3.0
Dieldrin	0.12	0.03
Fluoride	1706	426
Sulfate	282,840	70,710

[1] Intake is calculated on the basis of consumption of surface water. Daily water ingestion rates for birds tend to be higher than those for mammals. In addition, many of the small mammals in the offpost area do not ingest surface water. Thus, intakes developed for birds should be sufficiently protective of mammals as well.

µg/l = micrograms per liter
µg/kg-bw/day = micrograms per kilogram body weight per day

Appendix H4

HAZARD QUOTIENT SUMMARY TABLES FOR CATTLE

Table H4-1: Hazard Quotient Tables - Soil and Irrigation Water Exposure to Cattle
(Page 1 of 5)

	Tissue Concentration (CF_m) (mg/kg-bw)	Alpha	Dose (mg/kg-bw/day)	TRV (mg/kg-bw/day)	Hazard Quotient
Aldrin/Dieldrin Area					
1A	6.56E-04	7.72E+00	8.49E-05	2.5E+00	<1
1B	8.50E-04	7.72E+00	1.10E-04	2.5E+00	<1
1C	6.56E-04	7.72E+00	8.49E-05	2.5E+00	<1
2	9.08E-04	7.72E+00	1.17E-04	2.5E+00	<1
6	6.59E-04	7.72E+00	8.53E-05	2.5E+00	<1
Arsenic Area					
1A	1.43E-04	1.47E+00	9.71E-05	6.5E-03	<1
1B	8.93E-04	1.47E+00	6.07E-04	6.5E-03	<1
1C	1.43E-04	1.47E+00	9.71E-05	6.5E-03	<1
2	6.77E-04	1.47E+00	4.59E-04	6.5E-03	<1
6	0.00E+00	1.47E+00	0.00E+00	6.5E-03	<1
Atrazine Area					
1A	5.32E-05	2.16E-01	2.46E-04	5.0E+00	<1
1B	3.33E-04	2.16E-01	1.53E-03	5.0E+00	<1
1C	5.32E-05	2.16E-01	2.46E-04	5.0E+00	<1
2	6.15E-04	2.16E-01	2.85E-03	5.0E+00	<1
6	8.14E-05	2.16E-01	3.76E-04	5.0E+00	<1
Benzene Area					
1A	3.94E-06	1.13E-01	3.48E-05	3.1E-02	<1
1B	2.46E-05	1.13E-01	2.18E-04	3.1E-02	<1
1C	3.94E-06	1.13E-01	3.48E-05	3.1E-02	<1
2	2.57E-05	1.13E-01	2.27E-04	3.1E-02	<1
6	0.00E+00	1.13E-01	0.00E+00	3.1E-02	<1
CCL4 Area					
1A	0.00E+00	2.30E-01	0.00E+00	5.0E-01	0
1B	0.00E+00	2.30E-01	0.00E+00	5.0E-01	0
1C	0.00E+00	2.30E-01	0.00E+00	5.0E-01	0
2	9.76E-05	2.30E-01	4.25E-04	5.0E-01	<1
6	0.00E+00	2.30E-01	0.00E+00	5.0E-01	0
Chlordane Area					
1A	0.00E+00	3.91E-01	0.00E+00	5.0E+00	<1
1B	0.00E+00	3.91E-01	0.00E+00	5.0E+00	<1
1C	0.00E+00	3.91E-01	0.00E+00	5.0E+00	<1
2	1.43E-05	3.91E-01	3.65E-05	5.0E+00	<1
6	0.00E+00	3.91E-01	0.00E+00	5.0E+00	0
CLBenzene Area					
1A	2.21E-05	2.37E-01	9.37E-05	3.4E+00	<1
1B	1.38E-04	2.37E-01	5.85E-04	3.4E+00	<1
1C	2.22E-05	2.37E-01	9.37E-05	3.4E+00	<1

Table H4-1: Hazard Quotient Summary Tables - Soil and Irrigation Water Exposure to Cattle
(Page 2 of 5)

	Tissue Concentration (CF_m) (mg/kg-bw)	Alpha	Dose (mg/kg-bw/day)	TRV (mg/kg-bw/day)	Hazard Quotient
CLBenzene Area (continued)					
2	2.42E-04	2.37E-01	1.02E-03	3.4E+00	<1
6	2.76E-05	2.37E-01	1.17E-04	3.4E+00	<1
CHCl3 Area					
1A	9.51E-07	2.71E-02	3.51E-05	1.9E+00	<1
1B	5.94E-06	2.71E-02	2.19E-04	1.9E+00	<1
1C	9.51E-07	2.71E-02	3.51E-05	1.9E+00	<1
2	5.87E-04	2.71E-02	2.17E-02	1.9E+00	<1
6	4.63E-06	2.71E-02	1.71E-04	1.9E+00	<1
CPMS Area					
1A	0.00E+00	2.37E-01	0.00E+00	4.4E-02	0
1B	0.00E+00	2.37E-01	0.00E+00	4.4E-02	0
1C	0.00E+00	2.37E-01	0.00E+00	4.4E-02	0
2	0.00E+00	2.37E-01	0.00E+00	4.4E-02	0
6	0.00E+00	2.37E-01	0.00E+00	4.4E-02	0
CMPSO Area					
1A	0.00E+00	2.55E-02	0.00E+00	4.4E-02	0
1B	0.00E+00	2.55E-02	0.00E+00	4.4E-02	0
1C	0.00E+00	2.55E-02	0.00E+00	4.4E-02	0
2	9.31E-05	2.55E-02	3.64E-03	4.4E-02	<1
6	0.00E+00	2.55E-02	0.00E+00	4.4E-02	0
$CPMSO_2$ Area					
1A	0.00E+00	2.62E-02	0.00E+00	5.1E-02	0
1B	0.00E+00	2.62E-02	0.00E+00	5.1E-02	0
1C	0.00E+00	2.62E-02	0.00E+00	5.1E-02	0
2	2.80E-05	2.62E-02	1.07E-03	5.1E-02	<1
6	0.00E+00	2.62E-02	0.00E+00	5.1E-02	0
DCPD Area					
1A	0.00E+00	1.85E-01	0.00E+00	6.0E+00	0
1B	0.00E+00	1.85E-01	0.00E+00	6.0E+00	0
1C	0.00E+00	1.85E-01	0.00E+00	6.0E+00	0
2	5.54E-04	1.85E-01	2.98E-03	6.0E+00	<1
6	0.00E+00	1.85E-01	0.00E+00	6.0E+00	0
DDE/DDT Area					
1A	9.32E-04	6.18E+00	1.51E-04	3.8E-02	<1
1B	1.05E-03	6.18E+00	1.71E-04	3.8E-02	<1
1C	9.32E-04	6.18E+00	1.51E-04	3.8E-02	<1

Table H4-1: Hazard Quotient Summary Tables - Soil and Irrigation Water Exposure to Cattle
(Page 3 of 5)

	Tissue Concentration (CF_m) (mg/kg-bw)	Alpha	Dose (mg/kg-bw/day)	TRV (mg/kg-bw/day)	Hazard Quotient
DDE/DDT Area (continued)					
2	1.05E-03	6.18E+00	1.70E-04	3.8E-02	<1
6	9.08E-04	6.18E+00	1.47E-04	3.8E-02	<1
DBCP Area					
1A	0.00E+00	3.30E-02	0.00E+00	3.1E-02	0
1B	0.00E+00	3.30E-02	0.00E+00	3.1E-02	0
1C	0.00E+00	3.30E-02	0.00E+00	3.1E-02	0
2	3.92E-06	3.30E-02	1.19E-04	3.1E-02	<1
6	0.00E+00	3.30E-02	0.00E+00	3.1E-02	0
DCLB Area					
1A	7.66E-04	5.66E-01	0.00E+00	3.1E+00	0
1B	4.79E-03	5.66E-01	0.00E+00	3.1E+00	0
1C	7.66E-04	5.66E-01	0.00E+00	3.1E+00	0
2	5.21E-03	5.66E-01	5.15E-03	3.1E+00	<1
6	7.89E-04	5.66E-01	0.00E+00	3.1E+00	0
12DCLE Area					
1A	0.00E+00	6.38E-02	0.00E+00	4.2E-01	0
1B	0.00E+00	6.38E-02	0.00E+00	4.2E-01	0
1C	0.00E+00	6.38E-02	0.00E+00	4.2E-01	0
2	1.36E-05	6.38E-02	2.13E-04	4.2E-01	<1
6	0.00E+00	6.38E-02	0.00E+00	4.2E-01	0
DIMP Area					
1A	4.62E-05	3.09E-03	1.49E-02	8.3E+00	<1
1B	1.07E-04	3.09E-03	3.49E-02	8.3E+00	<1
1C	1.72E-05	3.09E-03	5.58E-03	8.3E+00	<1
2	1.21E-03	3.09E-03	3.39E-01	8.3E+00	<1
6	1.27E-06	3.09E-03	4.12E-04	8.3E+00	<1
Dithiane Area					
1A	0.00E+00	1.63E-02	0.00E+00	3.3E-01	0
1B	0.00E+00	1.63E-02	0.00E+00	3.3E-01	0
1C	0.00E+00	1.63E-02	0.00E+00	3.3E-01	0
2	0.00E+00	1.63E-02	0.00E+00	3.3E-01	0
6	0.00E+00	1.63E-02	0.00E+00	3.3E-01	0
EtBenzene Area					
1A	0.00E+00	3.71E-01	0.00E+00	6.1E+00	0
1B	0.00E+00	3.71E-01	0.00E+00	6.1E+00	0
1C	0.00E+00	3.71E-01	0.00E+00	6.1E+00	0

Table H4-1: Hazard Quotient Summary Tables - Soil and Irrigation Water Exposure to Cattle
(Page 4 of 5)

	Tissue Concentration (CF_m) (mg/kg-bw)	Alpha	Dose (mg/kg-bw/day)	TRV (mg/kg-bw/day)	Hazard Quotient
EtBenzene Area (continued)					
2	0.00E+00	3.71E-01	0.00E+00	6.1E+00	0
6	0.00E+00	3.71E-01	0.00E+00	6.1E+00	0
Endrin/Isodrin Area					
1A	4.27E-05	1.03E+00	4.15E-05	1.6E-04	<1
1B	9.22E-05	1.03E+00	8.95E-05	1.6E-04	<1
1C	4.27E-05	1.03E+00	4.15E-05	1.6E-04	<1
2	1.05E-04	1.03E+00	1.01E-04	1.6E-04	<1
6	3.96E-05	1.03E+00	3.84E-05	1.6E-04	<1
Malathion Area					
1A	0.00E+00	2.27E-01	0.00E+00	5.0E+00	0
1B	0.00E+00	2.27E-01	0.00E+00	5.0E+00	0
1C	0.00E+00	2.27E-01	0.00E+00	5.0E+00	0
2	3.26E-05	2.27E-01	1.44E-04	5.0E+00	<1
6	0.00E+00	2.27E-01	0.00E+00	5.0E+00	0
MN Area					
1A	0.00E+00	2.06E-01	0.00E+00	5.0E+00	0
1B	0.00E+00	2.06E-01	0.00E+00	5.0E+00	0
1C	0.00E+00	2.06E-01	0.00E+00	5.0E+00	0
2	1.83E-01	2.06E-01	8.87E-01	5.0E+00	<1
6	0.00E+00	2.06E-01	0.00E+00	5.0E+00	0
Oxathiane Area					
1A	0.00E+00	6.69E-03	0.00E+00	8.3E-01	0
1B	0.00E+00	6.69E-03	0.00E+00	8.3E-01	0
1C	0.00E+00	6.69E-03	0.00E+00	8.3E-01	0
2	0.00E+00	6.69E-03	0.00E+00	8.3E-01	0
6	0.00E+00	6.69E-03	0.00E+00	8.3E-01	0
TCLEE Area					
1A	1.31E-05	2.16E-01	6.05E-05	5.1E+00	<1
1B	8.18E-05	2.16E-01	3.78E-04	5.1E+00	<1
1C	1.31E-05	2.16E-01	6.05E-05	5.1E+00	<1
2	1.19E-03	2.16E-01	5.49E-03	5.1E+00	<1
6	3.14E-05	2.16E-01	1.45E-04	5.1E+00	<1
Toluene Area					
1A	0.00E+00	2.06E-01	0.00E+00	2.6E+01	0
1B	0.00E+00	2.06E-01	0.00E+00	2.6E+01	0
1C	0.00E+00	2.06E-01	0.00E+00	2.6E+01	0

Table H4-1: Hazard Quotient Summary Tables - Soil and Irrigation Water Exposure to Cattle
(Page 5 of 5)

	Tissue Concentration (CF_m) (mg/kg-bw)	Alpha	Dose (mg/kg-bw/day)	TRV (mg/kg-bw/day)	Hazard Quotient
Toluene Area (continued)					
2	0.00E+00	2.06E-01	0.00E+00	2.6E+01	0
6	0.00E+00	2.06E-01	0.00E+00	2.6E+01	0
TRCLE Area					
1A	0.00E+00	2.47E-01	0.00E+00	3.6E+00	0
1B	0.00E+00	2.47E-01	0.00E+00	3.6E+00	0
1C	0.00E+00	2.47E-01	0.00E+00	3.6E+00	0
2	9.40E-05	2.47E-01	3.80E-04	3.6E+00	<1
6	9.43E-05	2.47E-01	3.82E-04	3.6E+00	<1
Xylene Area					
1A	3.47E-05	3.70E-01	9.37E-05	1.6E+01	<1
1B	2.17E-04	3.70E-01	5.85E-04	1.6E+01	<1
1C	3.47E-05	3.70E-01	9.37E-05	1.6E+01	<1
2	0.00E+00	3.70E-01	0.00E+00	1.6E+01	0
6	0.00E+00	3.70E-01	0.00E+00	1.6E+01	0
CL6CP Area					
1A	4.00E-06	6.38E-01	6.27E-06	5.0E+00	<1
1B	2.50E-05	6.38E-01	3.92E-05	5.0E+00	<1
1C	4.00E-06	6.38E-01	6.27E-06	5.0E+00	<1
2	2.83E-05	6.38E-01	4.43E-05	5.0E+00	<1
6	0.00E+00	6.38E-01	0.00E+00	5.0E+00	0

mg/kg-bw = milligrams per kilogram-body weight
mg/kg-bw/day = milligrams per kilogram-body weight per day

Appendix H5

MAXIMUM ALLOWABLE TISSUE CONCENTRATION VALUES

DERIVATION OF MAXIMUM ALLOWABLE TISSUE CONCENTRATIONS

The U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS), and Shell Oil Company (Shell) invoked dispute concerning the maximum allowable tissue concentration (MATC) values used in the ecological assessment of the draft final of the Offpost Endangerment Assessment. As part of the dispute resolution process, EPA, USFWS, Shell, and the U.S. Department of the Army (Army) met and agreed on the MATC values listed in Table H5-1. The MATC values were derived on the basis of scientific consensus after review of pertinent scientific literature and consultation with recognized scientists.

The aldrin/dieldrin MATC values were based on data presented in Wiemeyer and others (1986) and consultation with Dr. Stanley Wiemeyer during the resolution meetings. The endrin MATC values were derived by consensus following a discussion of data presented in Spann and others (1986) and Fleming and others (1982). Several literature sources were consulted for the DDT/DDE MATC values. The bald eagle and great blue heron DDT/DDE MATCs were based on Blus and others (1972) and Wiemeyer and others (1986). The great horned owl and American kestrel MATCs were based on Wiemeyer and others (1970 and 1986). The water bird and small bird MATC values were derived from data presented by Longcore and Stendell (1977).

The acceptance of the MATC values for the Offpost OU does not imply that the Offpost procedures and values set precedent for use at other sites or locations.

Maximum Allowable Tissue Concentration References

Blus, L.J., Gish, C.D., Belisle, A.A., and Prouty, R.M., 1972, Logarithmic relationship of DDE residues to eggshell thinning. Nature, 235:376-377.

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Spann, J.W., Heinz, G.H., and Hulse, C.S., 1986, Reproduction and health of mallards fed endrin. Environmental Toxicology and Chemistry, 5:755-759.

Wiemeyer, S.N. and Porter, R.D., 1970, DDE thins eggshells of captive American kestrels. Nature, 227:737-738.

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Table H5-1: Maximum Allowable Tissue Concentration (MATC) Values (μg/g) for the Offpost EA Ecological Assessment

Receptor	Aldrin	Dieldrin	Endrin	DDT	DDE
Bald eagle	1.1	1.1	0.01	2.0	2.0
Great blue heron	1.1	1.1	0.1	2.0	2.0
Great horned owl	1.1	1.1	0.01	2.6	2.6
American kestrel	1.1	1.1	0.01	5.1	5.1
Water birds[1]	1.1	1.1	1.0	1.7	1.7
Small birds[2]	1.1	1.1	0.045	1.7	1.7

[1] Represents mallard ducks.
[2] Represents pheasants.

DDE = 2,2-Bis(p-chlorophenyl)-1,1-dichloroethene
DDT = 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane
μg/g = micrograms per gram

Appendix H6

SPATIAL WEIGHING ADJUSTMENT FACTORS

SPATIAL WEIGHTING ADJUSTMENT

The U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS), Shell Oil Company (Shell), and the U.S. Department of the Army (Army) agreed to incorporate a spatial weighting factor to adjust the predicted tissue concentrations and hazard indices for the bald eagle, great blue heron, great horned owl, and American kestrel. The spatial weighting adjustment factor for each animal was based on the home range information for that animal in a closely related species. The spatial adjustment was necessary to more accurately reflect the fraction of dietary intake potentially originating within the area of the Offpost Operable Unit (OU).

Shell provided a listing of home range data for the species, and the Army developed the spatial adjustment factor based on this information relative to the area of zones 3 and 4 of the Offpost OU. The home range values accepted by all organizations are listed in Table H6-1. The spatial adjustment factor was the quotient of the area of the affected habitat in the Offpost OU and the home range for a particular species. The spatial adjustment factor methodology, agreed to by all organizations, is applied as follows:

1. Exposure point concentration x total biomagnification factor (BMF) x $\frac{A_o}{A_L}$ = predicted tissue concentration

2. $\frac{\text{Daily intake}}{\text{Toxicity Reference Value}} \times \frac{A_o}{A_L}$ = hazard index

where:

A_o = affected habitat in the Offpost OU

Zone 3 = 88 acres for receptors feeding in the terrestrial food web

Zone 3 and 4 wetlands = 70 acres (based on an estimate of First Creek and First Creek Impoundment shoreline of approximately 8000 linear feet and a shoreline width of 300 feet [150 feet per side]) for receptors feeding in the aquatic food web

A_L = literature value (acres) for home range for the specific receptor

The acceptance of the home range values for the Offpost OU does not imply that the Offpost procedures and values set precedent for use at other sites or locations.

Avian Home Range References

Balbooyen, T.G., 1976, Behavior and ecology of the American kestrel: University of California Publications in Zoology, 103:1-83.

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Reinecke, O., 1910, The great blue heron: Oologist, 27:15-17.

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Table H6-1: Home Range and Spatial Weighting Adjustment Factors for Selected Avian Receptors

Species	Home Range	Spatial Adjustment Factor
Great blue heron	80 km or 1803a[a]	0.04
American kestrel	179 ha or 442a[b]	0.2
Great horned owl	2.5 mi^2 or 1600a[c]	0.06
Bald eagle	40,000 ha or 98,840a[d]	0.0009 (terrestrial) 0.0007 (aquatic)

[a] Source: Court (1908), Reinecke (1910), Miller (1943), Pratt (1980)
[b] Source: Craighead (1956), Balbooyen (1976), Hardin and Evans (1977), Cruz (1976)
[c] Source: Zeiner and others (1990)
[d] Source: Broley (1947), Welty (1982), USFWS (1983), Fenzel (1983)

km = kilometer
ha = hectare
a = acre
mi^2 = square mile

Appendix H7

ONPOST HHRC SOFTWARE BLUE VERSION 1.0
PREPARED FOR THE
PROGRAM MANAGER ROCKY MOUNTAIN ARSENAL
EBASCO SERVICES, INC.
MARCH 1992

The values presented in Appendix A7 were obtained from the Onpost Human Health Risk Characterization (HHRC) Software, Blue Version 1.0, prepared for the Program Manager Rocky Mountain Arsenal by Ebasco Services, Inc. These data were released for use in the Offpost OU Ecological Assessment in March 1992. Because the Onpost OU Ecological Risk Characterization has not been finalized, the use of these values does not set precedent for the Onpost OU or any other site or location.

Version: 0.296 | October 23, 1991 | Data Source: BCHEMVAR.XLS | Current as of February 19, 1992

AssimilationRate (Alpha)

Biota	Chemical	Distribution	P1	P2	P3
Eagle	Aldrin	Fixed	0.9	0	0
Eagle	DDE	Fixed	0.9	0	0
Eagle	DDT	Fixed	0.9	0	0
Eagle	Dieldrin	Fixed	0.9	0	0
Eagle	Endrin	Fixed	0.9	0	0
Eagle	Arsenic	Fixed	0.8	0	0
Eagle	Mercury	Fixed	0.9	0	0
WatrBird	Aldrin	Fixed	0.9	0	0
WatrBird	DDE	Fixed	0.9	0	0
WatrBird	DDT	Fixed	0.9	0	0
WatrBird	Dieldrin	Fixed	0.9	0	0
WatrBird	Endrin	Fixed	0.9	0	0
WatrBird	Arsenic	Fixed	0.8	0	0
WatrBird	Mercury	Fixed	0.9	0	0
LgFish	Aldrin	Fixed	0.9	0	0
LgFish	DDE	Fixed	0.787	0	0
LgFish	DDT	Fixed	0.787	0	0
LgFish	Dieldrin	Fixed	0.9	0	0
LgFish	Endrin	Fixed	0.85	0	0
LgFish	Arsenic	Fixed	0.8	0	0
LgFish	Mercury	Fixed	0.492	0	0
SmFish	Aldrin	Fixed	0.9	0	0
SmFish	DDE	Fixed	0.787	0	0
SmFish	DDT	Fixed	0.787	0	0
SmFish	Dieldrin	Fixed	0.9	0	0
SmFish	Endrin	Fixed	0.85	0	0
SmFish	Arsenic	Fixed	0.8	0	0
SmFish	Mercury	Fixed	0.834	0	0
Heron	Aldrin	Fixed	0.9	0	0
Heron	DDE	Fixed	0.9	0	0
Heron	DDT	Fixed	0.9	0	0
Heron	Dieldrin	Fixed	0.9	0	0
Heron	Endrin	Fixed	0.9	0	0
Heron	Arsenic	Fixed	0.8	0	0
Heron	Mercury	Fixed	0.9	0	0
Amph	Aldrin	Fixed	0.9	0	0
Amph	DDE	Fixed	0.9	0	0
Amph	DDT	Fixed	0.9	0	0
Amph	Dieldrin	Fixed	0.9	0	0
Amph	Endrin	Fixed	0.9	0	0
Amph	Arsenic	Fixed	0.8	0	0
Amph	Mercury	Fixed	0.9	0	0
ShoreBird	Aldrin	Fixed	0.9	0	0
ShoreBird	DDE	Fixed	0.9	0	0
ShoreBird	DDT	Fixed	0.9	0	0
ShoreBird	Dieldrin	Fixed	0.9	0	0
ShoreBird	Endrin	Fixed	0.9	0	0
ShoreBird	Arsenic	Fixed	0.8	0	0
ShoreBird	Mercury	Fixed	0.9	0	0

Version: 0.296 : October 23, 1991		
	Data Source: BNODE.XLS	
Fractions	Current as of February 19, 1992	
Parent	**Current**	**Fraction**
Null	Eagle	0
Eagle	LgFish	0.002
LgFish	SmFish	0.85
SmFish	AquInvert	0.8
SmFish	Plankton	0.03
SmFish	PltAqu	0.02
LgFish	AquInvert	0.14
LgFish	Plankton	0.01
Eagle	WatrBird	0.029
WatrBird	AquInvert	0.1
WatrBird	PltAqu	0.84
WatrBird	WaterIng	0.02
Eagle	MdMamml	0.915
MdMamml	Insct	0.04
MdMamml	PltTer	0.88
MdMamml	Soil	0.08
Eagle	SmBird	0.019
SmBird	Worm	0.05
Worm	PltTer	0.01
Worm	Soil	0.99
SmBird	Insct	0.72
SmBird	PltTer	0.17
SmBird	Soil	0.06
Eagle	Hrp	0
Hrp	SmMamml	0.38
SmMamml	Worm	0.03
SmMamml	Insct	0.48
SmMamml	PltTer	0.47
SmMamml	Soil	0.02
Hrp	SmBird	0.07
Hrp	Worm	0.02
Hrp	Insct	0.48
Hrp	PltTer	0.03
Hrp	Soil	0.02
Eagle	Soil	0.03
Insct	PltTer	1
AquInvert	Water	1
Plankton	Water	1
PltAqu	Water	1
PltTer	Soil	1
Eagle	SmMamml	0.005
WatrBird	Sediment	0.04
SmFish	Sediment	0.15
Null	Heron	0
Heron	Hrp	0.02
Heron	WaterIng	0.08
Heron	Soil	0.04
Heron	SmMamml	0.04
Heron	AquInvert	0.16
Heron	LgFish	0.24

Version: 0.296	October 23, 1991	
	Data Source: BNODE.XLS	
Fractions	Current as of February 19, 1992	
Parent	**Current**	**Fraction**
Heron	PltAqu	0.02
Heron	SmFish	0.37
Heron	Amph	0.03
Amph	AquInvert	1
Null	Owl	0
Owl	Hrp	0
Owl	Insct	0
Owl	MdMamml	0.25
Owl	SmBird	0.055
Owl	Soil	0.03
Owl	SmMamml	0.665
Null	Kestrel	0
Kestrel	SmBird	0.017
Kestrel	Insct	0.86
Kestrel	SmMamml	0.093
Kestrel	Soil	0.03
Null	ShoreBird	0
ShoreBird	AquInvert	0.1
ShoreBird	Insct	0.69
ShoreBird	PltTer	0.02
ShoreBird	Sediment	0.19

Version: 0.361	December 27, 1991		Data Source: BCHEMVAR.XLS		
			Current as of February 19, 1992		
Depuration Rate (K2)					
Biota	**Chemical**	**Distribution**	**P1**	**P2**	**P3**
Eagle	Aldrin	Lognormal	-4.452706643	0.539074248	0
Eagle	DDE	Lognormal	-5.567766671	0.303816952	0
Eagle	DDT	Lognormal	-5.567766671	0.303816952	0
Eagle	Dieldrin	Lognormal	-4.452706643	0.539074248	0
Eagle	Endrin	Uniform-Triangular	0.0102 0.025	0.099	0.1138 1
Eagle	Arsenic	Uniform-Triangular	0.0624 0.1287	0.46	0.5263 1
Eagle	Mercury	Lognormal	-3.761192116	0.871802023	0
WatrBird	Aldrin	Lognormal	-5.18332	2.04863	0
WatrBird	DDE	Lognormal	-3.97515	1.78436	0
WatrBird	DDT	Lognormal	-3.2703	1.98893	0
WatrBird	Dieldrin	Lognormal	-4.34064	1.88837	0
WatrBird	Endrin	Lognormal	-2.76067	1.81521	0
WatrBird	Arsenic	Lognormal	-4.04462	0.1	0
WatrBird	Mercury	Lognormal	-1.78562	0.1	0
LgFish	Aldrin	Lognormal	-2.37099	2.95601	0
LgFish	DDE	Lognormal	-4.960136	0.30382	0
LgFish	DDT	Lognormal	-4.960136	0.30382	0
LgFish	Dieldrin	Lognormal	-2.37099	2.95601	0
LgFish	Endrin	Lognormal	-1.89668	0.4958	0
LgFish	Arsenic	Lognormal	-0.39862	0.45737	0
LgFish	Mercury	Lognormal	-4.02871	1.12097	0
SmFish	Aldrin	Lognormal	-2.37099	2.95601	0
SmFish	DDE	Lognormal	-4.960136	0.30382	0
SmFish	DDT	Lognormal	-4.960136	0.30382	0
SmFish	Dieldrin	Lognormal	-2.37099	2.95601	0
SmFish	Endrin	Lognormal	-1.89668	0.4958	0
SmFish	Arsenic	Lognormal	-0.39862	0.45737	0
SmFish	Mercury	Lognormal	-4.024132	0.44705	0
Heron	Aldrin	Lognormal	-4.452706643	0.539074248	0
Heron	DDE	Lognormal	-5.567766671	0.303816952	0
Heron	DDT	Lognormal	-5.567766671	0.303816952	0
Heron	Dieldrin	Lognormal	-4.452706643	0.539074248	0
Heron	Endrin	Uniform-Triangular	0.0102 0.025	0.099	0.1138 1
Heron	Arsenic	Uniform-Triangular	0.0624 0.1287	0.46	0.5263 1
Heron	Mercury	Lognormal	-3.761192116	0.871802023	0
Amph	Aldrin	Lognormal	-2.37099	2.95601	0
Amph	DDE	Lognormal	-4.960136	0.30382	0
Amph	DDT	Lognormal	-4.960136	0.30382	0
Amph	Dieldrin	Lognormal	-2.37099	2.95601	0
Amph	Endrin	Lognormal	-1.89668	0.4958	0
Amph	Arsenic	Lognormal	-0.39862	0.45737	0
Amph	Mercury	Lognormal	-4.024132	0.44705	0
ShoreBird	Aldrin	Lognormal	-4.45809	1.60508	0
ShoreBird	DDE	Lognormal	-12.97544	2.38758	0
ShoreBird	DDT	Lognormal	-10.9633	2.84036	0
ShoreBird	Dieldrin	Lognormal	-8.786	1.44916	0
ShoreBird	Endrin	Lognormal	-5.36289	1.70611	0
ShoreBird	Arsenic	Lognormal	-6.05389	0.1	0
ShoreBird	Mercury	Lognormal	-6.05235	0.1	0
Note for tails with Uniform-Triangular distribution					
P3 values of 0 represent one-tailed distribution					
P3 values of 1 represent two-tailed distribution					

Version: 0.296	October 23, 1991		Data Source: BCHEM.XLS	
			Current as of February 19, 1992	
Equilibrium Partition Coefficient (KOC)				
Chemical	**Distribution**	**P1**	**P2**	**P3**
Aldrin	Lognormal	11.89000001	2.828999774	0
DDE	Lognormal	13.51390007	0.932299899	0
DDT	Lognormal	13.25069995	1.678699948	0
Dieldrin	Lognormal	10.34390015	1.989000016	0
Endrin	Lognormal	11.84680004	0.853099995	0
Arsenic	Lognormal	4.021499997	1.52979994	0
Mercury	Lognormal	5.043099903	1.230800112	0

Version: 0.415	January 15, 1992		Data Source: BBIOVAR.XLS	
			Current as of February 19, 1992	
Feed Rate (R)				
Biota	Distribution	P1	P2	P3
Eagle	Normal	0.089129	0.026892	0
WatrBird	Normal	0.076025	0.0245	0
LgFish	Normal	0.003123	0.001	0
SmFish	Normal	0.015007	0.004163	0
AquInvert	Fixed	1	0	0
PltAqu	Fixed	1	0	0
Plankton	Fixed	1	0	0
Heron	Normal	0.089129	0.026892	0
Amph	Normal	0.103028	0.0332	0
Owl	Normal	0.089129	0.026892	0
Kestrel	Normal	0.089129	0.026892	0
ShoreBird	Lognormal	-2.43154	0.501894	0

TECHNICAL SUPPORT FOR ROCKY MOUNTAIN ARSENAL

Offpost Operable Unit
Endangerment Assessment/Feasibility Study

Final Report

Volume V of VIII
(FS Sections 1.0, 2.0)

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Contract Number DAAA15-88-0021
Task RIFS1 (Delivery Order 0001)

PREPARED BY

Harding Lawson Associates

PREPARED FOR

PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL

THIS DOCUMENT IS INTENDED TO COMPLY WITH THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969.

THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATION RECORD FOR THIS CERCLA OPERABLE UNIT.

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PREFACE

The Feasibility Study (FS) is an element of a combined Endangerment Assessment/ Feasibility Study (EA/FS) for the Offpost Operable Unit (OU) and is consistent with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), the Superfund Amendments and Reauthorization Act (SARA), the revised National Contingency Plan (NCP), and the regulations implementing the National Environmental Policy Act of 1969. Volume I of the EA/FS contains an introduction that includes site history and a summary of the nature and extent of contamination in the Offpost OU. Volume I also provides an Executive Summary that presents an overview of the findings from each section and summarizes the selection of the preferred sitewide alternative for the Offpost OU.

PURPOSE AND ORGANIZATION

The primary objectives of the FS are:

- Develop and evaluate a range of remedial alternatives that protect human health and the environment
- Provide an analysis of the range of remedial alternatives that will support the selection of the final remedy

The FS is organized into seven sections and associated appendixes. Section 1.0 describes the purpose and the organization of the report. Section 2.0 presents the development of remedial action objectives (RAOs), the development of preliminary remediation goals (PRGs), and the identification and screening of technologies. Section 3.0 presents the development of alternatives. The screening of alternatives with respect to effectiveness, implementability, and cost is presented in Section 4.0. The detailed analysis of alternatives, considering the criteria mandated by the NCP, is presented in Section 5.0. Selection of the preferred sitewide alternative is contained in Section 6.0. Section 7.0 presents the references for the FS.

1.0 FEASIBILITY STUDY PURPOSE AND ORGANIZATION

The primary objective of the Feasibility Study (FS) for the Offpost OU is to evaluate remedial alternatives in accordance with CERCLA, as amended by SARA, and the NCP so that relevant information concerning the remedial alternatives can be presented to a decision maker and an appropriate remedy can be selected. The following subtasks further describe the purpose of the FS evaluation:

1. Develop and screen a range of remedial alternatives that provide for protection of human health and the environment and that consider effectiveness, implementability, and cost criteria.

2. Integrate this FS with all applicable Offpost Remedial Investigation (RI), Offpost RI Addendum, comprehensive monitoring program (CMP), Offpost Endangerment Assessment (EA), Onpost RI/FS, and interim response action (IRA) activities to ensure that all remedial alternatives are developed, screened, and evaluated in a systematic and objective manner.

3. Provide an analysis of the range of remedial alternatives developed that will support the selection of a remedial alternative(s) that is technically feasible and provides the necessary protection of human health and the environment in a cost-effective manner.

The FS was conducted in four steps:

- Step I - Development of Remedial Action Objectives
- Step II - Development and Screening of Alternatives
- Step III - Detailed Analysis of Alternatives
- Step IV - Selection of the Preferred Sitewide Alternative

1.1 STEP 1 - DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

Step I of the FS included the following activities:

1. To set the context of the FS, a summary of background information regarding the site and a concise statement of the problem were made.

2. RAOs were developed specifying the chemicals and media of concern, exposure pathways as documented in the Offpost EA (Volume II, Section 1.0), and PRGs that provide the guidelines for the development of a range of remedial alternatives. The PRGs were developed on the basis of chemical-specific applicable or relevant and appropriate requirements (ARARs), health-based criteria (HBC), exposure factors, and the statutory requirements stated in Section 121 of CERCLA.

3. General response actions that may be taken to satisfy RAOs were developed for each medium of concern, defining individual controls, such as containment, treatment, excavation, pumping, or other actions, singly or combined.

4. Volumes or areas of media to which general response actions might be applied were identified considering the requirements for protectiveness as identified in the RAOs and the chemical and physical characterization of each medium.

5. The technology types (e.g., containment, chemical treatment, thermal treatment) and corresponding process options (e.g., carbon adsorption, air stripping) were identified and screened on the basis of technical implementability. Technology types and process options not applicable to the media or contaminants in the Offpost OU were eliminated. Technically implementable technology types and process options, including innovative technologies, were retained for further evaluation.

6. Process options were screened on the basis of effectiveness, implementability, and cost to select a representative process option (RPO) for each technology type retained for consideration.

1.2 STEP II - DEVELOPMENT AND SCREENING OF ALTERNATIVES

Step II of the FS included the following activities:

1. The selected RPOs from Step I of the FS were assembled into a range of remedial alternatives addressing containment, source control, treatment, and satisfying the statutory requirements and preferences stated in Section 121 of CERCLA as amended by SARA.

2. The remedial alternatives were further refined and screened on a general basis to assess their effectiveness, implementability, and cost.

3. On the basis of this screening, a set of remedial alternatives was retained for further analysis in Step III.

1.3 STEP III - DETAILED ANALYSIS OF ALTERNATIVES

Step III of the FS included the following activities:

1. Retained alternatives were then further developed to provide the basis for a detailed analysis in accordance with the NCP and with U.S. Environmental Protection Agency (EPA) guidance.

2. ARARs and other pertinent advisories, criteria, or guidance were identified regarding specific actions proposed for each remedial alternative.

3. The alternatives were assessed and compared on the basis of relative performance with respect to the following evaluation criteria (categorized into three groups) specified in the NCP:

   - Threshold criteria

     o Overall protection of human health and the environment

- Compliance with ARARs

- Primary balancing criteria
  - Long-term effectiveness and permanence
  - Reduction of mobility, toxicity, or volume through treatment
  - Short-term effectiveness
  - Implementability
  - Cost

- Modifying criteria
  - State acceptance
  - Community acceptance

4. Based on the comparative analysis of remedial alternatives and risk management decisions, a preferred alternative was selected.

1.4 STEP IV - SELECTION OF THE PREFERRED SITEWIDE ALTERNATIVE

Step IV of the FS selects the U.S. Department of the Army's (Army's) preferred alternative, based on the detailed analysis of alternatives.

2.0 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES AND SCREENING OF TECHNOLOGIES

RAOs and general response actions that address the RAOs were developed. Technologies accomplishing a given response action were then identified and screened, and RPOs were selected to be carried forward into the development and screening of alternatives.

Section 2.0 presents an overview of development of RAOs, identification and screening of technology types and process options, and selection of RPOs.

2.1 OVERVIEW OF REMEDIAL ACTION OBJECTIVES DEVELOPMENT

RAOs are medium-specific goals designed to protect human health and the environment. RAOs address chemicals of concern (COCs), media of concern, exposure pathways, and PRGs. RAOs and PRGs were used to guide the evaluation of technologies and the development of remedial alternatives. PRGs are established considering chemical-specific ARARs, site-specific HBC, factors related to technical considerations (e.g., analytical detection limits), background concentrations, and ecological criteria. The PRGs were established using information developed in the Offpost EA and considering expected exposures, associated risks for each alternative, and land use. RAOs were developed to provide protection of human health and the environment. The RAOs guided the selection of response actions, technology types, process options, and remedial alternatives.

General response actions are defined as remedial measures that will satisfy RAOs. General response actions include no action, institutional controls, containment, removal, disposal, and treatment options. General response actions were identified to guide the process of evaluating technologies.

After the definition of general response actions, broad technology groups (i.e., technology types) and specific processes within a technology type (i.e., process options) were identified on the basis of chemicals present and the media in which they were detected at the site. Technology types and process options were screened in a first step, solely on the basis of technical implementability. The technical implementability criterion eliminated technology types and

process options that could not be effectively implemented because of site conditions in the Offpost OU.

During the second level of screening, process options within each technology type were evaluated and screened on the basis of three criteria: effectiveness, implementability, and cost. Subsequently, one or more RPO was selected for each technology type retained during this second level of screening. RPOs were carried forward to the development and screening of alternatives.

2.2 NATIONAL CONTINGENCY PLAN AND ACCEPTABLE RISK RANGE CONSIDERATIONS

This section describes NCP considerations for developing RAOs and PRGs for the Offpost OU. The section begins with a discussion of the cumulative risk for the Offpost OU as presented in the EA and compares the cumulative risk to the acceptable risk range. The Army's approach for evaluating cumulative risk and development of PRGs presented in the following sections is consistent with the NCP and EPA interpretive guidance. The Army has followed EPA guidance regarding (1) use of the acceptable cancer risk range in assessing whether remediation is required and (2) development of PRGs for sites exceeding the 10^{-4} acceptable risk level.

2.2.1 Comparison of Cumulative Risk With the Acceptable Risk Range

The cumulative Offpost OU hypothetical cancer risk is a maximum of 3×10^{-4} on the basis of the RME risks presented in the EA (Volume III, Section 4.0 and Volume IV, Appendix G). This value is a summation of the highest calculated risk in each medium regardless of zone. The calculated hazard indices (HIs) presented in the EA (Volume III, Section 4.0) are below 1.0, with the exception of zones 2,3 and 4, where the HIs slightly exceed 1.0. The RME risks calculated in the EA are a conservative estimate of Offpost OU hypothetical risk. The conservatism of the RME risks presented in the EA is discussed in detail in Volume III, Section 4.0. The quantitative uncertainty analysis presented in Volume III, Section 4.0 can be used to assess the level of conservatism of the RME estimates. The results of the uncertainty analysis suggest that RME estimates may be two to six times more conservative than the 95th percentile, the lower boundary for an RME estimate. Additionally, the future land-use scenario presented in the EA, Volume II,

Section 2.0, is highly conservative. The rural residential scenario used in zones 1, 2, and 6 includes all pathways contributing substantially to hypothetical risk, even though the majority of the total population is not exposed to the majority of the agricultural exposure pathways. The urban residential exposure scenario in zones 3 and 4 is very conservative because the probable future use of that land is commercial/industrial rather than residential for reasons listed in Volume V, Section 2.5.1.

The Offpost OU cumulative risk is within the acceptable cancer risk range specified by EPA. Risks attributable to the individual media are presented in Volume V, Table 2.2.1-1. The Army used the NCP and relevant EPA guidance to establish the acceptable risk range for the Offpost OU. For example, an EPA memorandum entitled "Role of the Baseline Risk Assessment in Superfund Remedy Decisions" (OSWER Directive 9355.0-30, April 22, 1991) (Risk Assessment Memorandum) provides guidance on interpreting the NCP mandate that remedial actions attain a 10^{-4} (one in 10,000) to 10^{-6} (one in 1,000,000) cancer risk. The Risk Assessment Memorandum makes the following conclusions:

- For sites where the cumulative risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4}, action is generally not warranted... (Risk Assessment Memorandum, page 4)

- The upper boundary of the risk range is not a discrete line at 1×10^{-4}, but EPA generally uses 1×10^{-4} in making risk-management decisions. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions (Risk Assessment Memorandum, page 1).

EPA Region VIII provided the following position to the Army with regard to use of the 10^{-4} risk level at the Offpost OU:

> Although EPA guidance states that the 10^{-4} is not an absolute trigger point, under proper site-specific circumstances, we consider use of a risk in excess of 5×10^{-4} to exceed the intent of the guidance's latitude (Letter to the Army dated February 21, 1992).

Relying on both EPA Headquarters and Region VIII guidance addressing the upper boundary of the acceptable cancer risk range, the Army interpreted that boundary to be 5×10^{-4}.

2.2.2 Identification of Media Requiring Remedial Action Objectives

Offpost OU remedial action is not warranted because Offpost OU cumulative risk is 3×10^{-4} at a maximum and below the previously mentioned acceptable risk range. Nevertheless, the Army recognizes that there are several site-specific factors, when considered in totality, that suggest remediation of groundwater is preferable to no action in the Offpost OU.

Groundwater contributes a maximum risk of 2×10^{-4}, or approximately 73 percent of the total, to the cumulative hypothetical risk in zones 2, 3, and 4. The following potential human exposure pathways were identified in the EA for groundwater: direct ingestion, inhalation during showering, consumption of crops irrigated with contaminated groundwater, and consumption of dairy products and beef produced from livestock watered with contaminated groundwater and/or fed grain irrigated with contaminated groundwater. Moreover, HIs for children slightly exceed 1.0 in zones 2,3, and 4.

Soil contributes a maximum risk of 8×10^{-5} in zone 3 to the cumulative hypothetical risk through a combination of the following potential human exposure pathways: direct ingestion, dermal contact, consumption of crops cultivated in contaminated soil, consumption of dairy products and beef from livestock inhabiting areas of contaminated soil, and consumption of eggs from poultry inhabiting areas of contaminated soil. That is, the maximum risk would only be realized for a population exposed at the RME levels for all pathways. Because this seems unlikely and because maximum cancer risks are within the EPA risk range, the Army concludes that soil requires no further action. Additionally, comparison of the geometric mean soil contaminant exposure point concentrations with the soil ecological criteria presented in Volume VII, Table C2, indicate no action is warranted. Therefore, RAOs and PRGs were not developed for soil.

Surface water and sediment contribute a maximum risk of 5×10^{-7} and 8×10^{-7}, respectively, to the cumulative hypothetical risk in zones 3 and 4. Both risks are below the lower limit of the acceptable risk range; hence, no remediation is appropriate for these media. Therefore, RAOs and PRGs were not developed.

Air and biota media in the Offpost OU do not require remediation for the following reasons. Air quality at RMA and within the Offpost OU has been monitored for particulates, asbestos, organic contaminants, and metals. Based on data collected through the air CMP (R.L. Stoller and Associates, Inc. [RLSA], 1990c) and presented in Volume I (Introduction - Nature and Extent of Contamination), air in the Offpost OU is not a medium of concern, and therefore, RAOs were not developed for the air medium. The biota medium consists of all plants and animals potentially exposed to Offpost OU contaminants in water, soil, and sediment. The source of biotic contamination originates from abiotic materials, such as water, soil, and sediment. Direct remediation of biota is not effective except by methods that temporarily eliminate receptor species from the area of contamination during remediation of the abiotic media. Therefore, biota is not a medium of concern. However, ecological criteria developed for the protection of species potentially at risk were considered as remediation goals during the development of RAOs. Specifically, information presented in the ecological risk assessment (Volume III, Section 5.0) and ecological-based criteria presented in Volume VII, Appendix C were evaluated during the development of RAOs.

Additional support for eliminating media that contribute minor levels of risk to the Offpost OU cumulative risk is presented in the EA through consideration of (1) multiple contaminants, (2) multiple exposure pathways, (3) sensitive subpopulations, (4) cross-media impacts, and (5) impacts on environmental receptors. Further, EPA also implies that for media with risks less than 10^{-4}, development of PRGs may not be appropriate (Risk Assessment Guidance for Superfund [RAGS]: Volume I - Human Health Evaluation Manual, Part B - Development of Risk-based Preliminary Remediation Goals, Office of Solid Waste and Emergency Response [OSWER] Directive 9285.7-01B, December 1991) (RAGS-B).

2.2.3 Site-specific Factors Considered for Groundwater Remedial Action Objectives Development

The Army considers the following factors to be important in assessing whether groundwater RAOs should be developed even though the cumulative risk in the Offpost OU is within the acceptable risk range

- Groundwater is the major contributor to total risk.
- Groundwater is a potential source of drinking water within the Offpost OU and Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) are exceeded.
- Groundwater can potentially impact human receptors through a number of exposure pathways, as described in Section 2.2.2.
- Significant reductions in groundwater contaminant concentrations and corresponding cumulative site risk can be attained by implementing groundwater remedial actions.
- Significant progress has already been made towards construction and implementation of a groundwater collection and treatment system.
- HIs for children slightly exceed 1.0 in zones 2,3, and 4, with groundwater contributing approximately 74 percent of the total risk.

For the reasons stated above, the Army considers groundwater PRG development to be appropriate even though cumulative Offpost OU cancer risk is within the acceptable risk range of 10^{-4} to 10^{-6} as specified in the NCP. Generally, EPA guidance suggests that PRGs be developed with 10^{-6} risk as the point of departure. Thus, groundwater PRGs were developed using the 10^{-6} point of departure.

2.3 DEVELOPMENT OF GROUNDWATER REMEDIAL ACTION OBJECTIVES

RAOs are medium-specific goals for protecting human health and the environment. The NCP states that RAOs should specify the following: (1) contaminants of concern, (2) media of concern, (3) exposure pathways, and (4) remediation goals. The development of groundwater RAOs was performed in a step-wise fashion:

Step 1: Identification of COCs

Step 2: Identification of exposure pathways

Step 3: Identification of PRGs

COCs were identified in the Offpost EA and are also discussed in the following section. Primary exposure pathways were identified in the Offpost EA and are presented in Section 2.3.2. Groundwater RAOs are identified in Section 2.4. The RAOs address the primary exposure pathways and the achievement of PRGs, which are developed in Section 2.5.

2.3.1 Development of Remedial Action Objectives, Step 1: Identification of Chemicals of Concern

COCs were identified in the Offpost EA (Volume II, Section 1.0), primarily on the basis of the following four criteria:

1. The primary criterion for identifying COCs was a statistically significant increase in concentration in samples collected from the Offpost OU when compared with samples from locations believed to be unaffected by RMA contamination (background).
2. Although certain chemicals may have not fully satisfied the statistical criterion stated above, if they were degradation products of COCs, they were selected as COCs.
3. Several COCs are essential human nutrients and have low toxicity at observed concentrations. These potential COCs include calcium, magnesium, potassium, and sodium, and were eliminated from consideration.

Background concentrations include naturally occurring chemicals and chemicals from anthropogenic sources, such as the agricultural application of pesticides.

Groundwater COCs are presented in Table 2.3.1-1. Groundwater PRGs are presented in Section 2.5.

2.3.2 Development of Groundwater Remedial Action Objectives Step 2: Identification of Potential Exposure Pathways

The primary potential pathways of exposure were identified in the Offpost EA (Volume II, Section 2.0). RAOs consider the protection of human health and the environment. Therefore, exposure pathways for both human and ecological receptors were considered in the development of RAOs.

The following primary exposure pathways were identified for groundwater:

- Human receptors
  - o Direct ingestion of contaminated groundwater

- Showering with contaminated groundwater
- Consumption of crops irrigated with contaminated groundwater
- Consumption of dairy products or beef produced from livestock watered with contaminated groundwater and/or fed crops irrigated with contaminated groundwater

- Environmental receptors
  - Watering of livestock with contaminated groundwater
  - Feeding of livestock with crops irrigated with contaminated groundwater

The Offpost EA considered three potential groundwater exposure pathways that were eliminated from further consideration on the basis that the pathways did not contribute significant potential health risks to humans. The following potential groundwater exposure pathways were eliminated:

- Inhalation of vapors in residences
- Dermal contact with groundwater for domestic uses
- Consumption of game harvested from the Offpost OU

All remaining groundwater exposure pathways were considered in the development of groundwater RAOs.

2.4 GROUNDWATER REMEDIAL ACTION OBJECTIVES

Groundwater RAOs for the Offpost OU were developed to provide protection of human health and the environment from potential exposure to contaminants detected in groundwater. RAOs were developed to meet the intent of CERCLA and include the general provision to reduce potential health risks associated with affected media to the NCP-prescribed cumulative 10^{-4} to 10^{-6} risk range for carcinogens and a hazard index < 1.0 for noncarcinogens by achieving PRGs. All remedial actions will be consistent with CERCLA, the NCP, and the Federal Facility Agreement (FFA) (EPA and others, 1989a).

EPA Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final, October 1988 (EPA, 1988b) provides that:

Remedial action objectives consist of medium-specific or operable unit specific goals for protecting human health and the environment...Remedial action objectives aimed at protecting human health and the environment should specify:

- The contaminant(s) of concern
- Exposure route(s) and receptor(s)
- An acceptable contaminant level or range of levels for each exposure route (i.e., a preliminary remediation goal)

Remedial action objectives for protecting human receptors should express both a contaminant level and an exposure route, rather than contaminant levels alone, because protectiveness may be achieved by reducing exposure (such as capping area, limiting access, or providing an alternate water supply) as well as by reducing contaminant levels.

2.4.1 Groundwater Remedial Action Objectives

Groundwater RAOs consist of goals for groundwater quality that are protective of human health and the environment.

2.4.1.1 Human Health[a]

1. Reduce the COC[b] concentrations in groundwater and/or prevent exposure associated with groundwater within the Offpost OU to meet groundwater remediation goals[c] and to attain the NCP-prescribed cumulative risk range.

2. Prevent domestic use of, ingestion of crops irrigated with, and ingestion of livestock watered with groundwater containing COCs[b] at concentration levels in excess of groundwater remediation goals[c].

2.4.1.2 Environmental Protection

1. Prevent acute or chronic toxicity to biota from groundwater within the Offpost OU at COC[b] concentrations in excess of groundwater remediation goals[c].

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[a] Several potential groundwater exposure pathways including inhalation of vapors in residences, direct contact with groundwater for domestic uses, and consumption of game (i.e., pheasants) harvested from the Offpost OU, were evaluated in the Offpost EA process and were eliminated from further consideration.

[b] Groundwater COCs were identified in the Offpost EA (Volume II, Section 1.0) and are listed in Table 2.3.1-1 of this report.

[c] The development of preliminary and final remediation goals, in accordance with the NCP and the FFA, is an ongoing process requiring continual evaluation of site-specific conditions and evolving health-based and regulatory standards to attain the NCP-prescribed cumulative risk range of 10^{-4} to 10^{-6} for carcinogens and a hazard index < 1.0 for noncarcinogens. These preliminary goals may change as the FS progresses. Final remediation goals may be based on but are not limited to HBC, ARARs, biota criteria, background concentrations, and CRLs.

2.5 DEVELOPMENT OF GROUNDWATER PRELIMINARY REMEDIATION GOALS

PRGs are chemical-specific remediation criteria that identify media requiring remediation and treatment goals. A set of remediation criteria may be composed of different types of PRGs. For example, groundwater PRGs may include ARARs (such as Maximum Contaminant Levels [MCLs]), HBC, background concentrations, ecological criteria, and certified reporting limits (CRLs). More than one type of cleanup criteria may be identified as being potentially suitable for evaluating remediation requirements.

The development of PRGs is an ongoing process requiring continual evaluation of site-specific conditions and evolving health-based and regulatory standards. In accordance with the NCP, Section 300.430(e)(i), PRGs were developed considering ARARs, HBC, factors related to technical limitations (e.g., detection limits), background concentrations, land use, and ecological criteria. Final remediation goals will be determined when the remedy is selected and the Record of Decision (ROD) is issued.

Section 121(d) of CERCLA establishes a process for developing and selecting remedial actions that are protective of human health and the environment. Remedial actions that limit an excess lifetime cancer risk to an individual to a level between 10^{-4} and 10^{-6} on the basis of methodologies and evaluations developed and presented in the Offpost EA (Volume III, Section 4.0) are protective (NCP, Section 300.430(e)(2)). EPA guidance specifies that where action is warranted, the 10^{-6} risk level should be used as the point of departure for identifying PRGs for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants or multiple pathways of exposure. Additionally, the EPA guidance document, Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions (EPA, 1991), states that:

> (1) For groundwater actions, MCLs, and non-zero MCLGs will generally be used to gauge whether remedial action is warranted, (2) For sites where the cumulative site risk to an individual is less than 10^{-4}, action generally is not warranted, but may be warranted if a chemical specific standard that defines acceptable risk is violated or unless there are noncarcinogenic effects or an adverse environmental impact that warrants action, (3) Furthermore, the upper boundary of the risk range is not a discrete line at 1×10^{-4}, although EPA generally uses 1×10^{-4} in

making risk management decisions, and (4) A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions including any uncertainties on the nature and extent of contamination and associated risks.

2.5.1 Effects of Future Land Use on the Development of Preliminary Remediation Goals

The Offpost OU is subdivided into six geographic zones (zones 1 through 6 in Figure 2.5.1-1) used in the Offpost EA (Volume II, Section 2.0) for assessing differences in expected exposures.

The EA (Volume II, Sections 2.2.2.1 and 2.2.2.2) provides the background discussion on current and future land use for the Offpost OU. The purpose of this section is to evaluate the information within the context of EPA guidance, and to select the most probable land use scenarios for the EA/FS.

Evaluation of land use for the Offpost OU considered the following sources for guidance and pertinent information:

1. The NCP
2. Risk Assessment Guidance for Superfund (RAGs)
3. Local City and County Planning Documents, including the Airport Environs Plan (Adams County Planning Commission, 1990) and the 96th Avenue/Quebec Street Area Transportation Study (CH2M Hill, 1988)
4. Discussions with local officials

The NCP states:

> The analysis for potential exposures under future land use conditions is used to provide decision-makers with an understanding of exposures that may potentially occur in the future. This analysis should include a qualitative assessment of the likelihood that the assumed future land use will occur. The reasonable maximum exposure estimate estimates for future uses of the site will provide the basis for the development of protective exposure levels.
>
> In general, a baseline risk assessment will look at a future land use that is both reasonable, from land use development patterns, and may be associated with the highest (most significant) risk, in order to be protective. The assumption of residential land use is not a requirement of the program but rather is an assumption that may be made, based on conservative but realistic exposures. An assumption of future residential land use may not be justifiable if the probability that the site will support residential use in the future is small, (NCP preamble [55 FR 8710] Remedial Investigation-baseline risk assessment).

The discussion above indicates that it is within the guidance to select a future land use other than residential before filing a ROD.

Based on the data presented in the EA (Volume II, Sections 2.2.2.2 and 2.2.2.3), the most likely future land uses for the Offpost OU are as follows:

- Rural residential for zones 1, 2, and 6
- Urban residential for zone 3 and 4
- Commercial/industrial for zone 5

A summary of the qualitative assessment of the likelihood of occurrence of these future land uses includes the following findings:

- The completion of the new Denver Airport and its proximity to the Offpost OU will stimulate growth, particularly along the East 96th Avenue Corridor, and said growth is most likely to include commercial and industrial development.
- Transportation agencies have mapped an enlargement and realignment of East 96th Avenue to handle increased traffic to the new Denver Airport, and said realignment is positioned within zones 2, 3, and 4 of the subject land parcels.
- Floodplains and wetlands occur primarily in zones 3 and 5 in the subject parcels and would tend to prevent buildings in these areas but may promote recreational uses.
- For the remaining Offpost OU, residential and agriculture are the most likely future land uses.

2.5.2 National Contingency Plan and Point of Departure Considerations for Development of Preliminary Remediation Goals

The FS followed EPA guidance in establishing groundwater PRGs. The NCP states:

> Initially, preliminary remediation goals are developed based on readily available information, such as chemical-specific ARARs or other reliable information. Preliminary remediation goals should be modified, as necessary, as more information becomes available during the RI/FS. Final remediation goals will be determined when the remedy is selected. Remediation goals shall establish acceptable exposure levels that are protective of human health and the environment and shall be developed by considering the following:
>
> (A) Applicable or relevant and appropriate requirements..., and the following factors:
>
> (1) For systemic toxicants, acceptable exposure levels shall represent concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety;

(2) For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper-bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6} using information on the relationship between dose and response. The 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of multiple contaminants at a site or multiple pathways of exposure...

Section 2.5.4.1 and Table 2.5.2-1 of the FS present groundwater chemical-specific ARARs for the Offpost OU. Section 2.5.4.2 and Table 2.5.2-2 present HBC (acceptable exposure levels) for COCs without ARARs that are systemic toxicants. The preliminary HBC are presented at an HI of <1.0 for noncarcinogens.

Volume VII, Appendix C, of the FS presents the methodology used in the calculation of HBC and PRGs. The NCP states that PRGs may be revised on the basis of consideration of appropriate factors, including, but not limited to exposure factors, uncertainty factors, and technical factors (EPA, 1990). This section describes how these factors were evaluated to select final PRGs.

According to the NCP and EPA guidance (EPA, 1990, 1989b), the exposure assessment considers the cumulative effect of multiple contaminants, multiple pathways, population sensitivities, potential impacts on environmental receptors, and cross-media impacts. Appendix C describes in detail how the Army calculated HBC and risk associated with PRGs to meet these requirements. These calculations were verified with the Automated Risk Evaluation System (ARES) software developed for the EA. HBC and risk development considered each of the reasonable maximum exposure (RME) factors described above, including multiple pathways, multiple contaminants, sensitive subpopulations (child chronic), and cross-media impacts. In addition, the development of PRGs considered environmental impacts on ecological receptors by using maximum allowable tissue concentrations (MATCs), literature-based biomagnification factor (BMF) values, as well as toxicity reference values (TRVs), and soil and dietary ingestion.

The Army also evaluated uncertainty factors in selecting HBC and PRGs. Uncertainty factors evaluated include the effectiveness of the alternatives, the weight of scientific evidence concerning exposures and cumulative health effects, and the reliability of exposure data. The

effectiveness of the alternatives is evaluated in Volume VI, Sections 4.0 and 5.0. The uncertainty associated with the performance of the selected groundwater treatment alternative is low because of the Army's experience with similar designs of the boundary containment systems (BCSs) for treating the COCs. Uncertainties associated with the weight of scientific evidence on exposure and health risks were investigated both qualitatively in each major section of the EA and quantitatively for the exposure assessment, which goes beyond the requirements of applicable EPA guidance. These uncertainties indicate the assumptions in the EA are predominantly conservative, and therefore, exposures may exceed by three-fold the 95th percentile of the potential exposure distributions (Volume II, Section 2.4.5). In this manner, the reliability of the exposure data was bounded and conservatively estimated as exceeding the 95th percentile targeted by the RME. In addition, all exposure assumptions were maintained at the RME level although EPA guidance allows use of a combination of RME and average exposure assumptions when the net result is still "reasonable maximum exposure" (EPA, 1989b).

The NCP also requires evaluation of technical factors in the selection of PRGs, such as detection/quantitation limits, technical limits to remediation, the ability to monitor and control movement of contaminants, and background levels of contaminants. The risk corresponding to MCLs and non-zero MCLGs exceeds 10^{-6}. Thus the Army evaluated detection limits, called certified reporting limits (CRLs) by the Army, for use as PRGs, attempting to lower the risk corresponding to PRGs. As a result, although the Army initially considered ARARs as PRGs, it was necessary to reduce many of the PRGs to CRLs to achieve the targeted carcinogenic risk range of 10^{-4} to 10^{-6}. In addition, naturally occurring arsenic in groundwater contributes significantly to the hypothetical risk attributable for groundwater (Volume III, Section 4.1.1.1). These technical and exposure factors were also considered in the evaluation. The FS also evaluated technical limitations to remediation (e.g., treatability) in the selection of representative process options and development of alternatives, in Volumes V and VI, Sections 2.0 and 3.0, and ability to monitor (Volume VI, Section 3.0) and control contaminant migration (Volume VII, Appendix E, Groundwater Modeling).

In summary, the EA/FS contains discussion and description necessary to evaluate exposure, uncertainty, and technical factors and criteria that support the selection of 10^{-4} risk for groundwater as the most health protective goal that is technically achievable, meets or exceeds ARARs, has low uncertainty and large conservatism, and complies with applicable guidance (EPA, 1990). Table 2.5.2-3 in Volume V presents the groundwater PRGs for the Offpost OU and the media-specific risk. The summary risk for all chemicals, pathways, and media is in Volume VII, Appendix C.

2.5.3 Types of Groundwater Preliminary Remediation Goals

A brief description of the types of PRGs evaluated for the Offpost OU is presented in the following subsections. The types of PRGs evaluated include ARARs, HBC, background concentrations, and ecological criteria.

2.5.3.1 Identification of Applicable or Relevant and Appropriate Requirements

EPA guidance (1988a), which is reflected in this section, describes the identification and application of ARARs for the RI/FS process. Under Section 121(d)(1) of CERCLA, remedial actions must attain a degree of remediation considered protective of human health and the environment. In addition, CERCLA remedial actions must attain a level or standard of control that at least meets standards, requirements, limitations, or criteria that are "applicable or relevant and appropriate" upon completion of the action. These requirements, known as ARARs, may be waived only in certain cases specified in Section 121(d)(4) of CERCLA.

ARARs are derived from both federal and state laws. The definitions of "applicable" or "relevant and appropriate" requirements are found in the NCP, 40 CFR 300.5.

Applicable requirements refer to those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility setting laws that specifically address a hazardous substance, pollutant, chemical, remedial action, location, or other circumstance found at a CERCLA site.

Relevant and appropriate requirements refer to those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility setting laws that, although not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

The analysis of requirements with respect to their relevance and appropriateness is somewhat flexible. Relevant statutes require comparison of the types of remedial actions contemplated to hazardous substances present, characteristics of the waste, physical characteristics of the site, and other appropriate factors to establish relevant and appropriate requirements. It is possible to consider only part of a requirement relevant and appropriate. Those state standards that are identified in a timely manner and are more stringent than federal requirements may be applicable or relevant and appropriate.

Within the confines of existing regulations and policy, the U.S. Department of the Army, as the lead agency, assesses the applicability or relevance and appropriateness of requirements.

Other criteria and advisories that are not promulgated regulations can be used as guidelines to ensure protection of human health and the environment. These "to be considered" (TBC) criteria may include EPA health advisories (HAs), proposed MCLs, and other similar advisories.

Three different classifications of ARARs exist. The first type includes chemical-specific requirements. Examples of potential ARARs include: (1) MCLs established under the Safe Drinking Water Act (SDWA), (2) National Ambient Air Quality Standards (NAAQS), (3) Ambient Water Quality Criteria (AWQC), and (4) The Basic Standards and Methodologies for Surface Water.

The second type of ARAR includes location-specific requirements that restrict activities on the basis of site characteristics and immediate site environment. These requirements may affect the type of remedial action that can be implemented. A limit on activities within flood plains is an example of a location-specific ARAR.

The third type of ARAR includes action-specific requirements. Such ARARs are technology based and are associated with the type of remedial alternative under consideration. An example of an action-specific ARAR is the Resource Conservation and Recovery Act's (RCRA) hazardous waste labeling requirements.

Chemical-specific ARARs were considered during the development of PRGs. Location- and action-specific ARARs were considered during the detailed analysis of specific remedial alternatives (Section 5.0) and are not related to the development of PRGs. An evaluation of ARARs with respect to the Offpost OU is in Appendix A.

2.5.3.1.1 Chemical-specific Applicable or Relevant and Appropriate Requirements

A chemical-specific ARAR is a health-based or risk-based numerical value or methodology that, when applied to site-specific conditions, results in the establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that is required to meet protectiveness criteria established for the site.

Identification of chemical-specific ARARs was performed in several steps. The first step was to identify chemicals for which an ARAR determination was warranted based on 42 USC 9621(d), which provides that ARARs are to be selected only for hazardous substances, pollutants, or contaminants. The second step was to determine whether specific standards existed for the designated hazardous substances, pollutants, or contaminants identified as COCs in the EA. The third step was to determine which ARARs were to be attained for purposes of remedial action for the Offpost OU. Chemical-specific ARARs are discussed in Appendix A and are addressed for each medium during the development and selection of PRGs.

Potential chemical-specific ARARs for the Offpost OU have been identified and are presented in the ARARs subsections for each medium of concern. For contaminants without potential ARARs, health-based levels, based on the risks identified in the EA (Volume III, Section 4.0), were developed and are presented in the HBC subsections for each medium of concern. Chemical-specific ARARs are identified and discussed in Appendix A.

2.5.3.1.2 Location-specific Applicable or Relevant and Appropriate Requirements

Location-specific ARARs generally are requirements placed upon the contaminated areas or upon the conduct of activities solely because they are in special locations, such as flood plains, wetlands, historic places, and sensitive ecosystems or habitats. Location-specific ARARs are identified and discussed in Appendix A. An evaluation of wetlands ecosystems within the Offpost OU is presented in Appendix B.

2.5.3.1.3 Action-specific Applicable or Relevant and Appropriate Requirements

Action-specific ARARs are usually technology-based or activity-based requirements or limitations on actions taken with respect to hazardous wastes or requirements to conduct certain actions to address particular circumstances at a site. Action-specific ARARs are identified and discussed in Appendix A.

2.5.3.2 Health-based Criteria

HBC presented in subsequent subsections for carcinogens correspond to the point of departure of 10^{-6} excess cancer risk in accordance with the NCP. Further, the NCP requires that acceptable exposure levels for noncarcinogens with an adequate margin of safety must not cause any adverse effect during all or part of a lifetime, including sensitive population groups. EPA's Risk Assessment Guidance for Superfund (EPA, 1989b) requires that individual calculated chemical intakes divided by the reference doses be summed into a hazard index (HI) for noncarcinogens. Further, the guidance specifies segregation of HIs by toxic effect and mechanism. This approach was used in establishing health-based PRGs for the noncarcinogens.

Expected future land use had an impact on the development of HBC in the Offpost OU. Three different exposure scenarios were developed in the Offpost EA. A rural residential (including agriculture) scenario was developed for zones 1, 2, and 6, an urban residential scenario was developed for zones 3 and 4, and a commercial/industrial scenario was developed for zone 5.

The Offpost EA (Volume II, Section 2.0) also developed exposure parameters consistent with both RME and Most Likely Exposure (MLE) estimates.

A summary of the approach used for the development of HBC is presented here. HBC for COCs are developed in the FS using the exposure parameters selected in the EA. The risk assessment software, ARES, was used to develop HBC at 10^{-6} risk for carcinogens and hazard indices of 1 for noncarcinogens. HBC were estimated by proportional analyses using the EA ARES risks presented in Volume IV, Appendix G. HBC risks were then calculated using HBC as input exposure concentrations in the ARES model. By using ARES, the individual risk of each HBC is determined, as well as the cumulative risk of multiple chemicals and media. The EA calculated risks use an intake equation in Section 2.4 of the EA and in Appendix C of the FS. To develop HBC, the intake equation is rearranged, an acceptable intake is calculated (see Appendix C), and the equation is rearranged and solved for concentration. This calculation is performed for each COC, exposure pathway, and medium of concern.

Groundwater HBC were calculated using an equation that normalizes the importance of individual exposure pathways by taking the inverse of each individual exposure pathway HBC, summing these, and taking the inverse of the calculated sum (see Appendix C).

The resultant groundwater HBC were then adjusted for the contributions of multiple carcinogens or noncarcinogens by dividing by the number of carcinogens that were contributors to risk. The resultant HBC corresponds to the target risk level (i.e., 10^{-4} to 10^{-6}) and to the risks calculated in the EA.

Quantitative uncertainty analysis was used to help assess the conservativeness of the RME estimates (Volume II, Section 2.4). For the several pathways studied, RME estimates were in reasonable agreement with the 95th percentile values from the exposure distributions, but the RME estimates were often higher. Differences ranged between factors of 1 and 6, and in general, the RME estimates exceeded the 95th percentile values by a factor of 3. Considering the uncertainty in knowledge of potential exposures, these differences are relatively small. However, the fact that the RME estimates were consistently higher suggests that the results of the quantitative uncertainty analysis can be used to support the conclusion that the RME estimates are

indeed conservative and can be used with confidence in the development of preliminary remediation goals.

2.5.3.3 Background Concentrations

Background concentrations were one of several types of criteria evaluated for selection of PRGs when there were contaminant sources in or contributing to a medium other than sources related to RMA. Background levels may also be considered as PRGs when remediation of a medium to below background levels is not technically feasible because of naturally occurring sources of COCs in the environment.

2.5.3.4 Ecological Criteria

Ecological criteria were developed for protection of predators at the top of the food chain including bald eagles, owls, herons, and kestrels. Ecological criteria address the requirement stated in the NCP for protection of the environment and therefore are included as PRGs. The methods used in developing ecological criteria are presented in Appendix C.

2.5.4 Development and Identification of Preliminary Remediation Goals - Groundwater

The evaluation of PRGs for groundwater in the Offpost OU includes an assessment of ARARs and HBC.

2.5.4.1 Groundwater Chemical-specific Applicable or Relevant and Appropriate Requirements

The chemical-specific ARARs pertaining to Offpost OU groundwater COCs are listed in Table 2.5.2-1.

Consistent with EPA guidance, MCLGs set at zero are not considered potential ARARs. MCLs from the National Primary Drinking Water Standards (NPDWS) and CBSG can be applicable or relevant and appropriate for remediation of groundwater in the Offpost OU. Consistent with EPA guidance, the Army selected the chemical-specific ARARs listed in Table 2.5.2-1.

DIMP is the subject of an EPA Health Advisory used to set the TBC at 600 micrograms per liter ($\mu g/l$). The TBC has been reviewed and found protective by the National Academy of Sciences. Therefore, the TBC will be adopted as an ARAR.

No ARAR determinations are final until the Offpost ROD is final. The levels listed as proposed are not ARARs but may be evaluated as ARARs if finalized before issuance of the ROD for the Offpost OU.

2.5.4.2 Groundwater Health-based Criteria

Groundwater HBC for carcinogens are risk-based values that correspond to the range of allowable risks (10^{-4} to 10^{-6}) prescribed in the NCP. HBC for noncarcinogens correspond to concentrations such that the calculated HI is below 1.0. HBC were developed for a residential (including agriculture), commercial/industrial exposure scenario. The methodology for calculating the HBC is presented in Appendix C. Table 2.5.2-2 presents the HBC for groundwater COCs without ARARs. Several groundwater COCs have only HBC as groundwater PRGs (because there are no ARARs for these COCs). These COCs include CPMS, CPMSO, $CPMSO_2$, dicyclopentadiene, dithiane, isodrin, malathion, and oxathiane. CRLs have been included in Table 2.5.2-2. For those cases where HBC are less than CRLs, the CRLs would be adopted as the performance standard because values below CRLs cannot be reliably quantified.

2.5.4.3 Selection of Groundwater Preliminary Remediation Goals

Groundwater PRGs were developed on the basis of ARARs and HBC. PRGs developed for consideration in assessing groundwater and developing remedial alternatives are presented in Table 2.5.2-3. Groundwater PRGs used ARARs for contaminants with promulgated standards, residential 10^{-6} RME HBC for carcinogens without ARARs, and residential RMEs for noncarcinogens without ARARs. CRLs are adopted as PRGs in cases where the ARARs or HBCs are below the CRL. Groundwater PRGs are consistent with the NCP. Additionally, the EPA Office of Solid Waste and Emergency Response (OSWER) Directive 9355.0-30, Role of the

Baseline Risk Assessment in Superfund Remedy Selection Decisions (EPA, 1991) allows for the use of either ARARs or HBC as remediation goals.

2.6 QUANTITIES OF GROUNDWATER REQUIRING REMEDIATION

The area of groundwater requiring remediation in the Offpost OU was calculated. This area was used in the development and screening of alternatives to evaluate the effectiveness, implementability, and cost of groundwater remedial alternatives.

The quantity of groundwater requiring remediation in the Offpost OU was calculated on the basis of PRGs and the extent of contamination as defined by data collected during the Offpost RI, the Offpost RI Addendum, and the CMP (RLSA, 1989; 1990a; 1990b; 1991a; 1991b). PRGs were compared with concentrations for each groundwater COC, taking into account overlapping volumes and areas for COCs.

The plumes of unconfined groundwater contamination exceeding PRGs are shown in Figure 2.6-1. Although not all PRGs for all contaminants are exceeded throughout the areas shown, the plumes shown in the figures represent the area over which at least one contaminant PRG is exceeded for groundwater. Within the areas shown on Figure 2.6-1 PRGs are exceeded for the carcinogens arsenic, chloroform, dibromochloropropane, tetrachloroethylene, trichloroethylene, and dieldrin. PRGs are also exceeded for the noncarcinogens chlorobenzene, dicylcopentadiene, DIMP. The total area of groundwater exceeding PRGs encompasses approximately 590 acres of the Offpost OU.

2.7 GENERAL RESPONSE ACTIONS

General response actions are defined as those actions that will satisfy the RAOs and PRGS described herein. General response actions were developed for each medium and include no action, institutional controls, containment, removal, disposal, and treatment. These response actions may be combined to produce appropriate remedial alternatives.

2.7.1 No Action

The No Action general response action recognizes, although does not incorporate, the substantial interim response actions already implemented. Under the No Action alternative, the current status of the site would not change except by natural attenuation and degradation processes. There would be no further effort to reduce risk to human health and the environment by physical restriction of access to affected areas or by other remedial actions. Operations at the boundary containment systems would cease, and IRA A would not continue. Groundwater monitoring would be used to monitor concentrations of contaminants, the areal extent of contamination, and its migration. A risk assessment would be performed every 5 years, as required by CERCLA Section 121(c).

2.7.2 Institutional Controls

Institutional controls are nonengineering methods by which federal, state, and local governments or private parties can prevent or limit access to affected environmental media. Institutional controls are commonly in the form of deed or access restrictions, but may include actions such as land acquisition, warning signs, zoning controls, well restrictions, property condemnation, provision for alternative water supplies, relocation of potentially affected populations, and biota management.

2.7.3 Containment

Containment response actions provide a means by which contaminant migration and risk associated with exposure pathways are minimized or eliminated by the use of physical and/or hydraulic barriers. Containment reduces or disrupts the mobility of the affected media, consequently reducing the migration of chemicals within the media and the risk associated with exposure pathways. Containment response actions can be implemented both in subsurface (e.g., slurry wall) and aboveground (e.g., soil cover).

2.7.4 Removal

Removal technologies are operations that remove the contaminated media and/or waste from its location onsite. They include extraction and transportation either offsite or to another location onsite for treatment or disposal. Removal may be accomplished by pumping, draining, and excavation.

2.7.5 Treatment

Treatment response actions for liquids or solids reduce or eliminate toxicity, mobility, or volume of a chemical by directly affecting the chemical through an external force that either would alter the structure of the chemical or would bond with, isolate, or completely destroy the chemical. Treatment response actions can be implemented onsite or offsite. Some treatment response actions can be implemented in-situ. SARA recommends that a range of treatment measures be developed and evaluated. The NCP requires that for source control actions, a range of alternatives be developed in which treatment that reduces the toxicity, mobility, or volume of the hazardous substances, pollutants, or contaminants is a principal element. Further, the NCP requires that for groundwater response actions, a limited number of remedial alternatives be developed that achieve site-specific remediation goals within different restoration timeframes utilizing one or more different technologies.

2.7.6 Disposal

When a remedial alternative includes removal or extraction and treatment, a contaminated medium or treatment residuals requiring proper management and disposal are usually produced. Depending on the treatment residuals, several disposal options may be considered. Representative disposal options for solids that require management include onsite land disposal complying with the intent of RCRA, and offsite disposal in a RCRA-approved landfill. Treated solids that no longer exhibit hazardous waste characteristics may be delisted and disposed as nonhazardous solids. Disposal options for treated liquid end products include discharge to surface water,

discharge to publicly owned treatment works (POTW), reinjection/recharge to groundwater, and land application.

2.8 IDENTIFICATION AND SCREENING OF TECHNOLOGY TYPES AND PROCESS OPTIONS

During the process of developing alternatives for remediation for the RMA Offpost OU, it was necessary to identify, evaluate, and screen the universe of potentially applicable technology types and process options. The screening determined which technology types and process options were unable to treat the contaminants present or were incompatible with the site conditions of the Offpost OU, thus eliminating them from further consideration. The screening also determined which technology types were appropriate, thus retaining them for further consideration.

Technology types were defined in accordance with EPA guidelines as general categories of technologies (EPA, 1988b). Examples of technology types include thermal treatment, solidification/stabilization, and chemical treatment. Process options are defined as specific processes, systems, or actions within each technology type. For example, the chemical treatment technology type includes such process options as precipitation, oxidation/reduction, and solvent extraction. Process options are usually combined to generate remedial alternatives. In some instances, a process option may be considered as a remedial alternative by itself if it meets specified RAOs for the affected media.

Technology types and process options were evaluated with respect to remediation of groundwater. Technology types and process options suitable for remediation of soil, surface water, sediment, air, and biota were not identified for the reasons presented in Volume V, Section 2.2.2.

The screening of technology types and process options is a two-step process. Universal screening is the first step and involves the identification of technology types and process options that are technically implementable. A universal list of technology types and process options developed for groundwater is presented in Figure 2.8-1a through e. The second screening step

involves the evaluation and screening of selected or representative process options utilizing three criteria: effectiveness, implementability, and cost.

2.8.1 Universal Screening

A screening of known process options for the technology types discussed in this section is summarized for groundwater in Table 2.8.1-1. Universal screening eliminated process options and technology types that were not technically implementable. The evaluation of technical implementability was based on two criteria. The first criterion is the ability of a process option to be implementable under conditions at the site. This includes conditions such as type of media contaminated, area and volume of contaminated media, depth to bedrock, subsurface geology, and subsurface hydraulic characteristics. The second criterion is the ability of the process option to be effective for reducing the mobility, toxicity, or volume of the specific contaminants present in the affected medium. These two criteria use information obtained during the Offpost RI, Offpost RI Addendum, and CMP on contaminant types, concentrations, and site characteristics. A summary of the process options remaining after the universal screening for groundwater is presented in Figure 2.7.1-1a through e.

2.8.2 Evaluation and Screening of Selected Process Options

In Sections 2.8.3 and 2.8.4, each applicable process option retained for further consideration from the universal screening is described and is further screened. The purpose of this screening is to select one RPO from each technology type (Section 2.10). The RPO will then be used in the assembly, development, and screening of remedial alternatives. In some cases, two or more RPOs within the same technology type may be different enough with respect to performance or effect that more than one option may be selected within a technology type to ensure proper representativeness. In other cases, an entire technology type may be eliminated after further examination. The basis for screening of the process options consists of the following three criteria:

1. Effectiveness

   - The potential effectiveness of process options in treating the estimated areas or volumes of media and meeting the cleanup goals defined in the RAOs

- The effectiveness of the process option in protecting human health and the environment during the construction and implementation phase
- The reliability of the process with respect to the contaminants and site conditions

2. Implementability
   - The ability to obtain permits for offsite actions
   - The availability of treatment, storage, and disposal services
   - The availability of skilled workers and equipment

3. Cost
   - Relative capital costs within technology types (high, medium, or low)
   - Relative operation and maintenance (O&M) costs within technology types (high, medium, or low)

Also, treatment process options are only retained if they are effective as a primary treatment process. Process options that may act only as a pretreatment process are not retained for further consideration but may be used in the final remedy.

2.8.3 Nonmedia-specific Process Options

2.8.3.1 No Action

The No Action option will be carried through the FS primarily as a baseline for comparison. Under this option, no additional remedial action would be performed within the Offpost OU to reduce the toxicity, mobility, or volume of contaminants. It is assumed that the NBCS and NWBCS containment and treatment systems would cease operation and IRA A would not continue. Natural attenuation would occur, resulting in a reduction in measurable contaminant levels over time. Defining the degree of natural attenuation and the length of time required to achieve the cleanup goals with certainty is not possible because there are no data corresponding to the non-operation of the boundary containment systems. However, contaminant concentrations would be monitored by continuation of groundwater and surface-water monitoring.

2.8.3.2 Institutional Controls

With respect to the protectiveness and risk-reduction considerations of the three identified evaluation criteria, institutional control options do not directly reduce the toxicity, mobility, or volume of the affected media. Institutional controls serve, in effect, as a barrier or exposure pathway interruption to minimize or eliminate direct human contact with groundwater at the site. Thus, they are effective in mitigating the risks from potential exposures associated with future-use scenarios.

Although institutional controls by themselves may not be completely effective in addressing the intent of CERCLA as amended by SARA, they can be instrumental in maintaining the integrity of any "action" alternative selected and will, therefore, be retained in combination with other process options for further evaluation during the development of alternatives.

2.8.3.2.1 Access Restrictions

Access restrictions provide a means to minimize or eliminate direct human contact with affected media and include land use/deed restrictions, fencing and warning signs, and land acquisition.

Land Use/Deed Restrictions

A deed restriction is a written and recorded document, usually kept on file in the county recorder's office. A deed restriction may contain a number of restrictions primarily related to activity on a particular property, including surface and subsurface activities, such as prohibiting subsurface foundation construction and domestic well installations.

Fencing and Warning Signs

Fencing and warning signs are self-explanatory. When fences are constructed properly and are adequately maintained, they act as an effective deterrent to public access to a contaminated area. Fences may also limit exposure of certain wildlife to a contaminated area. Implementation of fencing may require acquisition of property on portions of the Offpost OU. Warning signs,

alone and combined with fencing, can reduce the likelihood of human exposure to contaminated media.

Land Acquisition

Acquisition of property in the Offpost OU may be necessary to implement remedial actions. Land may be acquired for construction of treatment plants, providing pipeline right-of-way for pump-back to treatment facilities, or to reduce risk by implementing access/deed restrictions and exposure control options. Property would be purchased from land owners at a rate dependent on the current market value.

2.8.3.2.2 Alternative Water Supplies

Providing alternative water supplies to residents whose potable water supply has been affected by offpost contamination is a means of eliminating risk associated with use of the contaminated water. A short-term alternate water supply would include bottled water, and long-term alternate water supply options would entail either connection to South Adams County Water District's (SACWD's) municipal potable water distribution system, formation of water districts using groundwater from an uncontaminated aquifer, or provision of a private well completed in an uncontaminated aquifer. The Army has committed to providing an alternate water supply to future identified users whose wells exceed PRGs.

2.8.3.2.3 Monitoring

Monitoring consists of a specified data-collection activity designed to provide information concerning ongoing site conditions in specified media for use in decision making.

A monitoring program is an effective measure to track contaminant migration and evaluate remediation effects. Monitoring was implemented during the CMP and the Offpost RI and RI Addendum programs.

2.8.4 Groundwater Process Options

2.8.4.1 Removal

Removal refers to the extraction of contaminated and uncontaminated media. Removal may serve the purpose of mass removal of contaminants or be incorporated as part of a containment system. Removal process options for groundwater include pumping of well points, extraction wells, and/or subsurface drains, and may include water-flushing technologies for the enhancement of contaminant removal.

2.8.4.1.1 Groundwater Extraction

Groundwater extraction can consist of well points, extraction wells, and subsurface drains. Descriptions of these process options follow.

Well Points

Well-point systems are typically used for extraction of shallow groundwater in unstratified soil. Well-point systems are constructed by manifolding a group of closely spaced wells to a header pipe. Groundwater is removed using a suction pump. The primary disadvantages to well-point systems are the limited depth from which they can effectively extract groundwater and the limited flow rates achievable. The practical limit for the use of suction lift well points is about 22 feet (EPA, 1985). Most of the Offpost OU requiring groundwater remediation would require pumping at heads in excess of 22 feet.

Because well points are not effective for groundwater removal over most of the Offpost OU, well points are eliminated from further consideration.

Extraction Wells

Extraction wells may be used to remove affected groundwater (and hence chemical mass) from the groundwater flow system. The purposes of extraction wells include removal of water for treatment, gradient control for the purpose of plume containment, and increasing groundwater flux rates through the subsurface to enhance the rate of chemical mass removal. Extraction well arrays are often combined with subsurface injection to enhance cleanup by flushing clean water

through the aquifer. In relatively high-permeability materials, the areas of extraction and recharge can be laterally separated. If properly designed, such a system will achieve both containment and mass removal. In materials with lower permeability, extraction and injection wells may have to be interspersed in a grid pattern to reduce the distances between points of extraction and injection.

Extraction wells are more flexible than well-point systems because they can remove water from any depth. Extraction wells were chosen as a process option for removal of contaminated groundwater on the Offpost OU at Offpost IRA and are used onpost in association with the NWBCS, NBCS, and ICS containment and treatment systems.

Extraction wells will be retained for further consideration for the following reasons: (1) their utility in mass removal, pump and treat, and containment alternatives, (2) the conventional nature of their installation and ease of operation, and (3) their proven effectiveness at many hazardous waste sites, including RMA.

Subsurface Drains

Subsurface drains consist of linear structures having enhanced permeability that are designed to increase the efficiency of groundwater collection. They may be used for both containment and mass removal activities. For example, slurry wall containment systems often incorporate a subsurface drain to aid in containing migrating contaminants in shallow groundwater while providing mass removal before treatment. Drains can be constructed by excavating a trench below the water table and then backfilling the excavation with permeable granular material, which acts as a filter. In indurated materials, a drain may also be constructed with controlled blasting, which creates a linear rubble zone of enhanced permeability. In any case, groundwater is extracted from the drain by a limited number of sumps, which may be constructed as the drain is built or may consist of wells drilled into the drain. Subsurface drains are often the most efficient extraction system in low hydraulic conductivity soil.

Three types of subsurface drains include French/tile drains, dual-media drains, and trench/gallery drains. French/tile drains incorporate a section of perforated pipe placed in the

trench and surrounded by permeable fill. Dual-media drains are identical to French/tile drains except that a geotextile material is added to reduce clogging of the drain by fine particles. Trench or gallery drains are similar to French/tile drains, but are configured as a radial group of trenches that discharge into a common sump or gallery.

Because of the effectiveness of subsurface drains in extraction and containment systems and because they are a conventional readily implementable process option, subsurface drains are retained for further consideration.

Water Flushing

Water flushing can potentially enhance removal of contaminants by increasing the number of pore volumes of water flowing through a contaminated aquifer per unit time. Water flushing process options include injection and flooding/infiltration. Description of these process options follows:

- Injection

  Injection is a process option that flushes uncontaminated water into the subsurface using either recharge wells or trenches. The process stimulates groundwater flow by increasing the hydraulic gradient in the vicinity of the injection system and aids the removal of adsorbed contaminants by increasing the number of pore volumes of clean water flushed through the aquifer and/or the vadose zone in a given time interval. Water typically is extracted downgradient and treated before reinjection.

  Injection serves the dual purpose as a means of effectively enhancing contaminant removal and a method of disposing of treated water. Injection wells and trenches were implemented as part of the onpost boundary containment and treatment systems and will be used for the implementation of Offpost IRA. The injection systems onpost were used for disposal of treated groundwater; they were not used in flushing operations. Onpost injection systems have proved to be readily implementable. The effectiveness of flushing operations for organic contaminants similar to many of the contaminants in Offpost OU groundwater has been demonstrated at hazardous waste sites; therefore, injection is retained for further consideration.

- Flooding/Infiltration

  Flooding and infiltration are process options that use uncontaminated water applied at the ground surface by ponding or flooding to flush the vadose zone and the aquifer. This stimulates groundwater flow by increasing the hydraulic gradient in the vicinity of the injection and facilitates the removal of adsorbed contaminants by increasing the number of pore volumes of clean water flushed through the contaminated media in a given time interval. Water typically is extracted downgradient and treated before surface application.

Flooding and infiltration serve the same purpose as injection but have the disadvantages of requiring larger surface areas and losing water to evaporation. Also, during winter, freezing may be a problem. The advantage of using flooding or infiltration over injection is that percolating water through large areas of the vadose zone effectively remediates the vadose zone soil. However, the vadose zone in the Offpost OU is not a source of groundwater contamination and is not contaminated. Therefore, because of the large area requirements for flooding/infiltration and the lack of any additional benefits over injection, flooding and infiltration are eliminated from further consideration.

2.8.4.2 Disposal

Disposal of groundwater involves technologies that represent the final disposition of either contaminated or treated water. Disposal is divided into subsurface disposal and aboveground discharge technology types.

2.8.4.2.1 Subsurface Disposal

The subsurface disposal process options, including pump-back to boundary containment systems, deep well injection, and shallow aquifer recharge, are discussed in the following paragraphs.

Pump-back to Boundary Containment Systems

Pumping groundwater to the onpost boundary containment and treatment systems is an effective disposal process option. Contaminated groundwater would be extracted and pumped to either the NWBCS or NBCS facilities. The water would be treated by the facility along with extracted onpost water. Implementation of this process would require coordination with the facility operations and may require treatment facility expansion and additional recharge systems. Land acquisition may also be required to provide pipeline right-of-way. Water rights implications also require consideration.

The pump-back process option is effective and potentially implementable; therefore, this process is retained for further consideration.

Deep-Well Injection

The deep-well injection process option includes both onsite deep injection and transport to an offsite permitted deep-well injection facility. Deep-well injection involves pumping the

contaminated water into a deep hydraulically isolated formation under sufficient pressure to displace native fluids while avoiding excessive migration of the waste and fracturing of the formation. The formation should not have value as a resource.

Deep-well injection of treated water is not appropriate because risks associated with exposure to treated water are acceptable for unrestricted use. Therefore, treated water should be disposed in a manner that allows for future use (which is not the case for deep-well injection).

Under appropriate geologic conditions, deep-well injection is an effective process for disposing contaminated groundwater. However, both offsite and onsite injection are not implementable for the following reasons:

- Onsite deep-well injection
  - Past onpost deep-well injection activities may have induced earthquake activity.
  - Agency approval is difficult to obtain.
- Offsite deep-well injection at a permitted treatment, storage, and disposal (TSD) facility
  - It is not practical to transport large volumes of contaminated groundwater.
  - Water rights may require replacement of extracted groundwater.

Shallow-Aquifer Recharge

Recharge wells and trenches are process options for shallow aquifer disposal of treated or contaminated water. Recharge wells and trenches may provide for containment of contaminated groundwater and water flushing of contaminants. Recharge wells are constructed in essentially the same manner as extraction wells with the exception that treated groundwater is recharged into the aquifer. Treated groundwater is recharged by a gravity-induced head. Spacing of recharge wells is dependent on the hydraulic properties of the aquifer and the specific application such as gradient control. Recharge trenches vary in width depending on the construction method. Recharge trenches are commonly constructed using either of two methods:

- A one-pass trenching machine that installs pipe and installs fill in one operation
- Conventional trenching using a biopolymer slurry below the water table to stabilize the walls

Trenches are backfilled with drain rock up to a depth of 18 inches below ground surface. A slotted pipe is installed within the drain rock throughout the length of the trench. Treated groundwater is pumped into the trench via the perforated pipe and recharges through the drain rock into the aquifer.

Shallow-aquifer recharge of contaminated groundwater is not effective in reducing the mobility, toxicity, or volume of contamination and may increase the mobility and volume of contaminated media. Therefore, shallow-aquifer recharge of contaminated water is eliminated from further consideration.

Shallow-aquifer recharge provides an effective means of returning treated groundwater to the aquifer.

Recharge of treated groundwater into the UFS was implemented at the NBCS, NWBCS, and ICS. Also, recharge of treated water was selected as the method of disposal for Offpost IRA (HLA, 1989). Recharge of treated water into the shallow aquifer is readily implementable and effective. Replacing the extracted contaminated water with treated water aids in the reclamation of the site.

Because of its effectiveness and ease of implementation, recharge of treated groundwater into the shallow aquifer is retained for further consideration.

2.8.4.2.2 Aboveground Discharge

Three process options representing aboveground discharge, including discharge to POTW, discharge to surface water, and infiltration basins, are discussed in the following paragraphs.

Discharge to Publicly Owned Treatment Works

Discharge to a POTW is an effective process for disposing contaminated groundwater or treated groundwater. The implementability of discharging to a POTW is governed by numerous factors that include the proximity to a sanitary sewer line, the capacity of the sewer line and the treatment facility and pretreatment requirements.

Discharge of contaminated water to a POTW is eliminated from further consideration for the following reasons: (1) the water would not meet pretreatment requirements, and nonregulated compounds may interfere with operations at the treatment facility and (2) water rights may require replacement of extracted groundwater. Discharge of treated water to a POTW is retained as a potential means of disposal, recognizing that POTW capacity limitations are yet to be determined.

Discharge to Surface Water

Discharge of contaminated groundwater to a surface-water body is not implementable or effective for the following reasons: (1) the process is not implementable because contaminated water would not meet the requirements specified by the Clean Water Act; (2) the process is ineffective because it does not significantly reduce the mobility, toxicity, or volume of contamination; (3) discharge to surface water would likely contaminate the water body, the biota that use the water body, and the sediments within the water body; (4) there is a possibility of a fugitive emissions problem from volatile organic compounds; and (5) public and agency acceptance are unlikely. Therefore, discharge of contaminated groundwater to a surface-water body is eliminated from further consideration.

Discharge of treated groundwater to a surface-water body is an effective means of disposal. However, difficulties in implementing surface-water discharge of treated water arise from the impacts of increased water flow on the receiving water body. It has not yet been determined whether this difficulty would affect the implementation of discharging to surface water.

The discharge of treated groundwater to surface water is eliminated from further consideration.

Infiltration Basins

Disposal to infiltration basins involves the discharge of contaminated or treated groundwater into a man-made basin or natural surface depression.

Discharge of contaminated groundwater into an infiltration basin is not only a disposal option but can act as a form of land treatment. Contaminated groundwater may undergo limited remediation/treatment via three mechanisms when it is discharged into an infiltration basin: volatilization, adsorption, and biodegradation. Discharging contaminated water into an infiltration basin is difficult to implement for the following reasons: (1) there may be fugitive emissions from the volatilization of organic compounds, (2) although the infiltrating water may be treated, the effectiveness in reducing the concentration of COCs is limited, and (3) because of the limited effectiveness of the process option there may be an associated increase the volume of contaminated media to include the subsurface soil and groundwater adjacent to the infiltration basin. Therefore, disposal of contaminated groundwater via discharge into infiltration basins is eliminated from further consideration.

Discharge of treated groundwater into infiltration basins has the following implementation problems: (1) surface area required, (2) freezing during the winter, and (3) losses to evaporation during summer. Because of difficulties in implementation and effectiveness considerations, discharge of treated groundwater into infiltration basins is eliminated from further consideration.

2.8.4.3 In-vessel Treatment of Groundwater

In-vessel treatment refers to those technology types and process options that are implemented in constructed facilities after removal of the contaminated groundwater. Groundwater extracted by wells or drains would require treatment to specific cleanup levels before discharge to surface streams or reinjection to the aquifer.

2.8.4.3.1 Solids Removal

Removal of solids from a waste stream is a necessary pretreatment step for many downstream process options. Also, solids can cause accelerated wear on pumps and can form excessive heavy deposits in pipelines. Solids can cause premature fouling of membrane systems and rapid head loss in carbon adsorption columns and can reduce the efficiency of ion exchange units.

Solids removal process options that were retained from the universal screening process are discussed in the following paragraphs.

Filtration

Filtration is typically used for the removal of suspended solids. Filtration is often appropriate as a pretreatment process for carbon adsorption and membrane processes to prevent plugging or overloading problems. Also, filtration can be used for the removal of flocs formed during precipitation and coagulation/flocculation. Two common types of filters are granular media and bag filters.

Granular media filters usually contain the filter media within a vessel supported by an underdrain system. Commonly used filter media include sand and anthracite coal. Single or multimedia filters can be used, depending on the specific application. Filters are backwashed based on two criteria: breakthrough of suspended solids and/or significant head loss caused by excessive pore clogging.

Bag filters consist of filter bags supported by perforated steel baskets and are sealed in a metal housing. The bag material acts as the filtration medium. Standard bag materials include nylon, polyester, and polypropylene. Bags can be removed and replaced when pressure drop across the bags exceeds design limitations.

Filtration is not expected to be required as a primary treatment process and is not retained for consideration during the development of alternatives, but may be implemented as a pretreatment process option.

Sedimentation

Sedimentation is a process option that uses gravity to settle suspended solids out of an aqueous waste stream. Sedimentation may be implemented in the form of settling ponds, sedimentation basins, and clarifiers. Sedimentation is often used as a pretreatment step for carbon adsorption, stripping, membrane processes, and filtration. Suspended solids removal is not expected to be required as a primary treatment process for extracted groundwater. Therefore,

sedimentation is eliminated from further consideration but may be implemented as a pretreatment process option.

2.8.4.3.2 Phase Transfer

Phase transfer process options remediate contaminated aqueous media by enhancing mass transfer of contaminants from the liquid to the gaseous phase. Phase transfer process options retained in the universal screening include air stripping, steam stripping, and steam distillation. A discussion of these process options follows.

Air Stripping

Air stripping is an effective and reliable method for removing volatile organic compounds (VOCs) from aqueous waste streams. Of the COCs detected in the Offpost OU groundwater samples, chloroform is the most likely candidate for air stripping.

The most common air stripping method involves mixing large volumes of air with contaminated water in a packed-tower arrangement to promote transfer of the VOCs from the liquid phase to the gas phase. In packed-tower aeration, loosely packed material is placed within a vertical cylindrical tower. Water cascading through the packing breaks into small droplets, providing a large surface area to enhance mass transfer. Air forced upward through the packing from the tower base promotes the transfer of VOCs from the water phase to air phase. Depending on the compound stripped and its concentration, the contaminated air stream may require treatment.

Air stripping is retained for further evaluation during the development of alternatives because air stripping is a proven technology demonstrated to be effective for the removal of VOCs at hazardous waste sites.

Steam Stripping

Steam stripping removes VOCs and semi-volatile organic compounds (SVOCs) using the same principles as air stripping, except steam is used to raise the water temperature and, thereby, enhance organic contaminant volatilization. This process is more effective in removing organic

compounds with smaller Henry's Law constants than conventional air stripping, but requires a greater capital cost and higher O&M costs including construction of a steam-generating plant. Although steam stripping has the additional benefit over air stripping of removing SVOCs, carbon adsorption should also be effective in removing these compounds. Also, stream stripping is much more difficult to implement and is costlier than air stripping because of the required construction of a stream-generation facility. Steam stripping is eliminated from further consideration because of difficulties of implementation and increased cost as compared to technologies with similar effectiveness.

Steam Distillation

Steam distillation is a separation and recovery process consisting of evaporation followed by condensation. The process effectively concentrates inorganic compounds into the blowdown waste stream, thereby reducing the volume of heavy metals and other inorganic-containing liquids in the treated stream. VOCs and SVOCs are vaporized with the water and are recovered during condensation. If the system is designed appropriately, organic contaminants can be separated from the treated stream and recovered.

Components of a distillation system include a steam-production unit, a still, a condenser, and a product cooler and receiver. Blowdown water and still-bottom residues are recovered and treated.

Distillation units have low to moderate capital costs but have high O&M costs. The primary potential application for distillation at the site would be to separate organics from the waste stream. Because of the high cost of operating and maintaining a distillation unit and the availability of other processes with equal effectiveness for removal of organics, distillation is eliminated from further consideration.

2.8.4.3.3 Sorption

Sorption is a treatment technology type that includes process options that remove contaminants from the liquid phase by concentration onto a solid phase by adsorption and/or

absorption. Sorption process options retained in the universal screening were granular activated carbon adsorption and resin adsorption. These process options are discussed in the following paragraphs.

Granulated Activated Carbon (GAC) Adsorption

Activated carbon is a well-developed technology widely used in removal of organic contaminants from liquid hazardous waste streams and offgas airstreams. The waste stream comes in contact with GAC by flowing through one or more packed-bed reactors. Organics and, to some degree, inorganics are adsorbed onto the internal pores of the carbon granules by surface-attractive phenomena.

Activated carbon is generally used in granular form either in fixed-bed batch, pressure, or gravity vessels, or in fluidized-bed operations. Fixed-bed columns are the most common treatment configuration. Occasionally, activated carbon is used in powdered form. Primary design considerations for activated carbon include column configuration and loading rate, column size, carbon usage rate, and a spent-carbon handling program (i.e., regeneration or disposal). Activated carbon removes many nondegradable organic compounds and is most effective for nonpolar, high molecular weight, slightly soluble compounds.

Carbon adsorption is readily implementable. Carbon adsorption is a demonstrated, proven technology documented to be effective at the NWBCS, NBCS, and ICS systems onpost for removing DIMP, dieldrin, and dibromochloropropane. Carbon adsorption was chosen as the process option for treatment of offpost contaminated groundwater at Offpost IRA. Because of its proven effectiveness for removing RMA contaminants and its ease of implementation, carbon treatment is retained for further consideration.

Resin Adsorption

Resin adsorption is a process option that removes organic compounds from aqueous waste streams by adsorption onto a synthetic resin. Resin adsorption is similar to GAC adsorption except that resin beads act as the adsorbing medium instead of carbon. Adsorption resins are

more selective in removal of contaminants than carbon. Thus, specific resins must be chosen for effective removal of target compounds.

Resin adsorption is usually accomplished in a downflow, fixed-bed, stainless-steel or rubber-lined column. Resin performance is sensitive to suspended solids load and pH and may be damaged by oxidizing agents. Therefore, resin adsorption columns typically require pretreatment of the waste stream. After the resin adsorption capacity is exhausted, the bed is regenerated with an appropriate solvent. The regenerant solution requires subsequent treatment with potential for recovery of the contaminants.

Resin adsorption is a relatively new process primarily used in industrial applications for single-component waste streams and has limited demonstration in treatment at hazardous waste sites. Difficulties in implementation arise from limited experience and the fact that numerous resins may be required to remove all target organic compounds. Therefore, resin adsorption is eliminated from further consideration.

2.8.4.3.4 Oxidation

Oxidation is a chemical treatment technology type that uses chemical reagents (i.e., oxidizing agents such as chlorine, ozone, hydrogen peroxide) for detoxification of waste streams. Oxidation process options retained in the universal screening process include ozone oxidation, hydrogen peroxide oxidation, and ultraviolet (UV) light/ozone/hydrogen peroxide oxidation. These process options are discussed below.

Ozone Oxidation

Ozone is a strong oxidizing agent used for disinfection, purification, odor control, and micro-flocculation in the treatment of drinking water. Ozone has also been shown to oxidize organics in hazardous waste streams, but generally requires large doses and long reaction times to be effective for complete oxidation of chlorinated organics.

Ozone treatment systems typically consist of an ozone generator, a reactor where the gas is bubbled through the contaminated water in a contact chamber, and an offgas collection and

treatment system for handling unreacted residual ozone and VOC emissions. Incomplete oxidation byproducts produced during the reaction must be monitored and may require subsequent treatment. Based on its limited effectiveness in treating hazardous organics and implementation difficulties (e.g., offgas treatment requirements), ozone oxidation is eliminated from further consideration.

Hydrogen Peroxide Oxidation

Hydrogen peroxide is a moderately strong oxidizing agent commonly used in industrial applications. Hydrogen peroxide has been used to degrade many organic pollutants, but often generates toxic, incomplete oxidation byproducts.

Hydrogen peroxide treatment systems consist of a rapid-mix oxidizing solution addition system followed by a reaction vessel. Batch or continuous flow reactors can be used. Hydrogen peroxide dose and reactor retention time vary depending on the nature of the waste stream and the target compound's resistance to oxidation. Because of the nonspecific nature of hydrogen peroxide as an oxidizing agent, other contaminants (organic and inorganic) can reduce the effectiveness of removing the target compounds.

Hydrogen peroxide can be effective in the oxidation of hazardous waste streams but typically requires very large doses and long contact times to achieve high removal efficiencies. Oxidation byproducts may be toxic and the waste stream may require further treatment. For these reasons, hydrogen peroxide oxidation is eliminated from further consideration.

Ultraviolet Light/Ozone/Hydrogen Peroxide (Advanced Oxidation Processes)

Chemical oxidation using oxidizing agents with UV light and/or catalysts to increase process effectiveness are referred to as advanced oxidation processes (AOP).

Oxidizing agents used in AOP include ozone and hydrogen peroxide. UV light acts as a catalyst in the oxidation process and promotes the formation of the hydroxyl radical, which is a strong oxidizing agent. Also, UV light destroys organic compounds via photolysis. Other potential catalysts used are ferrous iron, platinum, copper, tungsten, and nickel. Oxidation

efficiency and kinetics may be pH-dependent, and may require pH adjustment to achieve optimum destruction efficiency.

The UV-peroxide treatment process is a combination of hydrogen peroxide and UV light that induces rapid photochemical oxidation of organic compounds. A UV-peroxide system includes a hydrogen peroxide feed system and a UV-peroxide reactor. Some systems combine ozone and hydrogen peroxide in the UV-oxidant reactor to increase organic destruction efficiency. Other systems use ozone in place of hydrogen peroxide, and some systems may include acid and catalyst addition to maximize destruction efficiency. In general, catalysis dramatically increases the destruction efficiency of both hydrogen peroxide and ozone. This increased efficiency leads to shorter retention time requirements, generally more complete oxidation, and fewer problems with oxidation byproducts.

AOP have been demonstrated at hazardous waste sites to be effective for removal of some chlorinated organics (EPA, 1989c). The organic constituents in the offpost groundwater that may be effectively treated by AOP include OCPs and DIMP. Therefore, AOP are retained for further consideration.

2.8.4.3.5 Radiation

Radiation treatment process options use electromagnetic energy for the destruction of contaminants in waste streams. Process options retained in the universal screening process include electron beam and gamma irradiation. These process options are discussed below.

Electron Beam

The electron beam irradiation process uses high-energy beta particles (electrons) for the destruction of hazardous waste constituents. The process can treat both aqueous waste streams and sludges. Electron beam irradiation has been used for full-scale treatment of municipal wastewater and sludges but has had limited use in hazardous waste treatment.

Process equipment required for an electron beam irradiation system includes an electron accelerator and a reactor into which the beam is directed. The electrons enter the waste stream

and ionize the water, producing aqueous electrons and hydrogen and hydroxyl radicals. These species react with the organics in the waste stream. This process has been shown to remove significant amounts of organic compounds in water; chloroform, benzene, and trichloroethylene have shown reductions ranging from 50 to near 100 percent where initial concentrations ranged from 400 to 1500 micrograms per liter.

Although the electron beam irradiation process has been demonstrated to be effective for removal of compounds contained in Offpost OU groundwater, the process is very difficult to implement. The electron accelerator has very high capital costs and requires specially trained personnel for operation. Also, the process has not been demonstrated at full scale for hazardous waste treatment. Therefore, the electron beam irradiation process is eliminated from further consideration.

Gamma Irradiation

Gamma irradiation is similar to electron beam irradiation with the exception that gamma particles are directed at the waste stream. Gamma particles have the advantage of much greater penetration depths than beta particles; however, this also requires more shielding for the reactor. This process has been used for sewage treatment but has less demonstration history than electron beam irradiation. Because of similar implementation difficulties in comparison with the electron beam process, gamma irradiation is eliminated from further consideration.

2.8.4.3.6 Biological Treatment

Biological degradation of hazardous organic substances can be accomplished by using aerobic bacteria or anaerobic bacteria. Cultures used in biological degradation processes can be indigenous microbes, selectively adapted microbes, or genetically altered microorganisms.

Biological degradation occurs when microbes use (i.e., metabolize) organic compounds (substrates) as a source of carbon and energy. Organic compounds are metabolized in the presence of enzymes produced by the microorganisms that act as catalysts. Production of enzymes can be induced by the presence of a primary substrate (i.e., can act as sole source of carbon) or by

conditions within the cell (e.g., low concentrations of adenosine triphosphate [ATP]). Hazardous waste organics can be degraded as a primary substrate or by cometabolism when enzymes are produced because of the presence of another primary substrate. Complete mineralization degrades the organic compounds to carbon dioxide and water. However, hazardous waste organic compounds may be only partially degraded. Partial degradation products may be toxic and require further treatment or may be used and further degraded by other microbial species present.

Biological hazardous waste treatment may occur in batch or continuous flow systems. The microbial population can be suspended or attached. Aerobic and anaerobic environment treatment technologies exist. The appropriate reactor configuration and environment depend on the waste stream to be treated.

Biological treatment is eliminated from further consideration for the following reasons:

- The concentration of organic compounds in Offpost OU groundwater is too low to sustain a significant microbial population and would require substrate addition to implement in-vessel biological treatment.
- Studies have shown that DIMP is not measurably degraded after 12 weeks of incubation even when conditions favoring cometabolism are promoted (EPA, 1989c)
- Dieldrin is very recalcitrant to biodegradation.

This eliminates the following process options: rotating biologic contractors (RBCs), activated sludge, PACT®, sequencing batch reactors, trickling filters, anaerobic digesters, and submerged fixed film reactors.

2.8.4.4 In Situ Treatment

In-situ treatment refers to technology types and process options designed to remediate the contaminated medium while it remains in place.

2.8.4.4.1 Water Flushing

The water flushing process option is an extraction process that uses liquid as a solvent to increase the rate of contaminant removal in the subsurface. Treated water is a commonly used flushing solution and was discussed as a removal process option in Section 2.8.4.1.1.

Water flushing acts as a treatment process because it reduces contamination in groundwater by enhancing the removal of contaminants. In some cases, chemicals can be added to the flushing solution to enhance the removal of contaminants. These chemicals include organic solvents, chelating agents, and surfactants.

Water flushing solutions can be actively injected into the subsurface in wells and trenches or can passively infiltrate through infiltration basins.

Water flushing is an effective, readily implementable process that may be incorporated in addition to other process options. Therefore, water flushing is retained for further consideration.

2.8.4.4.2 Enhanced Biological Treatment

Biological treatment is a technology used to remediate the zone of contamination by microbial degradation. Microbial degradation can be either aerobic or anaerobic. In general, most compounds are more rapidly and completely degraded aerobically. In-situ anaerobic biological treatment is not a well-developed process option. Anaerobic environments are difficult to maintain in large in-situ applications. Therefore, anaerobic biological treatment is eliminated from further consideration.

The feasibility of aerobic bioreclamation depends on numerous factors, which include biodegradability of the organic contaminants and environmental factors such as pH, temperature, redox conditions, and site hydrology. Bioreclamation may be enhanced by the addition of nutrients (e.g., nitrogen, phosphorus, and sulphur) and/or addition of an oxygen source such as air or hydrogen peroxide. Contaminants of interest can act as the sole carbon source/substrate, or an appropriate substrate can be added to stimulate cometabolic degradation. Appropriate microorganisms can also be injected into the contaminated media to enhance degradation. Evidence indicates that both DIMP and dieldrin are very resistant to degradation by biological processes (Khanna, 1989). Therefore, in-situ biological treatment is eliminated from further consideration.

2.8.4.5 Containment

Affected groundwater may be remediated by the processes of groundwater containment. Containment is achieved by minimizing the rate of chemical migration away from source areas. Depending on site conditions, containment may be achieved by the use of subsurface barriers, which include physical barriers and/or hydraulic barriers/gradient control (i.e., groundwater pumping).

2.8.4.5.1 Subsurface Barriers

Subsurface barriers include process options that prevent or reduce the migration of contaminants either by emplacement of a physical barrier in the subsurface or by controlling the hydraulic gradient. Process options retained in the universal screening include slurry walls, grout curtains, hydraulic controls, and subsurface dams. Discussion of these process options follows.

Slurry Wall

Slurry walls are physical subsurface barriers typically constructed of a mixture of water and soil, bentonite, and/or cement. Upgradient extraction systems are commonly used with slurry walls to prevent contaminant bypass. Slurry walls are constructed by excavation of a trench. The water-bentonite-soil slurry is mixed onsite and continuously added to the trench during excavation. Appropriate mixing ratios are determined by compatibility and permeability testing with groundwater at the site. Target slurry wall permeability is typically less than 10^{-7} cm/sec. Commonly used equipment includes backhoes, clam shells, loaders, and haul trucks. The trench may be excavated into bedrock in order to "key" the slurry wall into a layer of lower permeability. Slurry walls not keyed into bedrock are known as hanging slurry walls. Slurry walls have already been implemented onpost in association with the NBCS and NWBCS.

Because of documented effectiveness onpost and ease of implementation, slurry walls are retained for further consideration.

Grout Curtains

Grout curtains are subsurface barriers constructed by pressure injection of one of a variety of fluids into unconsolidated material. The grout sets after injection and forms a low-permeability barrier to groundwater flow and contaminant migration.

Grout curtains are constructed by pressure injection of a predetermined amount of grouting fluid into the strata to be sealed. Injection points are usually arranged in a triple line of primary and secondary grout holes. After primary holes have been injected and the grout has had time to solidify, the secondary holes are injected to fill any gaps left by the primary holes. Hole spacing is primarily dependent on the nature of the material into which the grout is being injected.

Various types of grout are available including cement, clay (e.g., kaolinite, illite), clay-cement mixtures, bentonite, alkali silicates, and organic polymer grouts. Selection of grout type is based on soil grain size and compatibility with contaminants present.

Grout curtains can have setting and durability problems in contaminated groundwater. Compatibility testing between the contaminants and the grouting fluid is often required. Grout curtains are typically more costly and more permeable than slurry walls. Therefore, grout curtains are eliminated from further consideration.

Hydraulic Gradient Control

Containment of affected groundwater may be achieved by modifying the hydraulic gradients driving groundwater flow, thus achieving a hydraulic barrier to contaminant migration via groundwater. Hydraulic gradients may be reduced or reversed by controlled groundwater extraction and/or injection. Extraction is typically achieved using extraction wells within or near a chemical source area. Recharge systems using groundwater injection wells are typically installed downgradient of a source area. Wells (rather than drains) are preferred for gradient control because extraction/recharge pumping rates can be individually controlled at each well location. Although gradient control by groundwater extraction may involve some removal of chemical mass, the primary purpose of the system is to contain, rather than remove, mass.

Hydraulic gradient control was chosen as the appropriate process option for groundwater extraction and containment of contaminants for IRA A (HLA, 1991b). In addition, hydraulic controls were implemented onpost as part of the NBCS, NWBCS, and ICS. Therefore, because of demonstrated effectiveness and ease of implementation, hydraulic gradient control is retained as a process option.

Subsurface Dam

The subsurface dam process option is a subsurface barrier technology constructed by backfilling an excavated trench with compacted clay.

Subsurface dams are potentially one of the most effective barriers to groundwater flow, but are difficult to implement. Difficulties arise from site conditions that include deep excavation in unconsolidated material, sidewall instability in unconsolidated materials, and large groundwater inflows during excavation and construction. Subsurface dams are much more costly to install than slurry walls. Therefore, because of difficulties in implementation and cost considerations, subsurface dams are eliminated from further consideration.

2.9 SUMMARY OF PROCESS OPTION SCREENING

A summary of the process option screening for groundwater is presented in Figure 2.9-1a through c. Process options that were eliminated were screened out on the basis of uncertainties with respect to effectiveness, difficulties associated with implementation, and excessive cost with respect to other effective and implementable process options. Figure 2.9-1a through c indicates those technologies that were retained and those that were eliminated (i.e., shaded process options were eliminated) for groundwater.

2.10 SELECTION OF REPRESENTATIVE PROCESS OPTIONS

Upon completion of the evaluation and screening of process options (Section 2.8) a representative process option (RPO) was selected for each technology type retained for consideration. One RPO was selected, if possible, for each technology type to simplify the subsequent development and evaluation of alternatives without limiting flexibility during remedial design. The process

option determined to be the most effective and most implementable within a technology type was selected as the RPO. A process option that was effective for all of the contaminants present was selected as the RPO. Process options that have been demonstrated at pilot- or full-scale were generally selected instead of emerging processes with little or no performance or cost data available. Innovative technology process options were selected if evaluation indicated that they may provide better treatment, fewer or less adverse effects, or lower costs than other process options. Cost was used as the criterion to select an RPO in cases where the effectiveness and implementability of two or more process options were equivalent. Selected RPOs were used to develop, screen, and perform a detailed analysis of remedial alternatives.

In some cases, varying conditions across the site make selection of a single RPO for a technology type inappropriate. For example, one process option may be readily implementable and effective under conditions present at one location, while different conditions elsewhere make selection of a different process option more appropriate. In addition, more than one process option within a technology type may be required to achieve PRGs. For example, effective implementation of access restrictions may incorporate land acquisition, use restrictions, and fences and warning signs to achieve effective protection of human health and the environment. For these reasons, more than one RPO was selected for some technology types.

The RPO that was chosen to develop, screen, and perform a detailed analysis of alternatives may be substituted with another process option from the same technology type at any time in the FS process or in remedial design if it is determined that the new process option is more effective or implementable than the original one. The specific process option used to implement the remedial action may not be selected until the remedial design phase.

The selection of RPOs for the groundwater medium is presented in Section 2.10.1.

2.10.1 Representative Process Options for Groundwater Remediation

Table 2.10.1-1 presents the selected RPOs and the criteria of selection for the groundwater medium. Figures 2.10.1-1a and b summarize the selection of groundwater RPOs. In a few instances, all process options within a technology type were screened out during the first and

second levels of screening presented in Section 2.8. These technology types are not represented by any process option and will not be used to develop remedial alternatives.

Table 2.2.1-1: Offpost Operable Unit Carcinogenic Risks for Each Medium

Zone	Groundwater	Soil	Surface Water	Sediment	Cumulative Risk
1A[a]	7×10^{-5}	4×10^{-5}	-	-	1×10^{-4}
1B[a]	9×10^{-5}	4×10^{-5}	-	-	1×10^{-4}
1C[a]	7×10^{-5}	4×10^{-5}	-	-	1×10^{-4}
2[a]	2×10^{-4}	4×10^{-5}	-	-	2×10^{-4}
3[a]	2×10^{-4}	8×10^{-5}	5×10^{-7}	8×10^{-7}	3×10^{-4}
4[b]	2×10^{-4}	1×10^{-5}	5×10^{-7}	8×10^{-7}	2×10^{-4}
5[b]	3×10^{-5}	5×10^{-5}	-	-	8×10^{-5}
6[a]	3×10^{-5}	4×10^{-5}	-	-	7×10^{-5}

[a] Urban residential exposure scenario.
[b] Commercial/industrial exposure scenario.

- = pathway not included in exposure scenario

Table 2.3.1-1: Offpost Operable Unit Groundwater Chemicals of Concern

Groundwater Chemicals of Concern
Aldrin
Arsenic
Atrazine
Benzene
Carbon tetrachloride
Chlordane
Chloride
Chlorobenzene
Chloroform
CPMS
CPMSO
$CPMSO_2$
Dibromochlopropane
1,3-Dichlorobenzene
1,2-Dichloroethene
Dicyclopentadiene
DDE
DDT
Dieldrin
DIMP
Dithiane
Ethylbenzene
Endrin
Fluoride
Hexachlorocyclopentadiene
Isodrin
Malathion
Manganese
Oxathiane
Sulfate
Tetrachloroethene
Toluene
Trichloroethene
Xylene

Table 2.5.2-1: Preliminary Chemical-specific Applicable or Relevant and Appropriate Requirements for Groundwater

Compound	Level	Source
Arsenic	50	MCL
Atrazine	3	MCL
Benzene	5	MCL
Chloroform	100[a]	MCL
Dibromochloropropane	0.2	MCL
DDE/DDT	0.001	40 CFR 129.101
1,3-Dichlorobenzene	75	MCLG
1,2-Dichloroethane	5	MCL
DIMP	600	HA[b]
Endrin	0.2	MCL
Fluoride	4000	MCL
Tetrachloroethene	5	MCL
Toluene	1000	MCL
Trichloroethene	5	MCL
Xylene	10,000	MCL

All concentrations are micrograms per liter (μg/l).

[a] total trihalomethanes
[b] DIMP is the subject of an EPA Health Advisory that has been reviewed and found protective by the National Academy of Sciences.

EPA = U.S. Environmental Protection Agency
HA = EPA Health Advisory
MCL = maximum contaminant level
MCLG = maximum contaminant level goal

Table 2.5.2-2: Health-based Criteria for Groundwater Chemicals of Concern Without Applicable or Relevant and Appropriate Requirements

Chemical of Concern	Adjusted Rural Residential[a]	Certified Reporting Limit
	RME	
Chloride	VLT	278
Hexachlorocyclopentadiene	0.23	0.048
Chlorobenzene	25	0.82
CPMS	30	5.69
CPMSO	36	11.5
$CPMSO_2$	36	4.7
Dicyclopentadiene	46	5.00
Dithiane	18	0.114
Isodrin	0.06	0.051
Malathion	100	0.373
Oxathiane	160	2.38
Sulfate	VLT	175

All concentrations are micrograms per liter (μg/l).

[a] Values consider the number of contaminants in groundwater that affect the same target organ. Concentrations for noncarcinogens are reported at levels such that the calculated hazard index is below 1.0. See Appendix C.

RME = reasonable maximum exposure
VLT = very low toxicity

Table 2.5.2-3: Preliminary Remediation Goals for Offpost Operable Unit Groundwater

Chemicals of Concern	Groundwater Preliminary Remediation Goals[a]		Rural Residential Hypothetical Cancer Risk
Aldrin	0.05	(CRL)	1×10^{-5}
Arsenic	2.35	(CRL[b])	6×10^{-5}
Atrazine	4.03	(CRL)	NA
Benzene	3	(HBC[b])	2×10^{-6}
Carbon tetrachloride	0.99	(CRL[b])	3×10^{-6}
Chlordane	0.095	(CRL[b])	2×10^{-6}
Chlorobenzene	25	(HBC[b])	NA
Chloroform	15	(HBC[b])	2×10^{-5}
CPMS	30	(HBC)	NA
CPMSO	36	(HBC)	NA
$CPMSO_2$	36	(HBC)	NA
Dibromochloropropane	0.195	(CRL[b])	4×10^{-6}
Dicyclopentadiene	46	(HBC)	NA
DDE	0.054	(CRL)	5×10^{-7}
DDT	0.049	(CRL)	2×10^{-7}
1,3-Dichlorobenzene	6.5	(HBC[b])	NA
1,2-Dichloroethane	1.1	(CRL[b])	3×10^{-6}
Dieldrin	0.05	(CRL)	3×10^{-5}
DIMP	600	(HA)	NA
Dithiane	18	(HBC)	NA
Ethylbenzene	200	(HBC)	NA
Endrin	0.2	(MCL)	NA
Fluoride	4000	(MCL)	NA
Hexachlorocyclopentadiene	0.23	(HBC)	NA
Isodrin	0.06	(HBC)	NA
Malathion	100	(HBC)	NA
Oxathiane	160	(HBC)	NA
Tetrachloroethene	5	(MCL)	4×10^{-6}
Toluene	1000	(MCL)	NA
Trichloroethene	3	(HBC[b])	1×10^{-6}
Xylene	1000	(HBC[b])	NA
		Total	1×10^{-4}

All concentrations are micrograms per liter ($\mu g/l$).

There are no preliminary remediation goals for manganese, chloride, and sulfate.

[a] Concentrations for noncarcinogens without ARARs are reported at levels such that the calculated hazard index (HI) is below 1.0.

[b] Chemicals of concern with ARARs that were adjusted to reduce overall risk.

ARAR = applicable or relevant and appropriate requirement
CRL = certified reporting limit
HA = U.S. Environmental Protection Agency (EPA) Health Advisory
HBC = residential reasonable maximum exposure health-based criteria
MCL = maximum contaminant level
NA = not applicable, either noncarcinogenic or EPA Category C carcinogen (insufficient human evidence)
OU = operable unit

Table 2.8.1-1: Screening of Process Options for Groundwater
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General Response Action	Technology Type	Process Option	Further Consideration	Comment
No Further Action	No Action	None	Yes	National Contingency Plan requires No Action to be carried through the detailed analysis of alternatives.
Institutional Controls	Access Restrictions	Land use/deed restrictions	Yes	Effective means of reducing exposure to contaminated water.
		Fencing and warning signs	Yes	Effective means of limiting access to contaminated areas.
		Land acquisition	Yes	May be required to allow for implementation of remedial alternatives.
	Alternative Water Supplies	Alternative water supplies	Yes	Already implemented for residents whose potable water supply has been affected; alternative water supply has included wells completed in the Arapahoe Formation.
	Monitoring	Groundwater monitoring	Yes	Groundwater monitoring has already been implemented during site characterization and the Comprehensive Monitoring Program and will continue as specified in the Final Technical Plan, Groundwater Element, Comprehensive Monitoring Program (R.L. Stollar & Associates, 1989).
Removal	Groundwater Extraction	Well points	Yes (3)	Effective technology for shallow groundwater extraction in unstratified soils.
		Extraction wells	Yes (3)	Will be implemented in conjunction with Interim Response Action A; extracted water is subsequently treated onsite; it is likely that extraction wells will be used in conjunction with any future onsite treatment technologies.
		Subsurface drains	Yes (3)	Effective technology for removal of shallow groundwater; efficient removal in areas with low hydraulic conductivity.
	Water Flushing	Injection/flooding-infiltration	Yes (3)	Potentially effective technology for enhancing groundwater flow and contaminant removal; water is typically extracted downgradient and subsequently treated.

Table 2.8.1-1: Screening of Process Options for Groundwater
(Page 2 of 13)

General Response Action	Technology Type	Process Option	Further Consideration	Comment
Disposal	Subsurface Injection	Pump back to boundary containment systems	Yes	Effective for disposal of extracted groundwater. Groundwater would be treated at either the Northwest Boundary Containment System or Northern Boundary Containment System. May require facility expansion.
		Deep well injection	Yes (3)	Technology utilized for contaminated water disposal; water is pumped into an appropriate geologic formation which prevents migration of the waste.
		Shallow aquifer recharge	Yes (3)	Potential technology for replacement of treated water but not effective for reduction of mobility, toxicity or volume of contaminants when disposing of contaminated groundwater.
	Aboveground Discharge	Discharge to publically-owned treatment works	Yes	Potential technology for disposal of treated water, implementability depends on proximity to available sewer pipelines, publicly owned treatment works and collection system capacities, and pretreatment requirements; not implementable for untreated water.
		Surface water discharge	Yes	Potential technology for disposal of treated water; not implementable for contaminated water due to lack of effectiveness in contaminant removal and associated risk to human health and the environment.
		Infiltration basin	Yes (8)	Potential technology for the disposal of treated water and as a component of water flushing operations; difficult to implement for disposal of contaminated water.
In-Vessel Treatment: Physical/Chemical	Solidification/ Stabilization	Solidification/stabilization	No (1, 3, 5,)	Rarely implemented for immobilization of dilute liquid wastes; not implementable for high volume low concentration waste stream due to the production of large volumes of waste which must be disposed of.
	Chemical Inorganics Treatment	Magnetic separation	No (27)	Process may be utilized for removal of paramagnetic metals; these metals are not present above preliminary remediation goal concentrations in groundwater at the Offpost Operable Unit; not effective for removal of organic contaminants.

Table 2.8.1-1: Screening of Process Options for Groundwater
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General Response Action	Technology Type	Process Option	Further Consideration	Comment
In-Vessel Treatment: Physical/Chemical (continued)	Chemical Inorganics Treatment (continued)	Chemical precipitation	No (3, 5, 17, 18)	Process may be utilized for removal of inorganic contaminants; inorganic contaminants are not present above preliminary remediation goal concentrations in groundwater at the Offpost Operable Unit; not effective for removal of organic contaminants.
		Complexation	No (3)	Process generally ineffective for removal of inorganic and organic contaminants; complexing agents typically increase the solubility of constituents.
	Solids Removal	Filtration	Yes (3)	Effective conventional technology for removal of suspended solids from liquid waste streams.
		Sedimentation	Yes (3)	Effective conventional technology for separation of suspended solids from waste stream utilizing sedimentation and gravitational techniques.
	Liquid Phase Separation	Liquid phase separation	No (4, 9)	Processes utilized for separation of nonaqueous phase liquids (e.g., oils, greases, insoluble organics) from aqueous portion of a waste stream; not effective for dilute, organic, single-phase waste streams.
	Membrane Separation	Reverse osmosis	No (1, 3, 17)	Process may be utilized for removal of inorganic contaminants; inorganic contaminants are not present above preliminary remediation goal concentrations in groundwater at the Offpost Operable Unit; not effective for removal of organic contaminants.
		Ultrafiltration	No (1, 6)	Not effective for removal of molecules with a molecular weight less than 500 atomic mass units.
		Dialysis	No (12)	Not effective for removal of dilute contaminant waste streams; process driven by concentration gradients across a membrane requiring high concentrations of individual contaminants.
		Electrodialysis	No (5, 17)	Process may be utilized for removal of inorganic contaminants; inorganic contaminants are not present above preliminary remediation goal concentrations in groundwater at the Offpost Operable Unit; not effective for removal of organic contaminants.

Table 2.8.1-1: Screening of Process Options for Groundwater
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General Response Action	Technology Type	Process Option	Further Consideration	Comment
In-Vessel Treatment: Physical/Chemical (continued)	Phase Transfer	Air stripping	Yes (1, 3, 5)	Well-developed technology effective in the removal of volatile organics compounds from aqueous waste streams; resulting air emissions may require further treatment.
		Steam stripping	Yes (1, 5)	Well-developed technology effective in the removal of volatile and selected semivolatile organics from aqueous waste streams; more effective than air stripping for removal of less volatile, higher boiling point, and more soluble organics; can handle broader concentration ranges than air stripping; requires steam source.
		Steam distillation	Yes (1, 5, 12)	Well-developed technology effective in removal of volatile and semivolatile organics. Distillate and still bottoms require further treatment and disposal.
	Sorption	Granular activated carbon (GAC) adsorption	Yes (3)	Well-developed technology effective in the removal of mixed organics from waste streams; already implemented onpost for treatment of groundwater extracted containment systems (i.e., Northern Boundary Containment System and Nnorthwest Boundary Containment System); will be implemented offpost during treatment of Interim Remedial Action A extracted water; carbon must be disposed of or regenerated.
		Resin adsorption	Yes (1)	Potentially effective process for removal of organic contaminants from aqueous waste streams; effectiveness depends on specific type of resin used; typically used as a polishing step; resin regenerants require further treatment.
		Ion exchange	No (1, 3, 17, 18)	Process may be utilized for removal of inorganic contaminants; inorganic contaminants are not present above preliminary remediation goal concentrations in groundwater at the Offpost Operable Unit; not effective for removal of organic contaminants.

Table 2.8.1-1: Screening of Process Options for Groundwater
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General Response Action	Technology Type	Process Option	Further Consideration	Comment
In-Vessel Treatment: Physical/Chemical (continued)	Sorption (continued)	Activated alumina	No (18, 19)	Process may be utilized for removal of inorganic contaminants; inorganic contaminants are not present above preliminary remediation goal concentrations in groundwater at the Offpost Operable Unit; not effective for removal of organic contaminants.
	Chemical Organics Treatment	Hydrolysis	No (5)	Primarily used as a pretreatment process for organic compounds that are otherwise refractory to treatment; none of the organics present in water on the Offpost Operable Unit require hydrolysis in order to implement treatment.
		Solvent extraction	No (1, 5)	Not implementable for the following reasons: large volume of dilute groundwater to be treated and the corresponding large volume of required solvent; numerous solvents may be required to achieve efficient extraction of each organic contaminant; generally both the raffinate and the extract require further treatment.
		Dechlorination	No (5)	Not implementable for aqueous media.
	Oxidation	Chlorination	No (3, 5)	Implementable but is likely to form chlorinated organics such as chloroform; not effective for oxidation of low molecular weight chlorinated organics.
		Ozone oxidation	Yes (5)	Effective oxidizing agent for many organic compounds; by-product analyses should be conducted; additional treatment may be required.
		Hydrogen peroxide oxidation	Yes (5)	Utilized for oxidation of organics; common industrial process; often requires addition of catalysts which include ferrous iron and ultraviolet light radiation (see ozone/hydrogen peroxide).
		Ultraviolet light /ozone/-hydrogen peroxide	Yes (6)	Effective in oxidation of halogenated organics, including halogenated solvents, chlorophenols, pesticides and polychlorinated biphenyls; utilizes ultraviolet light radiation hydrogen peroxide, and/or ozone; has been demonstrated on contaminated groundwater and leachate.

Table 2.8.1-1: Screening of Process Options for Groundwater
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General Response Action	Technology Type	Process Option	Further Consideration	Comment
In-Vessel Treatment: Physical/Chemical (continued)	Reduction	Chemical reduction	No (3)	Not applicable; used primarily for reduction of chromium (VI), mercury, lead; heavy metals are not contaminants of concern in groundwater at the Offpost Operable Unit; not effective for removal of organics.
		Electrochemical reduction	No (3)	Reduction not applicable (see Chemical reduction).
	Radiation	Ultraviolet photolysis	No (5)	Generally not effective for complete destruction of organic compounds; by-products formed would require subsequent treatment.
		Electron beam/gamma irradiation	Yes (13, 14)	Process has not been demonstrated for full-scale hazardous waste treatment, but has been demonstrated at pilot/bench scale to be effective for destruction of chloroform and other halogenated organics.
In-Vessel Treatment: Biological	Biological	Rotating biological contactor	Yes (1, 5, 10)	Potentially effective for degradation of some organic compounds in Offpost Operable Unit groundwater (literature indicates that DIMP and dieldrin are very resistant to biodegradation); organic substrate concentrations in groundwater may be too low and require supplemental substrate addition; additional treatment may be required due to biorefractory nature of chloroform, and DIMP.
		Stabilization pond/lagoon	No (7)	Odor and offgas problems creating a fugitive emission and exposure pathway problems; not effective for halogenated organics removal; affected by temperature fluctuations.
		Activated sludge	Yes (1, 3, 5, 10)	Effective conventional process for removal of many organic compounds (DIMP and dieldrin are resistant to biodegradation); heavy metals and some organics can be harmful to organisms; potentially effective for halogenated organics; additional treatment may be required; treatment of generated offgases may be required.
		Powder activated carbon treatment (PACT®)	Yes (1, 6)	Utilizes activated sludge technology with the addition of powder activated carbon; advantages over conventional activated sludge treatment include ability to deal with shock loading of toxic organics, improved removal of chlorinated organics, and reduced offgas production of volatile organic compounds.

Table 2.8.1-1: Screening of Process Options for Groundwater
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General Response Action	Technology Type	Process Option	Further Consideration	Comment
In-Vessel Treatment: Biological (continued)	Biological (continued)	Sequencing batch reactor	Yes (10)	Potentially effective for degradation of some organic compounds detected in Offpost Operable Unit groundwater (DIMP and dieldrin are very resistant to biodegradation); additional organic substrate may be required to sustain microbial population; additional treatment may be required due to biorefractory nature of chloroform, dieldrin, and DIMP.
		Trickling filter	Yes (1, 5, 10)	Potentially effective for degradation of some organic compounds detected in Offpost Operable Unit water (DIMP and dieldrin are very resistant to biodegradation); organic substrate concentrations may be too low and require supplemental substrate addition; additional treatment may be required due to biorefractory nature of chloroform, dieldrin, and DIMP.
		Publicly owned treatment works	No	Difficult to implement for the following reasons: publicly owned treatment works unlikely to accept water containing RMA contaminants; water rights may require replacement of groundwater.
				Potentially effective for degradation of some organic compounds in Offpost Operable Unit groundwater; water may require supplemental organic substrate addition; not as well demonstrated as aerobic treatment processes for hazardous waste treatment; does not degrade as broad a range of organic compounds but is more effective for degradation of some halogenated organics; additional treatment may be required.
		Submerged fixed film reactor	Yes (2, 10)	Potentially effective for degradation of some organic compounds detected in Offpost Operable Unit groundwater (DIMP and dieldrin are very resistant to biodegradation); organic substrate concentrations may be too low and require supplemental substrate addition; additional treatment may be required due to biorefractory nature of chloroform, dieldrin, and DIMP.

Table 2.8.1-1: Screening of Process Options for Groundwater
(Page 8 of 13)

General Response Action	Technology Type	Process Option	Further Consideration	Comment
In-Vessel Treatment: Thermal	Evaporation	Solar evaporation	No (1, 11, 12)	Not implementable due to the large area that would be required to treat the volumes of contaminated groundwater and fugitive emissions problems associated with the volatilisation of contaminants.
		Enhanced evaporation	No (1, 11, 12)	Not implementable due to area requirements and fugitive emissions control of volatile contaminants.
	Thermal oxidation/ incineration	Rotary hearth incineration	No (15)	Effective but difficult to implement due to large volumes of water to be treated and the low concentrations of contaminants.
		Multiple hearth incineration	No (3)	Effective but difficult to implement due to large volumes of groundwater to be treated and the low concentrations of contaminants.
		Fluidized bed incineration	No (3, 5)	Effective but difficult to implement due to large volumes of groundwater to be treated and the low concentration of contaminants.
		Circulating bed combustion	No (3, 5, 6)	Effective modified fluidized bed technology but difficult to implement for large volumes of groundwater to be treated and the low concentration of contaminants.
		Rotary kiln incineration	No (3, 5)	Effective but difficult to implement due to large volumes of groundwater to be treated and the low concentration of contaminants.
		Submerged quench liquid incineration	No (20)	Effective but difficult to implement due to large volumes of groundwater to be treated and the low concentration of contaminants.
		High temperature fluid wall reactor	No (3, 5)	Effective but difficult to implement due to large volumes of groundwater to be treated and the low concentration of contaminants.
		Molten salt destruction/sodium fluxing	No (5)	Not implementable for liquid wastes; low water content waste is required.
		Plasma arc	No (3, 5)	Effective for contaminants present but difficult to implement due to large volumes of groundwater and the dilute concentrations of waste to be treated.

Table 2.8.1-1: Screening of Process Options for Groundwater
(Page 9 of 13)

General Response Action	Technology Type	Process Option	Further Consideration	Comment
In-Vessel Treatment: Thermal (continued)	Thermal oxidation/ incineration (continued)	Supercritical water oxidation	No (3, 5)	Effective for contaminants present but difficult to implement for large volumes of dilute groundwater requiring treatment.
		Wet air oxidation	No (5)	Potentially effective for contaminants present but difficult to implement due to large volumes of dilute groundwater requiring treatment.
		Pyrolysis	No (3, 5)	Effective for contaminants present but difficult to implement due to the large volumes of dilute groundwater to be treated.
In Situ Treatment	Physical/Chemical	Permeable treatment bed	No (3)	Potentially effective but not implementable for large volumes and areas of contaminated groundwater.
		Hydrolysis	No (5)	Controlling and predicting hydrolysis products which may be toxic is difficult; likely that hydrolysis would be ineffective in achieving remedial alternative objectives.
		Oxidation	No (3)	Potentially effective but difficult to implement due to extensive area requiring treatment. Complete oxidation of contaminants would be difficult to achieve and there is potential for the formation of toxic oxidation by-products.
		Reduction	No (3)	Not applicable; used primarily for reduction of chromium (VI), mercury, and lead to less soluble forms; not effective for treatment of organics.
		Water flushing (saturated zone)	Yes (3, 5)	Potentially effective method for removing contaminants; potential for inadvertent mobilization of wastes and further plume development; process increases the rate of contaminant removal and is typically a component of pump and treat alternatives.

Table 2.8.1-1: Screening of Process Options for Groundwater
(Page 10 of 13)

General Response Action	Technology Type	Process Option	Further Consideration	Comment
In-situ Treatment (continued)	Enhanced Biological	Aerobic degradation	Yes (1, 3, 5, 6)	Potentially effective for degradation of some of the organic contaminants detected in Offpost Operable Unit groundwater (DIMP is resistant to biological treatment); may require organic substrate and nutrient supplements.
		Anaerobic degradation	Yes (3,5)	Potentially effective for degradation of organics (DIMP is resistant to biodegradation); difficult to implement due to difficulties in maintaining an anaerobic environment in the aquifer.
Containment	Subsurface Barriers	Slurry wall	Yes (3)	Effective method of controlling groundwater and contaminant migration when associated with groundwater extraction; already implemented for RMA onpost contamination (i.e., Northern Boundary Containment System and Northwest Boundary Containment System).
		Grout curtain	Yes (3)	Implementable for system of limited size; effectiveness depends on ability to achieve a continuous barrier; typically grout curtains are less effective than slurry walls.
		Sheet piling	No (3)	Difficult to achieve effective seals at joints in sandy soils; difficult to penetrate weathered bedrock; piling can be damaged by rocky soil; implementability depends on size of system required and depth to bedrock.
		Bottom sealing	No (3)	Not implementable due to the depth of contaminated groundwater, the geologic conditions, and the broad areal extent of the plume; effectiveness depends on achieving complete bottom seal which is difficult to ensure.
		Pneumatic seal	No	Difficult to implement over large areas of contamination, effectiveness depends on complete pneumatic seal which is difficult to achieve.
		Synthetic membrane cutoff wall	No	Difficult to implement due to depth to bedrock; ineffective if not keyed into impermeable bedrock.

Table 2.8.1-1: Screening of Process Options for Groundwater
(Page 11 of 13)

General Response Action	Technology Type	Process Option	Further Consideration	Comment
Containment (continued)	Subsurface Barriers (continued)	Dynamic deep compaction	No	Difficult to implement; usually used as a process to consolidate foundation materials; generally not effective in the prevention of groundwater migration.
		Hydraulic controls	Yes (3)	Effective means of controlling groundwater migration by extraction and injection of water which is used to modify hydraulic gradients; selected as a part of the system for Interim Response Action A, Northwest Boundary Containment System, Northern Boundary Containment System, and Irondale Containment System groundwater intercept and treatment systems; readily implementable.
		Subsurface dam	Yes	Potentially effective means of controlling contaminant migration when combined with extraction; difficult implementation due to problems of construction in unconsolidated alluvium.
		Freezing	No	Difficult to implement due to the large number of closely spaced wells required; effective as temporary barrier to groundwater flow.
	Caps/Covers	Caps/covers	No (3)	Although caps and covers are effective, readily implementable process options, they are not applicable to groundwater remediation on the Offpost Operable Unit. Caps and covers are utilized to prevent infiltration of precipitation and runoff. Caps and covers may be utilized as technologies for the remediation of groundwater if they act to reduce plume development by significantly reducing groundwater flow or if they eliminate a source of groundwater contamination by preventing the contact of infiltrating water with soluble contaminants in the vadose zone. Neither of these applications applies to conditions on the Offpost Operable Unit. Infiltration from precipitation has been evaluated to be a very minor contribution to groundwater flow on the offpost. No potential sources for groundwater contamination exist in the offpost soil and vadose zone, except for low concentrations of organochlorine pesticides in surficial soil. Organochlorine pesticides present in soil are immobile and sufficiently low in concentration such that they are not believed to be a source of groundwater contamination.

Table 2.8.1-1: Screening of Process Options for Groundwater
(Page 12 of 13)

General Response Action	Technology Type	Process Option	Further Consideration	Comment
	Storage	Surface impoundment	No	Difficult to implement due to fugitive emission problem and risk associated with volatile contaminants.
		Containers	No	Not effective for large volumes of contaminated groundwater.

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Table 2.10.1-1: Selection of Representative Process Options for Groundwater
(Page 1 of 2)

Technology Type	Process Options Retained From Second Level of Screening	Selected Representative Process Option	Criteria for Selection
No Further Action	None	No Further Action	Retained as required by the National Contingency Plan.
Access Restrictions	Land Use/Deed Restrictions	Land Use/Deed Restrictions	Effective in minimizing human contact with groundwater and restricting use of groundwater for crop irrigation and watering of livestock.
	Fencing and Warning Signs	Fencing and Warning Signs	Effective in reducing human exposure to contaminated media.
	Land Acquisition	Land Acquisition	May be required to implement remedial action on privately owned land.
Alternative Water Supplies	Alternative Water Supplies	Alternative Water Supplies	Effective in preventing human contact with groundwater for residents who rely on wells for domestic use.
Monitoring	Groundwater Monitoring	Groundwater Monitoring	Effective in tracking plume development, natural attenuation, and remediation effects.
Groundwater Extraction	Extraction Wells	Extraction Wells	Demonstrated effective at the boundary containment systems for removal of groundwater; readily implementable at depths which make for difficult installation of subsurface drains.
	Subsurface Drains		
Water Flushing	Injection	Injection	Demonstrated effective at the boundary containment systems; minimizes losses to evaporation in summer months, no difficulties associated with freezing in winter months.
Subsurface Injection	Pump Back to Boundary Containment System	Pump Back to Boundary Containment System	Injection and treatment facilities already constructed and operational; cost-effective disposal and treatment option for limited quantities of groundwater dependent on facility (North Boundary Containment System, Northwest Boundary Containment System) capacity.
	Shallow Aquifer Injection	Shallow Aquifer Injection	Shallow aquifer injection demonstrated effective at the boundary containment systems, minimizes losses to evaporation, allows for control of groundwater gradient; Shallow aquifer injection includes both injection wells and trenches.

Table 2.10.1-1: Selection of Representative Process Options for Groundwater
(Page 2 of 2)

Technology Type	Process Options Retained From Second Level of Screening	Selected Representative Process Option	Criteria for Selection
Chemical Inorganics Treatment	Chemical Precipitation	Chemical Precipitation	Conventional process option, readily implementable, well-demonstrated, effective for removal of inorganics.
Phase Transfer	Air Stripping	Air Stripping	Readily implemented; reliable and effective process option for removing volatile organic compounds, easily operated.
Sorption	Granular Activated Carbon Adsorption	Granular Activated Carbon Adsorption	Demonstrated effective for removal of organics at the boundary containment systems.
Oxidation	Ultraviolet Light/Ozone/Hydrogen Peroxide	Ultraviolet Light/Ozone/Hydrogen Peroxide	Effective for destruction of a broad range of organic compounds.
In Situ Physical/Chemical	Water Flushing (Saturated Zone)	Water Flushing (Saturated Zone)	Potentially effective for enhancing removal of contaminants as a component of pump and treat alternatives.
Subsurface Barriers	Slurry Wall	Slurry Wall	Demonstrated effective at the boundary containment systems.
	Hydraulic Controls	Hydraulic Controls	Demonstrated effective at the boundary containment systems.

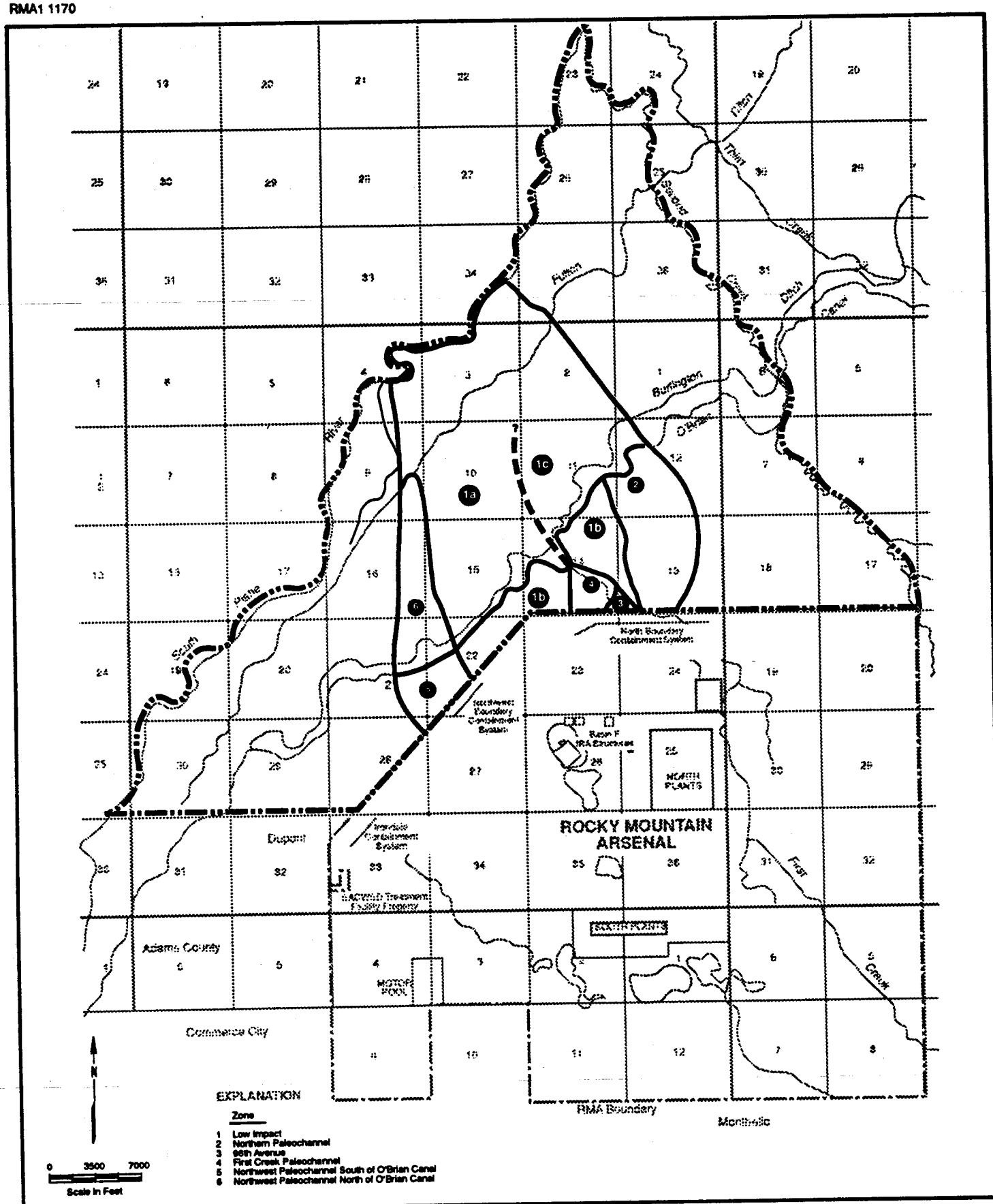

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Figure 2.5.1-1

OFFPOST OPERABLE UNIT FEASIBILITY STUDY CONTAMINANT DISTRIBUTION ZONES

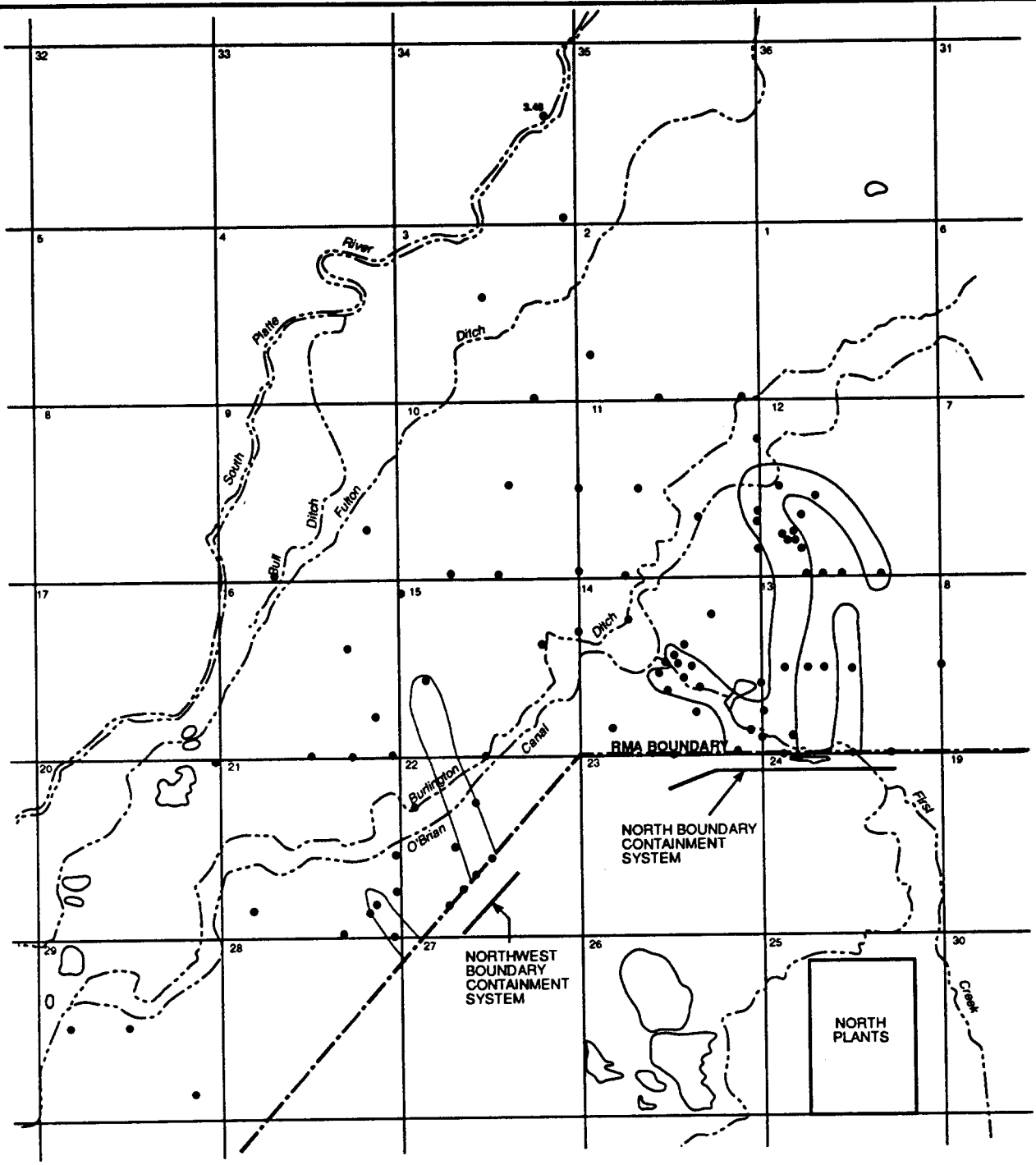

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Figure 2.6-1

AREAS OF EXCEEDANCES OF GROUNDWATER PRGs IN THE OFFPOST UNCONFINED FLOW SYSTEM

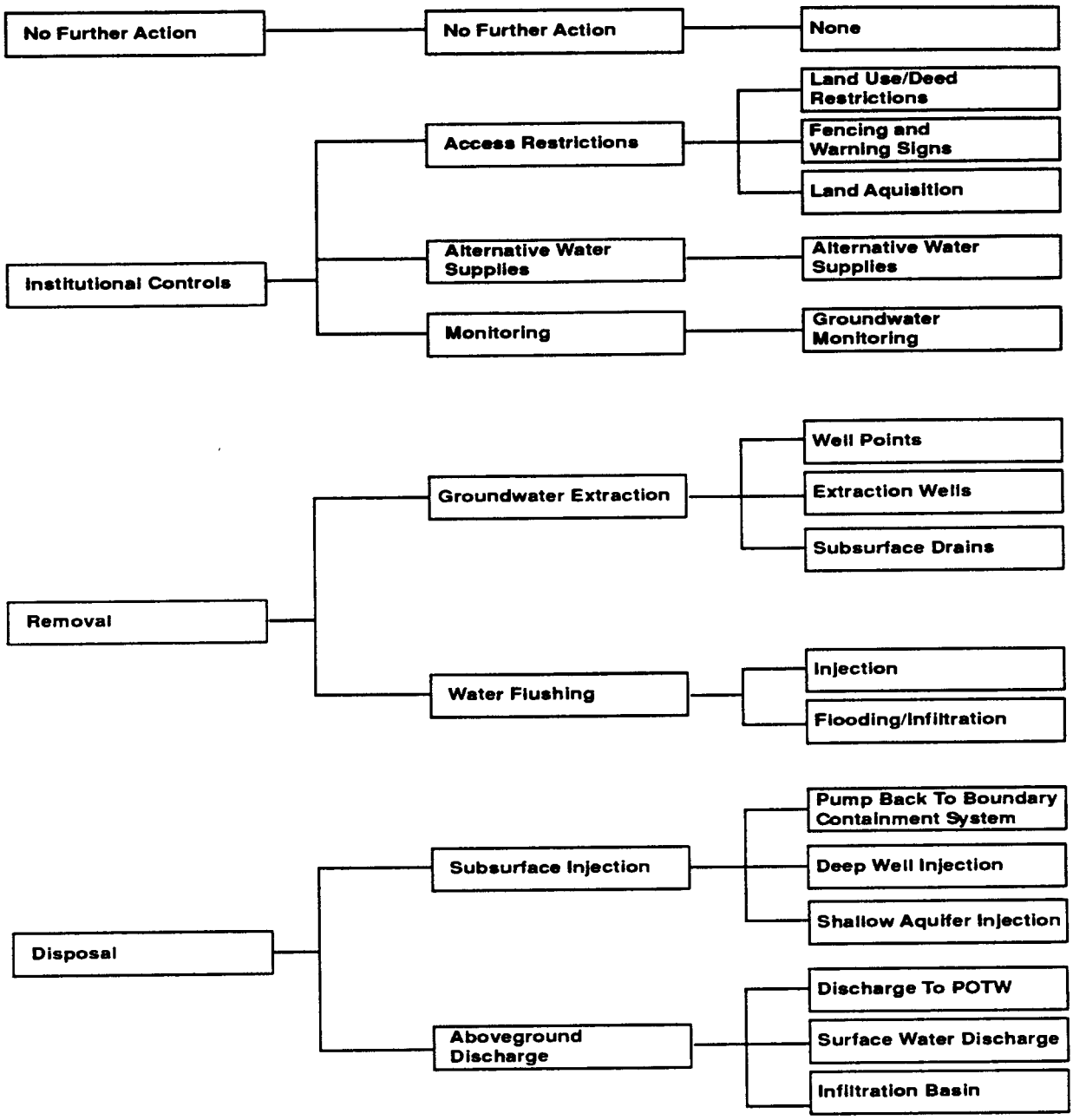

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Figure 2.8-1a

GROUNDWATER PROCESS OPTIONS

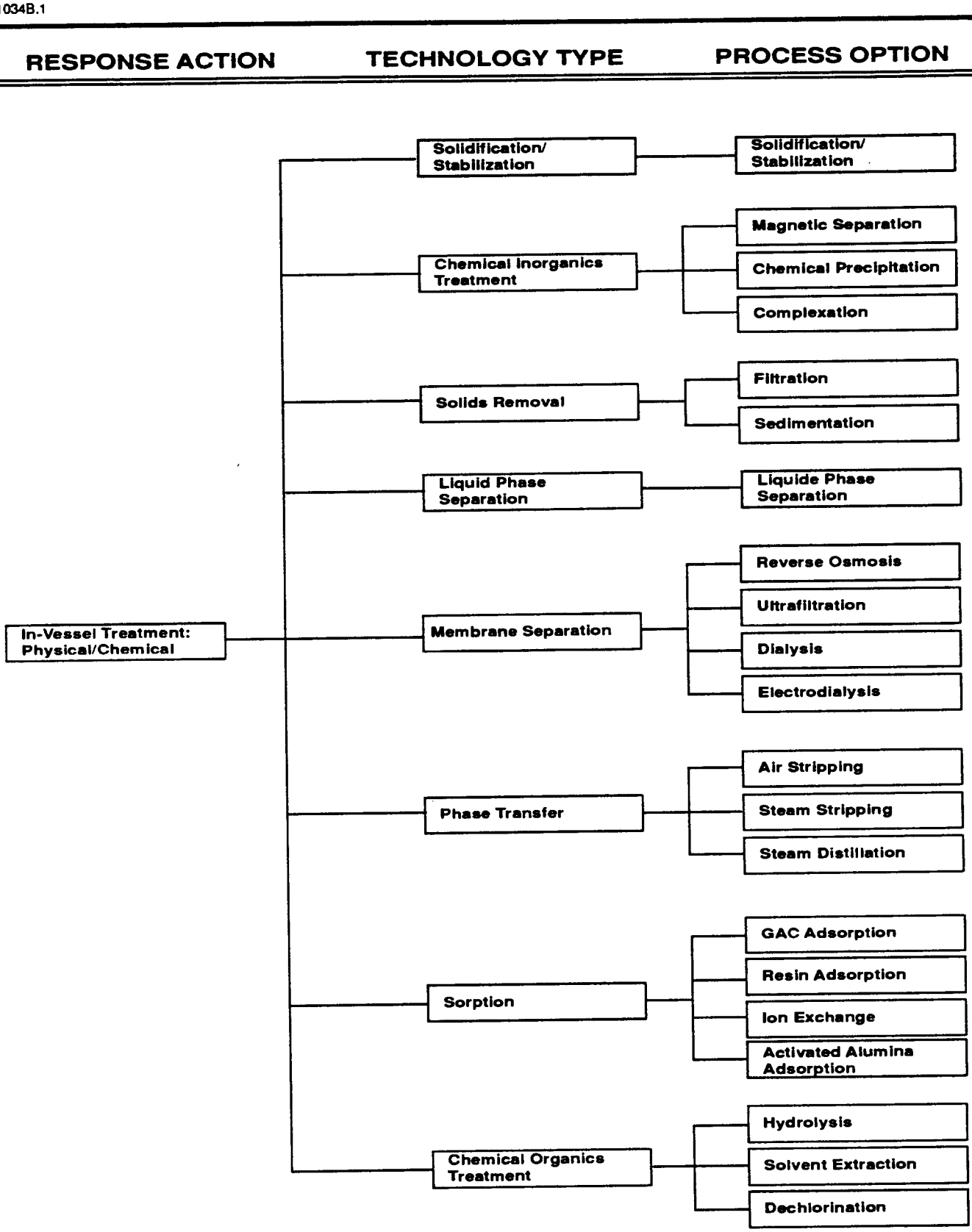

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Figure 2.8-1b

GROUNDWATER PROCESS OPTIONS

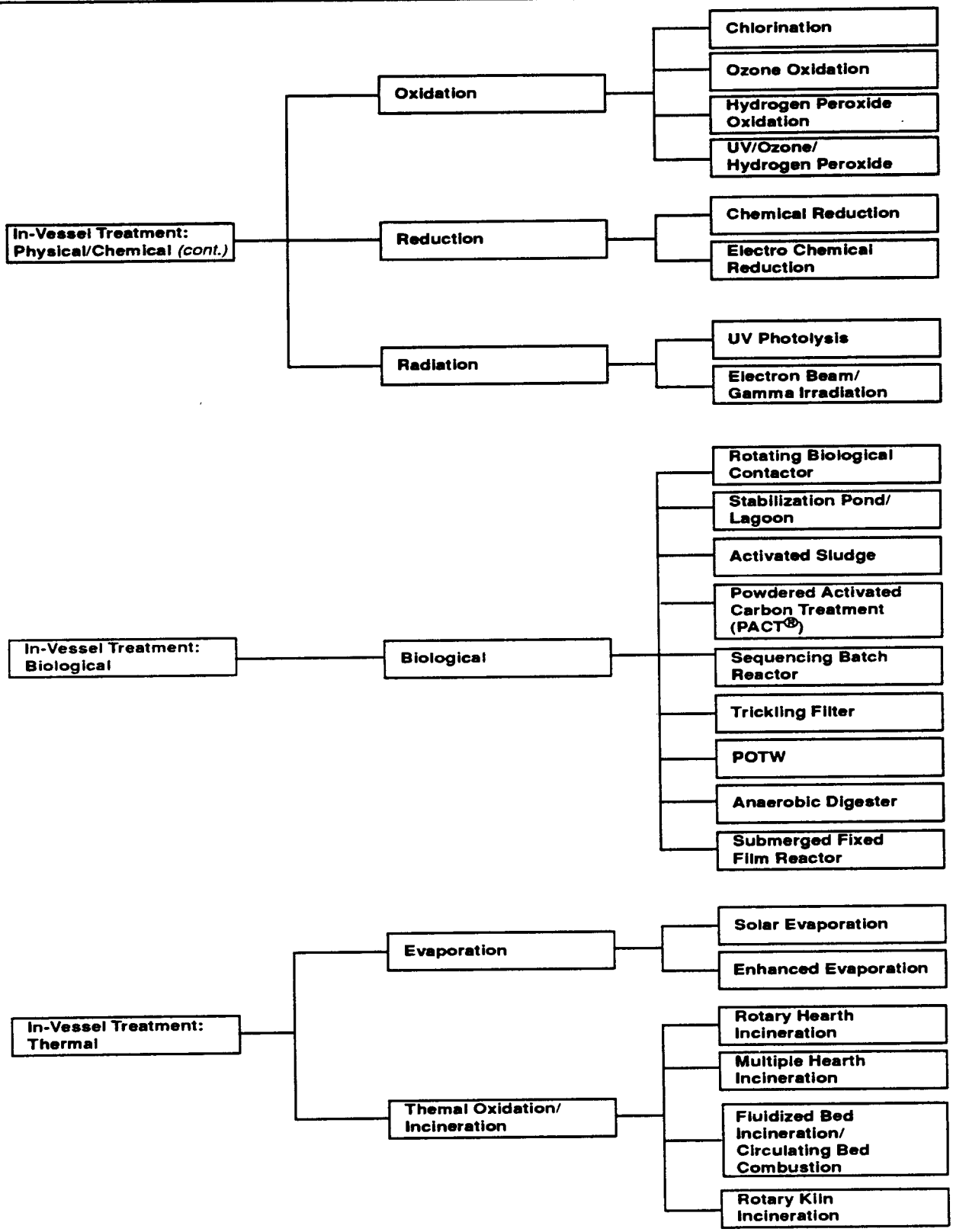

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Figure 2.8-1c

GROUNDWATER PROCESS OPTIONS

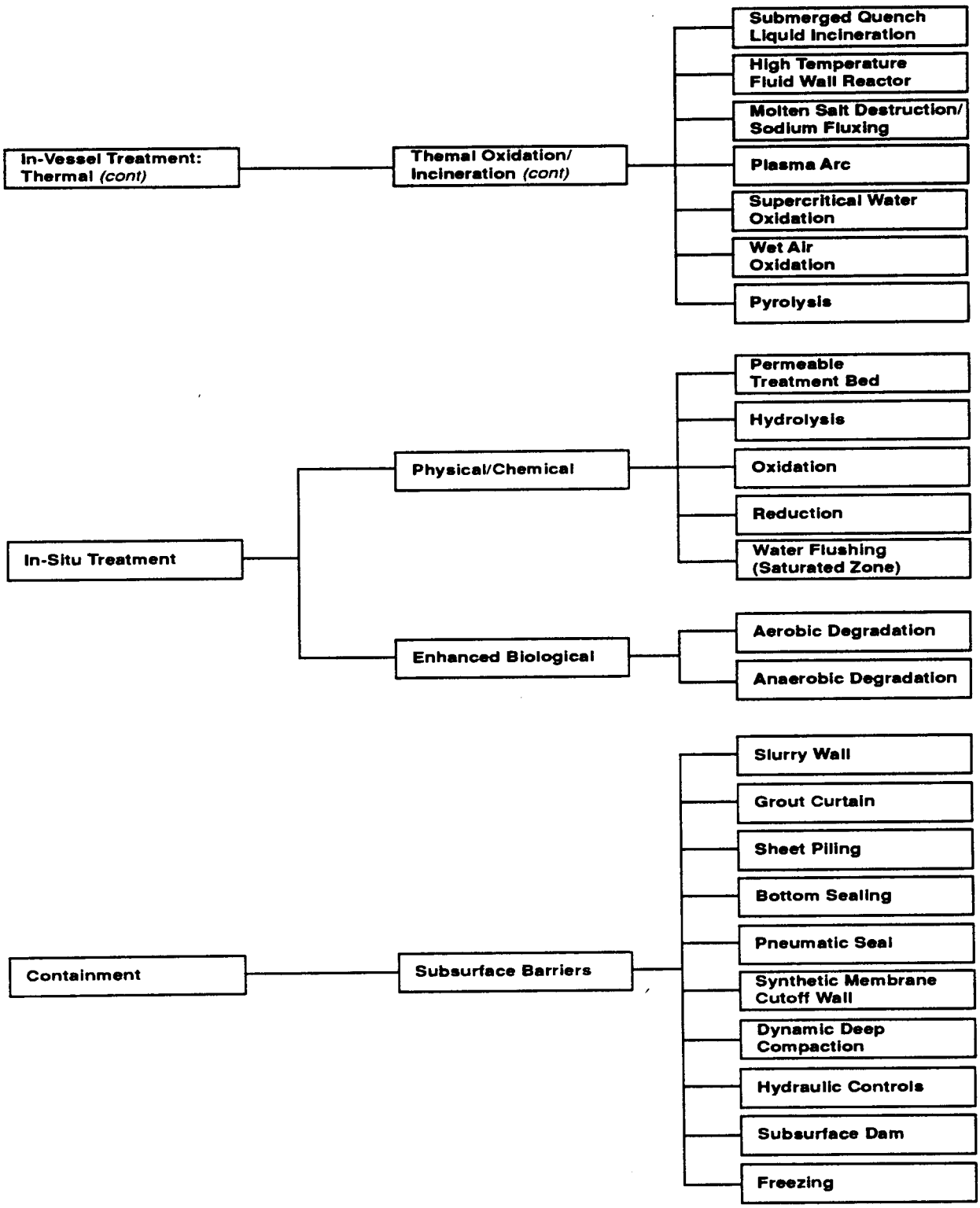

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Figure 2.8-1d

GROUNDWATER PROCESS OPTIONS

RESPONSE ACTION	TECHNOLOGY TYPE	PROCESS OPTION

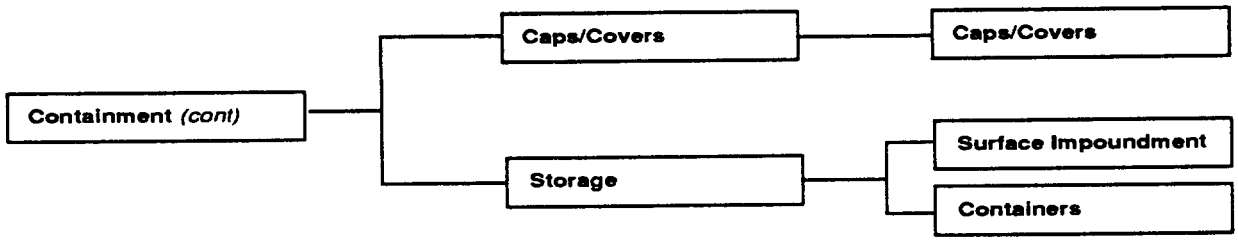

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Figure 2.8-1e

GROUNDWATER PROCESS OPTIONS

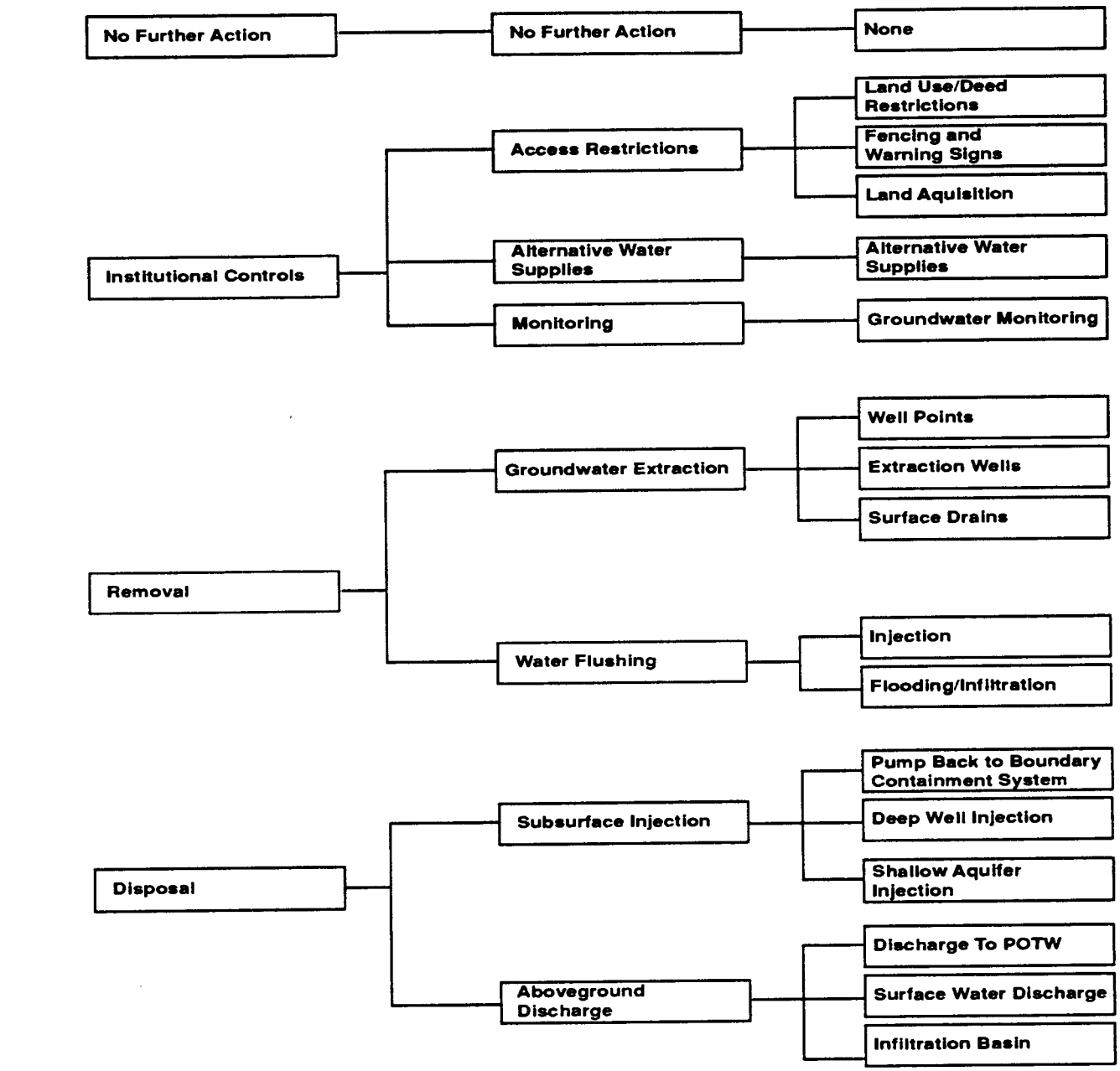

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Figure 2.8.1-1a

RESULTS OF UNIVERSAL SCREENING OF GROUNDWATER PROCESS OPTIONS

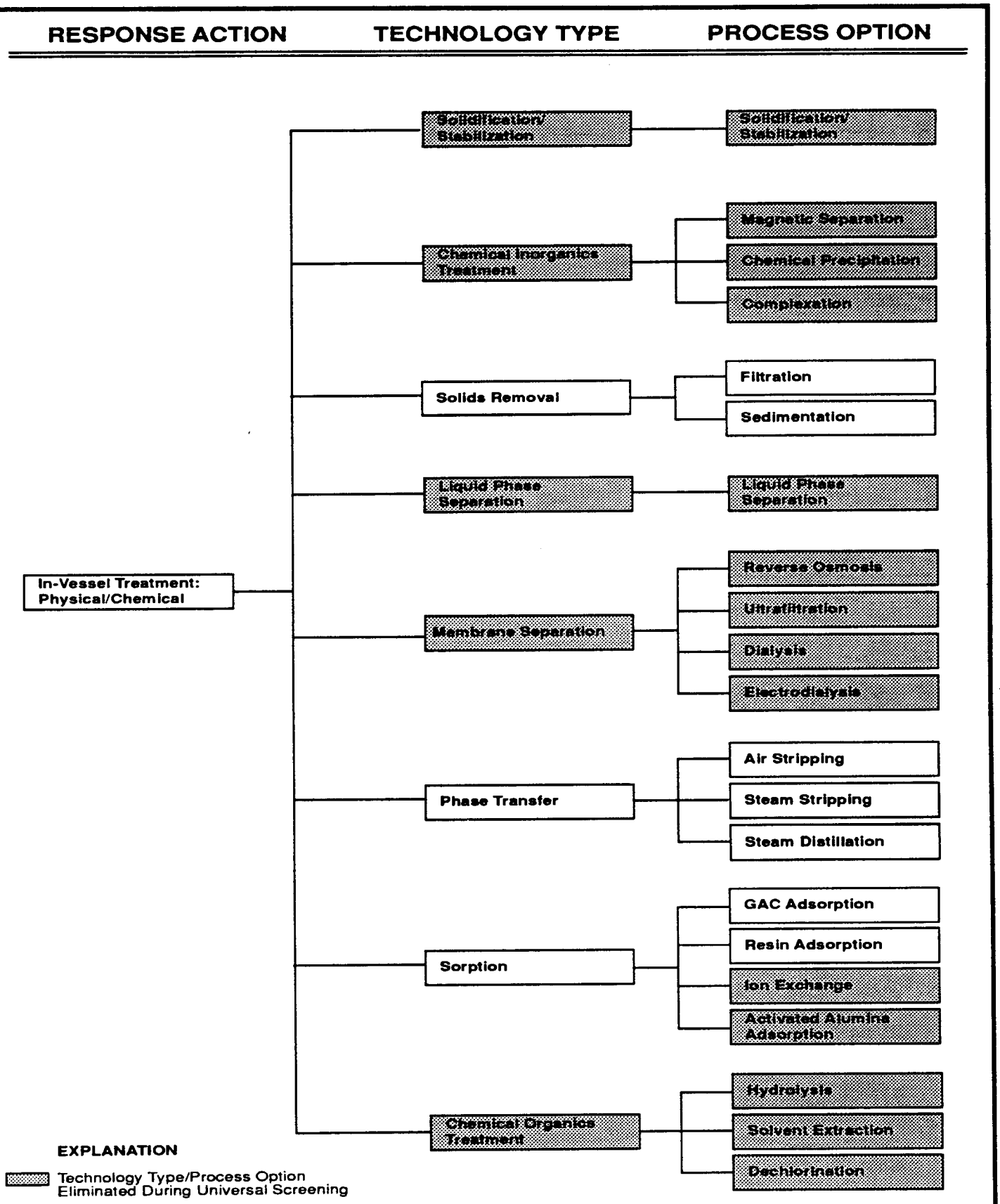

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Figure 2.8.1-1b

RESULTS OF UNIVERSAL SCREENING OF GROUNDWATER PROCESS OPTIONS

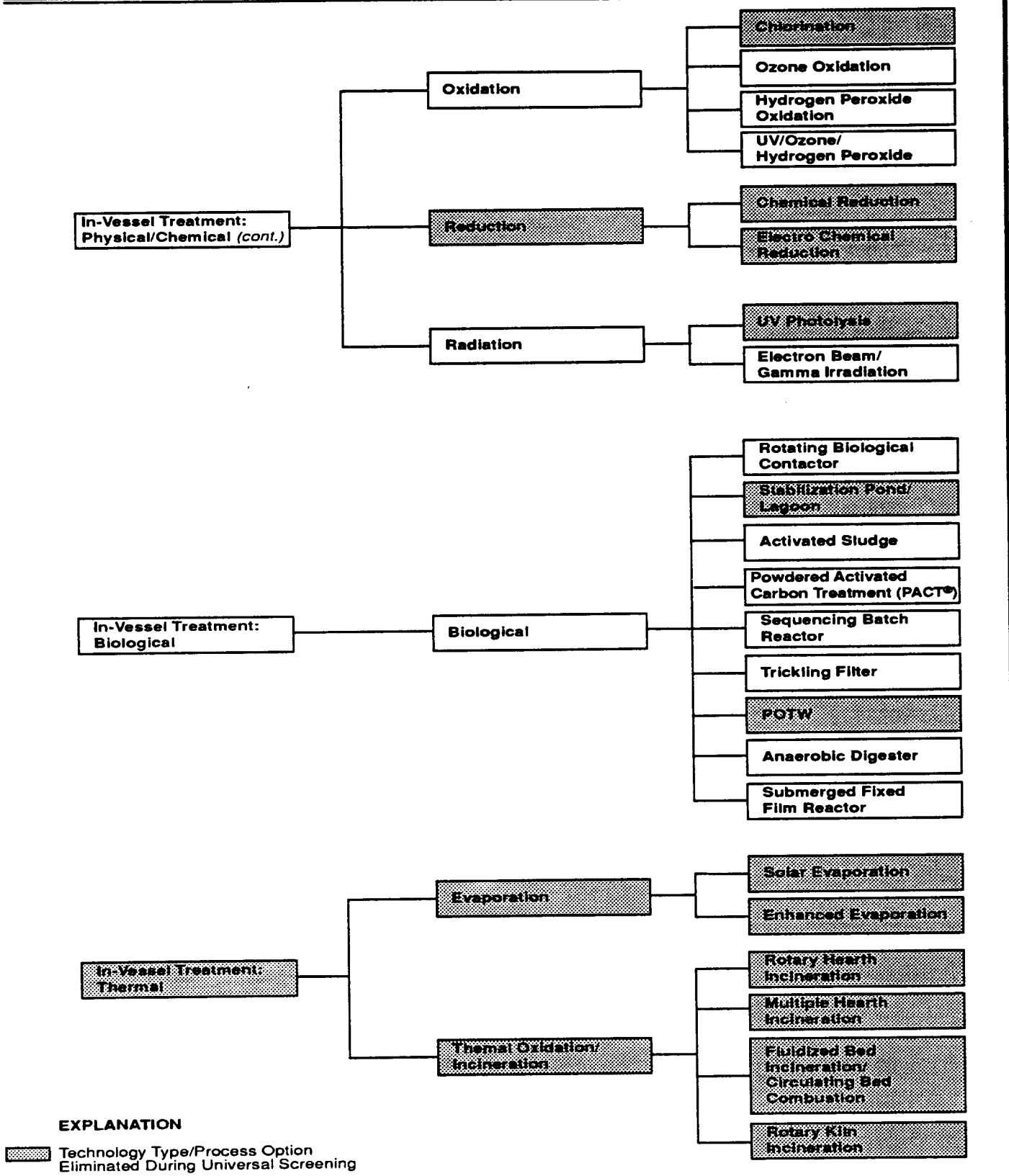

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Figure 2.8.1-1c

RESULTS OF UNIVERSAL SCREENING OF GROUNDWATER PROCESS OPTIONS

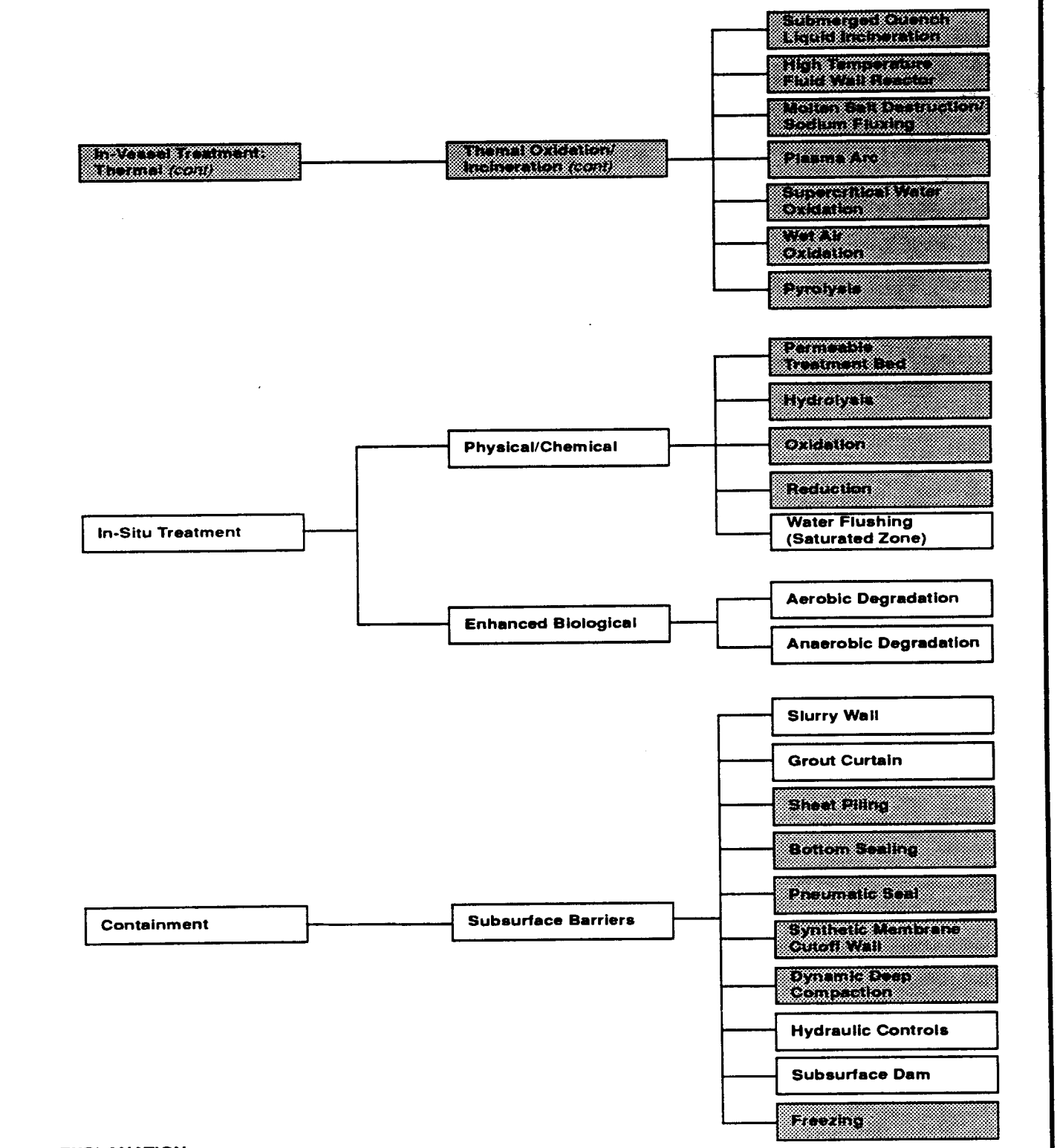

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Figure 2.8.1-1d

RESULTS OF UNIVERSAL SCREENING OF GROUNDWATER PROCESS OPTIONS

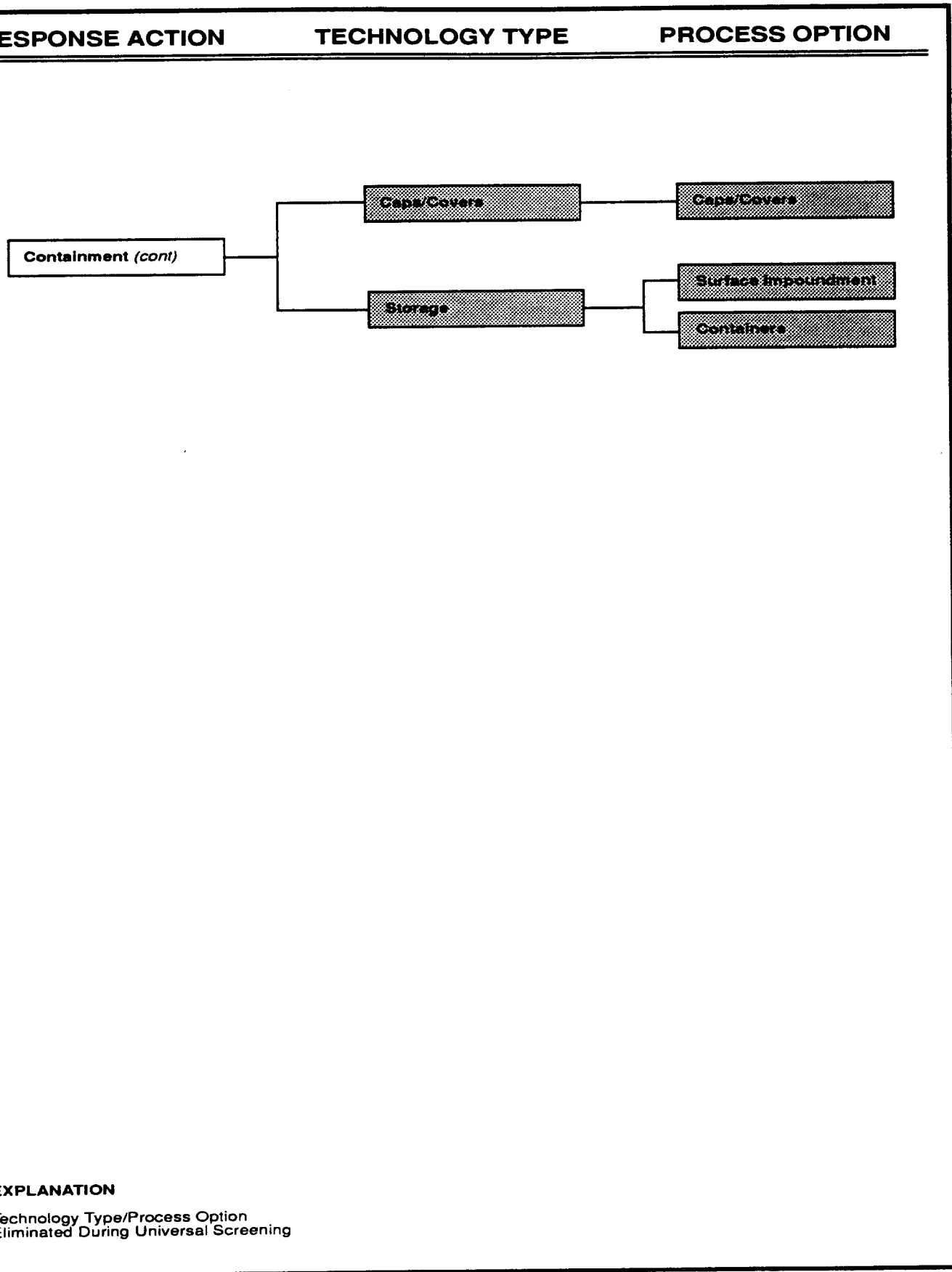

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Figure 2.8.1-1e

RESULTS OF UNIVERSAL SCREENING OF GROUNDWATER PROCESS OPTIONS

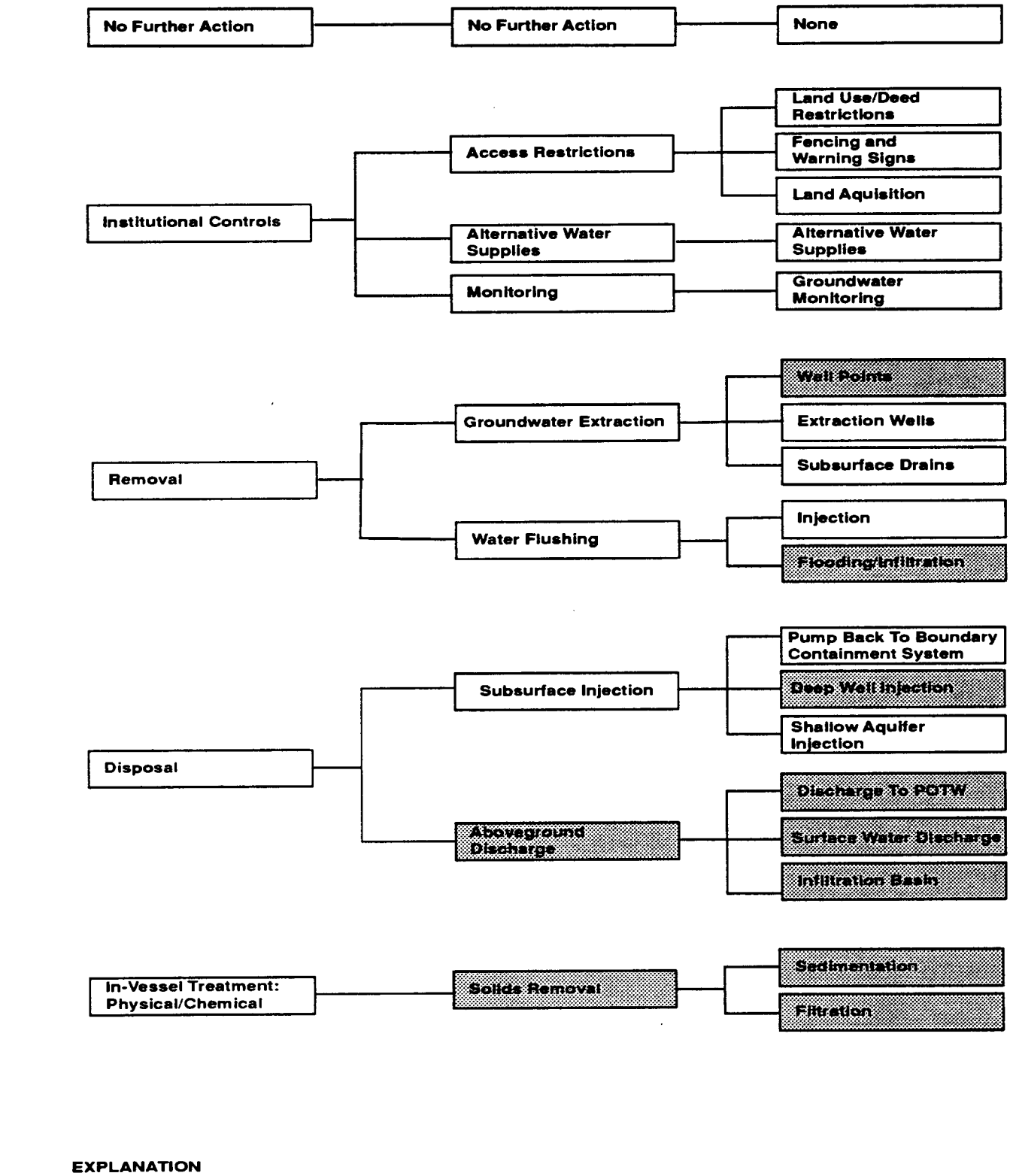

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Figure 2.9-1a

RESULTS OF THE SECOND LEVEL SCREENING OF GROUNDWATER PROCESS OPTIONS

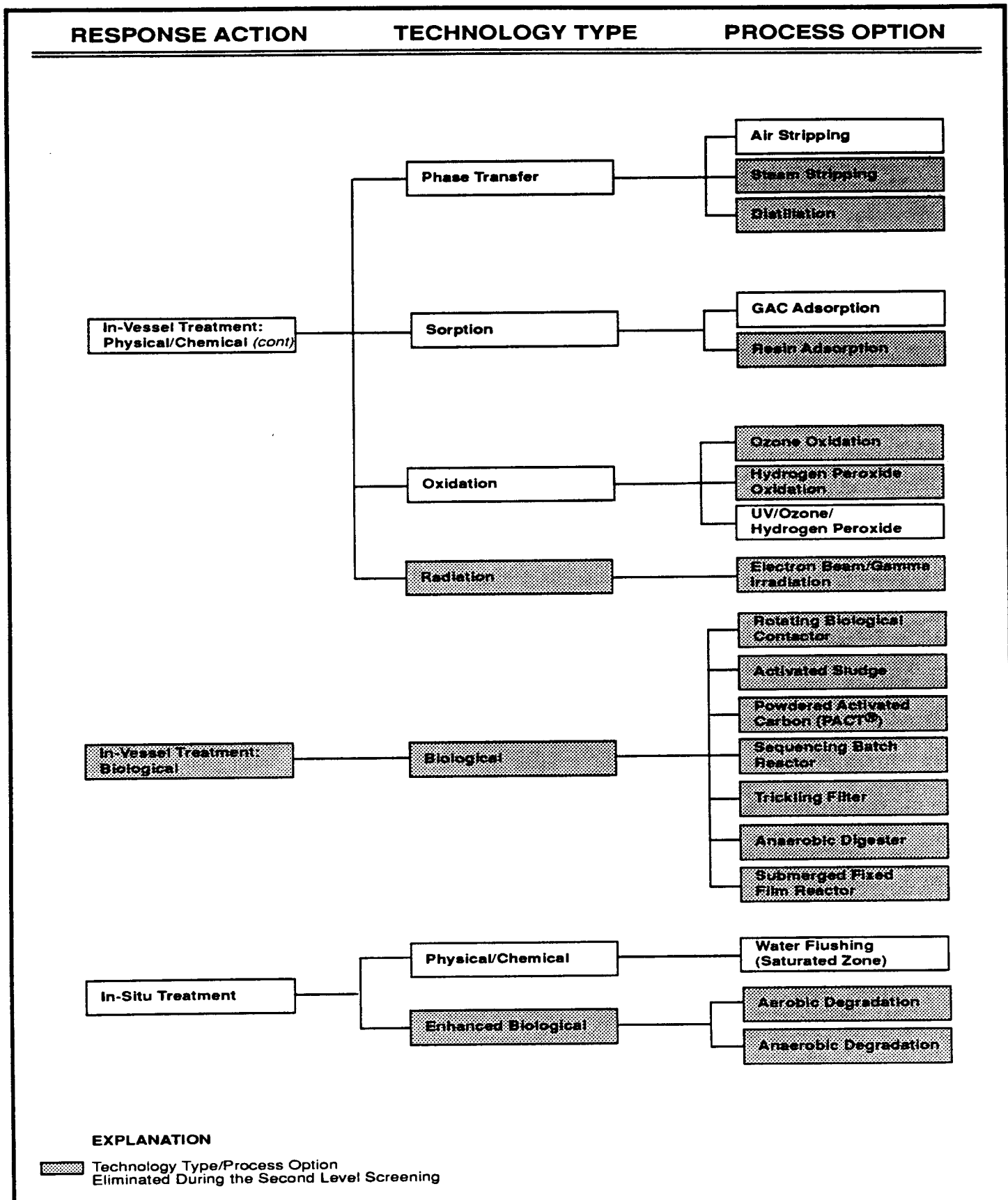

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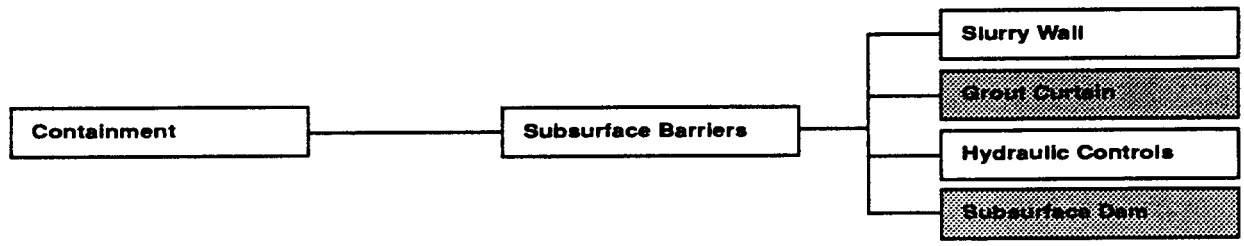
Figure 2.9-1b

RESULTS OF THE SECOND LEVEL SCREENING OF GROUNDWATER PROCESS OPTIONS



EXPLANATION

Technology Type/Process Option Eliminated During the Second Level Screening

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Figure 2.9-1c

RESULTS OF THE SECOND LEVEL SCREENING OF GROUNDWATER PROCESS OPTIONS

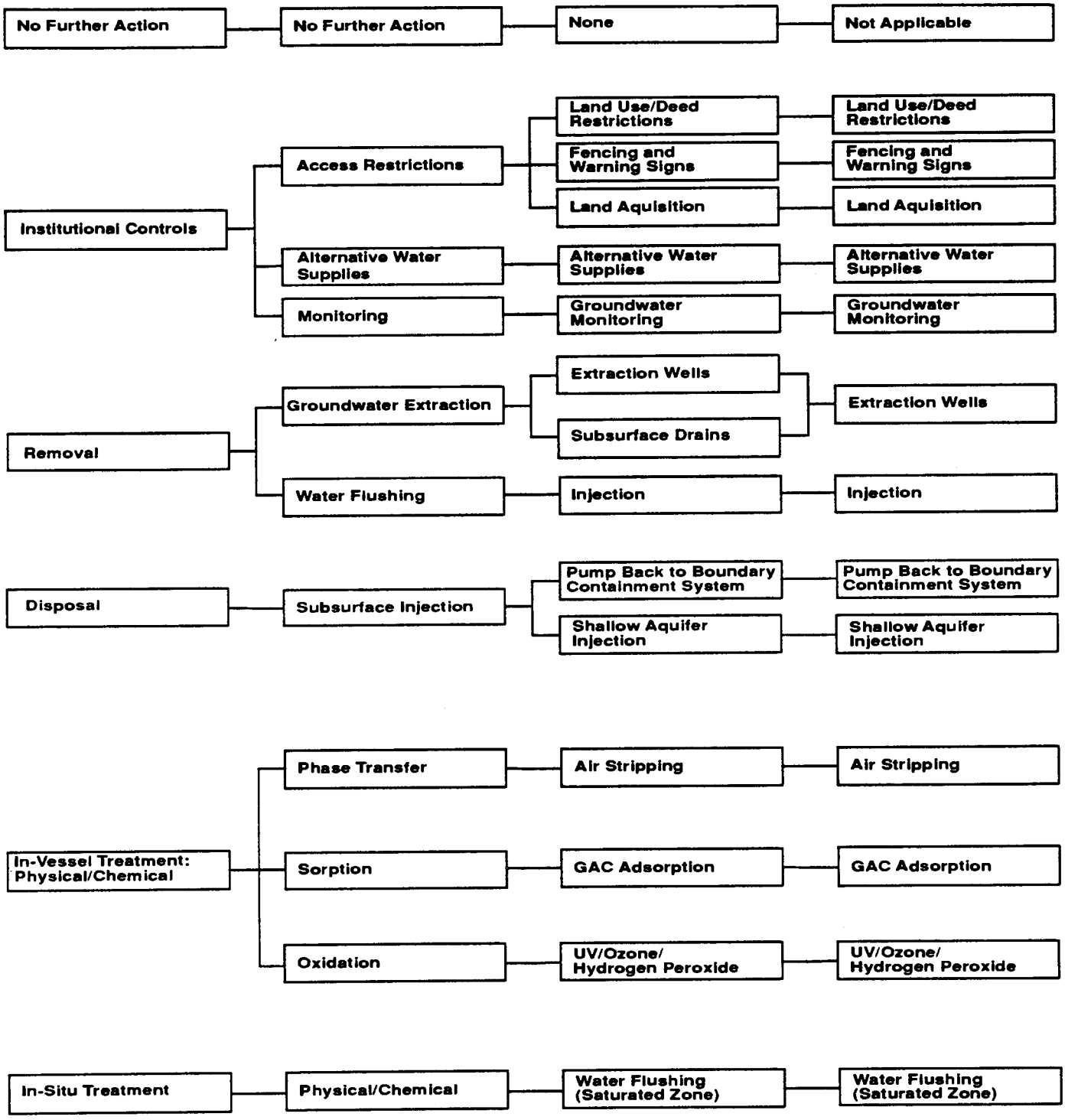

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Figure 2.10.1-1a

SELECTED REPRESENTATIVE PROCESS OPTIONS FOR DEVELOPMENT OF GROUNDWATER REMEDIAL ALTERNATIVES

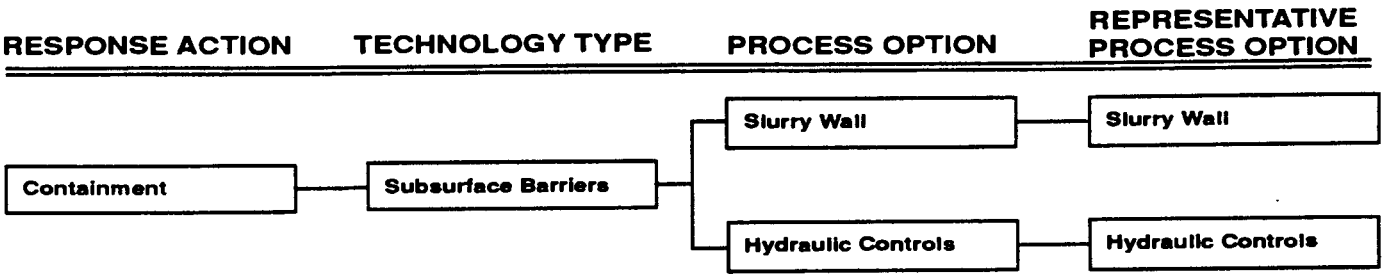

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Figure 2.10.1-1b

SELECTED REPRESENTATIVE PROCESS OPTIONS FOR DEVELOPMENT OF GROUNDWATER REMEDIAL ALTERNATIVES

TECHNICAL SUPPORT FOR ROCKY MOUNTAIN ARSENAL

Offpost Operable Unit
Endangerment Assessment/Feasibility Study

Final Report

Volume VI of VIII
(FS Sections 3.0, 4.0, 5.0, 6.0, 7.0)

November 24, 1992
Contract Number DAAA15-88-0021
Task RIFS1 (Delivery Order 0001)

PREPARED BY

Harding Lawson Associates

PREPARED FOR

PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL

THIS DOCUMENT IS INTENDED TO COMPLY WITH THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969.

THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATION RECORD FOR THIS CERCLA OPERABLE UNIT.

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Volume VI

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Volume II - ENDANGERMENT ASSESSMENT

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(Continued)

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3.0 DEVELOPMENT OF REMEDIAL ALTERNATIVES

Section 3.0 presents the development of alternatives, using the RPOs presented previously in Section 2.10. The following sections present the approach to alternatives development, commonalities of alternatives, and detailed descriptions of each alternative considered in the FS.

3.1 FEASIBILITY STUDY OVERVIEW

This portion of the FS addresses the development and screening of alternatives, that were developed by combining general response actions and RPOs into a range of options addressing RAOs. The alternatives were subsequently screened (Section 4.0) to identify those alternatives to be evaluated in the detailed analysis of alternatives (Section 5.0). Consistent with EPA FS Guidance (EPA, 1988b), the development and screening of alternatives is a three-step process consisting of the following:

1. Developing a range of remedial alternatives by assembling combinations of selected RPOs (Section 2.10) that address containment, source control, and treatment of media requiring remediation within the Offpost OU
2. Refining and screening identified alternatives on a general basis to evaluate their effectiveness, implementability, and cost (Section 4.0), which reduces the number of alternatives while preserving a range of options
3. Identifying remedial alternatives retained for further analysis in Section 5.0

EPA guidance regarding the development and screening of alternatives is further discussed below.

3.1.1 U.S. Environmental Protection Agency Guidance for Alternatives Development and Evaluation

Remedial alternatives were developed and evaluated according to guidelines set forth in the following regulations and guidance:

- National Contingency Plan (NCP) 40 CFR Part 300
- EPA Guidance on Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final, October 1988 (EPA, 1988b)
- EPA CERCLA Compliance with Other Laws Manual, June 1988, OSWER Directive No. 9234.1-01 (EPA, 1988a)

- Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions, April 1991, OSWER Directive 9355.0-30 (EPA, 1991)

- Guidance Document for Providing Alternate Water Supplies, OSWER Directive No. 944.3-03 (EPA, 1988c)

- Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites, OSWER Directive No. 9238.1-2 (EPA, 1988d)

Guidelines contained in the documents listed above were developed by EPA in response to CERCLA Section 121. The NCP indicates that alternatives should be developed that protect human health and the environment by eliminating, reducing, and/or controlling risk posed through each contaminant exposure pathway at the site. CERCLA provides for selection of a remedial action that is protective of human health and the environment, is cost-effective, and attains federal and state ARARs.

The NCP requires that, at a minimum, the following remedial alternatives be developed:

- The No-Action Alternative

- One or more alternatives that involve little or no treatment but provide protection of human health and the environment primarily by preventing or controlling exposure to hazardous substances, pollutants, or contaminants through engineering controls (e.g., containment) and, as necessary, institutional controls (e.g., land use and access restrictions) to assure continued effectiveness of the response action

- Treatment alternatives that reduce toxicity, mobility, or volume as their principal element

- A limited number of remedial alternatives for media that attain site-specific remediation levels within different restoration periods, using one or more different technologies

- Treatment alternatives that, at a minimum, treat the principal threats posed by the site but vary in the degree of treatment employed and the quantities and characteristics of the treatment residuals and untreated waste that must be managed

- Treatment alternatives that remove or destroy hazardous substances, pollutants, or contaminants to the maximum extent feasible, eliminating or minimizing the need for long-term management (including monitoring) at the site

- One or more alternatives incorporating innovative treatment technologies (if those technologies offer the potential for comparable or superior performance or implementability, fewer or less adverse impacts than other available approaches, or lower costs for levels of performance similar to that of demonstrated treatment technologies)

3.2 ALTERNATIVES IDENTIFICATION

Remedial alternatives for the Offpost OU were developed by (1) identifying the media in which COCs were detected at levels exceeding PRGs, (2) calculating the areas and volumes of media exceeding PRGs, and (3) assembling combinations of RPOs into alternatives representing a range of treatment and containment combinations that address the RAOs developed for groundwater. Remedial alternatives were developed with the intent of providing a range of remedial options using various technology types and RPOs. Consistent with the NCP, a range of alternatives for media exceeding PRGs was developed from no action to complete removal or destruction of contaminants.

The range of alternatives for the groundwater medium is presented in Section 3.5. As discussed in Section 2.2, soil, surface water, air, biota, and sediment were not identified as media requiring remediation. Thus, remedial alternatives for these media were not developed.

3.2.1 Approach

This section describes the approach used to develop groundwater remedial alternatives to address the RAOs and PRGs presented in Sections 2.4 and 2.5. Alternatives were developed for the groundwater medium, based on the assumption that the boundary control systems will achieve PRGs for groundwater migrating from RMA to the Offpost OU.

Due to differences in hydrogeology, contaminants present, and concentration levels, two groups of contaminant plumes have been identified in groundwater in the Offpost OU. The plume groups are identified as the North and Northwest Plume Groups. Figure 3.2.1-1 presents the general areas encompassed by each plume group. In Section 3.0, groundwater alternatives were developed separately for the two plume groups, and the plume group alternatives were screened separately in Section 4.0. In Section 6.0, alternatives for the North and Northwest Plume Groups were combined into the sitewide groundwater alternative.

3.2.1.1 Groundwater Model Input Into Alternatives Development

This section describes the general approach to the integration of the groundwater modeling results into the development of groundwater alternatives. A detailed description of the groundwater model development is presented in Appendix E of the FS.

3.2.1.1.1 Chemicals of Concern

The groundwater COCs were presented previously in Section 2.3, Table 2.3.1-1. A total of 28 organic compounds are listed as COCs. The remaining COCs are either inorganic ions, such as chloride, or inorganic chemicals, such as arsenic. A total of 15 COCs are classified as carcinogens, as identified in the Offpost EA (Volume II, Section 1.0). The carcinogens were shown to contribute the largest portion of the risk from groundwater. The noncarcinogens contribute only slightly to the overall calculated potential risk. The Offpost RI Addendum used data from sampling events performed under the RI Addendum, IRA A, and the fall 1989 and winter 1990-1991 groundwater CMP programs. The above data sources were adequate to provide interpretation of "plumes" for only 6 of the 15 carcinogenic COCs present in the Offpost OU groundwater. These chemicals are arsenic, chloroform, dibromochloropropane, dieldrin, tetrachloroethene, and trichloroethene. The remaining nine carcinogens either have limited extent or sporadic detections and thus were not interpreted to be present as plumes.

In conducting the groundwater modeling, the six carcinogenic COCs were assessed with respect to the following: contaminant concentrations, areal extent, relative magnitude of contaminant exceedance of PRGs, and relative transport properties. A comparison of the groundwater PRGs with the concentrations detected for the six carcinogens indicates that there are no exceedances for arsenic. Of the five remaining carcinogens, three are halogenated volatiles (chloroform, tetrachloroethene, and trichloroethene), dibromochloropropane is a halogenated hydrocarbon, and dieldrin is an OCP. A comparison of literature values of the transport properties of these five compounds indicates that chloroform, tetrachloroethene, trichloroethene, and dibromochloropropane have similar ranges of both calculated and measured distribution

coefficients (K_d), and the distribution coefficients for dieldrin were generally not similar to this group (Ebasco, 1991).

Dieldrin was chosen as a contaminant requiring transport modeling because it is the only OCP among the six carcinogenic COCs defined as plumes in the Offpost OU, and because its areal distribution and presumed K_d are different from the other five carcinogenic COCs defined as plumes in the Offpost OU. Dieldrin is also important as a risk-driver based on its relative high toxicity.

The areal extents of chloroform, tetrachloroethene, trichloroethene, and dibromochloropropane in the Offpost OU are generally similar. These four compounds are found predominately in the northern paleochannel as opposed to the First Creek paleochannel. Chloroform exhibits a larger areal extent and occurs at generally higher relative concentrations than tetrachloroethene, trichloroethene, and dibromochloropropane. Based on these observations, chloroform was chosen to represent this group of carcinogenic COCs for the purpose of modeling dissolved chemical transport.

DIMP was chosen as the third compound to be modeled primarily because of its historical importance in understanding the contaminant transport issues at RMA even though it is not a carcinogen.

3.2.1.1.2 Use of the Model in Alternatives Development

Two numerical models (North Plume Group and Northwest Plume Group) were prepared to simulate the groundwater flow and dissolved chemical transport in the Offpost OU. The model development, assumptions, and results are described in detail in Appendix E of the FS.

The parameters controlling the hydrogeologic framework and contaminant transport in the Offpost OU were analyzed using the numerical models. Groundwater velocity in the paleochannels was found to be important in terms of contaminant transport in the Offpost OU. The estimated average linear groundwater velocity is approximately 1000 to 1500 feet per year (ft/yr) in the northern paleochannel, approximately 500 to 1500 ft/yr in the First Creek paleochannel, and approximately 2500 to 3500 ft/yr in the northwestern paleochannel (Figure 3.2.1-1), using

hydraulic gradient, hydraulic conductivity, and representative porosity data presented in Volume VII, Appendix E. Also, the estimated average linear groundwater velocities in zone 3 are approximately twice those estimated in zone 4 of the First Creek paleochannel. The controlling contaminant characteristics include spatial distribution and estimated retardation factors (R) of the contaminants. Chloroform is present primarily in the northern and northwestern paleochannels (see Volume 1, Figure 7), dieldrin is present in the highest concentrations in the First Creek paleochannel and at concentrations slightly greater than the CRL in the northern and northwestern paleochannels (see Volume 1, Figure 5), and DIMP is present in the First Creek and northern paleochannels (see Volume I, Figure 3). Contaminant retardation factors, defined as the ratio of average linear groundwater velocity divided by the average contaminant velocity, were estimated as described in Volume VII, Appendix E, using a range corresponding to a lower-bound (optimistic) and upper-bound (pessimistic) retardation factor. Model-estimated ranges for the time to attain PRGs were made corresponding to the range of retardation factors for each contaminant. In summary, the numeric model showed that the controlling factors were the relatively higher northern and northwestern paleochannel groundwater velocities compared to the First Creek paleochannel, the distribution of dieldrin, and the higher range of retardation factors for dieldrin compared to chloroform or DIMP.

Simulations of contaminant transport, using the numeric groundwater modeling presented in Volume VII, Appendix E, were made corresponding to the continued operation of the boundary systems and additional extraction and/or injection alternatives for both the North Plume Group and the Northwest Plume Group. Initial conditions were chosen to reflect the contaminant plume extent consistent with the data set described in the Introduction (Volume I) and to reflect contaminant removal at the NBCS and NWBCS consistent with attainment of Offpost OU PRGs at the boundary systems. The model results indicated that dieldrin transport is slower relative to DIMP and chloroform, most notably in areas of slower groundwater velocity (i.e., the First Creek paleochannel). DIMP was shown to decrease in concentration, rapidly attaining PRGs in a short time. Chloroform concentrations were also reduced rapidly to attain PRGs quickly, except for an

area of low hydraulic conductivity in the northern paleochannel near the O'Brian Canal. Dieldrin concentrations were reduced slowly in the First Creek paleochannel and rapidly in the northern and northwestern paleochannels (where the initial concentrations of dieldrin are slightly above the CRL and the groundwater velocity is high).

Based on these observations regarding the controlling hydrogeologic and contaminant characteristics from the initial model simulations and on data from analytical wellfield simulator studies in the First Creek and northern paleochannels (HLA, 1991b), additional model runs were made to analyze the effect of groundwater extraction wells and recharge systems on contaminant concentration reduction. These additional model runs varied both the placement of extraction and recharge components and the flow rates of these components in a screening approach to develop alternatives that evaluated varying levels of complexity while attaining acceptable estimated aquifer drawdown/mounding. Model screening runs are not presented explicitly in the FS because the runs were preliminary working tools used to develop the array of alternatives presented in the FS.

Various combinations of extraction and recharge components were evaluated for the First Creek, northern, and northwestern paleochannels. The following discussion describes the different configurations evaluated for each paleochannel.

Groundwater extraction and recharge configurations were evaluated for the First Creek paleochannel, using the results of an analytical wellfield simulator for First Creek axial, transverse, and combination axial/transverse extraction and recharge systems (HLA, 1991b). The wellfield simulator was used to assess the relative performance of axial versus transverse or combination well configurations for conditions (or probable ranges of conditions) considered to exist in the First Creek paleochannel. The wellfield simulations evaluated location and spacing of wells for extraction and recharge, total effluent flow rate, and significance of groundwater recycling from recharge components back to extraction wells. Based on these simulations, an axial system was selected for evaluation in the numeric groundwater transport model over the transverse and combination axial/transverse systems for the First Creek paleochannel to optimize

contaminant removal along the length of the paleochannel. The presence of dieldrin (a contaminant with a relatively higher retardation factor) at high concentrations in the relatively slower groundwater velocity First Creek paleochannel make an axial system more effective in the First Creek paleochannel than a transverse or combination system. Thus, the numeric modeling presented in Volume VII, Appendix E focused on studying the relative differences between axial groundwater collection and recharge systems in the First Creek paleochannel.

The northern paleochannel groundwater extraction and recharge configurations were similarly evaluated. Data derived from the initial numerical groundwater transport modeling indicated that the combination of high groundwater flow velocities in the northern paleochannel and contaminant distribution (i.e., contaminant concentrations slightly above CRLs immediately downgradient of the NBCS) result in rapid attainment of PRGs for contaminants in the northern paleochannel immediately downgradient of the NBCS in the absence of remedial components other than the NBCS. Initial concentrations of dieldrin at levels slightly exceeding the CRL immediately downgradient of the NBCS are reduced to nondetect levels in a model-estimated timeframe of one to three years. At the northern edge of the paleochannel, however, contaminant concentrations in excess of PRGs remain for a model-estimated timeframe of 15 to 30 years, in the absence of remedial components other than the NBCS. Because an axial system scenario would evaluate placement of extraction wells in areas without groundwater PRG exceedances, additional screening model runs varying the placement and flow rates of transverse extraction and recharge configurations were used to develop the array of groundwater alternatives presented in the FS.

The contaminant distribution and hydrogeology in the northwestern paleochannel were similarly evaluated in the initial groundwater modeling runs. The model estimated attainment of contaminant PRGs with continued operation of the NWBCS in one to five years. To assess the impact of extraction and recharge components downgradient of the NWBCS, axial and transverse extraction well and recharge components targeting the dieldrin plumes were then evaluated using numeric groundwater modeling. The results of these screening model runs were used to develop the array of alternatives presented in the FS.

The methodology described above were used to develop groundwater alternatives for the two plume groups. Groundwater modeling was used for the following purposes in developing groundwater alternatives:

1. Developing conceptual designs for sizing and locating groundwater extraction and recharge systems
2. Estimating system flow rates for the purpose of sizing treatment system components
3. Evaluating the relative effectiveness of proposed systems to ensure a range of groundwater alternatives varying in the degree of treatment employed and the timeframe required for remediation

In each case, the results of the transport simulations were evaluated with respect to achievement of the PRGs and the estimation of time required to achieve PRGs. The evaluation of numbers and placement of extraction wells and recharge trenches/wells is intended to be used for comparison of alternatives. The number and placement of extraction/recharge facilities actually required would be determined during the remedial design/remedial action (RD/RA) phase of final remedy implementation for the Offpost OU.

3.2.1.2 Groundwater Alternative Types

Groundwater alternatives have been assigned a numerical designation in discussion and reference. The numbering scheme used to identify groundwater alternatives employs abbreviations that identify the plume group and a successive numbering of alternatives within the identified plume group.

The first identifier in the alternative number indicates the plume group that the alternative addresses (see Figure 3.2.1-1). The abbreviations to identify the plume group are as follows:

N = North Plume Group

NW = Northwest Plume Group

The second identifier in the alternative numerical designation indicates the order of the alternative within the specified plume group. The order in which the alternatives are listed is

consistent with the order of RPOs presented in Volume V, Section 2.10. For example, Alternative No. N-2 is the second alternative in the North Plume Group.

3.3 LAND OWNERSHIP IMPLICATIONS FOR IMPLEMENTING REMEDIAL ALTERNATIVES

Complications that arise when proposing the implementation of remedial alternatives on privately owned land were considered. Considerations that may have an impact on the implementation of remedial alternatives include the following:

1. Potential short-term loss of livelihood for landowners, associated with restriction of activities (e.g., farming, grazing) or disruption of agricultural activity during remedial action
2. Landowners' reluctance to allow remedial action to be conducted on their property

Implementation of groundwater alternatives may require negotiations with landowners when extraction wells, pipelines, containment systems, or other construction and long-term operation activities are proposed for location on private land. Solutions to these issues can be addressed through negotiation with the landowner. Consideration of land ownership directly affects the implementability of proposed remedial alternatives. During this FS, land ownership considerations were included in the alternatives developed in Section 3.5, as follows:

1. Land Acquisition: Shell Oil Company or the Army purchases land that requires remedial action or acquires pipeline easements for certain remedial actions.
2. Temporary Relocation and Land Use Compensation: relocate landowner/residents during remedial action; relocate livestock during remedial action, when applicable or necessary; compensate landowners for monetary losses associated with remedial action (e.g., crop losses, rental fees incurred due to relocation of residents, boarding fees for relocated livestock).
3. Land Lease/Use Compensation: lease land while landowner/residents remain at residence; compensate landowner for any monetary losses incurred during remedial action.

3.4 COMMONALITIES OF ALTERNATIVES

Alternatives developed for the Offpost OU, with the exception of the No Action alternatives, contain commonalities, including institutional controls, pretreatment process options

appropriate to implementing many of the alternatives, and continuation of boundary systems operation (NBCS, NWBCS, Irondale Containment System [ICS]).

3.4.1 Commonalities of Groundwater Remedial Alternatives

The following subsections discuss commonalities of groundwater alternatives, including institutional controls, pretreatment process options, and continuation of boundary systems operation in conjunction with compliance with Offpost OU PRGs.

3.4.1.1 Groundwater Alternatives Institutional Controls

Institutional controls, such as provision of an alternative water supply, groundwater monitoring, and five-year site review, are used as appropriate to supplement engineering controls for short- and long-term management to prevent or limit exposure to hazardous substances, pollutants, or contaminants. Although institutional controls do not reduce mobility, toxicity, or volume of contaminants, they will likely be necessary to maintain the integrity of any remedial action alternative selected and may reduce the potential for human exposure to contaminated groundwater.

3.4.1.1.1 Provision of an Alternative Water Supply (Exposure Control)

All groundwater alternatives, with the exception of the No Action alternative, include the potential provision of an alternative water supply, as necessary, to any identified future users of groundwater containing COCs at concentrations that exceed PRGs (Table 2.5.2-3) (i.e., exposure control). Bottled water would be provided for domestic consumptive use and would be a temporary measure until an alternative water supply could be provided. At the present time, no domestic-use wells contain groundwater COCs at concentrations exceeding PRGs. The ongoing Army commitment to provide an alternative water supply, as necessary, is developed as a contingency program.

3.4.1.1.2 Monitoring Networks

The monitoring programs developed in this report are preliminary conceptual designs with the primary purpose of providing cost estimates for each alternative. The final monitoring program for the Offpost OU would be designed during the RD/RA program.

The purpose of the groundwater monitoring program would be to assess changing aquifer conditions during and after remedial action. Groundwater monitoring is part of all remedial alternatives, including the No Action alternative. The following monitoring programs were developed (for costing purposes) for the North and Northwest Plume Groups:

- North Plume Group
  - All alternatives — 36 wells sampled semiannually
- Northwest Plume Group
  - All alternatives — 13 wells sampled semiannually

The North Plume Group monitoring program would also include a total of seven semiannual surface-water samples from First Creek and the O'Brian Canal to evaluate the effects of groundwater remediation on surface-water quality. Monitoring programs would consist of semiannual water-level measurements and analysis of samples from Offpost OU wells for COCs. In addition to the monitoring programs discussed above, groundwater monitoring will continue onpost. This program will monitor the potential for onpost contaminant plumes approaching the RMA boundaries. Monitoring data from this program will provide information that may be used to evaluate whether modifications are necessary to the boundary systems. The design and implementation of a monitoring program is an essential component of all remedial alternatives.

3.4.1.1.3 Site Review

In accordance with CERCLA, a site review would be conducted at least every five years until groundwater PRGs were achieved to assure that human health and the environment are protected during and after remediation. The site review would use monitoring-program data to assess whether additional action would be warranted.

3.4.1.2 Groundwater Pretreatment Process Options

Groundwater alternatives that involve extraction, in-vessel treatment, and reinjection would require pretreatment to reduce the introduction of fine-grained particles that may wash through the extraction system and into the treatment system. Particulates entering the treatment system may interfere with the operation of in-vessel treatment process options and cause excessive wear to pumps. Influent groundwater filters, such as bag filters, would be used to guard against the introduction of particulates into the treatment system.

3.4.1.3 Continued Operation of the Boundary Systems and Compliance With Offpost Operable Unit Preliminary Remediation Goals

The development and evaluation of all groundwater alternatives, with the exception of the No Action alternative, assumes that boundary response actions would comply with Offpost OU PRGs at the RMA boundary. Compliance of boundary response actions with Offpost OU PRGs would include the following requirements:

1. Boundary containment systems would continue to operate. Approximately 125 million gallons per year at the NBCS and 450 million gallons per year at the NWBCS are currently treated. Changing conditions caused by operation of IRA A and/or onpost response actions may change the system flow rates.

2. Offpost OU groundwater COC PRGs would not be exceeded in boundary containment system effluent.

3. Additional boundary containment system improvements would be implemented, as necessary, to achieve Offpost OU PRGs.

3.5 GROUNDWATER REMEDIAL ALTERNATIVES IDENTIFICATION

A description of alternatives for groundwater is presented in this section. The identification of groundwater alternatives is divided into two sections corresponding to the North and Northwest Plume Groups identified in Figure 3.2.1-1. Alternatives developed for each plume group are identified and described in the subsections that follow.

Information presented in each alternative description includes:

- A description of the RPOs that comprise the alternative
- A brief description of the location, area, and COCs to which the alternative will be applied

3.5.1 Identification of Groundwater Alternatives: North Plume Group

The following subsections identify the alternatives developed for achievement of groundwater PRGs. Groundwater PRGs, as discussed in Section 2.5.4, use ARARs for contaminants with promulgated standards, residential 10^{-6} RME HBC for carcinogens without ARARs, and residential RME HBC for noncarcinogens without ARARs. Table 3.5.1-1 presents the alternatives corresponding to the North Plume Group and identifies process options, number of wells and trenches, flow rates, remediation timeframes, treatment plant location, and process residuals generated.

3.5.1.1 Alternative No. N-1: No Action

Under Alternative No. N-1, the operation of the NBCS would be discontinued. Alternative No. N-1 would therefore not provide for active remediation of affected groundwater within the North Plume Group. Ceasing operation of the NBCS would likely cause an increase in contaminant concentrations within the North Plume Group. Natural fate processes, including degradation and attenuation, would continue to reduce contaminant concentrations with time in groundwater within the North Plume Group. The components of Alternative No. N-1 include the following:

- Long-term groundwater monitoring
- Five-year site reviews

A long-term groundwater monitoring program would be implemented. The purpose of the groundwater monitoring program is to assess changing UFS and CFS aquifer conditions during and after remedial action. As part of Alternative No. N-1, a site review would be conducted at least every five years until PRGs were achieved.

3.5.1.2 Alternative No. N-2: Continued Operation of the North Boundary Containment System With Improvements as Necessary

Alternative No. N-2 would provide for active remediation of affected groundwater approaching the north boundary of RMA through continued remediation of groundwater at the

NBCS. Also, with time, natural fate processes, including degradation and attenuation, would continue to reduce contaminant concentrations in groundwater within the North Plume Group. The major components are as follows:

- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

Under Alternative No. N-2, the NBCS would continue to contain, extract, treat, and recharge approximately 125 million gallons of groundwater per year. Improvements would be made to the NBCS if it was determined that the system was allowing groundwater containing COCs at concentrations exceeding offpost groundwater PRGs to migrate from RMA to the North Plume Group.

A long-term groundwater monitoring program would be implemented. The purpose of the groundwater monitoring program is to assess changing UFS and CFS aquifer conditions during and after remedial action. As part of Alternative No. N-2, a site review would be conducted at least every five years until PRGs were achieved.

3.5.1.3 Alternative No. N-3: Land Acquisition and Use Restrictions

Under Alternative No. N-3, areas within the Offpost OU that exceed groundwater PRGs would be purchased and institutional controls would be implemented to limit exposure to affected groundwater. The NBCS would continue to operate. These measures would meet the following objectives:

- Acquisition of land to facilitate implementation of institutional controls for groundwater
- Limitation of potential exposure to chemicals in groundwater

The major components are as follows:

- Land acquisition

- Access and deed restrictions
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative would be applied to the North Plume Group where contaminants have been reported to exceed PRGs (see Figure 2.6-1). Section 2.6 (Quantities of Affected Media) presents a detailed discussion of the contaminants present and exceedances of PRGs. A total of approximately 440 acres are judged to exceed PRGs.

Land acquisition is assumed, for the purposes of this report, to include activities associated with and necessary to conclude negotiations on a fair market value for parcels of land under private ownership or controlled by municipalities. A deed restriction is a written and recorded document kept on file in the county recorder's office that regulates a number of restrictions primarily related to activities on a property. For this alternative, deed restrictions would prohibit subsurface activities, such as domestic well installation, or any other activities that have a potential for direct contact with affected groundwater, ingestion of affected groundwater, or use of affected groundwater for the irrigation of crops or watering of livestock. Restrictions on drilling new domestic wells would reduce the potential for exposure to affected groundwater.

3.5.1.4 Alternative No. N-4: Interim Response Action A

Under Alternative No. N-4, the NBCS would continue to operate, and the Groundwater Intercept and Treatment System North of RMA (IRA A) would be constructed and operated to remove, contain, treat, and recharge affected groundwater in the First Creek and northern paleochannels downgradient of the NBCS. The elements of the alternative are presented in the Final Implementation Document for IRA A (HLA, 1991b).

The major components are as follows:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels using IRA A groundwater extraction wells
- Treatment of the organic COCs present in the groundwater using carbon adsorption
- Recharge of treated groundwater to the UFS using IRA A wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS and IRA A as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

Alternative No. N-4 remediates UFS groundwater in the First Creek and northern paleochannels that is contaminated with COCs at concentration levels exceeding PRGs, as shown in Figure 2.6-1.

Extraction wells have been selected as the RPO and were used in the IRA A design for the groundwater extraction technology type. Extraction wells use conventional equipment for the removal of contaminated groundwater. Extracted groundwater would be conveyed to the treatment facility via polyvinyl chloride (PVC) pipelines.

Based on the numeric groundwater modeling discussed in Section 3.2.1.1.2, the configuration of extraction wells and recharge systems shown in Figure 3.5.1.4-1 would capture and remove contaminants (primarily dieldrin) axially in the First Creek paleochannel where the groundwater velocity is relatively slower than the northern paleochannel groundwater velocity. Also, in the higher groundwater velocity northern paleochannel system, capture would be attained using a transverse system of extraction and injection wells.

Alternative No. N-4 would use a line of 12 extraction wells (see Figure 3.5.1.4-1), pumping a total of approximately 300 gpm, at the leading edge of the northern paleochannel for the removal and capture of groundwater contaminated with organic COCs at concentrations exceeding PRGs. In the northern paleochannel, treated groundwater would be injected via a line

of 24 recharge wells directly downgradient of the extraction wells. A total of five extraction wells would be placed at the leading edge and along the First Creek paleochannel axis, pumping a total of approximately 180 gpm, to allow contaminant mass removal in the First Creek paleochannel. Thus, Alternative No. N-4 would extract approximately 480 gpm. A total of six recharge trenches would be placed both downgradient of the extraction wells and along the outer boundaries of the First Creek paleochannel. In this manner, the recharge trenches would provide both lateral hydraulic containment of the First Creek paleochannel and water flushing for enhancing the removal of contaminants. Construction of this system began in November 1991 and will be completed by approximately January 1993.

Extracted groundwater from both paleochannels would be conveyed by pipeline to a central carbon adsorption treatment facility located on land in the Offpost OU that was previously purchased by Shell Oil Company. Treatment would achieve PRGs for all organic COCs before disposal via the injection systems.

An intensive short-term monitoring component would be included in this alternative as part of the long-term monitoring program. For costing purposes, it is assumed that the intensive short-term program would consist of monitoring 60 wells in a network that would be finalized through implementation of the alternative. Two years of data would be collected during the period commencing with IRA A operations start-up. Such a program is necessary to evaluate the performance of the NBCS and IRA A systems and to provide increased understanding of contaminant transport, estimated time to achieve PRGS, and the potential necessity of improvements to IRA A.

3.5.1.5 Alternative No. N-5: Expansion 1 to Interim Response Action A

Similar to Alternative No. N-4, this alternative addresses remediation of the First Creek and northern paleochannel groundwater downgradient of the NBCS. Based on the numeric groundwater modeling discussed in Section 3.2.1.1.2, the configuration of extraction wells and recharge systems shown in Figure 3.5.1.5-1 would place additional extraction wells in locations where the limiting hydrogeologic and contaminant characteristics are controlling remediation

timeframes. Alternative No. N-5 is an expansion of IRA A that evaluates placement of two additional extraction wells and four recharge trenches in the area of relatively slower groundwater velocity and high dieldrin concentrations in the First Creek paleochannel to remediate the dieldrin plume faster than Alternative No. N-4 and an additional extraction well and two recharge trenches in the area of low hydraulic conductivity in the northern paleochannel to remediate the chloroform plume faster than Alternative No. N-4.

The major components are as follows:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels, using IRA A groundwater extraction wells
- Expansion 1 of IRA A
- Treatment of organic COCs present in the groundwater using carbon adsorption
- Recharge of treated groundwater to the UFS, using wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

The expansion of IRA A is shown on Figure 3.5.1.5-1. The three additional extraction wells would each pump 30 gpm (90 gpm additional) and the additional trenches would recharge the same volume. Thus, Alternative No. N-5 would extract and treat a total of 600 gpm compared to 480 gpm for Alternative No. N-4.

See Section 3.5.1.4 (Alternative No. N-4) for a discussion of the IRA A components.

3.5.1.6 Alternative No. N-6: Expansion 2 to Interim Response Action A

Alternative No. N-6 addresses remediation of First Creek and northern paleochannel groundwater downgradient of the NBCS. Based on the numeric groundwater modeling discussed in Section 3.2.1.1.2, the configuration of the extraction wells and recharge systems shown in Figure 3.5.1.6-1 would place additional extraction wells in locations in the First Creek

paleochannel of relatively low groundwater velocity and high dieldrin concentrations. Additional recharge trenches would be placed along the paleochannel margins to flush contaminants out of the low conductivity aquifer materials. This alternative places close to the maximum possible practical number of extraction wells and recharge trenches along the entire length of the First Creek paleochannel (see Figure 3.5.1.6-1). The model-estimated well drawdowns and recharge mounding are at or near the bounds of acceptable elevation differences using this configuration, making additional wells or trenches impracticable. This alternative is an expansion of IRA A that evaluates placement of an additional four extraction wells and eight recharge trenches in the First Creek paleochannel to remediate the dieldrin plume faster than IRA A alone and an additional three extraction wells and five recharge trenches in the northern paleochannel to remediate the chloroform plume faster than IRA A alone.

The major components are as follows:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels, using IRA A groundwater extraction wells
- Expansion 2 of IRA A
- Treatment of the organic COCs present in the groundwater, using carbon adsorption
- Recharge of treated groundwater to the UFS, using wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

Expansion 2 of IRA A is presented on Figure 3.5.1.6-1. The seven additional extraction wells would each pump 30 gpm. The 13 additional recharge trenches would recharge the same volume. Thus, Alternative No. N-6 would extract and treat a total of 690 gpm compared to 480 gpm for Alternative No. N-4 and 600 gpm for Alternative No. N-5. See Section 3.5.1.4 (Alternative No. N-4) for a discussion of the IRA A components.

3.5.1.7 Summary of Alternatives Identified for the North Plume Group

Six alternatives have been identified for addressing the remediation of groundwater within the North Plume Group. Table 3.5.1-1 presents alternative process options for the North Plume Group, numbers of wells and trenches required for groundwater remediation, flow rate to treatment plants, and remediation timeframes for each alternative. Additional detail for process options incorporated in each alternative is in Table 3.5.1.7-1. The range of alternatives presented in Table 3.5.1.7-1 is consistent with the range of alternatives specified by the NCP.

The treatment alternatives incorporating active remediation in the North Plume Group, Alternative Nos. N-4, N-5, and N-6, vary substantially in the level of complexity as defined by the number of extraction wells and recharge trenches required, approximate length of recharge trenching, and total flow rate to the treatment plant. Sections 3.5.1.4, 3.5.1.5, and 3.5.1.6 describe the components of each alternative, rationale for placement of extraction wells and recharge trenches based on groundwater modeling, and the location of components for Alternative Nos. N-4, N-5, and N-6, respectively.

The results of numerous groundwater model screening runs were used to develop these three alternatives allowing analysis of contaminant transport as numbers of wells/trenches, well/trench placement, and flow rates were varied. Figures 3.5.1.4-1, 3.5.1.5-1, and 3.5.1.6-1 show the increasing complexity as the total number of extraction wells, recharge trenches, and total flow rate increases from 17 wells, 6 trenches (1500 ft), and 480 gpm total flow for Alternative No. N-4, to 24 wells, 19 trenches (5400 ft), and 610 gpm total flow for Alternative No. N-6. The estimated time to attain PRGs was evaluated using approximate groundwater models developed for FS analysis. Because of the approximate nature of the models and the considerable uncertainty in the conceptual model and hydrogeologic parameters, none of the model-estimated timeframes should be construed as accurate predictions. Rather, the model results should be viewed as tools for assessing relative differences among alternatives. The estimated timeframe to attain PRGs was 15 to 30 years for Alternative No. N-4, 10 to 20 years for Alternative No. N-5, and 10 to 20 years for Alternative No. N-6. Because of spatial limitations (see Figure 3.5.1.6.-1) and estimated well

drawdown and recharge trench mounding limitations, Alternative No. N-6 is the upper-bound level of complexity practicable for inclusion as an alternative for the North Plume Group.

3.5.2 Identification of Groundwater Alternatives: Northwest Plume Group

The following subsections identify the alternatives developed for achievement of groundwater PRGs for the Northwest Plume Group. Table 3.5.2-1 presents the alternatives corresponding to the Northwest Plume Group and identifies process options, numbers of wells and trenches, flow rate, remediation timeframes, treatment plant location, and process residuals generated.

3.5.2.1 Alternative NW-1: No Action

Under Alternative No. NW-1, the operation of the NWBCS extraction, treatment, and reinjection system would be discontinued. Alternative No. NW-1 would therefore not provide active remediation of affected groundwater within the Northwest Plume Group. Ceasing operation of the NWBCS would likely cause an increase in contaminant concentrations within the Northwest Plume Group. Natural fate processes, including degradation and attenuation, would continue to reduce contaminant concentrations with time in groundwater within the Northwest Plume Group. A long-term groundwater monitoring program would be implemented. The purpose of the groundwater monitoring program is to assess changing UFS and CFS aquifer conditions during and after remedial action. As part of Alternative No. NW-1, a site review would be conducted at least every five years until PRGs were achieved.

The major components are as follows:

- Long-term monitoring
- Five-year site reviews

3.5.2.2 Alternative NW-2: Continued Operation of the Northwest Boundary Containment System

Alternative No. NW-2 would provide for active remediation of affected groundwater approaching the northwest boundary of RMA through continued remediation of groundwater at the NWBCS. Also, natural fate processes, including degradation and attenuation, would continue

to reduce contaminant concentrations with time in groundwater within the Northwest Plume Group.

The major components are as follows:

- Continued operation of the NWBCS
- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

Under Alternative No. NW-2, the NWBCS would continue to contain, extract, treat, and recharge approximately 450 million gallons of groundwater per year. Improvements would be made to the NWBCS if it was determined that the system was allowing groundwater containing COCs at concentrations exceeding offpost groundwater PRGs to migrate from Onpost RMA to the Northwest Plume Group. A long-term groundwater monitoring program would be implemented. The purpose of the groundwater monitoring program is to assess changing UFS and CFS aquifer conditions during and after remedial action. As part of Alternative No. NW-2, a site review would be conducted at least every five years until PRGs were achieved.

3.5.2.3 Alternative No. NW-3: Land Acquisition With Use Restrictions

Under Alternative No. NW-3, areas within the Offpost OU that exceed groundwater PRGs would be purchased, and institutional controls would be implemented to limit exposure to affected groundwater. These measures would meet the following objectives:

- Acquisition of land to facilitate implementation of institutional controls for groundwater
- Limitation of potential exposure to chemicals in groundwater

The major components of Alternative No. NW-3 are as follows:

- Land acquisition
- Access and deed restrictions
- Continued operation of the NWBCS

- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

See Section 3.5.1.3 (Alternative No. N-3) for a description of the deed/well restriction and the land acquisition components.

This alternative would be applied to the Northwest Plume Group, where contaminants have been reported to exceed PRGs (see Figure 2.6-1). Section 2.6 (Quantities of Affected Media) presents a detailed discussion of the contaminants present and exceedances of PRGs. A total of approximately 440 acres is judged to exceed PRGs.

3.5.2.4 Alternative No. NW-4: Northwest Plume Group Extraction/Recharge System

This alternative addresses active remediation of the dieldrin plumes in the northwestern paleochannel downgradient of the NWBCS. Based on the numeric groundwater modeling presented in Section 3.2.1.1.2, the configuration of extraction (recharge systems shown in Figure 3.5.2.4-1) would place extraction wells in the dieldrin plume in the northwestern paleochannel. Placement of three extraction wells and five recharge wells (see Figure 3.5.2.4-1) was evaluated for faster dieldrin plume remediation than Alternative No. NW-2 provides.

The three extraction wells would pump 50 gpm each for a total of an additional 150 gpm above Alternative Nos. 2 and 3 , and the five recharge wells would recharge 30 gpm each. Extracted groundwater would be pumped to the NWBCS for treatment. Following treatment, the groundwater would be pumped to the reinjection wells for disposal. The major components of Alternative No. NW-4 follow:

- Removal of contaminated UFS groundwater northwest of the RMA boundary, using three groundwater extraction wells
- Treatment of organic COCs present in the groundwater, using carbon adsorption
- Recharge of treated groundwater to the UFS, using five wells
- Continued operation of the NWBCS

- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

3.5.2.5 Summary of Alternatives Identified for the Northwest Plume Group

Four alternatives have been identified for addressing the remediation of groundwater within the Northwest Plume Group. A summary of Northwest Plume Group alternatives indicating the process options incorporated in each alternative is presented in Table 3.5.2.5-1. The range of alternatives presented in Table 3.5.2.5-1 is consistent with the range of alternatives specified by the NCP.

The alternatives developed for the Northwest Plume Group were developed using the results of groundwater modeling screening runs, similar to the approach described for the North Plume Group in Section 3.5.1.7. Alternative No. NW-2 contemplates continued operation of the NWBCS, which treats a total of 850 gpm. Figure 3.5.2.4-1 presents the groundwater extraction and recharge configuration for Alternative No. NW-4. Alternative No. NW-4 contemplates three extraction wells and five recharge wells pumping a total of 1000 gpm in addition to the continued operation of the NWBCS. The estimated time to attain PRGs was evaluated using approximate groundwater models developed for FS analysis. As stated previously in Section 3.5.1.7, the model-estimated timeframes should be viewed as tools for assessing relative differences between alternatives. The estimated timeframe to attain PRGs is three to eight years for Alternative No. NW-2 and two to five years for Alternative No. NW-4. Based on the groundwater modeling results, Alternative No. NW-4 represents the upper-bound of complexity required for developing a full range of Northwest Plume Group alternatives because contaminant PRGs are attained in approximately identical timeframes under both Alternative Nos. NW-2 and NW-4.

4.0 SCREENING OF ALTERNATIVES

The objective of the screening of alternatives is to reduce the number of alternatives identified in Section 3.0 that will undergo a thorough and extensive analysis during the detailed analysis of alternatives (DAA) (Section 5.0) but at the same time to preserve a range of options. Section 4.0 describes the screening process methodology, defines the screening evaluation criteria (Section 4.1), presents the screening of alternatives, and summarizes the results of the screening process identifying alternatives retained for analysis during the DAA (Section 4.2).

4.1 METHODOLOGY

All alternatives identified in Section 3.0 were evaluated on the basis of the following three criteria as specified by the NCP: (1) effectiveness, (2) implementability, and (3) cost. These three criteria are described in the following subsections. Comparisons were made between similar alternatives; that is, those alternatives that address the same plume group and employ the same general response actions (e.g., treatment).

4.1.1 Effectiveness Evaluation

In accordance with the NCP, the effectiveness of each alternative was evaluated with respect to the degree to which the alternative (1) reduces toxicity, mobility, or volume through remedial action; (2) minimizes residual risks and affords long-term protection; (3) complies with chemical-specific ARARs; (4) minimizes short-term impacts; and (5) requires time to achieve protection. Reduction in mobility, toxicity, or volume refers to changes in at least one characteristic of the hazardous substances or contaminated media via treatment that decreases the inherent threats or risks associated with the hazardous substances, pollutants, or contaminants. The degree to which each alternative minimizes residual risk and affords long-term protection was assessed by evaluating the ability of each alternative to control or eliminate the exposure pathways identified in the Offpost EA. The ability of each alternative to comply with ARARs was assessed by considering the ability of an alternative to achieve the chemical-specific ARARs identified in Section 2.5. The degree to which each alternative minimizes short-term impacts was qualitatively

evaluated by considering the potential for emissions of site contaminants beyond those that occur or may occur under the No Action alternative. Finally, the time required for each alternative to achieve protection was evaluated by estimating the time required to control or eliminate the exposure pathways through achievement of PRGs. Timeframe estimates were derived from groundwater-modeling results presented in Appendix E.

In accordance with the NCP, alternatives that do not provide adequate protection of human health or the environment or that provide significantly less effectiveness than other more promising alternatives have been eliminated from further consideration.

4.1.2 Implementability Evaluation

Implementability is a measure of both the technical and administrative feasibility of constructing, operating, and maintaining a remedial alternative, given the site conditions in accordance with the NCP. Technical feasibility refers to (1) the ability to construct, reliably operate, and meet technology-specific requirements for process options until a remedial action is complete; (2) the reliability and level of demonstration of process options included in an alternative; and (3) the ability to replace, maintain, and monitor the technical components of an alternative, if required, after the remedial action is complete.

Administrative feasibility refers to the activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies for offsite activities. Administrative feasibility may also consider landowner acceptance of proposed remedial alternatives. Evaluation of landowner acceptance has been evaluated to be a public acceptance issue and is an evaluation criterion in the DAA portion of the FS (Section 5.0).

In accordance with NCP, alternatives that are technically or administratively infeasible or that would require equipment, specialists, or facilities that are not available within a reasonable time have been eliminated from further consideration.

4.1.3 Cost Evaluation

The cost of each alternative is an estimate of construction and any long-term costs to operate and maintain the alternative in accordance with the NCP. The objective of the cost evaluation was to eliminate alternatives that do not provide substantially greater protection of human health and the environment but have costs that are approximately an order of magnitude greater than the costs of other similar alternatives. The cost evaluation included estimating capital costs, long-term operation and maintenance (O&M) costs, indirect costs, and present worth, given the site-specific conditions within the Offpost OU. The cost estimates were based on vendor information, cost estimating guides, and review of published cost data at similar sites.

The capital cost of each alternative (with the exception of the No Action alternative and the Land Acquisition and Deed Restriction alternative) was multiplied by a factor to estimate total indirect costs. This factor was based on the following percentages of capital costs:

- Engineering and design 15 percent
- Construction management 10 percent
- Resident engineering 2.5 percent
- Regulatory oversight 10 percent
- Contingency 30 percent

Present-worth analysis was used to evaluate expenditures that occur during different periods. Discounting all costs to a common base year was used to compare the costs for different remedial alternatives on the basis of a single figure for each alternative. Present worth was calculated according to the following formula:

$$\text{Present Worth} = \text{Capital Cost} + (\text{O\&M Cost})\ (P/A)$$

Annual O&M maintenance costs are multiplied by the uniform series present worth factor, (P/A) and are added to the capital cost.

where: $(P/A) = \frac{(1 + i)^n - 1}{i(1 + i)^n}$

P = present single sum of money

A = the amount of each payment in a uniform series of equal payments made at the end of each period

i = discount rate per period

n = number of interest periods in the project evaluation life

The value of P/A for an interest rate of 5 percent over a 30-year period is 15.37. An interest rate of 5 percent was used on the basis of the EPA guidance (EPA, 1988e).

In accordance with the NCP, cost is a factor that may be used to eliminate alternatives. Alternatives providing effectiveness and implementability similar to that of another alternative by employing a similar method of treatment and or engineering control, but at greater cost, may be eliminated in the screening of alternatives.

4.2 SCREENING OF ALTERNATIVES

The screening of alternatives was divided into two sections corresponding to the alternative sets for the North and Northwest Plume Groups developed in Section 3.0. Section 4.2.1 screens alternatives developed to achieve PRGs for the North Plume Group and Section 4.2.2 screens alternatives developed to achieve PRGs for the Northwest Plume Group. Each alternative was screened based on effectiveness, implementability, and cost.

4.2.1 Screening of Alternatives - North Plume Group

The following subsections present the screening of groundwater alternatives developed for addressing groundwater remediation in the North Plume Group.

4.2.1.1 Alternative No. N-1: No Action

Under Alternative No. N-1, the operation of the NBCS extraction treatment and reinjection system would be discontinued. Alternative No. N-1 would therefore not provide for active

remediation of groundwater within the North Plume Group. A description of this alternative was presented previously in Section 3.5.1.1.

4.2.1.1.1 Effectiveness

The effectiveness evaluation for Alternative No. N-1 is presented below.

- Reduction in mobility, toxicity, or volume through remedial action
  - o There would be no reduction in mobility, toxicity, or volume from treatment because of discontinuation of the operation of the NBCS. However, reductions in toxicity, mobility, and volume will occur through natural attenuation processes.
- Residual risk and long-term protection
  - o Under the No Action Alternative, no provisions are made for addressing exposure pathways, reducing residual risk, or affording long-term protection to potential users of affected groundwater from the North Plume Group.
- Compliance with ARARs
  - o Affected groundwater in the North Plume Group would not be treated and would not comply with groundwater ARARs.
- Short-term impacts
  - o There would be no short-term impacts.
- Timeframe for achievement of protection
  - o Not evaluated.

Under Alternative No. N-1, no action would be performed to reduce the mobility, toxicity, or volume of contaminated groundwater within the North Plume Group. Operation of the NBCS would cease, and contaminant concentrations would correspondingly increase in groundwater entering the Offpost OU. Exposure pathways would not be addressed. Therefore, no provisions would be made for reducing residual risk and affording long-term protection. Under Alternative No. N-1, natural attenuation processes would be the only mechanism to reduce COC concentrations to PRGs levels. After ceasing operations at the NBCS, onpost groundwater would act as a source of North Plume Group contamination. No data is available for evaluating the impact of ceasing the operations at the NBCS. Therefore, the time frame for achieving PRGs has not been estimated. Groundwater monitoring and periodic site review would indicate when contaminant

levels in groundwater have attained PRGs. There would be no short-term impacts under this alternative.

4.2.1.1.2 Implementability

The implementability evaluation for Alternative No. N-1 is presented below.

- Technical feasibility
  - o Monitoring and site review are readily performed and well-demonstrated at hazardous waste sites.
- Administrative feasibility
  - o No permits are required.
  - o Equipment and technical personnel required for monitoring and site review are readily available.

Periodic groundwater monitoring and site review are the only actions that would be taken under Alternative No. N-1. Groundwater monitoring wells identified for sampling under the proposed Groundwater Monitoring Program (GMP) have already been installed, and installation of additional wells would be readily implemented, if necessary. Groundwater monitoring data would be used in performing a site review every five years until PRGs are achieved. Alternative No. N-1 would not require permits.

4.2.1.1.3 Cost

The capital costs, long-term O&M costs, and total present worth costs for Alternative No. N-1 are presented below:

- Total Capital Costs = $ - 0 -
- Total Long-term Operation and Maintenance Costs = $4.1 - 6.0 million
- Total Present Worth Costs = $4.1 - 6.0 million

4.2.1.2 Alternative No. N-2: Continued Operation of the North Boundary Containment System With Improvements as Necessary

Under Alternative No. N-2, groundwater exceeding PRGs in the North Plume Group would continue to be extracted, treated, and reinjected through continued operation of the NBCS. The

NBCS system would be upgraded as necessary to achieve PRGs in the North Plume Group. A description of this alternative was presented previously in Section 3.5.1.2.

4.2.1.2.1 Effectiveness

The effectiveness evaluation for Alternative No. N-2 is presented below:

- Reduction in mobility, toxicity, or volume through remedial action
  - o Continued operation of the NBCS through removal, treatment, and recharge of approximately 125 million gallons of groundwater per year would result in a reduction in the toxicity, mobility, and volume of contaminated groundwater entering the Offpost OU.
  - o The alternative contains no active measures to address the reduction of the toxicity, mobility, or volume of existing contamination within the North Plume Group north of the NBCS; however, some reduction in toxicity, mobility, and volume would occur through decreases in contaminant concentrations attributable to natural attenuation and flushing with treated water from the NBCS.
- Residual risk and long-term protection
  - o Continued operation of the NBCS would result in increased long-term protection and reduced residual risk attributable to a reduction in contaminant concentrations entering the Offpost OU.
  - o No provisions would be made for addressing exposure pathways, reducing residual risk, or affording long-term protection associated with existing contamination within the North Plume Group north of the NBCS.
- Compliance with ARARs
  - o Treatment of affected groundwater, source control provided by the NBCS, and natural attenuation processes in the North Plume Group would achieve compliance with groundwater ARARs.
- Short-term impacts
  - o There would be no short-term impacts.
- Timeframe for achievement of protection
  - o Reductions in contaminant concentrations would occur through natural attenuation processes and flushing with treated water from the NBCS; monitoring and site review would indicate when PRGs were achieved; groundwater modeling indicates that PRGs would be achieved within 15 to 30-plus years.

Under Alternative No. N-2, continued operation of the NBCS to achieve Offpost OU PRGs would reduce contaminant concentrations in groundwater entering the Offpost OU and correspondingly reduce the toxicity, mobility, and volume of groundwater migrating from RMA to the

North Plume Group. Through treatment of approximately 125 million gallons of groundwater per year at the NBCS, long-term protectiveness is substantially improved in the North Plume Group area. Under Alternative No. N-2, natural attenuation processes, source control provided by the NBCS, and flushing the North Plume Group with treated groundwater would reduce COC concentrations to PRGs within 15 to 30-plus years. Groundwater monitoring and periodic site review would indicate when contaminant levels in groundwater have attained PRGs. There would be no short-term impacts under this alternative.

4.2.1.2.2 Implementability

The implementability evaluation for Alternative No. N-2 is presented below.

- Technical feasibility
  - o Groundwater monitoring and periodic site review are readily performed and well demonstrated at hazardous waste sites.
- Administrative feasibility
  - o No permits are required.
  - o Equipment and technical personnel required for groundwater monitoring and site review are readily available.

No implementability considerations are associated with continued operation of the NBCS. Groundwater monitoring wells have already been installed in the Offpost OU, and installation of additional wells would be readily implemented, if necessary. Groundwater monitoring data would be used in performing a site review every five years until PRGs were achieved. Alternative No. N-2 would not require permits.

4.2.1.2.3 Cost

The capital costs, long-term O&M costs, and total present worth costs for Alternative No. N-2 are presented below:

- Total Capital Costs = $ - 0 -
- Total Long-term Operation and Maintenance Costs = $30.6 - 32.5 million
- Total Present Worth Costs = $30.6 - 32.5 million

4.2.1.3 Alternative No. N-3: Land Acquisition and Deed Restrictions

Under alternative No. N-3, areas within the Offpost OU that exceed groundwater PRGs would be purchased, and institutional controls would be implemented to limit exposure to affected groundwater. A description of this alternative was previously presented in Section 3.5.1.3.

4.2.1.3.1 Effectiveness

The effectiveness evaluation for Alternative No. N-3 is presented below.

- Reduction in mobility, toxicity, or volume through remedial action
  - o Continued operation of the NBCS through removal, treatment, and recharge of approximately 125 million gallons of groundwater per year would result in a reduction in the toxicity, mobility, and volume of contaminated groundwater entering the Offpost OU.
  - o The alternative contains no active measures to address the reduction of the toxicity, mobility, or volume of existing contamination within the North Plume Group north of the NBCS; however, some reduction in toxicity, mobility, and volume would occur through decreases in contaminant concentrations attributable to natural attenuation and flushing with treated water from the NBCS.
- Residual risk and long-term protection
  - o Exposure pathways would be controlled and residual risk would be reduced by minimizing exposure pathways through well installation/deed restrictions.
  - o Continued operation of the NBCS would result in increased long-term protection and reduced residual risk attributable to a reduction in contaminant concentrations entering the Offpost OU.
- Compliance with ARARs
  - o Treatment and source control provided by the NBCS and natural attenuation processes in the North Plume Group would achieve compliance with groundwater ARARs.
- Short-term impacts
  - o There would be no short-term impacts.
- Timeframe for achievement of protection
  - o Reduction in contaminant concentration would occur through natural attenuation processes and flushing with treated water from the NBCS. Monitoring and site review would indicate when PRGs were achieved; groundwater modeling indicates PRGs would be achieved within 15 to 30-plus years.

Alternative No. N-3 would reduce the mobility, toxicity, and volume of contaminated groundwater entering the North Plume Group. Continued operation of the NBCS would continue to reduce contaminant concentrations and would achieve Offpost OU PRGs . Exposure pathways would be addressed through land acquisition and well installation/deed restrictions. Thus, hypothetical risk would be reduced by preventing the use of contaminated groundwater. Purchasing land overlying affected groundwater would aid in controlling the use of contaminated ground-water. Source control actions provided by continued operation of the NBCS, combined with natural attenuation processes, would reduce COC concentrations to PRGs within 15 to 30-plus years. Alternative No. N-3 would not create any short-term impacts.

4.2.1.3.2 Implementability

The implementability evaluation for Alternative No. N-3 is presented below.

- Technical feasibility
  - o Construction is not required
  - o Well installation/deed restrictions are common components of remedial alternatives at hazardous waste sites.
- Administrative feasibility
  - o No permits are required
  - o Technical personnel and equipment are not required

Implementing Alternative No. N-3 would be technically feasible. No construction would be required. Areas of the Offpost OU have already been purchased by Shell Oil Company, and additional property could be purchased by the Army or Shell Oil Company as necessary. Well installation/deed restrictions are common components of remedial action at hazardous waste sites. Enforcement of use and access restrictions would be simplified by acquisition of the affected areas. No permits, technical personnel, or equipment would be required under Alternative No. N-3.

4.2.1.3.3 Cost

The capital costs, long-term O&M costs, and total present worth costs for Alternative No. N-3 are presented below:

- Total Capital Costs = $5.3 million
- Total Long-term Operation and Maintenance Costs = $30.4 - 32.3 million
- Total Present Worth Costs = $35.8 - 37.7 million

4.2.1.4 Alternative No. N-4: Interim Response Action A

Under alternative No. N-4, the NBCS would continue to operate and IRA A would be constructed and operated to extract, treat, and recharge affected groundwater in the First Creek and northern paleochannels downgradient of the NBCS. A description of this alternative was presented previously in Section 3.5.1.4.

4.2.1.4.1 Effectiveness

The effectiveness evaluation for Alternative No. N-4 is presented below.

- Reduction in mobility, toxicity, or volume through remedial action
  - Continued operation of the NBCS through removal, treatment, and recharge of approximately 125 million gallons per year would result in a reduction of mobility, toxicity, and volume of affected groundwater entering the Offpost OU.
  - Removal, treatment, and recharge of approximately 250 million gallons of groundwater per year at the IRA A facilities would result in a reduction in the toxicity, mobility, and volume of contaminated groundwater in the Offpost OU within the North Plume Group. In addition, some reduction in toxicity, mobility, and volume would occur through natural attenuation and flushing.
- Residual risk and long-term protection
  - Continued operation of the NBCS and operation of the IRA A would result in increased long-term protection and reduced residual risk attributable to a reduction in contaminant concentrations entering the Offpost OU and within the North Plume Group.
- Compliance with ARARs
  - Extraction, treatment, and recharge of affected groundwater associated with operation of the IRA A and NBCS systems would achieve compliance with groundwater ARARs.
- Short-term impacts
  - There would be no short-term impacts.

- Timeframe for achievement of protection

  - Groundwater modeling indicates that contaminant PRGs would be achieved within 15 to 30 years.

Alternative No. N-4 would intercept, pump, treat, and recharge UFS groundwater, thereby reducing organic COC concentrations within the North Plume Group. Treatment of groundwater with carbon adsorption would reduce the toxicity and volume of contaminated groundwater. Alternative No. N-4 would reduce the mobility of contaminated groundwater by downgradient interception and extraction in the northern paleochannel and by axial interception and extraction in the First Creek paleochannel. Hypothetical risk would be reduced substantially through a reduction of COC concentration levels in UFS groundwater. However, some risk would remain until groundwater PRGs have been achieved in UFS groundwater. Treatment of groundwater with carbon adsorption would achieve groundwater PRGs for all COCs. Alternative No. N-4 would not cause any short-term impacts to human health or the environment. On the basis of groundwater modeling, it is expected that PRGs would be achieved within 15 to 30 years.

4.2.1.4.2 Implementability

The implementability evaluation for Alternative No. N-4 is presented below.

- Technical feasibility

  - Construction and operation of the facility could be readily implemented.

  - Carbon adsorption is a reliable and well-demonstrated process option for removal of organic contaminants in RMA groundwater.

- Administrative feasibility

  - No permits are required. The IRA A Implementation Document has been finalized.

Alternative No. N-4 would be technically feasible. Construction and operation of the IRA A system could be readily implemented. Final design has been approved. Carbon adsorption is a reliable and well-demonstrated process option for removal of organic contaminants from RMA groundwater. The administrative feasibility of Alternative No. N-4 would be high because

no permits would be required and the Implementation Document for IRA A has already been approved.

4.2.1.4.3 Cost

The capital costs, long-term O&M costs and total present worth costs for Alternative No. N-4 are presented below:

- Total Capital Costs = $16.7 million
- Total Long-term Operation and Maintenance Costs = $39.8 - 46.4 million
- Total Present Worth Costs = $56.5 - 63.1 million

4.2.1.5 Alternative No. N-5: Expansion 1 to Interim Response Action A

Under Alternative No. N-5, an expansion of IRA A was evaluated to remediate the dieldrin plume faster in the First Creek paleochannel and the chloroform plume faster in the northern paleochannel. Section 3.5.1.5 presented a description of this alternative.

4.2.1.5.1 Effectiveness

The effectiveness evaluation for Alternative No. N-5 is presented below.

- Reduction in mobility, toxicity, or volume through remedial action
  - Continued operation of the NBCS through removal, treatment, and recharge of approximately 125 million gallons of groundwater per year would result in a reduction of toxicity, mobility, and volume of contaminated groundwater entering the Offpost OU.
  - Removal, treatment, and recharge of approximately 250 million gallons of groundwater per year at the IRA A facilities would result in a reduction in the toxicity, mobility, and volume of contaminated groundwater in the Offpost OU within the North Plume Group. In addition, some reduction in toxicity, mobility, and volume would occur through natural attenuation and flushing.
- Residual risk and long-term protection
  - Continued operation of the NBCS and operation of IRA A and Expansion 1 to IRA A would result in increased long-term protection and reduced residual risk attributable to a reduction in contaminant concentrations entering the Offpost OU and within the North Plume Group.

- Compliance with ARARs
  - o Extraction, treatment, and recharge of groundwater associated with the operation of IRA A, Expansion 1 to IRA A, and the NBCS would achieve compliance with groundwater ARARs.
- Short-term impacts
  - o There would be no short-term impacts.
- Timeframe for achievement of protection
  - o Groundwater modeling indicates that PRGs would be achieved within 10 to 20 years.

Alternative No. N-5 would intercept, pump, treat, and recharge UFS groundwater, therefore reducing COC concentrations in the North Plume Group. Treatment of groundwater with carbon adsorption would reduce the toxicity and volume of contaminated groundwater. The additional wells and injection trenches provided for in Expansion 1 to IRA A would enhance the rate of contaminant removal by extracting and flushing groundwater from areas upgradient of the interception extraction well systems presented in IRA A Alternative No. N-3. Consequently, Alternative No. N-4 would increase the rate of both toxicity and volume reduction in contaminated groundwater. Hypothetical risk would be reduced through a reduction in COC concentrations in UFS groundwater; however, some hypothetical risk arising from the potential for the use of UFS groundwater before completion of remediation would remain until PRGs were achieved. Alterative No. N-5 would achieve groundwater PRGs. Alternative No. N-5 would not present any short-term impacts. On the basis of groundwater modeling results, it is expected that protectiveness would be achieved within 10 to 20 years.

4.2.1.5.3 Implementability

The implementability evaluation for Alternative No. N-5 is presented below.

- Technical feasibility
  - o Construction and operation of a facility are readily implemented.
  - o Carbon adsorption is a reliable and well-demonstrated process option for removal of organic contaminants in RMA groundwater.

- Administrative feasibility
  - o No permits are required.
  - o Required equipment and technical personnel are readily available.

Alternative No. N-5 would be technically feasible. Construction and operation of the treatment and extraction facility would be readily implemented. Carbon adsorption is a reliable and well-demonstrated process option for removal of organic contaminants from RMA groundwater. The administrative feasibility of Alterative No. N-5 would be high because no permits would be required. Equipment and technical personnel required to implement Alternative No. N-5 would be readily available.

4.2.1.5.3 Cost

The capital costs, long-term O&M costs, and total present worth costs for Alternative No. N-5 are presented below:

- Total Capital Costs = $19.4 million
- Total Long-term Operation and Maintenance Costs = $36.9 - 43.6 million
- Total Present Worth Costs = $56.2 - 63.0 million

4.2.1.6 Alternative No. N-6: Expansion 2 to Interim Response Action A

Under Alternate No. N-6, a different expansion of IRA A was evaluated to remediate the dieldrin plume faster in the First Creek paleochannel and the chloroform plume faster in the northern paleochannel. This alterative was described previously in Section 3.5.1.7.

4.2.1.6.1 Effectiveness

The effectiveness evaluation for Alternative No. N-6 is presented below.

- Reduction in mobility, toxicity, or volume through remedial action
  - o Continued operation of the NBCS through removal and recharge of approximately 125 million gallons of groundwater per year would result in a reduction of toxicity, mobility, and volume of contaminated groundwater entering the Offpost OU.
  - o Removal, treatment, and recharge of approximately 250 million gallons of groundwater per year at the IRA A facilities would result in a reduction in the toxicity, mobility, and

volume of contaminated groundwater in the Offpost OU within the North Plume Group. In addition, some reduction in toxicity, mobility, and volume would occur through natural attenuation and flushing.

- Residual risk and long-term protection

  - Continued operation of the NBCS and operation of IRA A would result in increased long-term protection and reduced residual risk attributable to a reduction in contaminant concentrations entering the Offpost OU and within the North Plume Group.

- Compliance with ARARs

  - Extraction, treatment, and reinjection of affected groundwater associated with the operation of the NBCS, IRA A, and Expansion 2 to IRA A would achieve compliance with groundwater ARARs.

- Timeframe for achievement of protection

  - Groundwater modeling estimates that PRGs would be achieved in 10 to 20 years.

Alternative No. N-6 would intercept, pump, treat, and recharge UFS groundwater in the North Plume Group. Treatment of groundwater with carbon adsorption would reduce the toxicity and volume of contaminated groundwater. The additional wells and injection trenches provided for in Expansion 2 to IRA A would enhance the rate of contaminant removal by extracting and flushing groundwater from areas upgradient of the interception extraction well systems presented in Expansion 1 to IRA A Alternative No. N-5. Consequently, Alternative No. N-6 would increase the rate of toxicity and volume reduction in contaminated groundwater. Hypothetical risk would be reduced through a reduction in COC concentrations in UFS groundwater; however, some hypothetical risk arising from the potential for the use of UFS groundwater before completion of remediation would remain until PRGs were achieved. Alternative No. N-6 would achieve groundwater PRGs. Alternative No. N-6 would not present any short-term impacts. On the basis of groundwater modeling results, it is expected that PRGs would be achieved within 10 to 20 years.

4.2.1.6.2 Implementability

The implementability evaluation for Alternative No. N-6 is presented below.

- Technical feasibility
  - o Construction and operation of the facility are readily implemented.
  - o Carbon adsorption is a reliable and well-demonstrated process option for removal of organic contaminants in RMA groundwater.
- Administrative feasibility
  - o No permits are required.
  - o Required equipment and technical personnel are readily available.

Alternative No. N-6 would be technically feasible. Construction and operation of the treatment and extraction facility would be readily implemented. Carbon adsorption is a reliable and well-demonstrated process option for removal of organic contaminants from RMA groundwater. The administrative feasibility of Alternative No. N-6 would be high because no permits would be required. Equipment and technical personnel required to implement Alternative No. N-6 would be readily available.

4.2.1.6.3 Cost

The capital costs, long-term O&M costs, and total present worth costs for Alternative No. N-6 are presented below:

- Total Capital Costs = $22.0 million
- Total Long-term Operation and Maintenance Costs = $37.6 - 44.2 million
- Total Present Worth Costs = $59.6 - 66.2 million

4.2.1.7 Alternative Screening Summary and Recommendation

Six alternatives were evaluated for remediation of UFS groundwater within the North Plume Group. The results of this evaluation and recommendations for selection of alternatives to be carried forward to the DAA are summarized in Table 4.2.1.7-1. The screening of the six alternatives, with respect to the effectiveness criterion, shows that the four alternatives with active extraction/treatment/recharge remediation components at the NBCS and/or within the Offpost OU afford the best reduction in toxicity, mobility, and volume, the best long-term protection, and

the best compliance with PRGs. With regard to the estimated time to achieve protection, both Alternative Nos. N-5 and N-6 have slightly reduced timeframes, as compared to Alternative No. N-4, and Alternative No. N-4 has a reduced timeframe compared to alternatives without active extraction and treatment in the Offpost OU (i.e., Alternative Nos. N-1 and N-2). Alternative No. N-6, however, affords no reduction in estimated timeframe above Alternative No. N-5.

With respect to the implementability criterion, there are no prohibitive implementability concerns with any of the six alternatives.

A comparison of the costs associated with the six alternatives is presented in Table 4.2.1.7-1. The costs range from $4.1 - 6.0 million for Alternative No. N-1 to $59.6 - 66.2 million for Alternative No. N-6.

Table 4.2.1.7-1 indicates that on the basis of effectiveness, implementability, and cost, three alternatives were selected for evaluation in the DAA. In addition, as required by the NCP, the No Action alternative was selected for evaluation in the DAA. The four alternatives selected for further evaluation follow:

Alternative No. N-1: No Action

Alternative No. N-2: Continued Operation of the NBCS with Improvements as Necessary

Alternative No. N-4: Interim Response Action A

Alternative No. N-5: Expansion 1 to Interim Response Action A

4.2.2 Screening of Groundwater Alternatives - Northwest Plume Group

The following subsections present the screening of groundwater alternatives developed for addressing groundwater remediation in the Northwest Plume Group.

4.2.2.1 Alternative No. NW-1: No Action

Under Alternative No. NW-1, the operation of the NWBCS would be discontinued. Alternative No. NW-1 would therefore not provide for active remediation of groundwater within the Northwest Plume Group. This alternative was described previously in Section 3.5.2.1.

4.2.2.1.1 Effectiveness

The effectiveness evaluation for Alternative No. NW-1 is presented below.

- Reduction in mobility, toxicity, or volume through remedial action
  - o There would be no reduction in mobility, toxicity or volume from treatment because of discontinuation of the operation of the NWBCS. In addition, reductions in toxicity, mobility, and volume will occur through natural attenuation processes.
- Residual risk and long-term protection
  - o Under the No Action Alternative, no provisions are made for addressing exposure pathways, reducing residual risk, or affording long-term protection to potential users of affected groundwater from the Northwest Plume Group.
- Compliance with ARARs
  - o Affected groundwater in the Northwest Plume Group would not be treated and would not comply with groundwater ARARs.
- Short-term Impacts
  - o There would be no short-term impacts.
- Timeframe for achievement of protection
  - o Not evaluated.

Under Alternative No. NW-1, no further action would be performed to reduce the mobility, toxicity, or volume of contaminated groundwater within the Northwest Plume Group. Operation of the NWBCS would cease, and contaminant concentrations in groundwater entering the Offpost OU would increase. Exposure pathways would not be addressed. Therefore, no provision would be made for reducing residual risk and affording long-term protection. Under Alternative No. NW-1, natural attenuation processes would be the only mechanism to reduce COC concentrations to PRGs. After ceasing operations at the NWBCS, onpost groundwater would act as a source of Northwest Plume Group contamination. No data are available for evaluating the impact of ceasing operations at the NWBCS. Therefore, the timeframe for achieving protection has not been estimated. Groundwater monitoring and periodic site review would indicate when contaminant levels in groundwater have attained PRGs. There would be no short-term impacts under Alternative No. NW-1.

4.2.2.1.2 Implementability

The implementability evaluation for Alternative No. NW-1 is presented below.

- Technical feasibility
  - o Monitoring and site review are readily performed and well-demonstrated at hazardous waste sites.
- Administrative feasibility
  - o No permits are required.
  - o Equipment and technical personnel required for monitoring and site review are readily available.

Periodic groundwater monitoring and site review are the only actions that would be taken under Alternative No. NW-1. Groundwater monitoring wells identified for sampling under the proposed GMP have already been installed in the Offpost OU, and installation of additional wells would be readily implemented, if necessary. Groundwater monitoring data would be used in performing a site review every five years until PRGs are achieved. Alternative No. NW-1 would not require permits.

4.2.2.1.3 Cost

The capital costs, long-term O&M costs, and the total present worth costs for Alternative No. NW-1 are presented below:

- Total Capital Costs = $- 0 -
- Total Long-term Operation and Maintenance Costs = $0.6 - 1.3 million
- Total Present Worth Costs = $0.6 - 1.3 million

4.2.2.2 Alternative No. NW-2: Continued Operation of the Northwest Boundary Containment System With Improvements As Necessary

Under Alternative No. NW-2, groundwater exceeding PRGs in the Northwest Plume Group would continue to be extracted, treated, and reinjected through continued operation of the NWBCS. The NWBCS would be upgraded as necessary to achieve PRGs in the Northwest Plume Group. This alternative was described previously in Section 3.5.2.2.

4.2.2.2.1 Effectiveness

The effectiveness evaluation for Alternative No. NW-2 is presented below.

- Reduction in mobility, toxicity, or volume through remedial action

  - Continued operation of the NWBCS through removal, treatment, and recharge of approximately 450 million gallons of groundwater per year would result in a reduction in the mobility, toxicity, and volume of contaminated groundwater entering the Offpost OU.

  - The alternative contains no active measures to address the reduction of the mobility, toxicity, or volume of existing contamination within the Northwest Plume Group; however, some reduction in toxicity, mobility, and volume would occur through decreases in contaminant concentrations attributable to natural attenuation and flushing with treated water from the NWBCS.

- Residual risk and long-term protection

  - Continued operation of the NWBCS would result in increased long-term protection and reduced residual risk attributable to reduction in contaminant concentrations entering the Offpost OU.

  - No provisions would be made for addressing exposure pathways and reducing residual risk or affording long-term protection associated with existing contamination within the Northwest Plume Group.

- Compliance with ARARs

  - Treatment of affected groundwater and source control provided by the NWBCS and natural attenuation processes in the Northwest Plume Group would achieve compliance with groundwater ARARs.

- Short-term impacts

  - There would be no short-term impacts.

- Timeframe for achievement of protection

  - Reduction in contaminants would occur through natural attenuation processes; monitoring and site review would indicate when PRGs would be achieved; groundwater modeling indicates that PRGs would be achieved within three to eight years.

Under Alternative No. NW-2, continued operation of the NWBCS to achieve Offpost OU PRGs would reduce contaminant concentrations in groundwater entering the Offpost OU and correspondingly reduce the toxicity, mobility, and volume of groundwater migrating from RMA to the Northwest Plume Group. Through treatment of approximately 450 million gallons of groundwater per year at the NWBCS, long-term protectiveness is substantially improved in the

Northwest Plume Group. Under Alternative No. NW-2, natural attenuation processes and source control provided by the NWBCS and flushing the Northwest Plume Group with treated groundwater would reduce COC concentrations to PRGs within three to eight years. Groundwater monitoring and periodic site review would indicate when contaminant levels in groundwater have attained PRGs. There would be no short-term impacts under Alternative No. NW-2.

4.2.2.2.2 Implementability

The implementability evaluation for Alternative No. NW-2 is presented below.

- Technical feasibility
  - o Groundwater monitoring and site review are readily performed and well demonstrated at hazardous waste sites.
- Administrative feasibility
  - o No permits are required.
  - o Equipment and technical personnel required for groundwater monitoring and site review are readily available.

No implementability considerations are associated with continued operation of the NWBCS. Groundwater monitoring wells have already been installed in the Offpost OU and installation of additional wells would be readily implemented, if necessary. Groundwater monitoring data would be used in performing a site review every five years until PRGs are achieved. Alternative No. NW-2 would not require permits.

4.2.2.2.3 Cost

The capital costs, long-term O&M costs, and total present worth costs for Alternative No. NW-2 are presented below:

- Total Capital Costs = $ - 0 -
- Total Long-term Operation and Maintenance Costs = $12.4 - 13.1 million
- Total Present Worth Costs = $12.4 - 13.1 million

4.2.2.3 Alternative No. NW-3: Land Acquisition and Deed Restrictions

Under Alternative No. NW-3, areas within the Offpost OU that exceed groundwater PRGs would be purchased and institutional controls would be implemented to limit exposure to affected groundwater. This alternative was described previously in Section 3.5.2.3.

4.2.2.3.1 Effectiveness

The effectiveness evaluation for Alternative No. NW-3 is presented below.

- Reduction in mobility, toxicity, or volume through remedial action
  - o Continued operation of the NWBCS through removal, treatment, and recharge of approximately 450 million gallons of groundwater per year would result in a reduction in the mobility, toxicity, and volume of contaminated groundwater entering the Offpost OU.
  - o The alternative contains no active measures to address the reduction of the mobility, toxicity, or volume of existing contamination within the Northwest Plume Group; however, some reduction in toxicity, mobility, and volume would occur through decreases in contaminant concentrations attributable to natural attenuation and flushing with treated water from the NWBCS.
- Residual risk and long-term protection
  - o Exposure pathways would be controlled, and residual risk would be reduced by minimizing exposure pathways through use and access restrictions.
- Compliance with ARARs
  - o Treatment of affected groundwater and source control provided by the NWBCS and natural attenuation processes in the Northwest Plume Group would achieve compliance with groundwater ARARs.
- Short-term impacts
  - o There would be no short-term impacts.
- Timeframe for achievement of PRGs
  - o Reduction in contaminant concentrations would occur through natural attenuation processes and flushing with treated groundwater from the NWBCS. Monitoring and site review would indicate when protectiveness is achieved; modeling indicates PRGs would be achieved within approximately three to eight years.

Alternative No. NW-3 would reduce the mobility, toxicity and volume of contaminated groundwater entering the Northwest Plume Group. Continued operation of the NWBCS would reduce contaminant concentration in groundwater entering the Offpost OU and would achieve

Offpost PRGs. Exposure pathways would be reduced through land acquisition and use restrictions. Thus, hypothetical risk would be reduced by preventing the use of contaminated groundwater for crop irrigation, watering of livestock, and domestic purposes. Purchasing land overlying affected groundwater would aid in controlling the use of contaminated groundwater. Alternative No. NW-3 would not create any short-term impacts. Source control actions provided by continued operation of the NWBCS in combination with natural attenuation processes would reduce COC concentrations to PRGs in 3 to 8 years.

4.2.2.3.2 Implementability

The implementability evaluation for Alternative No. NW-3 is presented below.

- Technical feasibility
  - Construction is not required.
  - Use and access restrictions are common components of remedial alternatives at hazardous waste sites.
- Administrative feasibility
  - No permits are required.
  - Technical personnel and equipment are not required.

Alternative No. NW-3 would be technically feasible. No construction would be required. Property could be purchased as necessary. Use and access restrictions are common components of remedial action at hazardous waste sites. Enforcement of use restrictions would be simplified by acquisition of the affected areas. No permits, technical personnel, or equipment would be required under Alternative No. NW-3.

4.2.2.3.3 Cost

The capital costs, long-term O&M costs, and total present worth costs for Alternative No. NW-3 are presented below:

- Total Capital Costs = $2.1 million

- Total Long-term Operation and Maintenance Costs = $12.3 - 12.9 million
- Total Present Worth Costs = $14.4 - 15.0 million

4.2.2.4 Alternative No. NW-4: Northwest Plume Group Extraction/Recharge System

Under Alternative No. NW-4, two additional extraction wells and recharge trenches would be installed to remediate the dieldrin plume in a shorter timeframe than Alternative No. NW-2. This alternative was described previously in Section 3.5.2.4.

4.2.2.4.1 Effectiveness

The effectiveness evaluation for Alternative No. NW-4 is presented below.

- Reduction in mobility, toxicity, or volume through remedial action
  - o Installation and operation of the Northwest Plume Group extraction/recharge system would reduce mobility, toxicity, and volume of contaminated groundwater within the Northwest Plume Group.
  - o Continued operation of the NWBCS through removal, treatment, and recharge of approximately 450 million gallons of groundwater per year would result in a reduction in the mobility, toxicity, and volume of contaminated groundwater entering the Offpost OU. In addition, some reduction in toxicity, mobility, and volume would occur through natural attenuation and flushing.
- Residual risk and long-term protection
  - o Continued operation of the NWBCS and operation of the Northwest Plume Group extraction/recharge system would result in increased long-term protection and reduced residual risk attributable to a reduction in contaminant concentrations entering the Offpost OU and within the Northwest Plume Group.
- Compliance with ARARs
  - o Extraction, treatment, and recharge associated with the operation of the NWBCS and the Northwest Plume Group extraction/recharge system would achieve compliance with groundwater ARARs.
- Short-term impacts
  - o There would be no short-term impacts.
- Timeframe for achievement of PRGs
  - o Groundwater modeling indicates the approximate time to achieve PRGs is two to five years.

Alternative No. NW-4 would intercept, pump, and treat UFS groundwater, thus reducing organic COC concentrations before reinjection. Carbon adsorption would reduce the toxicity and volume of contaminated groundwater through treatment. Alternative No. NW-4 would reduce the mobility of contaminated groundwater by downgradient interception and extraction in the northwest paleochannel. Hypothetical risk would be reduced through a reduction of COC concentrations in UFS groundwater; however, some hypothetical risk would remain until groundwater PRGs have been achieved in UFS groundwater. Carbon adsorption would achieve groundwater PRGs for all COCs. Alternative No. NW-4 would not cause any short-term impacts to human health or the environment. Groundwater modeling indicates that PRGs would be achieved within two to five years. Additionally, groundwater modeling shows that there would be no COCs exceeding PRGs north of O'Brian Canal after approximately one year.

4.2.2.4.2 Implementability

The implementability evaluation for Alternative No. NW-4 is presented below.

- Technical feasibility
  - Construction and operation of facility are readily implemented.
  - Carbon adsorption is a reliable and well demonstrated process option for removal of organic contaminants in RMA groundwater.
- Administrative feasibility
  - No permits are required.
  - Required equipment and technical personnel are readily available.

Alternative No. NW-4 would be technically feasible. Expansion of the NWBCS system would be readily implemented. Carbon adsorption is a reliable and well demonstrated process option for removal of organic contaminants from RMA groundwater. The administrative feasibility of Alternative No. NW-4 would be high because no permits would be required and because equipment and personnel required to install and operate the extraction and recharge system would be readily available.

4.2.2.4.3 Cost

The capital costs, long-term O&M costs, and total present worth costs for Alternative No. NW-4 are presented below:

- Total Capital Costs = $2.8 million
- Total Long-term Operation and Maintenance Costs = $12.2 - 12.5 million
- Total Present Worth Costs = $15.0 - 15.3 million

4.2.2.5 Alternative Screening Summary and Recommendation

Four alternatives were evaluated for remediation of UFS groundwater within the Northwest Plume Group. The results of this evaluation and recommendations for selection of alternatives to be carried forward to the DAA are summarized in Table 4.2.2.5-1. The screening of alternatives, with respect to the effectiveness criterion, shows that the three alternatives that include NWBCS operation afford the best reduction in toxicity, mobility, and volume; the best long-term protection; and the best compliance with PRGs. There is no appreciable decrease in the estimated time to achieve PRGs provided by the additional offpost extraction, treatment, and recharge in Alternative No. NW-4.

With respect to the implementability criterion, there are no prohibitive implementability concerns with any of the four alternatives.

A comparison of the costs associated with the four alternatives is presented in Table 4.2.2.5-1. The total present worth costs range from $0.6 - 1.3 million for Alternative No. NW-1 to $2.8 - 15.3 million for Alternative No. NW-4.

Table 4.2.2.5-1 indicates that on the basis of effectiveness, implementability, and cost, Alternative No. NW-2, Continued Operation of the NWBCS with Improvements as Necessary, was selected for evaluation in the DAA. In addition, as required by the NCP, the No Action alternative was selected for evaluation in the DAA.

5.0 DETAILED ANALYSIS OF ALTERNATIVES

A range of site remedial alternatives was screened in Section 4.0, based on effectiveness, implementability, and cost. A decision was presented in Section 4.0 indicating whether the alternative was retained or eliminated for the detailed analysis of alternatives (DAA).

Four remedial alternatives were analyzed for the North Plume Group:

- Alternative No. N-1: No Action
- Alternative No. N-2: Continued Operation of the North Boundary Containment System (NBCS) With Improvements as Necessary
- Alternative No. N-4: Interim Response Action A
- Alternative No. N-5: Expansion 1 to Interim Response Action A

Two remedial alternatives were analyzed for the Northwest Plume Group. These alternatives are:

- Alternative No. NW-1: No Action
- Alternative No. NW-2: Continued Operation of the Northwest Boundary Containment System (NWBCS) With Improvements as Necessary

These remedial action alternatives were evaluated with respect to threshold and primary balancing criteria as required by the NCP. The criteria are as follows

Threshold Criteria

- Overall protection of human health and the environment
- Compliance with ARARs

Primary Balancing Criteria

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost

Evaluation of modifying criteria (i.e., the state and community acceptance) was deferred until completion of the state and public comment period.

The evaluation criteria are defined and described below in Section 5.1. A summary of the groundwater modeling results, as it applies to alternatives evaluation, is presented in Section 5.2. The detailed analysis of the four alternatives for the North Plume Group and the two alternatives for the Northwest Plume Group is presented in Section 5.3. Section 5.4 presents the comparative analysis of alternatives, which identifies the advantages and disadvantages of each alternative relative to the others.

5.1 CRITERIA

Each group of criteria (i.e., threshold, primary balancing, and modifying) has its own weight when it is evaluated. Threshold criteria must be satisfied. Primary balancing criteria are used to weigh trade-offs among alternatives. Modifying criteria may be used to alter a proposed remedial alternative.

This section presents a brief description of the evaluation criteria and the items considered when assessing alternatives with respect to each criterion.

5.1.1 Overall Protection of Human Health and the Environment

This evaluation criterion serves as a final check in assessing whether each alternative provides adequate protection of human health and the environment. The detailed analysis conducted for long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs was used to evaluate the overall protection of human health and the environment. This criterion was also used to evaluate how risks would be eliminated, reduced, or controlled through treatment, engineering, institutional controls, or other remedial activities.

5.1.2 Compliance With Applicable or Relevant and Appropriate Requirements

This evaluation criterion is used to determine whether each alternative will attain federal and state ARARs. The detailed analysis summarizes which requirements are applicable or relevant and appropriate to each alternative and describes how each alternative exceeds, attains, or

does not attain these requirements. Other information such as advisories, criteria, or guidance documents have been considered where appropriate, during the ARARs analysis, and is presented in Appendix A.

5.1.3 Long-term Effectiveness and Permanence

This criterion addresses the risk remaining at the site after response objectives have been met. Components of the criterion that were addressed for each alternative are:

- Attainment of PRGs at the end of remedial activities
- Adequacy and reliability of controls that are used to either manage treatment residuals or untreated materials that remain at the site

5.1.4 Reduction of Toxicity, Mobility, or Volume

This evaluation criterion addresses the statutory preference for selecting remedial actions that permanently and significantly reduce toxicity, mobility, and/or volume of hazardous materials at the site. This preference is satisfied when treatment is used to reduce principal risks through destruction or irreversible reductions of toxicity, mobility, and/or volume. The criterion focuses on

- The degree of expected reduction in toxicity, mobility, and volume
- The degree of irreversibility of the process
- The type and quantity of residuals remaining following treatment
- The statutory preference for treatment as a principal element
- The relative amount of hazardous materials that will be destroyed or treated

5.1.5 Short-term Effectiveness

Short-term effectiveness addresses the effects of each alternative in the protection of human health and the environment during the construction and implementation phase. The following factors were addressed during the evaluation process

- Protection of the community during remedial actions - This addresses any risk that results from implementation of the proposed remedial alternative, such as dust from excavation or transportation of hazardous material.

- Protection of the workers during remedial actions - This factor assesses threats that may be posed to workers and the effectiveness and reliability of measures to be taken.

- Environmental impacts of the remedial action - This factor addresses the potential adverse environmental impacts that may result from construction and implementation of a remedial alternative and evaluates the reliability of mitigation measures, if necessary, to prevent or reduce potential impacts.

- Time lapse before achievement of response objectives - This factor includes an estimate of the time required to achieve protection for the site.

5.1.6 Implementability

This criterion evaluates the technical and administrative feasibility of implementing each alternative, and it addresses the availability of required services and materials during its implementation. The following factors were addressed during the evaluation process:

- Construction and operation - This factor relates to the technical difficulties and the unknowns associated with the technology.

- Reliability of the technology - This factor focuses on the likelihood that problems associated with implementation may result in schedule delays.

- Implementing additional remedial action - This factor is not applicable to this FS because the alternatives considered are not interim measures.

- Monitoring the effectiveness of the remedy - This factor addresses the ability to evaluate the effectiveness of the remedy and includes an evaluation of the risks of exposure should monitoring be insufficient to detect a system failure.

- Coordination with other offices and agencies needed to implement remedial alternatives

- Availability of necessary equipment, specialists, services and materials, and adequate offsite treatment, storage, and disposal services

5.1.7 Cost

The cost analysis consists of the evaluation of both capital costs and any long-term costs to operate and maintain an alternative. The basis for the cost estimates was explained in Section 4.1.3. Detailed cost tables for each alternative are presented in Appendix F.

5.1.8 State Acceptance

The intent of this section is to evaluate technical and administrative concerns the state may communicate in its comments concerning each alternative. The state will review the Revised

Draft Final EA/FS Report. The state's comments will be evaluated and addressed after their review.

5.1.9 Community Acceptance

The preferred alternative for a site is presented to the public in a Proposed Plan, which provides a brief summary of all of the alternatives studied in the DAA of the FS. In accordance with the NCP, the public will have an opportunity to review and comment on the selected remedial alternatives presented in the Proposed Plan. The public's comments will be addressed in the responsiveness summary and ROD for the Offpost FS.

5.2 MODELING RESULTS SUMMARY

To assist in evaluating the alternatives with respect to the NCP criteria, two numerical models were developed. The models simulated alluvial groundwater flow and dissolved contaminant transport in the Offpost OU for the North and Northwest Plume Groups. The models were used to evaluate the relative merits of remedial alternatives developed in Section 3.0.

The two models, referred to as the North and Northwest Models, were constructed using the U.S. Geological Survey (USGS) finite element code SUTRA (Voss, 1984). The North Model, which encompassed the area between the NBCS and the South Platte River, accounted for flow and transport in the northern and First Creek paleochannels as well as a third pathway stemming from the west end of the NBCS (see Appendix E). The Northwest Model covered the area lying between RMA's northwest boundary in the vicinity of the NWBCS and the South Platte River. Due to the concerns about lateral dispersion during transport simulation and the potential effects of model boundaries on remedial schemes, the lateral boundaries were located considerable distances away from the plumes being modeled. Consequently, the two model areas overlap.

The models prepared for the FS analysis are approximate in nature. Because comparative evaluation of the benefits derived from each remedial alternative does not require highly accurate models, attempts have been made to produce models that incorporate general features of groundwater flow and associated transport phenomena in the Offpost OU. Nonetheless, the

resulting models are sufficiently detailed that predicted flow and chemical transport phenomena agree with historical and current hydrogeologic data and observed contaminant distributions. Due to the approximate nature of the models and the considerable uncertainty in the conceptual model and hydrogeologic parameters, none of the modeling results should be construed as accurate predictions of future contaminant distribution. Rather, the models and modeling results should be viewed as tools for assessing the relative merits of remedial alternatives. Although there are inherent uncertainties in the groundwater model, it is the tool being used by the FS for evaluation of alternatives, and predicted differences in remediation timeframes are considered with respect to evaluating alternative effectiveness.

The flow modeling was limited to simulation of groundwater movement in unconsolidated alluvial materials in the Offpost OU. Consequently, regions where alluvial materials are not saturated were excluded from the North and Northwest Models (see Appendix E, Figure E1). In the North Model, the exclusion has resulted in the confinement of groundwater flow into distinct and separate pathways.

Chemical transport simulations were performed using dieldrin, DIMP, and chloroform to evaluate the effects of current remedial actions (i.e., the NBCS and NWBCS) as well as potential additional remedial actions. Transport simulation results were compared on the basis of maximum concentration versus time plots. Simulations were conducted using the most recent plume configuration interpretations based on fall 1989, 1990, and 1991 data, as presented in the Offpost RI Addendum (HLA, 1991a). Simulations were carried out for a period of 30 years.

For the North Model, the following remedial action scenarios were simulated: (1) Continued Operation of the NBCS with Improvements as Necessary (Alternative No. N-2), (2) IRA A (Alternative No. N-4), and (3) Expansion 1 to IRA A (Alternative No. N-5). The results of these simulations were evaluated on the basis of estimated remediation times measured on the maximum concentrations versus time graphs. The range of estimated remediation times was based on attainment of the PRGs for DIMP, chloroform, and dieldrin, using a range of retardation factors (See Appendix E).

Simulations performed for the North Model show generally decreasing estimated timeframes for attainment of PRGs with increasing complexity of remedial components. Of the three contaminants simulated, estimated remediation times for DIMP are the quickest, and estimated remediation times for dieldrin are the slowest. This appears to be related to the lower range of retardation factors for DIMP relative to dieldrin.

For the Northwest Model, the remedial action scenario for Continued Operation of the NWBCS with Improvements as Necessary (Alternative No. NW-2) was simulated. For reasons presented in the description of the No Action alternative (Alternative No. NW-1) in Section 5.3.1, groundwater modeling was not performed for Alternative No. NW-1. A qualitative comparison of the remedial systems described in Alternatives Nos. NW-1 and NW-2 indicates that Alternative No. NW-2 would attain PRGs in a substantially shorter timeframe than Alternative No. NW-1.

5.3 FURTHER DEFINITION OF ALTERNATIVES

The following subsections present additional information about the alternatives. Common to all alternatives are long-term groundwater monitoring and five-year site reviews.

5.3.1 Alternative No. N-1: No Action

The No Action alternative was described previously in Section 3.5.1.1. The major components are as follows:

- Long-term groundwater monitoring
- Five-year site reviews

Continued site groundwater monitoring and five-year reviews are the only components of this alternative. Groundwater modeling was not performed for this alternative. Because this alternative contemplates the hypothetical situation where the NBCS is not operated to extract, treat, and recharge groundwater, there is no groundwater monitoring data corresponding to the scenario. Thus a hypothetical, assumed set of contaminant concentrations would be required as input to the groundwater model for this alternative. Because there would be substantial uncertainty associated with the estimation of groundwater contaminant concentrations entering the

Offpost OU in the hypothetical situation of not operating the NBCS, the modeling was not conducted. However, the analysis of the No Action alternative, as a baseline case, for comparison with respect to the other alternatives is substantially unaffected.

5.3.2 Alternative No. N-2: Continued Operation of the North Boundary Containment System With Improvements as Necessary

This alternative was described previously in Section 3.5.1.2. The major components are as follows:

- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term monitoring
- Five-year site reviews
- Exposure control

Model simulations for Alternative No. N-2 assume that the concentrations of contaminants in the NBCS effluent would remain at values equivalent to the average measured effluent concentrations. Dieldrin and chloroform were not detected in the NBCS effluent and DIMP was detected at low concentrations. Effluent concentrations for dieldrin, DIMP, and chloroform used as input to the model were set at 0.025 μg/l (one-half the CRL), 3.00 μg/l, and 0.25 μg/l (one-half the CRL), respectively.

Modeling runs performed for Alternative No. N-2 are presented in the form of maximum contaminant concentrations in the UFS as a function of time (see Appendix E, Figures E13, E15, and E17).

5.3.3 Alternative No. N-4: Interim Response Action A

The description of Alternative No. N-4 was previously presented in Section 3.5.1.4. The major components of this alternative include:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels using IRA A groundwater extraction wells
- Treatment of the organic COCs present in the groundwater using carbon adsorption

- Recharge of treated groundwater to the UFS using IRA A wells and trenches
- Continued operation of the NBCS and IRA A as necessary
- Improvements to IRA A and the NBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

Similar to Alternative No. N-2, the groundwater modeling assumed that concentrations of the contaminants in the NBCS effluent were set at 0.025μg/l, 3.00μg/l, and 0.25μg/ for dieldrin, DIMP, and chloroform, respectively.

As shown in Figure 3.5.1.4-1, IRA A consists of two areas of groundwater extraction and recharge. Five extraction wells and six recharge trenches would be located in the First Creek paleochannel. As estimated in the Final Implementation Document for IRA A (HLA, 1991b) for the system in the First Creek paleochannel, 180 gallons per minute (gpm) total flow was used for the model simulation. The flow was divided equally among the five extraction wells and six recharge trenches, with each extraction well pumping at 36 gpm and each recharge trench receiving 30 gpm of treated effluent. The northern paleochannel portion of IRA A consists of a row of 12 extraction wells and a row of 24 recharge wells forming a hydraulic barrier across the northern paleochannel. As estimated in the IRA A Implementation Document for the system in the northern paleochannel, 300 gpm total flow was used for modeling simulations. The flow was divided equally among the 12 extraction and 24 recharge wells, with each extraction well pumping at 25 gpm and each recharge well receiving 12.5 gpm of treated effluent.

For model simulations, the concentrations of contaminants in the IRA A treatment plant effluent were assumed to be at the same concentrations as the treated effluent from the NBCS.

Model simulations for the implementation of IRA A are presented in the form of maximum concentration versus time graphs in Appendix E, Figures E18 to E20.

5.3.4 Alternative No. N-5: Expansion 1 to Interim Response Action A

Alternative No. N-5 was previously described in Section 3.5.1.5. The major components of this alternative include:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels using IRA A groundwater extraction wells
- Expansion 1 of IRA A
- Treatment of organic COCs present in the groundwater using carbon adsorption
- Recharge of treated groundwater to the UFS using wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

As shown in Figure 3.5.1.5-1, Expansion 1 to IRA A consists of two areas of groundwater extraction and recharge that correspond to the IRA A systems previously described in Section 5.3.3. Expansion 1 to IRA A was configured in the groundwater modeling to include two additional extraction wells and four additional recharge trenches added to the IRA A system in the First Creek paleochannel. In the northern paleochannel, Expansion 1 was configured to include one additional extraction well and two additional recharge trenches added to the IRA A system. The additional extraction wells were included in the model at a rate of 30 gpm, and the recharge trenches were prescribed to recharge 15 gpm each. For the model simulations, the concentrations of contaminants in the treatment plant effluent were assumed to be at the same concentrations as the treated effluent from the NBCS. Dieldrin and chloroform were not detected in NBCS effluent, and DIMP was detected at low concentrations. Effluent concentrations used as model input were prescribed to be 0.025 μg/l, 3.00 μg/l, and 0.25 μg/l for dieldrin, DIMP, and chloroform, respectively.

Appendix E presents the groundwater modeling simulation results as maximum concentration versus time graphs (Appendix E, Figures E21 to E23).

5.3.5 Alternative No. NW-1: No Action

This alternative was previously described in Section 3.5.2.1. The components of this alternative are limited to continued groundwater monitoring and five-year site reviews. Groundwater modeling was not performed for this alternative for the reasons outlined under Section 5.3.1, Alternative No. N-1 (No Action for the North Plume Group). The major components are as follows:

- Long-term groundwater monitoring
- Five-year site reviews

5.3.6 Alternative No. NW-2: Continued Operation of the Northwest Boundary Containment System With Improvements as Necessary

This alternative was previously described in Section 3.5.2.2. The major components of Alternative NW-2 include:

- Continued operation of the NWBCS
- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

Groundwater modeling simulations for this alternative included 850 gpm treated and recharged at the NWBCS. Average NWBCS effluent concentrations from 1986 to 1990 were used as influent concentrations to the model. The concentrations were 0.025 μg/l and 13.8 μg/l for dieldrin and chloroform, respectively. The groundwater modeling results for this alternative are presented in Appendix E, Figures E29 and E30.

5.4 DETAILED ANALYSIS OF ALTERNATIVES

The following subsections present an assessment of each of the alternatives carried forward into the DAA from the Screening of Alternatives, Section 4.0, with respect to the threshold and primary balancing criteria mandated in the NCP. Each alternative is discussed under subheadings for each of the criteria. Additional detail necessary to complete the evaluation of the criteria is provided for each alternative, as required, in the following section.

5.4.1 Overall Protection of Human Health and the Environment

In this section, each remedial alternative is evaluated in terms of the extent of protection provided for human health and the environment.

5.4.1.1 Alternative No. N-1: No Action

This alternative does not provide protection of human health and the environment because it contemplates a set of circumstances whereby the extraction and treatment of contaminated groundwater, as a source control measure for the Offpost OU, would not be performed by the NBCS. This is a hypothetical alternative because the Army has operated the NBCS since 1979 and has made the commitment to continue operation and, further, to improve the NBCS as necessary to achieve Offpost OU PRGs.

For this alternative, the evaluation of performance with respect to controlling, eliminating, or reducing hypothetical risks is based on a hypothetical scenario of not operating the NBCS. However, the Offpost EA presented risks for the Offpost OU considering continued operation of the NBCS (baseline risks). Thus, the hypothetical risks would be higher for the No Action alternative than the baseline EA risks. The groundwater exposure pathways used in the calculation of the baseline risks presented in the Offpost EA (Volume II, Section 2.0) would not be addressed by the No Action alternative. Natural attenuation would be solely relied upon to reduce contaminant concentrations. Hypothetical risks associated with the domestic use pathways (direct ingestion and inhalation during showering) would be higher than the estimated baseline risks presented in the Offpost EA due to the lack of source control and contaminant removal provided by the NBCS.

Similarly, the hypothetical risks associated with the agricultural pathways (beef, dairy products, poultry products, and crops) would also be higher than the estimated baseline risks presented in the Offpost EA for the same reason.

5.4.1.2 Alternative No. N-2: Continued Operation of the North Boundary Containment System With Improvements as Necessary

This alternative provides overall protection of human health and the environment through the continued operation of the NBCS to achieve Offpost OU PRGs. Because there are no active remedial components treating groundwater in the North Plume Group (north of the RMA boundary), direct remediation of contaminant plumes north of the NBCS is not provided by this alternative in the near-term. Through the extraction, treatment, and recharge of approximately 125 million gallons of groundwater annually, the contaminant concentrations entering the Offpost OU from RMA would continue to be greatly reduced. The hypothetical risks attributable to contaminant concentrations in the North Plume Group would be consistent with those calculated in the Offpost EA. However, through continued operation of the NBCS (with improvements as necessary), contaminant concentrations within the North Plume Group would decrease over time and correspondingly decrease hypothetical risks. There would be no provisions for addressing the exposure pathways identified in the Offpost EA, with the exception of the Army's continued commitment to provide alternative water for domestic uses, should a user of groundwater exceeding PRGs be identified in the future.

Because there would be no active measures in this alternative to reduce the contaminant concentrations in the North Plume Group, the time to attain PRGs as estimated by the groundwater modeling would be greater than alternatives employing extraction and treatment of groundwater within the North Plume Group. Natural attenuation mechanisms would be relied upon for contaminant reduction rather than active measures.

The groundwater modeling estimate of time to attain PRGs is approximately 15 to 30-plus years, corresponding to the range of retardation factors used in the groundwater modeling (see Section 5.2 and Appendix E).

5.4.1.3 Alternative No. N-4: Interim Response Action A

Under this alternative, implementation of the groundwater extraction, treatment, and recharge components of IRA A to remediate North Plume Group groundwater would substantially reduce hypothetical risks and provide protection of both human health and the environment. IRA A is designed to treat approximately 95 million gallons in the First Creek paleochannel and 158 million gallons in the northern paleochannel annually for a total annual volume of 253 million gallons. This is in addition to the 125 million gallons treated annually at the NBCS. Through the combined operation of these two systems, the hypothetical risks calculated in the Offpost EA would be greatly reduced. The Army's commitment to provide alternative water to any users of groundwater exceeding PRGs that may be identified in the future would serve as a measure of protection during the time required to achieve PRGs.

The extraction and recharge configuration of IRA A is an aggressive remediation component that, in combination with the treatment performed at the NBCS (and improvements to both systems as necessary), would substantially reduce contaminant concentrations in the North Plume Group and would reduce remediation timeframes. As with other alternatives, natural attenuation mechanisms would also provide contaminant concentration reduction. The groundwater modeling estimate of time to attainment of PRGs is approximately 15 to 30 years, corresponding to the range of retardation factors used in the groundwater modeling (see Section 5.2 and Appendix E).

The intensive short-term groundwater monitoring component of Alternative No. N-4, described in Section 3.5.1.4, would provide for increased understanding and increased accuracy in the estimation of cleanup times through the acquisition of a large amount of contaminant concentration data in the North Plume Group. An approximate two-year period of intensive groundwater monitoring commencing with the start-up of the IRA A system would provide the opportunity for collection of full-scale system operation data providing information on contaminant plume movement in response to operation of both IRA A and the NBCS. Such data would be invaluable to predict the expected performance of Alternative No. N-4 more accurately.

5.4.1.4 Alternative No. N-5: Expansion 1 to Interim Response Action A

Alternative No. N-5 would provide overall protection of human health and the environment similar to Alternative No. N-4. This alternative is an expansion to the groundwater extraction, treatment, and recharge components of IRA A that would provide for a similar reduction in hypothetical risks through a reduction in contaminant concentrations. The First Creek paleochannel component of this alternative would treat approximately 125 million gallons of groundwater annually and the northern paleochannel component would treat approximately 173 million gallons annually, totaling 298 million gallons. This is in addition to the 125 million gallons treated annually at the NBCS. The combined operation of Expansion 1 to IRA A and the NBCS would substantially reduce the hypothetical risks calculated in the Offpost EA. The potential for exposure to affected groundwater during the estimated timeframe until achievement of PRGs would be reduced by the Army's commitment to provide alternative water to any future identified affected groundwater users. The groundwater modeling estimate of time to attain PRGs is approximately 10 to 20 years, corresponding to the range of retardation factors used in the groundwater modeling (see Section 5.2 and Appendix E).

Expansion 1 to IRA A is a small addition to the extraction and recharge components of IRA A. In combination with the continued operation of the NBCS (and improvements to both systems as necessary), North Plume Group contaminant concentrations would be substantially reduced and remediation timeframes would be reduced. Natural attenuation mechanisms would also contribute to contaminant concentration reduction.

5.4.1.5 Alternative No. NW-1: No Action

Alternative No. NW-1 does not provide adequate protection of human health and the environment for the Northwest Plume Group because it contemplates ceasing groundwater extraction, treatment, and recharge at the NWBCS, similar to Alternative No. N-1 for the North Plume Group. This is a hypothetical circumstance because the Army has operated the NWBCS since 1984 and has committed to continue operations and implement improvements as necessary to attain Offpost OU PRGs.

As discussed in Section 5.4.1.1 for Alternative No. N-1, hypothetical risks associated with this alternative would be higher than those presented in the Offpost EA because it was assumed in the EA that the NWBCS operation would be continued. Also, natural attenuation would be the only mechanism for contaminant concentration reduction in the absence of active remedial measures at the NWBCS or in the Northwest Plume Group.

5.4.1.6 Alternative No. NW-2: Continued Operation of the Northwest Boundary Containment System With Improvements as Necessary

This alternative provides for both protection of human health and protection of the environment through groundwater extraction, treatment, and recharge at the NWBCS to meet Offpost OU PRGs. The NWBCS treats approximately 450 million gallons of groundwater annually. Continued operation of this system would allow the Northwest Plume Group groundwater to attain Offpost PRGs. Hypothetical risks calculated in the Offpost EA would be substantially reduced through implementation of this alternative. Through the Army's commitment to provide alternative water to any identified future users of groundwater exceeding PRGs, hypothetical risks during the period until PRGs are attained would be reduced.

The groundwater modeling estimates of the time necessary to attain PRGs is approximately three to eight years, corresponding to the range of retardation factors used in the modeling (see Section 5.2 and Appendix E).

5.4.2 Compliance With Applicant or Relevant and Appropriate Requirements

In accordance with CERCLA guidance, a remedial alternative is required to meet ARARs or be subject to a waiver. However, CERCLA recognizes that ARARs are not available for all circumstances encountered at Superfund sites. Federal or state advisories or guidance may be classified as TBC criteria. This section discusses the ability of an alternative to meet ARARs and TBCs.

5.4.2.1 Alternative No. N-1: No Action

This alternative would likely not achieve ARARS and PRGs because the groundwater extraction, treatment, and recharge currently provided by the NBCS would not be provided.

5.4.2.1.1 Chemical-specific Applicable or Relevant and Appropriate Requirements

The chemical-specific ARARs that must be complied with apply to potable drinking water supplies. The requirements are listed in Section 2.5, Table 2.5.2-1. This alternative is not expected to meet the chemical-specific ARARs presented in Table 2.5.2-1.

5.4.2.1.2 Action-specific Applicable or Relevant and Appropriate Requirements

Action-specific ARARs are activity-based or technology-based requirements intended to set standards for the actions taken with respect to hazardous wastes or contaminants at a site. Because there are no remedial actions except groundwater monitoring contemplated under this alternative, there are no action-specific ARARS.

5.4.2.1.3 Location-specific Applicable or Relevant and Appropriate Requirements

Location-specific ARARs are requirements placed on an area or the conduct of activities within an area intended to protect such things as wetlands or sensitive ecosystems. Because there are no remedial actions except groundwater monitoring contemplated under this alternative, there would be no location-specific ARARs.

5.4.2.2 Alternative No. N-2: Continued Operation of the North Boundary Containment System With Improvements as Necessary

5.4.2.2.1 Chemical-specific Applicable or Relevant and Appropriate Requirement

This alternative may achieve chemical-specific ARARs presented in Table 2.5.2-1, as estimated by the groundwater modeling timeframes to attain PRGs. An estimated time range of 15 to 30-plus years, corresponding to the range of retardation factors used in the modeling, is predicted for attainment of groundwater chemical-specific ARARs presented in Table 2.5.2-1. Thus, this alternative would meet chemical-specific ARARs for the low end of the model-estimated timeframe (corresponding to the lower retardation factors). However, for the high end

of the estimated timeframe (corresponding to the higher retardation factors) chemical-specific ARARs would not be attained within at least a 30-year timeframe.

5.4.2.2.2 Action-specific Applicable or Relevant and Appropriate Requirements

Appendix A presents the action-specific ARARs.

5.4.2.2.3 Location-specific Applicable or Relevant and Appropriate Requirements

Appendix A presents the location-specific ARARs.

5.4.2.3 Alternative No. N-4: Interim Response Action A

5.4.2.3.1 Chemical-specific Applicable or Relevant and Appropriate Requirements

This alternative is expected to meet or exceed all chemical-specific ARARs presented in Table 2.5.2-1. Based on the estimates of the timeframe required for attainment of PRGs as calculated by the groundwater modeling, ARARs would be attained in approximately 15 to 30 years. This range in predicted time to cleanup corresponds to the lower and upper estimates of retardation factors used in the modeling.

5.4.2.3.2 Action-specific Applicable or Relevant and Appropriate Requirements

Appendix A presents the location-specific ARARs.

5.4.2.3.3 Location-specific Applicable or Relevant and Appropriate Requirements

Appendix A presents the location-specific ARARs.

5.4.2.4 Alternative No. N-5: Expansion 1 to Interim Response Action A

5.4.2.4.1 Chemical-specific Applicable or Relevant and Appropriate Requirements

Alternative No. N-5 is expected to meet or exceed all chemical-specific ARARs as listed in Table 2.5.2-1. The timeframe for attainment of groundwater PRGs, as estimated by the groundwater modeling, is 10 to 25 years. This range of estimated cleanup times corresponds to the lower and upper ends, respectively, of the range of retardation factors used in the modeling.

5.4.2.4.2 Action-specific Applicable or Relevant and Appropriate Requirements

Appendix A presents the action-specific ARARs.

5.4.2.4.3 Location-specific Applicable or Relevant and Appropriate Requirements

Appendix A presents the location-specific ARARs.

5.4.2.5 Alternative No. NW-1: No Action

5.4.2.5.1 Chemical-specific Applicable or Relevant and Appropriate Requirements

Alternative No. NW-1 would likely not achieve the chemical-specific ARARs listed in Table 2.5.2-1 because this alternative would not include operation of the NWBCS. The ARARs would not be attained due to the lack of groundwater interception, treatment, and recharge contemplated under this alternative. As discussed previously, groundwater modeling was not performed for this alternative to estimate the time to attain PRGs. However, without continued operation of the NWBCS, the concentration of contaminants entering the Offpost OU from RMA would exceed PRGs, and ARARs would not be attained in the Offpost OU.

5.4.2.5.2 Action-specific Applicable or Relevant and Appropriate Requirements

Appendix A presents the action-specific ARARs.

5.4.2.5.3 Location-specific Applicable or Relevant and Appropriate Requirements

Appendix A presents the location-specific ARARs.

5.4.2.6 Alternative No. NW-2: Continued Operation of the Northwest Boundary Containment System With Improvements as Necessary

5.4.2.6.1 Chemical-specific Applicable or Relevant and Appropriate Requirements

This alternative is expected to meet or exceed all ARARs presented in Table 2.5.2-1. The time required to attain groundwater PRGs, as estimated by the groundwater modeling, is three to eight years. This timeframe corresponds to the lower and upper estimates of the retardation factors, respectively, used in the groundwater modeling.

5.4.2.6.2 Action-specific Applicable or Relevant and Appropriate Requirements

Appendix A presents the action-specific ARARs.

5.4.2.6.3 Location-specific Applicable or Relevant and Appropriate Requirements

Appendix A presents the location-specific ARARs.

5.4.3 Long-term Effectiveness and Permanence

Under this criterion, alternatives were evaluated with respect to the risk remaining at the site after the alternative has been implemented and the response objectives have been met.

5.4.3.1 Alternative No. N-1: No Action

Alternative No. N-1 would not reduce the magnitude of residual risk associated with groundwater within the North Plume Group. No remedial action would be performed to reduce contaminant concentration levels or control exposure pathways associated with groundwater within the North Plume Group. Because contaminated groundwater at the NBCS and within the North Plume Group would not be treated, the hypothetical risk and groundwater exposure pathways identified through the Offpost EA would continue to pose a threat to human health and the environment.

5.4.3.2 Alternative No. N-2: Continued Operation of North Boundary Containment System With Improvements as Necessary

Alternative No. N-2 would reduce residual risk associated with groundwater within the North Plume Group through extraction, treatment, and recharge of groundwater exiting the RMA north boundary at the NBCS. Treated groundwater recharged at the NBCS would flush the North Plume Group portion of the UFS. Groundwater modeling indicates that PRGs would be achieved within the North Plume Group in 15 to 30-plus years. Improvements to the system would be added as necessary to correct system inadequacies. Monitoring and five-year site review would indicate when PRGs had been achieved. Residuals generated at the NBCS consist of spent carbon, which would be removed from the site and regenerated at a RCRA-permitted facility.

Regeneration would destroy all adsorbed contaminants. Therefore, no risks would be associated with treatment residuals.

5.4.3.3 Alternative No. N-4: Interim Response Action A

Alternative N-4 would reduce residual risk associated with groundwater within the North Plume Group through extraction, treatment, and recharge of groundwater exiting the RMA north boundary at the NBCS and interception, extraction, and treatment of groundwater within the First Creek and northern paleochannels. Groundwater modeling indicates that the combined operation of the two systems would achieve PRGs within the North Plume Group in 15 to 30 years. Performance for the NBCS and IRA A systems would be monitored using the groundwater monitoring component of this alternative, and the data gathered during this program would be evaluated to allow for identification of any system inadequacies (e.g., contaminant bypass). Improvements to the two systems would be implemented, as necessary, to correct system inadequacies. Long-term groundwater monitoring and site review would indicate when PRGs had been achieved. Treatment residuals generated at the NBCS and IRA A treatment facilities would consist of spent carbon, which would be removed from the site and regenerated at a RCRA-approved facility. Regeneration would destroy all adsorbed contaminants. Therefore, no risks would be associated with treatment residuals.

5.4.3.4 Alternative No. N-5: Expansion 1 to Interim Response Action A

Alternative N-5 would reduce residual risk associated with groundwater within the North Plume Group through extraction, treatment, and recharge of groundwater exiting the RMA north boundary at the NBCS and interception, extraction, and treatment of groundwater within the First Creek and northern paleochannels. Groundwater modeling indicates that the combined operation of the two systems would achieve PRGs within the North Plume Group in 10 to 20 years. Performance for the NBCS, IRA A, and IRA A Expansion 1 systems would be monitored, and the data gathered during the groundwater monitoring program would be evaluated to allow for identification of any system inadequacies (e.g., contaminant bypass). Improvements to the two

systems would be implemented, as necessary, to correct system inadequacies. Long-term groundwater monitoring and site review would indicate when PRGs had been achieved. Treatment residuals generated at the NBCS and IRA A treatment facilities would consist of spent carbon, which would be removed from the site and regenerated at a RCRA permitted facility. Regeneration would destroy all adsorbed contaminants. Therefore, no risks would be associated with treatment residuals.

5.4.3.5 Alternative No. NW-1: No Action

Alternative No. NW-1 would not reduce the magnitude of residual risk associated with groundwater within the Northwest Plume Group. No remedial action would be performed to reduce contaminant concentration levels or control exposure pathways associated with groundwater within the Northwest Plume Group. Because contaminated groundwater at the NWBCS within the Northwest Plume Group would not be treated, the hypothetical risk and potential groundwater exposure pathways identified in the Offpost EA would continue to pose a threat to human health and the environment.

5.4.3.6 Alternative No. NW-2: Continued Operation of the Northwest Boundary Containment System With Improvements as Necessary

Alternative No. NW-2 would reduce residual risk associated with groundwater within the Northwest Plume Group through extraction, treatment, and recharge of groundwater exiting the RMA northwest boundary at the NWBCS. Treated groundwater recharged at the NWBCS would flush the Northwest Plume Group portion of the UFS. Groundwater modeling indicates that PRGs would be achieved within the Northwest Plume Group in three to eight years. Improvements to the system would be added as necessary to correct system inadequacies. Groundwater monitoring and five-year site review would indicate when PRGs had been achieved. Residuals generated at the NWBCS consist of spent carbon, which would be removed from the site and regenerated at a RCRA permitted facility. Regeneration would destroy all adsorbed contaminants. Therefore, no risk would be associated with treatment residuals.

5.4.4 Reduction of Toxicity, Mobility, or Volume

Under CERCLA guidance for selecting remedial action alternatives, preference is given to remedial technologies that significantly reduce the toxicity, mobility, or volume of the affected media through treatment. This evaluation criterion assesses the degree of reduction of toxicity, mobility, or volume of the hazardous material. Considerations include an analysis of the extent of irreversibility of the treatment and the disposition of treatment materials.

5.4.4.1 Alternative No. N-1: No Action

Under Alternative No. N-1, no action would be performed to reduce the toxicity, mobility, or volume of groundwater exceeding PRGs within the North Plume Group. Alternative No. N-1 would not employ any groundwater treatment process and thus would not address the statutory preference for treatment as a principal element. The threats associated with potential groundwater exposure pathways would not be addressed.

5.4.4.2 Alternative No. N-2: Continued Operation of the North Boundary Containment System With Improvements as Necessary

Continued operation of the NBCS would reduce the toxicity, mobility, and volume of groundwater migrating from RMA to the Offpost OU. Groundwater mobility would be reduced by the slurry wall and extraction system. Groundwater toxicity would be reduced by treatment with activated carbon. Alternative No. N-2 would reduce the toxicity of groundwater and the volume of groundwater exceeding PRGs within the North Plume Group by flushing the UFS with water treated at the NBCS. Residuals remaining after treatment would consist of spent carbon, which would be regenerated offsite. The regeneration process would destroy all adsorbed organic contaminants. Because Alternative No. N-2 would employ carbon adsorption, Alternative No. N-2 would satisfy the statutory preference for treatment as a principal element.

5.4.4.3 Alternative No. N-4: Interim Response Action A

Alternative No. N-4 would reduce the toxicity, mobility, and volume of groundwater within the North Plume Group and groundwater migrating from RMA to the Offpost OU. The mobility

of contaminated groundwater migrating from RMA would be reduced by the slurry wall at the NBCS. The mobility of contaminated groundwater currently within the North Plume Group would be reduced through hydraulic containment in the northern and First Creek paleochannels. Alternative No. N-4 would reduce the toxicity of groundwater extracted at the NBCS and IRA A systems through carbon treatment. Performance monitoring at the NBCS indicates that carbon treatment is capable of reducing COC concentrations to achieve PRGs. The volume of contaminated groundwater within the North Plume Group would be reduced by carbon treatment and recharge of the treated water at the NBCS and IRA A recharge systems. Residuals remaining after treatment would consist of spent carbon, which would be regenerated offsite. Because Alternative No. N-4 would employ carbon treatment, Alternative No. N-4 would satisfy the statutory preference for treatment as a principal element.

5.4.4.4 Alternative No. N-5: Expansion 1 to Interim Response Action A

Alternative No. N-5 would reduce the toxicity, mobility, and volume of groundwater within the North Plume Group and groundwater migrating from RMA to the Offpost OU. The mobility of contaminated groundwater migrating from RMA would be reduced by the slurry wall at the NBCS. The mobility of contaminated groundwater currently within the North Plume Group would be reduced through hydraulic containment in the northern and First Creek paleochannels. Alternative No. N-5 would reduce the toxicity of groundwater extracted at the NBCS and Expansion 1 to IRA A Systems through carbon treatment. Performance monitoring at the NBCS indicates that carbon treatment is capable of reducing COC concentrations to achieve PRGs. The volume of contaminated groundwater within the North Plume Group would be reduced by carbon treatment and recharge of the treated water at the NBCS, IRA A and Expansion 1 to IRA A recharge systems. Residuals remaining after treatment would consist of spent carbon, which would be regenerated offsite. Because Alternative No. N-5 would employ carbon treatment, Alternative No. N-5 would satisfy the statutory preference for treatment as a principal element.

5.4.4.5 Alternative No. NW-1: No Action

Under Alternative No. NW-1, no action would be performed to reduce the toxicity, mobility, or volume of groundwater exceeding PRGs within the Northwest Plume Group. Alternative No. NW-1 would not employ any treatment process options and thus would not address the statutory preference for treatment as a principal element. The threats associated with potential groundwater exposure pathways would not be addressed.

5.4.4.6 Alternative No. NW-2: Continued Operation of Northwest Boundary Containment System With Improvements as Necessary

Continued operation of the NWBCS would reduce the toxicity, mobility, and volume of groundwater migrating from RMA to the Offpost OU. Groundwater mobility would be reduced by the slurry wall and extraction system. Groundwater toxicity would be reduced by treatment with activated carbon. Alternative No. NW-2 would reduce the toxicity of groundwater and the volume of groundwater exceeding PRGs within the Northwest Plume Group by flushing the UFS with water treated at the NWBCS. Residuals remaining after treatment would consist of spent carbon, which would be regenerated offsite. The regeneration process would destroy all adsorbed organic contaminants. Because Alternative No. NW-2 would employ carbon adsorption, Alternative No. NW-2 would satisfy the statutory preference for treatment as a principal element.

5.4.5 Short-term Effectiveness

The impacts of the alternative during the construction and implementation phase are assessed under this criterion. Factors to be considered include protection of the community and workers during remedial operations, time required to implement the alternative, and potential adverse environmental impacts that may result.

5.4.5.1 Alternative No. N-1: No Action

5.4.5.1.1. Protection of Community and Workers

Short-term conditions at the site would remain unchanged. Potential human health risks would continue to exist and may increase due to increased contaminant concentrations in the North Plume Group after operations at the NBCS would have ceased.

5.4.5.1.2 Adverse Environmental Impacts

Again, short-term conditions at the site would remain unchanged. The concentration of contaminants of affected groundwater in the North Plume Group would increase due to discontinuing extraction and treatment of groundwater at the NBCS.

5.4.5.1.3 Implementation Period

There is no implementation period for Alternative No. N-1.

5.4.5.2 Alternative No. N-2: Continued Operation of North Boundary Containment System

5.4.5.2.1 Protection of Community and Workers

Short-term conditions at the site would remain unchanged. Potential human health risks would decrease as the concentration of contaminants in affected groundwater decreased due to extraction, treatment, and recharge at the NBCS. Minimal impacts are expected.

5.4.5.2.2 Adverse Environmental Impacts

Short-term conditions at the site would remain unchanged. The concentration of contaminants in affected groundwater would decrease over time due to extraction and treatment of groundwater at the NBCS. Minimal impacts are expected.

5.4.5.2.3 Implementation Period

There is no implementation period for continued operation of the NBCS.

5.4.5.3 Alternative No. N-4: Interim Response Action A

5.4.5.3.1 Protection of Community and Workers

The short-term impact on the hypothetical risks to the community and workers would be minimal during construction of the IRA A facility. Past experience at the Offpost OU indicates that workers would be adequately protected by adhering to standard health and safety practices. Trenching operations would be performed using the one-pass method, and thus worker exposure would be minimized. Protection of the community and workers' health would be achieved through adherence to an approved health and safety plan.

5.4.5.3.2 Adverse Environmental Impacts

Minimal adverse impacts to air quality would result from dust generation during construction. Dust control measures would limit these impacts. No adverse environmental impacts associated with groundwater are foreseen during construction of IRA A. Water generated during trench construction dewatering activities would be treated and recharged to the UFS.

5.4.5.3.3 Implementation Period

The implementation for Alternative No. N-4 would proceed as follows: (1) 10 months to construct the treatment facility, (2) 4 months for the extraction, recharge, and conveyance systems for the northern paleochannel, (3) 2 months of system start-up, and (4) 4 months of construction of First Creek paleochannel extraction wells and recharge trenches. Therefore, approximately 20 months would be required from initiation of construction to full facility operation.

5.4.5.4 Alternative No. N-5: Expansion 1 to Interim Response Action A

5.4.5.4.1 Protection of Community and Workers

Short-term conditions associated with this alternative are similar to those associated with Alternative No. N-4.

5.4.5.4.2 Adverse Environmental Impacts

Environmental impacts are the same as Alternative No. N-4.

5.4.5.4.3 Implementation Period

Approximately one additional year would be required for the implementation period of Alternative No. N-5 compared to Alternative No. N-4. The additional time would be required for design and construction of the additional extraction wells, recharge trenches, and conveyance system. Therefore, the total implementation period for Alternative No. N-5 would be approximately 32 months.

5.4.5.5 Alternative No. NW-1: No Action

5.4.5.5.1 Protection of Community and Workers

Short-term conditions at the site would remain unchanged. Potential human-health risks would continue to exist and may increase due to increased contaminant concentrations in the Northwest Plume Group after operations at the NWBCS would have ceased.

5.4.5.5.2 Adverse Environmental Impacts

Short-term conditions at the site would remain unchanged. The concentration of contaminants in affected groundwater in the Northwest Plume Group would increase due to discontinuing extraction and treatment at the NWBCS.

5.4.5.5.3 Implementation Period

There is no implementation period for Alternative No. NW-1.

5.4.5.6 Alternative No. NW-2: Continued Operation of Northwest Boundary Containment System With Improvements as Necessary

5.4.5.6.1 Protection of Community and Workers

Short-term conditions at the site would remain unchanged. Potential human-health risks would decrease as the concentration of contaminants in affected groundwater decreased due to extraction, treatment, and recharge at the NWBCS. Minimal impacts are expected.

5.4.5.6.2 Adverse Environmental Impacts

Short-term conditions at the site would remain uncharged. The concentration of contaminants within the Northwest Plume Group would decrease over time due to extraction, treatment, and recharge at the NWBCS. Minimal impacts are expected.

5.4.5.6.3 Implementation Period

There is no implementation period for Alternative No. NW-2.

5.4.6 Implementability

Two major issues are addressed when assessing the implementability of a remedial action alternative:

1. Technical feasibility - The ability to implement and construct the technology, the reliability of the technology, and the ability to monitor the effectiveness of the remedy
2. Administrative feasibility - The effort and resources required to obtain approval from regulatory agencies

5.4.6.1 Alternative No. N-1: No Action

The only technical aspect of the No Action alternative is the implementation of a monitoring program to re-evaluate the site in five years. Groundwater monitoring wells currently exist, and no additional wells would be installed to monitor conditions in the system.

The administrative feasibility of obtaining approval from the agencies is expected to be minimal for this alternative.

5.4.6.2 Alternative No. N-2: Continued Operation of North Boundary Containment System With Improvements as Necessary

The NBCS has treated approximately 125 million gallons of groundwater per year with activated carbon since 1979. Effluent data from the NBCS have shown that contaminant concentrations in the effluent attain Offpost OU PRGs. Operational assessments on the effectiveness of the system are issued to the Organizations and State annually. Therefore, technical implementability is judged to be high.

5.4.6.3 Alternative No. N-4: Interim Response Action A

IRA A consists of extracting and treating contaminated groundwater and recharging treated groundwater to prevent plume migration. The ability to extract groundwater with extraction wells, treat contaminated groundwater with carbon to remove organic compounds, and recharge treated groundwater has been demonstrated to be a reliable technology at the NBCS, NWBCS, and ICS. The ability to monitor the effectiveness of these technologies by monitoring wells has also been demonstrated at the three existing boundary systems. An Implementation Document for IRA A (HLA, 1991b) has been finalized.

5.4.6.4 Alternative No. N-5: Expansion 1 to Interim Response Action A

IRA A consists of extracting and treating contaminated groundwater and recharging treated groundwater to prevent plume migration. The ability to extract groundwater with extraction wells, treat contaminated groundwater with carbon to remove organic compounds, and recharge treated groundwater has been demonstrated to be a reliable technology at the NBCS, NWBCS, and ICS. The ability to monitor the effectiveness of these technologies by monitoring wells has also been demonstrated at the three existing boundary systems. The Implementation Document for IRA A has been finalized. However, an additional remedial design and construction phase would be required to implement the additional systems included under Alternative No. N-5.

5.4.6.5 Alternative No. NW-1: No Further Action

The only technical aspect of the No Action alternative is the implementation of a monitoring program to re-evaluate the site in five years. Groundwater monitoring wells currently exist, and no additional wells would be installed to monitor conditions in the system.

The administrative feasibility of obtaining approval from the agencies is expected to be minimal for this alternative.

5.4.6.6 Alternative No. NW-2: Continued Operation of the Northwest Boundary Containment System With Improvements as Necessary

The NWCS has treated approximately 450 million gallons of groundwater per year with activated carbon since 1981. Effluent data from the NWBCS have shown that contaminant concentrations in the effluent attain Offpost OU PRGs. Operational assessments on the effectiveness of the system are issued annually.

5.4.7 Cost

The following subsections present summary cost estimates for each of the alternatives. Detailed cost estimates are included in Appendix F.

5.4.7.1 Alternative No. N-1: No Action

Estimated costs for Alternative No. N-1 are developed in Appendix F and are presented in Table F1. Cost evaluation of Alternative No. N-1 includes groundwater monitoring and five-year site review. The capital costs, long-term O&M costs, and total present worth costs for Alternative No. N-1 are presented below:

- Total Capital Costs = $ -0-
- Total Long-term Operation and Maintenance Costs = $4.1 - 6.0 million
- Total Present Worth Costs = $4.1 - 6.0 million

5.4.7.2 Alternative No. N-2: Continued Operation of the North Boundary Containment System With Improvements as Necessary

Estimated costs for this remedial action alternative are developed in Appendix F and are presented in Table F3. Long-term O&M costs were extended for 30 years because it is unknown when groundwater approaching RMA boundaries will comply with Offpost PRGs. The capital costs, long-term operation and maintenance costs, and total present worth costs for Alternative No. N-2 are presented below:

- Total Capital Costs = $ -0-
- Total Long-term Operation and Maintenance Costs = $30.6 - 32.5 million
- Total Present Worth Costs = $30.6 - 32.5 million

5.4.7.3 Alternative No. N-4: Interim Response Action A

Estimated costs for Alternative No. N-4 are developed in Appendix F and are presented in Table F4. The capital costs, long-term operation and maintenance costs, and total present worth costs for Alternative No. N-4 are presented below:

- Total Capital Costs = $ 16.7 million
- Total Long-term Operation and Maintenance Costs = $39.8 - 46.4 million
- Total Present Worth Costs = $56.5 - 63.1 million

5.4.7.4 Alternative No. N-5: Expansion 1 to Interim Response Action A

Estimates costs for Alternative No. N-5 are developed in Appendix F and presented in Table F5. The capital costs, long-term operation and maintenance costs, and total present worth costs for Alternative No. N-5 are presented below:

- Total Capital Costs = $19.4 million
- Total Long-term Operation and Maintenance Costs = $36.9 - 43.6 million
- Total Present Worth Costs = $56.2 - 63.0 million

5.4.7.5 Alternative No. NW-1: No Action

Estimated costs for Alternative No. NW-1 are developed in Appendix F and are presented in Table F8. The capital costs, long-term operation and maintenance costs, and total present worth costs for Alternative No. NW-1 are presented below:

- Total Capital Costs = $ -0-
- Total Long-term Operation and Maintenance Cost = $0.6 - 1.3 million
- Total Present Worth Costs = $.6 - 1.3 million

5.4.7.6 Alternative No. NW-2: Continued Operation of the Northwest Boundary Containment System With Improvements as Necessary

Estimated costs for Alternative No. NW-2 are developed in Appendix F and are presented in Table F8. The capital costs, long-term operation and maintenance costs, and total present worth costs for Alternative No. NW-2 are presented below:

- Total Capital Costs = $ -0-
- Total Long-term Operation and Maintenance Cost = $12.4 - 13.1 million
- Total Present Work Costs = $12.4 - 13.1 million

5.5 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section provides a comparative analysis of the remedial action alternatives evaluated using the criteria presented in Section 5.1. The purpose of this comparative analysis is to identify the advantages and disadvantages of each alternative relative to one another. Critical tradeoffs were identified to assist in the decision of which alternative to select as the preferred remedy. State and community acceptance is not included in this analysis because these criteria cannot be assessed until the state and public comment period has been concluded.

5.5.1 Comparison of Alternatives - North Plume Group

A brief comparison of each alternative with respect to the evaluation criteria is presented below. As previously discussed, each of the alternatives incorporates commonalities including the Army's commitment to provide alternative water to any future identified users of groundwater exceeding PRGs (i.e., exposure control), groundwater monitoring, five-year site review, and continued operation of the boundary containment systems (with the exception of the No Action alternative). Accordingly, these components of the alternatives were not evaluated in the comparative analysis. A comparison of the alternatives follows.

5.5.1.1 Overall Protection of Human Health and the Environment

Overall protection of human health and the environment would be provided by all alternatives with the exception of Alternative No. N-1. Alternative Nos. N-4 and N-5 would provide greater protection than Alternative No. N-2 because extraction, treatment, and recharge systems within the North Plume Group would decrease contaminant concentrations and reduce hypothetical risks within a shorter time period. Although groundwater modeling indicates that Alternative No. N-5 would achieve PRGs in a shorter time period than Alternative No. N-4, the two alter-

natives are essentially equivalent with respect to providing protection of human health and the environment for the reasons that follow:

- The groundwater monitoring program proposed under Alternative No. N-4 would provide full-scale system performance information that could be used to identify any necessary or beneficial improvements to the system and to provide information on optimal location of these additional systems without incurring additional capital costs.
- Uncertainties inherent in the groundwater modeling results make the prediction of remediation times imprecise.

5.5.1.2 Compliance With Applicable or Relevant and Appropriate Requirements

Compliance with chemical-specific ARARs would be achieved by all alternatives with the exception of Alternative No. N-1. Groundwater modeling indicates that chemical-specific ARARs would be achieved in the shortest time by Alternative No. N-5, followed by Alternative No. N-4, followed by Alternative No. N-2. Compliance with location-specific and action-specific ARARs selected in Appendix A will be achieved by all treatment alternatives.

Because no remediation would take place under Alternative No. N-1, there would be no federal and state location- or action-specific ARARs.

5.5.1.3 Long-term Effectiveness and Permanence

Comparison of alternatives with respect to long-term effectiveness and permanence indicates that the three treatment alternatives are essentially equivalent. All of the alternatives with the exception of the No Action alternative would reduce hypothetical risk and address exposure pathways through reducing COC concentrations in North Plume Group. Under the No Action alternative, hypothetical risks would likely increase after ceasing operations at the NBCS. Due to inherent uncertainties in groundwater modeling, predicted differences between treatment alternatives in time to achieve PRGs may not be reliable.

5.5.1.4 Reduction in Toxicity, Mobility, and Volume

All alternatives with the exception of the No Action alternative would reduce the toxicity, mobility, and volume of contaminated groundwater entering the Offpost OU north of the NBCS. Groundwater contaminant concentrations under the No Action alternative would likely increase.

The two alternatives with active remedial components in the North Plume Groups, Alternative Nos. N-4 and N-5 would provide the greatest reduction in toxicity, mobility, and volume of contaminated groundwater, through extraction, treatment, and recharge. As stated previously, the uncertainty associated with the remediation timeframes estimated by the groundwater modeling suggests that, in practical terms, the estimated timeframes for both Alternative Nos. N-4 and N-5 are equivalent. Further, the groundwater monitoring component of Alternative No. N-4 would allow for full-scale performance data regarding the reduction of contaminant concentrations. Such data would be necessary to assess the need for and optimum location of any modifications to Alternative No. N-4.

5.5.1.5 Short-term Effectiveness

The assessment of the alternatives with respect to short-term adverse environmental impacts, implementation period, and protection of the community and workers shows that the No Action alternative and Alternative No. N-2 are slightly better than the alternatives with active remediation components. However, during the implementation period, Alternative Nos. N-4 and N-5 would be able to minimize adverse short-term impacts through standard engineering controls and adherence to standard health and safety practices.

5.5.1.6 Implementability

All alternatives evaluated would be technically feasible to implement. The No Action alternative and Alternative No. N-2 would be the easiest to implement with respect to technical feasibility because the monitoring wells have already been installed and the NBCS system is currently operational. Alternative Nos. N-4 and N-5 would be readily constructed. However, Alternative No. N-5 would require additional design, and Alternative No. N-4 final design has already been approved. All treatment alternatives would use carbon treatment, which has been demonstrated at the boundary containment systems to be a reliable groundwater treatment process option. Groundwater monitoring is a component of all four alternatives and would provide information regarding the effectiveness of each alternative.

All alternatives with the exception of the No Action alternative would be administratively feasible. It is unlikely that the regulatory agencies or the public would accept shutdown of the NBCS as proposed under the No Action alternative. Additionally, the Army does not intend to cease operating the NBCS. No permits would be required under the remaining treatment alternatives. Each of the three treatment alternatives would meet federal and state substantive requirements for recharging the treated groundwater to the UFS.

The No Action alternative and Alternative No. N-2 would not require additional equipment and services. The implementation of Alternative Nos. N-4 and N-5 would not be limited with respect to availability of services and materials. Contractors with the equipment and knowledge to construct and implement these two alternatives are readily available.

5.5.1.7 Cost

The total present worth costs range from $4.1 - 6.0 million for No Action to $56.5 - 63.1 million for Alternative No. N-4. The present worth costs are nearly identical for Alternative Nos. N-4 and N-5 because the additional capital expenditures required for Alternative No. N-5 are balanced by the additional O&M costs incurred through the estimated 10-year differences in remediation timeframe for Alternative No. N-4.

The additional capital expenditure of approximately $2.7 million for Alternative No. N-5 as compared to Alternative No. N-4 is probably not justified in light of the need to collect full-scale data on contaminant transport and actual plume remediation timeframes through the intensive short-term monitoring program. Such data would allow for more informed decision-making as to the potential need for and placement of improvements to Alternative No. N-4.

5.5.2 Comparison of Alternatives - Northwest Plume Group

A brief comparison of each alternative with respect to the evaluation criteria is presented below. As previously discussed, Alternative No. NW-2 incorporates commonalities, including the Army's commitment to provide alternative water to any future identified user of groundwater exceeding PRGs (i.e., exposure control), groundwater monitoring, five-year site review, and

continued operation of the NWBCS. The No Action alternative includes only monitoring and the five-year site review.

5.5.2.1 Overall Protection of Human Health and the Environment

The No Action alternative would not be protective of human health and the environment because operation of the NWBCS would be ceased. Overall protection of human health and the environment would be provided by Alternative No. NW-2. Alternative No. NW-2 would decrease contaminant concentrations and reduce hypothetical risks associated with groundwater entering the Offpost OU from RMA. Recharge of groundwater treated at the NWBCS would reduce the contaminant concentrations in the Northwest Plume Group UFS through flushing. Groundwater modeling estimates that Alternative No. NW-2 would achieve PRGs in approximately three to eight years. The No Action alternative would likely not achieve PRGs, because the NWBCS would not be operated.

5.5.2.2 Compliance With Applicable or Relevant and Appropriate Requirements

Compliance with chemical-specific ARARs would be achieved only by Alternative No. NW-2. Groundwater modeling indicates that chemical-specific ARARs would be achieved in approximately three to eight years for this alternative. Alternative No. NW-2 would comply with location- and action-specific ARARs selected in Appendix A.

5.5.2.3 Long-term Effectiveness and Permanence

Comparison of the alternatives with respect to long-term effectiveness and permanence indicates that Alternative No. NW-2 reduces hypothetical risk and addresses exposure pathways through reducing COC concentrations in Northwest Plume Group. Under the No Action alternative, hypothetical risks would likely increase after operations at the NWBCS cease.

5.5.2.4 Reduction in Toxicity, Mobility, and Volume

Alternative No. NW-2 would reduce the toxicity, mobility, and volume of contaminated groundwater entering the Offpost OU north of the NWBCS. Groundwater contaminant concen-

trations under the No Action alternative would likely increase; thus toxicity, mobility, and volume would not be reduced.

5.5.2.5 Short-term Effectiveness

The assessment of the two alternatives with respect to short-term adverse environmental impacts, implementation period, and protection of the community and the workers shows that the No Action alternative and Alternative No. NW-2 are essentially equivalent except that the discontinued operation of the NWBCS, as part of the No Action alternative, has an adverse environmental impact. Neither alternative, with the exception noted above, has significant short-term effectiveness issues.

5.5.2.6 Implementability

Both alternatives evaluated would be technically feasible to implement. The No Action alternative and Alternative No. NW-2 would be implementable with respect to technical feasibility because the monitoring wells have already been installed and the NWBCS is currently operational. Alternative No. NW-2 would use carbon treatment, which has been demonstrated at the boundary containment systems to be a reliable groundwater treatment process option. Groundwater monitoring is a component of both alternatives and would provide information regarding the effectiveness of each alternative.

The No Action alternative would not be administratively feasible. It is unlikely that the regulatory agencies or the public would accept shutdown of the NWBCS as proposed under the No Action alternative. Additionally, the Army does not intend to cease operating the NWBCS. No permits would be required for either alternative. Alternative No. NW-2 would meet federal and state substantive requirements for recharging the treated groundwater to the UFS. Neither alternative would require additional equipment and services.

5.5.2.7 Cost

The total present worth costs range from $0.6 - 1.3 million for the No Action alternative to $12.4 - 13.1 million for Alternative No. NW-2.

5.5.3 Ranking of Alternatives - North Plume Group and Northwest Plume Group

A summary of the detailed analysis for each alternative and overall ranking are presented in Tables 5.5.3-1 and 5.5.3-2.

6.0 SELECTION OF THE PREFERRED SITEWIDE ALTERNATIVE

The following sections select the preferred sitewide alternative, describe the components of the preferred alternative, illustrate consistency with the requirements of CERCLA and the NCP, and present a summary statement.

6.1 IDENTIFICATION OF THE PREFERRED SITEWIDE ALTERNATIVE

The preferred sitewide alternative consists of implementation of Alternative No. N-4 for remediation of groundwater in the North Plume Group and Alternative No. NW-2 for remediation of groundwater in the Northwest Plume Group. Each of the components of the preferred sitewide alternative is described below in Sections 6.1.1.1 and 6.1.1.2.

This section describes the rationale for the selection of the preferred alternative. Specifically, key components of the preferred alternative are identified, and compliance with CERCLA and the NCP are documented.

The comparative analysis of the groundwater alternatives presented in Section 5.5 discussed the relative merits of the alternatives with respect to the seven detailed analysis criteria for both the North and Northwest Plume Groups. Due to the approximate nature of the models and because the Offpost OU is characterized by considerable conceptual model and parameter uncertainty, none of the modeling results should be viewed as accurate predictions of future contaminant distribution. Rather, the models and modeling results should be viewed as tools for assessing the relative merits of remedial alternatives during the detailed analyses. The detailed analysis of alternatives showed that for overall protectiveness, compliance with ARARs, effectiveness, and reduction of toxicity, mobility, and volume, Alternative Nos. N-4 and N-5 are superior to Alternative Nos. N-1 and N-2. Alternative No. N-4 is equal to Alternative No. N-2 in implementability. Alternate No. 4 is more readily implementable than Alternative Nos. N-1 and N-5 because Alternative No. N-1 would not be administratively feasible, and Alternative No. N-5 would require a second design and construction phase. Alternative Nos. N-4 and N-5 are approximately equal in cost when compared to each other and higher in cost when compared to

Alternative Nos. N-1 and N-2. Therefore, Alternative Nos. N-4 and N-5 were identified as being superior to Alternative Nos. N-1 and N-2. Direct comparison of Alternative Nos. N-4 and N-5 is presented below.

Alternative No. N-4 was demonstrated to be superior to Alternative No. N-5 with respect to the seven detailed analysis criteria for the reasons that follow:

- Groundwater modeling estimated that Alternative No. N-5 would achieve PRGs in a shorter time than Alternative No. N-4. However, the two alternatives are essentially equivalent with respect to providing protection of human health and the environment because

  - The intensive short-term groundwater monitoring program included under Alternative No. N-4 would provide full-scale system performance information that could be used to identify any necessary or beneficial improvements to the system and to provide information on optimal location of these additional systems without incurring additional capital costs.

  - Uncertainties inherent in the groundwater modeling results make the prediction of absolute remediation timeframes imprecise.

- The additional capital expenditure of approximately $2.7 million for Alternative No. N-5 as compared to Alternative No. N-4 is probably not justified in light of the need to collect full-scale data on contaminant transport and actual plume remediation timeframes through the intensive short-term monitoring program. These data will allow for informed decisions as to the possible need for and placement of improvements to Alternative No. 4.

- Alternative No. N-4 is more readily implementable than Alternative No. N-5 because implementation of Alternative No. N-5 would require additional remedial design and construction.

- Alternative Nos. N-4 and N-5 are essentially equivalent with respect to evaluation of compliance with ARARs, long-term effectiveness and performance, short-term effectiveness, and reduction in mobility, toxicity, or volume.

Therefore, Alternative No. N-4 is the selected alternative for the North Plume Group.

Alternative No. NW-2 ranks above Alternative No. NW-1 in all criteria except cost; however, the additional costs are not prohibitive in light of the reduction in time for remediation. Therefore, Alternative No. NW-2 is the selected alternative for the Northwest Plume Group. In summary, Alternative No. N-4 and Alternative No. NW-2 are the Army's preferred alternatives for the North and Northwest Plume Groups, respectively.

6.1.1 Preferred Sitewide Alternative Description

A description of the preferred sitewide remedial alternative is presented in this section. The preferred alternative is composed of the following components addressing remediation of groundwater in the North and the Northwest Plume Groups:

North Plume Group - IRA A (Alternative No. N-4)

Northwest Plume Group - Continued Operation of the NWBCS with Improvements as Necessary, (Alternative No. NW-2)

6.1.1.1 Alternative No. N-4: Interim Response Action A

The IRA A system design has been approved, and construction began in November 1991, with system start-up scheduled for approximately January 1993. For additional detail concerning design specifics, the reader is referred to the Final Implementation Document for the Groundwater Intercept and Treatment System North of RMA (HLA, 1991b). The major components of this alternative include:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels, using IRA A groundwater extraction wells
- Treatment of the organic COCs present in the groundwater, using carbon adsorption
- Recharge of treated groundwater to the UFS, using IRA A wells and trenches
- Continued operation of the NBCS
- Improvements to IRA A and the NBCS and IRA A, as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

The groundwater intercept and treatment system comprising IRA A is an aggressive array of extraction wells and recharge trenches in the northern and First Creek paleochannels. The system is configured to extract and treat UFS groundwater exceeding PRGs and recharge the treated groundwater. Figure 3.5.1.4-1 presents the placement of extraction wells and recharge wells in the northern paleochannel and the placement of extraction wells and recharge trenches in the First

Creek paleochannel. The location of the treatment plant is also shown. The northern paleochannel collection system consists of a total of 12 extraction wells oriented across the paleochannel perpendicular to the direction of groundwater flow and placed approximately 200 feet apart. The recharge system in the northern paleochannel consists of 24 recharge wells spaced 100 feet apart and placed parallel to and approximately 300 feet downgradient of the collection system. The First Creek paleochannel collection system consists of five extraction wells spaced 200 to 500 feet apart. The wells are placed along the axis of the groundwater flow pathway. Recharge trenches are placed such that four of the six trenches are parallel to the flow axis and located on the margins of the paleochannel, with the remaining two trenches located downgradient of the extraction well system and oriented perpendicular to the flow axis.

The system is designed to extract and treat an average flow of 300 gpm from the northern paleochannel, an average flow of 180 gpm from the First Creek paleochannel and a peak flow of 1.5 times the average flow. The treatment plant basic process flow includes influent storage, pumping, bag filtration for particulate removal, granular activated carbon (GAC) adsorption, multimedia filtration, treated-water storage, treated-water pumping, and final bag filtration.

A total of approximately 250 million gallons per year would be treated by the IRA A facility at the above-referenced average flows. Operation of the NBCS component of this alternative would treat approximately 125 million gallons per year. Thus, a total of approximately 375 million gallons of UFS groundwater would be treated annually to attain Offpost OU PRGs (Table 2.5.2-3) under this alternative.

An intensive short-term monitoring component would be included in this alternative as part of the long-term monitoring program. For costing purposes, it is assumed that this program would consist of a network of approximately 60 wells to be sampled semiannually for two to three years, beginning with the IRA A system start-up. The intensive monitoring program would allow the collection and subsequent interpretation of performance data for the full-scale operation of both the IRA A system and the NBCS. The data will also be used to assess the need for any

improvements to the systems. The acquisition of such data would allow for increased accuracy in assessing the response of the UFS groundwater to the NBCS and IRA A remediation systems.

A brief description of the IRA A treatment plant process units and their purpose follows. The influent tank has a capacity of 20,000 gallons and is used for flow equalization and storage. Centrifugal pumps are used to convey the untreated groundwater from the influent storage tank through the remainder of the treatment plant. Two bag filters, each with the capacity of the average flow, are used for particulate removal before the carbon units. Three upflow carbon contractors are used, each with a design flow of 360 gpm. One of the carbon units is held in reserve for reliability and operational flexibility. Untreated groundwater is pumped upward through the contractors and 2000-pound "pulses" of GAC are moved downward through the unit. Multimedia filters, composed of sand with anthracite, will be used after GAC treatment, to remove carbon fines. A treated-water storage basin with a total capacity of 66,000 gallons is provided for storage of fire protection water, backwashing capacity for the carbon and multimedia filters, and flow equalization. Another set of bag filters is provided for final particulate removal before treated-water recharge.

The NBCS collection system consists of a 6740-foot-long soil bentonite barrier and 54 extraction wells upgradient from the soil bentonite barrier. The recharge system initially consisted of 38 recharge wells downgradient from the soil bentonite barrier. The treatment system is made up of a cartridge-type prefilter to remove particulates from the water, three 30,000-pound upflow pulsed-bed carbon adsorbers, a carbon transfer and storage vessel, and cartridge-type and bag-type postfilters. The NBCS system was constructed in four phases. The first phase consisted of a pilot system that began operation in June 1978. The second phase was an expansion of the pilot system and began operation in January 1982. The third phase consisted of an additional ten recharge trenches that began operation in December 1988. The fourth phase was the addition of five recharge trenches, with operation beginning May 1990.

6.1.1.2 Alternative No. NW-2: Continued Operation of the Northwest Boundary Control System With Improvements as Necessary

This section summarizes the Continued Operation of the NWBCS with Improvements as Necessary alternative. For additional details of the extraction/recharge systems, the recent upgrades to the system, and the treatment facility at the NWBCS, the reader is referred to the following reports: Implementation Document for NWBCS Short-Term Improvements IRA (MKES, 1990a); NWBCS Long-Term Improvements IRA B(ii) Final Assessment Document (WWC, 1991a); Proposed Decision Document NWBCS RMA Long-Term Improvements IRA (WWC, 1991b); and Report of Field Investigations, Assessment, and Final Decision Document for the NWBCS Short-Term Improvements IRA (MKES, 1990b). The major components of this alternative include:

- Continued operation of the NWBCS
- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

The NWBCS was put into operation in 1984. The collection system consisted of 15 extraction wells and a slurry wall approximately 1600 feet in length. The recharge system consisted of 21 downgradient recharge wells. The existing slurry wall was extended 665 feet to the northeast to prevent contaminant bypass in July 1990 (MKES, 1990a), and one additional extraction well and two additional recharge wells were added. Three additional extraction wells and four additional recharge wells were added to the southwest portion of the NWBCS in August 1991.

The NWBCS treatment system consists of a collection sump, inlet transfer pumps, inlet bag filters, three upflow carbon contractors, effluent bag filters, effluent sump, and effluent transfer pumps (WWC, 1991a). The approximate treatment rate is 850 gpm or approximately 450 million gallons annually.

6.2 CONSISTENCY WITH THE REQUIREMENTS OF CERCLA AND THE NATIONAL CONTINGENCY PLAN

The following subsections describe the principal threats addressed by the preferred sitewide alternative, compliance with the statutory requirements of CERCLA, and consistency with the NCP.

6.2.1 Principal Threats Addressed by the Preferred Sitewide Alternative

The preferred sitewide alternative will result in the remediation of the Offpost OU consistent with RAOs (Section 2.4) and PRGs (Section 2.5). The principal threat posed by the site, namely contaminated groundwater in the North and Northwest Plume Groups, will be addressed by implementation of the preferred alternative through groundwater extraction, treatment, and recharge.

6.2.2 Consistency With the Statutory Requirements of CERCLA in Section 121

The statutory requirements of CERCLA section 121, as described below, and the statutory preference for treatment are met through implementation of this alternative.

6.2.2.1 Protection of Human Health and the Environment

The groundwater remedial actions described above in Sections 6.1.1.1 and 6.1.1.2 (and in Sections 3.0 and 5.0) will permanently address the principal threats to human health and the environment for the Offpost OU through treatment to reduce the toxicity, mobility, and volume of groundwater contaminants. It should be recognized, however, that studies conducted at other sites (by EPA and by others) have indicated that it may not always be possible to reach groundwater PRGs due to the limitations of technology used to assess groundwater hydrogeological properties, the technology used to estimate aquifer remediation timeframes, and the technology used to extract and recharge groundwater. If it becomes apparent during operation of the groundwater treatment systems that the UFS groundwater contaminant levels are remaining constant at levels higher than the Offpost OU groundwater PRGs, the design and operation of the systems may require reevaluation.

6.2.2.2 Compliance With Applicable or Relevant and Appropriate Requirements

Groundwater PRGs are based on chemical-specific ARARs for those chemicals having promulgated standards and on HBC for those chemicals without ARARs (Table 2.5.2-3). The preferred sitewide alternative is expected to attain or exceed chemical-specific ARARs. The preferred sitewide alternative will also comply with location-specific and action-specific ARARs identified in Appendix A.

6.2.2.3 Cost-effectiveness

The sitewide preferred alternative is cost-effective in its approach to remediating Offpost OU groundwater. The groundwater monitoring program will let the Army more accurately assess the contaminant removal rates as a function of time, using the full-scale data available during operation of both IRA A and the NBCS. The analysis of this data will allow for cost-effective decisions regarding any future improvements that may be required for the remedial systems.

6.2.2.4 Utilization of Permanent Solutions to the Maximum Extent Practicable

The individual components of the sitewide preferred alternative use technologies that are permanent solutions to remediation of the Offpost OU. Specifically, the use of groundwater extraction coupled with GAC treatment results in a permanent reduction in the concentrations of COCs in the UFS groundwater.

6.2.3 Consistency With the National Contingency Plan

The NCP requires that the following two features be present in the remedy selection process:

- The nine criteria used to evaluate alternatives in the detailed analysis are used to select a remedy.
- Selected Superfund remedies must employ the nine criteria to make the following four determinations
    - Each remedial action selected shall be protective of human health and the environment.
    - Onsite remedial actions selected in an ROD must attain ARARs or provide grounds for invoking a waiver.

- Each remedial action selected shall be cost-effective, provided that it first satisfies the threshold criteria (defined previously in Section 5.0)
- Each remedial action shall use permanent solutions to the maximum extent practicable.

The preferred sitewide alternative is fully consistent with the NCP, as is the selection process used to arrive at the preferred alternative. Alternatives were developed and screened, and the detailed analysis of alternatives was performed in a manner consistent with the NCP.

6.3 SUMMARY

The preferred sitewide alternative for remediation of the Offpost OU is Alternatives Nos. N-4 and NW-2. The preferred alternative was selected in accordance with the requirements of CERCLA and the NCP. The remedial actions that comprise the sitewide preferred alternative will permanently address the principal threats through groundwater extraction and treatment to reduce the toxicity, mobility, and volume of contaminants for protection of human health and the environment.

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Table 3.5.1-1: Groundwater Alternatives for the North Plume Group

	Alternative[a]	Process Options	Paleochannel	Extractions Wells (total number)	Recharge Wells/Trenches (total number/ total length)	Total Flow Rate (gpm)	Remediation Timeframe (years)	Treatment Plant Location	Residuals Generated
N-1	No Action	Monitoring five-year site reviews	FC, N	None	None	N/A	Unknown	N/A	None
N-2	Continued Operation of the NBCS with Improvements as Necessary	NBCS operation (slurry wall, carbon adsorption)	FC, N	No additional	No additional	240	15 to 30+	NBCS	No additional
N-3	Land Acquisition and Use Restrictions	NBCS operation Land acquisition and Use restrictions	FC, N	No additional	No additional	240	15 to 30+	NBCS	No additional
N-4	Interim Response Action A	Carbon adsorption NBCS operation	FC N	5 12	6 trenches: 1500 feet	180 300	15 to 30	T2S, R67W, Sec 14, NE 1/4 Sec	Spent carbon
N-5	Expansion 1 to Interim Response Action A	Carbon adsorption NBCS operation	FC N	7 13	10 trenches: 2700 feet 2 trenches: 600 feet	240 330	10 to 20	T2S, R67W, Sec 14, NE 1/4 Sec	Spent carbon
N-6	Expansion 2 to Interim Response Action A	Carbon adsorption NBCS operation	FC N	9 15	14 trenches: 3900 feet 5 trenches: 1500 feet	300 390	10 to 20	T2S, R67W, Sec 14, NE 1/4 Sec	Spent carbon

[a] All alternatives include groundwater monitoring and five-year site reviews.

FC = First Creek
N = northern
N/A = not applicable
NBCS = North Boundary Containment System

Table 3.5.1.7-1: Summary of Preliminary North Plume Group Groundwater Alternatives

		Land Acquisition	Use Restrictions	NBCS Operation	IRA A System Extraction Wells	IRA A System Recharge Wells/Trends	Carbon Adsorption Treatment	Three Additional[a] Extraction Wells; Six Additional Recharge Trenches	Seven Additional[a] Extraction Wells; Thirteen Additional Recharge Trenches
N-1	No Action								
N-2	Continued Operation of the NBCS With Improvements as Necessary			x					
N-3	Land Acquisition and Use Restrictions	x	x						
N-4	Interim Response Action A			x	x	x	x		
N-5	Expansion 1 to Interim Response Action A			x	x	x	x	x	
N-6	Expansion 2 to Interim Response Action A			x	x	x	x		x

All alternatives include groundwater monitoring and five-year site reviews.

[a] Additional extraction wells and recharge trenches refers to the number of wells/trenches in addition to the IRA A system.

IRA = interim response action
NBCS = North Boundary Containment System

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Table 3.5.2-1: Groundwater Alternatives for the Northwest Plume Group

Alternative[a]	Process Options	Paleochannel	Extractions Wells (total number)	Recharge Wells/Trenches (total number/ total length)	Total Flow Rate (gpm)	Remediation Timeframe (years)	Treatment Plant Location	Residuals Generated
NW-1 No Action	Monitoring five-year site reviews	NW	None	None	N/A	Unknown	N/A	None
NW-2 Continued Operation of the NWBCS With Improvements as Necessary	NWBCS operation	NW	No additional	No additional	850	3 to 8	NWBCS	No additional
NW-3 Land Acquisition and Use Restrictions	Land acquisition Use restrictions NWBCS operation	NW	No additional	No additional	850	3 to 8	NWBCS	No additional
NW-4 Northwest Plume Group Extraction/Recharge System	Carbon adsorption NWBCS operation	NW	3	5 wells	1000	2 to 5	NWBCS	Spent carbon

[a] All alternatives include groundwater monitoring and five-year site reviews.

N/A = not applicable
NW = northwest
NWBCS = Northwest Boundary Containment System

Table 3.5.2.5-1: Summary of Preliminary Northwest Plume Group Groundwater Alternatives

		Land Acquisition	Use Restrictions	NWBCS Operation	Extraction Wells	Recharge Wells/Trenches	Carbon Adsorption Treatment
NW-1	No Action						
NW-2	Continued Operation of the NWBCS with Improvements as Necessary			x			
NW-3	Land Acquisition and Use Restrictions	x	x	x			
NW-4	Northwest Plume Group Extraction/Recharge System			x	x	x	x

All alternatives include groundwater monitoring and five-year site reviews.

NW = northwest
NWBCS = Northwest Boundary Containment System

Table 4.2.1.7-1: Summary of Screening of Groundwater Alternatives; North Plume Group
(Page 1 of 2)

	Effectiveness					Implementability		Cost			
Alternative	Reduction of MTV	Long-term Protection	Complies With PRGs	Short-term Impacts	Time to Achieve Protection (years)	Technically Feasible	Administratively Feasible	Capital Cost ($\times 10^3$ dollars)	Long-term O&M Cost ($\times 10^3$ dollars)	Present Worth ($\times 10^3$ dollars)	Recommended for DAA
N-1 No Action	None	None	No	None	Unknown	Yes	Yes	-0-	4,061 - 6,012	4,061 - 6,102	Retained for further evaluation on the basis of NCP requirements
N-2 Continued Operation of the NBCS With Improvements as Necessary	Reduces M, T, and V at the NBCS only	Provides some long-term production through reducing COC concentrations at the NBCS	Yes	None	15 to 30+	Yes	Yes	-0-	30,600 - 32,500	30,600 - 32,500	Retained for further evalauation
N-3 Land Acquisition and Deed Restrictions	Reduces M, T and V at the NBCS only	Controls exposures pathways through use and access restrictions and provides some long-term protection through reducing COC concentrations at the NBCS.	Yes	None	15 to 30+	Yes	Yes	5,348	30,400 - 32,330	35,800 - 37,700	Eliminated from further evalauation on the basis of effectiveness issues
N-4 Interim Response Action A	Reduces M, T, and V at the NBCS and within the North Plume Group	Addresses exposure pathways through reducing COC concentrations at the NBCS and within the North Plume Group	Yes	None	15 to 30	Yes	Yes	16,700	40,000 - 46,400	56,500 - 63,100	Retained for further evaluation
N-5 Expansion 1 to IRA A	Reduces M, T, and V at the NBCS and within the North Plume Group	Addresses exposure pathways through reducing COC concentrations at the NBCS and within the North Plume Group	Yes	None	10 to 20	Yes	Yes	19,400	36,900 - 43,600	56,200 - 63,000	Retained for further evaluation
N-6 Expansion 2 to IRA A	Reduces M, T, and V at the NBCS and within the North Plume Group	Addresses exposure pathways through reducing COC concentrations at the NBCS and within the North Plume Group	Yes	None	10 to 20	Yes	Yes	22,000	37,600 - 44,200	59,600 - 66,200	Eliminated from further evaluation on the basis of similar preformance comparison with Alternative No. N-5 at higher cost

Table 4.2.1.7-1: Summary of Screening of Groundwater Alternatives; North Plume Group
(Page 2 of 2)

COC = chemical of concern
DAA = detailed analysis of alternatives
MTV = mobility, toxicity, and volume
NBCS = North Boundary Containment System
NCP = National Contingency Plan
O&M = Operation and Maintenance
PRG = preliminary remediation goal

Table 4.2.2.5-1: Summary of Screening of Groundwater Alternatives; Northwest Plume Group
(Page 1 of 2)

	Effectiveness					Implementability		Cost			
Alternative	Reduction of MTV	Long-term Protection	Complies With PRGs	Short-term Impacts	Time to Achieve Protection (years)	Technically Feasible	Administratively Feasible	Capital Cost ($\times 10^3$ dollars)	Long-term O&M Cost ($\times 10^3$ dollars)	Present Worth ($\times 10^3$ dollars)	Recommended for DAA
NW-1 No Action	None	None	No	None	Unknown	Yes	Yes	-0-	608 - 1,260	608 - 1,260	Retained for further evaluation on the basis of NCP requirements
NW-2 Continued Operation of the NWBCS and Improvements as Necessary	Reduces M, T, and V at the NWBCS only	Provides some long-term protection through reducing COC concentrations at the NWBCS	Yes	None	3 - 8	Yes	Yes	-0-	12,400 - 13,100	12,400 - 13,100	Retained for further evaluation on the basis of effectiveness, ease of implementation, and low cost in comparison with other Northwest Plume Group alternatives
NW-3 Land Acquisition and Use Restrictions	Reduces M, T, and V at the NWBCS	Controls exposure pathways through use and access restrictions and provides some long-term protection through reducing COC concentrations at the NWBCS	Yes	None	3 - 8	Yes	Yes	2,100	12,300 - 12,900	14,400 - 15,000	Eliminated from further evaluation on the basis of similar performance in comparison with Alternative No. NW-2 at higher cost
NW-4 Northwest Plume Group Extraction/Recharge System	Reduces M, T, and V at the NWBCS and within the Northwest Plume Group	Addresses exposure pathways through reducing COC concentrations at the NWBCS and within the Northwest Plume Group	Yes	None	2 - 5	Yes	Yes	2,774	12,200 - 12,500	15,000 - 15,300	Eliminated from further evaluation on the basis of similar performance in comparison with Alternative No. NW-2 at higher cost

Table 4.2.2.5-1: Summary of Screening of Groundwater Alternatives; Northwest Plume Group
(Page 2 of 2)

COC = chemical of concern
DAA = detailed analysis of alternatives
MTV = mobility, toxicity, and volume
NBCS = North Boundary Containment System
NCP = National Contingency Plan
O&M = Operation and Maintenance
PRG = preliminary remediation goal

Table 5.5.3-1: Summary of the Detailed Analysis and Ranking of Groundwater Alternatives for the North Plume Group
(Page 1 of 3)

Criteria	Alternative No. N-1 No Action	Alternative No. N-2 Continued Operation of the North Boundary Containment System With Improvements as Necessary	Alternative No. N-4 Interim Response Action A	Alternative No. N-5 Expansion I to Interim Response Action A
Overall Protection of Human Health and the Environment	This alternative would not provide protection of human health and the environment.	This alternative provides limited overall protection of human health and the environment by preventing migration of contaminants from RMA to the Offpost OU north of the NBCS. Hypothetical risk associated with groundwater in the North Plume Group would decrease over time.	Reduces hypothetical risk and provides protection of both human health and the environment by remediating North Plume Group groundwater.	Reduces hypothetical risk and provides protection of both human health and the environment by remediating North Plume Group groundwater.
Compliance With ARARs	This alternative is not expected to achieve chemical-specific ARARs.	Groundwater modeling indicates that chemical-specific ARARs may be attained 15 to 30-plus years.	Chemical-specific ARARs would be attained in approximately 15 to 30 years, as estimated by groundwater modeling.	Chemical-specific ARARs would be attained in approximately 10 to 20 years, as estimated by groundwater modeling.
Long-term Effectiveness and Permanence	This alternative would not reduce the residual risk associated with groundwater exposure pathways.	This alternative would reduce residual risk associated with North Plume Group groundwater by preventing contaminant migration at the NBCS and continuing recharge of treated groundwater to flush contaminants in the North Plume Group.	This alternative would reduce residual risk associated with North Plume Group groundwater, through operation of the NBCS and the IRA A systems and improvements to both systems as necessary.	Through tretment, this alternative would reduce residual risk associated with North Plume Group groundwater through operation of the NBCS, the IRA A, and the Expansion I systems.
Reduction of Mobility, Toxicity, or Volume	This alternative would not employ any treatment process options and would not reduce toxicity, mobility, or volume of groundwater within the North Plume Group or groundwater migrating from RMA to the Offpost OU.	This alternative would reduce toxicity, mobility, and volume of groundwater migrating from RMA to the Offpost OU.	Through treatment, this alternative would reduce toxicity, mobility, and volume of groundwater within the North Plume Group and groundwater migrating from RMA to the Offpost OU.	This alternative would reduce the toxicity, mobility, and volume of groundwater within North Plume Group and groundwater migrating from RMA to the Offpost OU through treatment.

Table 5.5.3-1: Summary of the Detailed Analysis and Ranking of Groundwater Alternatives for the North Plume Group
(Page 2 of 3)

Criteria	Alternative No. N-1 No Action	Alternative No. N-2 Continued Operation of the North Boundary Containment System With Improvements as Necessary	Alternative No. N-4 Interim Response Action A	Alternative No. N-5 Expansion 1 to Interim Response Action A
Short-term Effectiveness	Because no remedial action would be performed, there would be no short-term impacts. There would be no implementation period.	There would be no short-term impacts because the NBCS is already operating. There would be no implementation period.	Community and workers would be protected by adhering to standard health and safety practices. The implementation period would be approximately 20 months.	Community and workers would be protected during construction through adhering to standard health and safety practices. The implementation period would be approximately 32 months.
Implementability	Technical feasibility would be high. The administrative feasibility would be low.	This alternative is readily implementable, and administrative feasibility would be high.	This alternative is readily implementable. Technical and administrative feasibility would be high.	This alternative is readily implementable. However, the construction would be conducted in two time periods due to the design phase for the expansion. Technical and administrative feasibility would be high.
Cost	Total Capital Cost = $ -0- Total Long-term O&M Cost = $4.1 to 6.0 million Total Present Worth Cost = $4.1 to 6.0 million	Total Capital Cost = $ -0- Total Long-term O&M Cost = $30.6 to 32.5 million Total Present Worth Cost = $30.6 to 32.5 million	Total Capital Cost = $16.7 million Total Long-term O&M Cost = $39.8 to 46.4 million Total Present Worth Cost = $56.5 to 63.1 million	Total Capital Cost = $19.4 million Total Long-term O&M Cost = $36.9 to 43.6 million Total Present Worth Cost = $56.2 to 63 million
Overall Rank Based on Achievement of Criteria	4	3	1	2

Table 5.5.3-1: Summary of the Detailed Analysis and Ranking of Groundwater Alternatives for the North Plume Group
(Page 3 of 3)

ARAR = applicable or relevant and appropriate requirement
IRA = Interim Response Action
NBCS = North Boundary Containment System
O&M = Operation and Maintenance
OU = operable unit
RMA = Rocky Mountain Arsenal

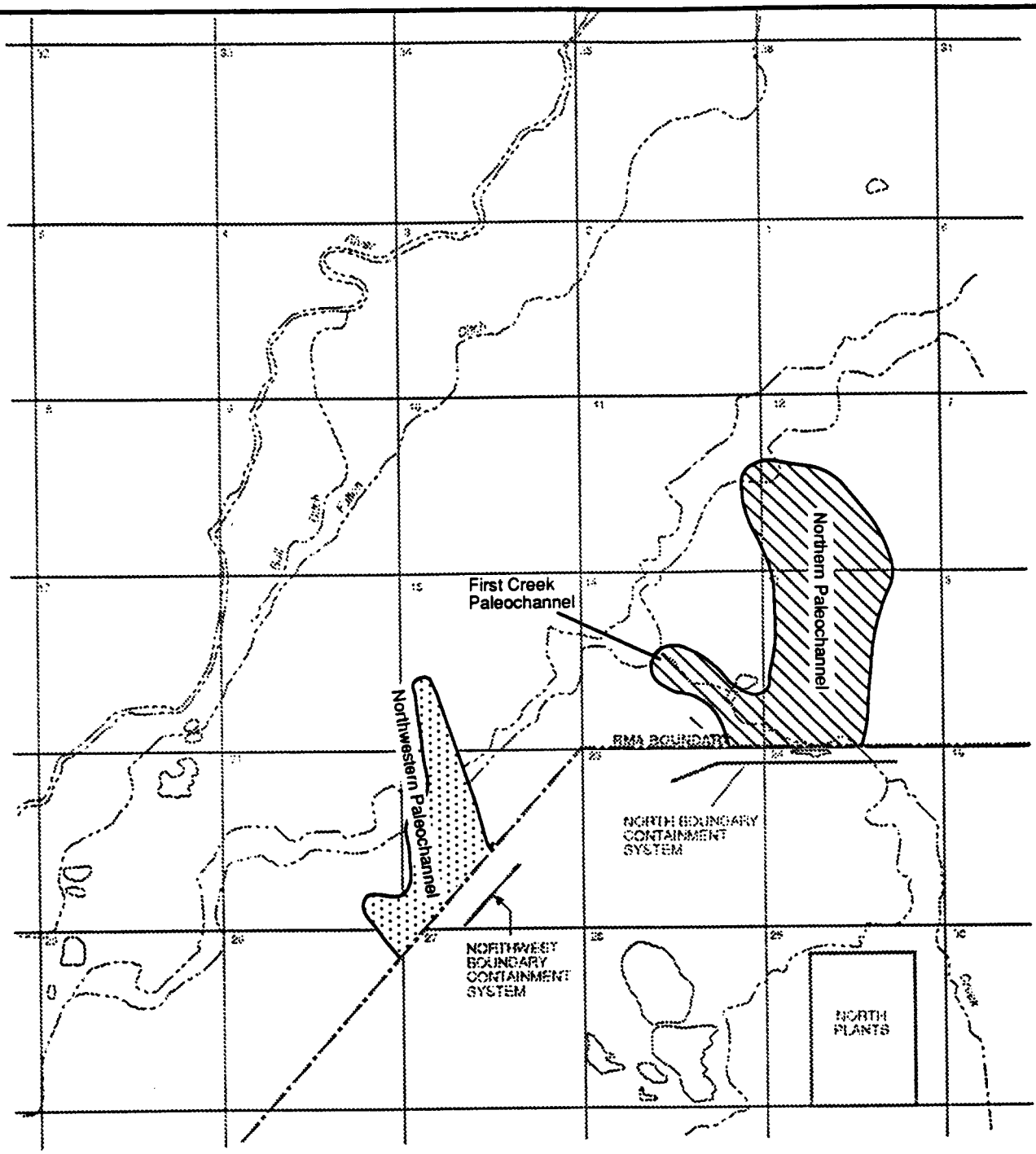
Table 5.5.3-2: Summary of the Detailed Analysis and Ranking of Groundwater Alternatives for the Northwest Plume Group
(Page 1 of 2)

Criteria	Alternative No. NW-1 No Action	Alternative No. NW-2 Continued Operation of the Northwest Boundary Contaminated System With Improvements if Necessary
Overall Protection of Human Health and the Environment	This alternative would not provide protection of human health and the environment.	This alternative would provide protection of human health and the environment by preventing migration of contaminants from RMA to the Offpost OU north of the NWBCS. Potential risks associated with the Northwest Plume Group groundwater would be substantially reduced through continued operation of the NWBCS and improvements as necessary.
Compliance With ARARs	This alternative is not expected to achieve chemical-specific ARARs.	This alternative is expected to meet or exceed chemical specific ARARs in approximately 3 to 8 years, as estimated by groundwater modeling.
Long-term Effectiveness and Permanence	This alternative would not reduce the residual risk associated with potential groundwater exposure pathways.	This alternative would reduce residual risk associated with groundwater within the Northwest Plume Group through preventing contaminant migration at the NWBCS and recharging treated groundwater to flush contaminants in the Northwest Plume Group.
Reduction of Toxicity, Mobility, or Volume	This alternative would not employ any treatment process options and would not reduce the toxicity, mobility, or volume of groundwater within the Northwest Plume Group or groundwater migrating from RMA to the Offpost OU.	This alternative would reduce toxicity, mobility, and volume of groundwater migrating from RMA to the Offpost OU. Groundwater contaminant concentrations would be reduced within the Northwest Plume Group by flushing provided by recharge of treated water at the NWBCS.
Short-term Effectiveness	Because no remedial action would be performed, there would be no short-term impacts. There would be no implementation period.	There would be no short-term impacts.
Implementability	The technical feasibility would be high. The administrative feasibility would be low.	This alternative is readily implementable. Technical and administrative feasibility would be high.

Table 5.5.3-2: Summary of the Detailed Analysis and Ranking of Groundwater Alternatives for the Northwest Plume Group
(Page 2 of 2)

Criteria	Alternative No. NW-1 No Action	Alternative No. NW-2 Continued Operation of the Northwest Boundary Contaminated System With Improvements if Necessary
Cost	Total Capital Cost = $ -0- Total Long-term O&M Cost = $0.6 to 1.3 million Total Present Worth Cost = $0.6 to 1.3 million	Total Capital Cost = $ -0- Total Long-term O&M Cost = $12.4 to 13.1 million Total Present Worth Cost = $12.4 to 13.1 million
Overall Rank Based on Achievement of Criteria	2	1

ARAR = applicable or relevant and appropriate requirement
IRA = Interim Response Action
NBCS = North Boundary Containment System
O&M = Operation and Maintenance
OU = operable unit
RMA = Rocky Mountain Arsenal



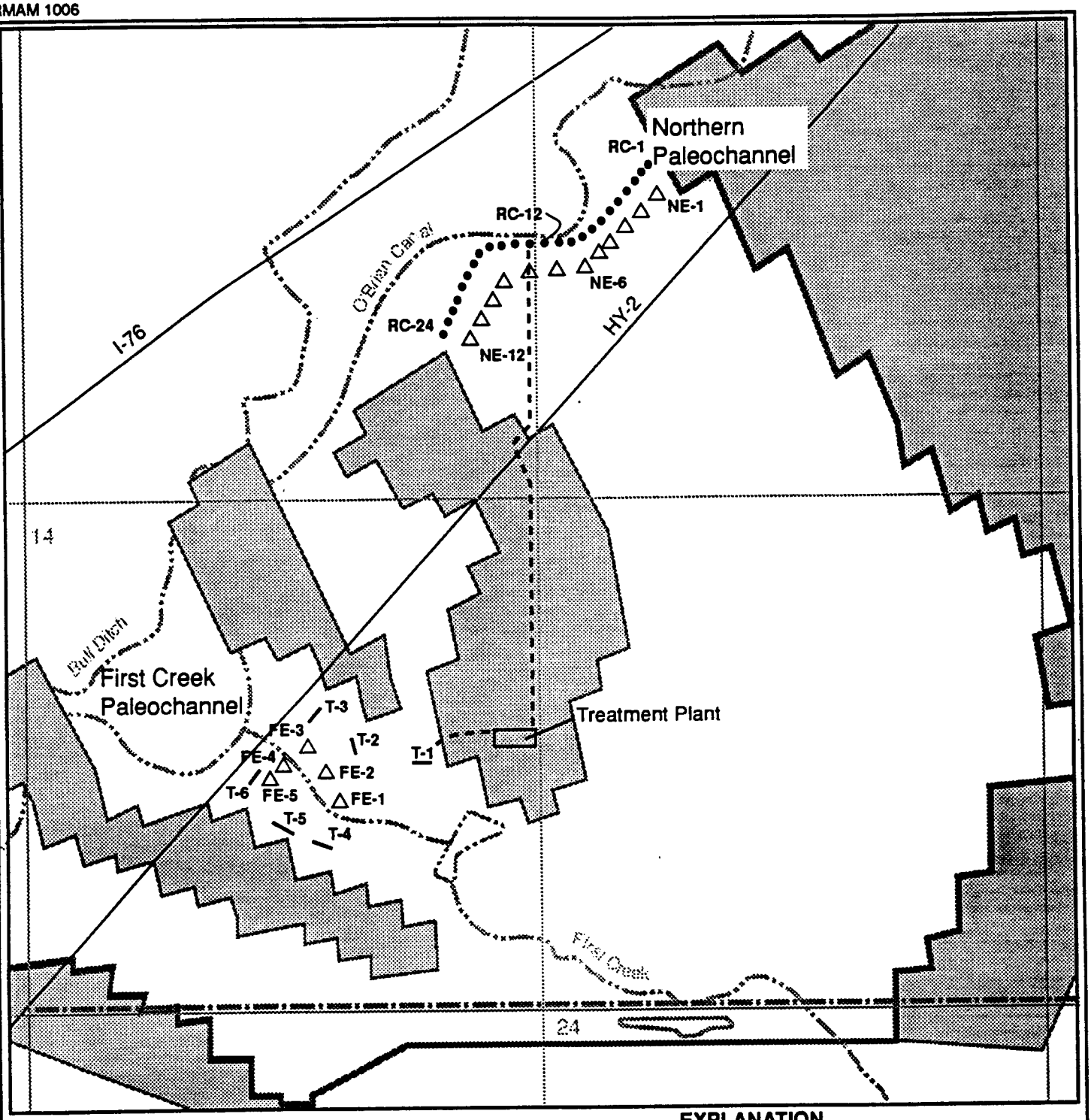
Note: Outlined plume group areas are generalized and do not correspond exactly to areas where PRGs are exceeded

Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 3.2.1-1

OFFPOST OPERABLE UNIT
GROUNDWATER PLUME GROUPS



EXPLANATION

- Planned IRA pumping well
- Planned IRA recharge well
- Planned IRA recharge trench
- Pipeline
- Unsaturated alluvium

N

0 750 1500

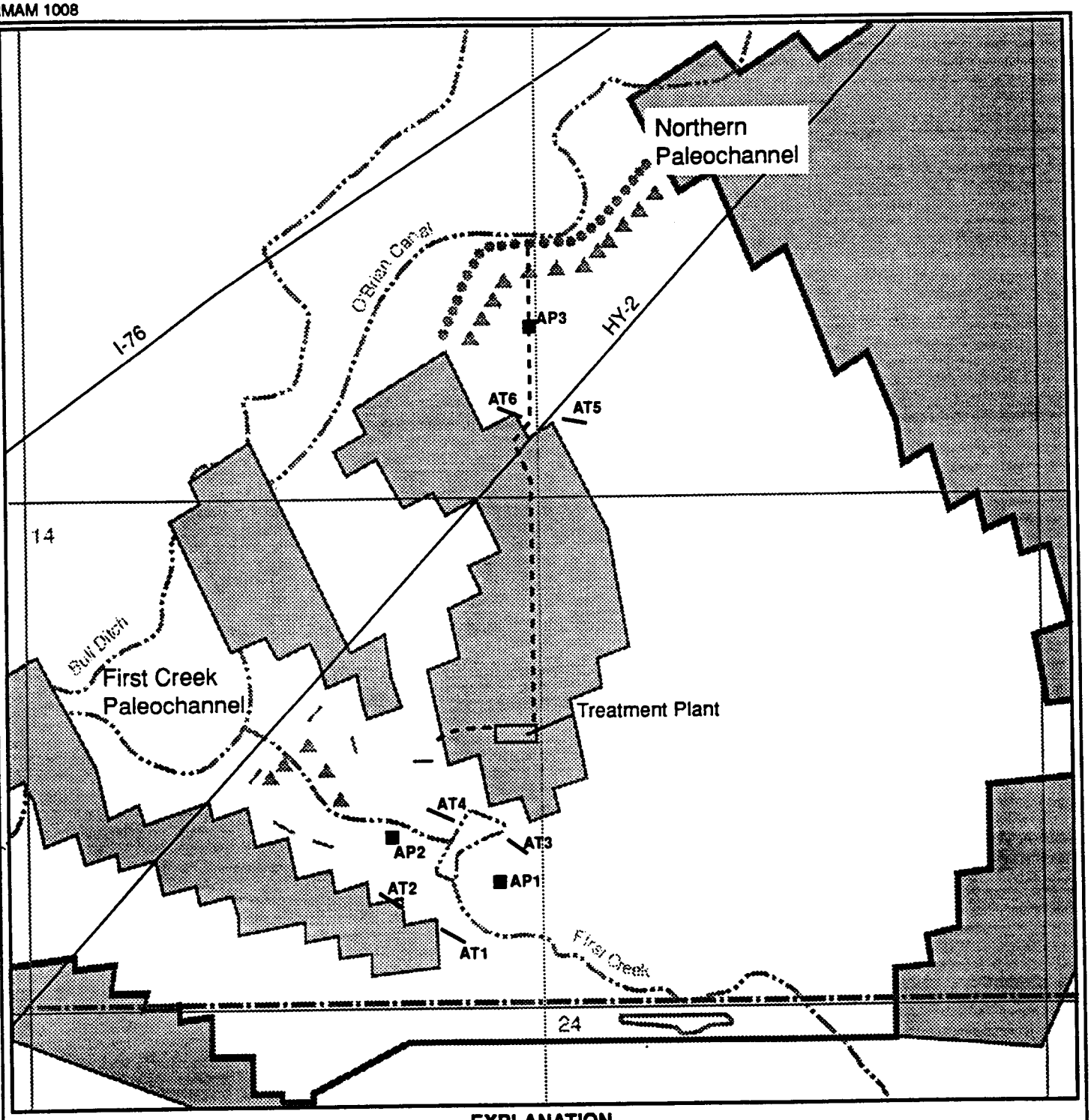
Scale in Feet

Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 3.5.1.4-1

ALTERNATIVE NO. N-4:
INTERIM RESPONSE ACTION A



EXPLANATION

- Planned IRA pumping well
- Planned IRA recharge well
- Planned IRA recharge trench
- Expansion 1 recharge trench
- Expansion 1 pumping well
- Pipeline
- Unsaturated alluvium

N

0 750 1500
Scale in Feet

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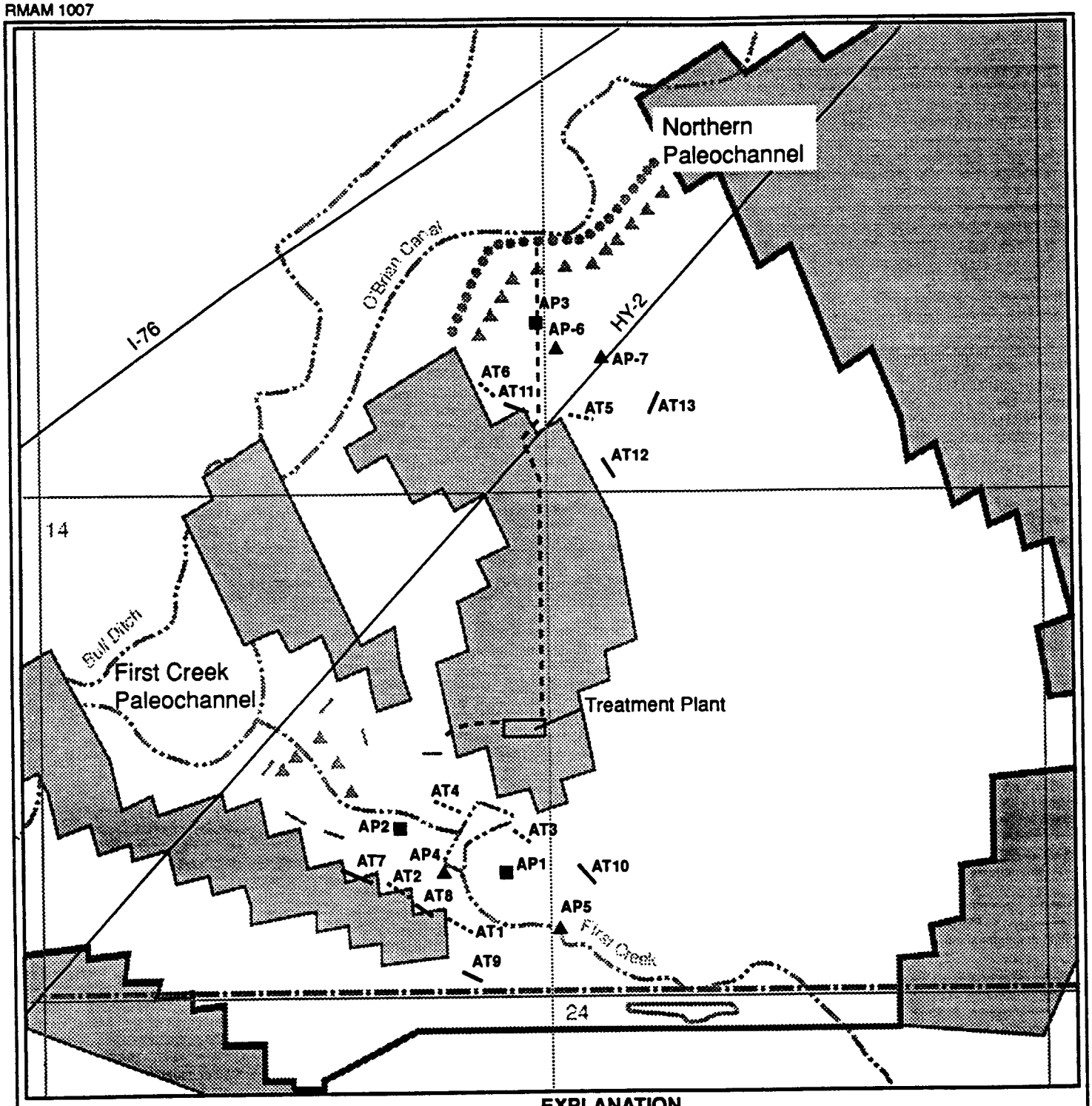
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 3.5.1.5-1

ALTERNATIVE NO. N-5:
EXPANSION 1 TO INTERIM RESPONSE ACTION A

RMAM 1007



EXPLANATION

- Planned IRA pumping well
- Planned IRA recharge well
- Planned IRA recharge trench
- Expansion 1 recharge trench
- Expansion 1 pumping well
- Expansion 2 recharge trench
- Expansion 2 pumping well
- Pipeline
- Unsaturated alluvium

N

0 750 1500

Scale in Feet

Prepared for:
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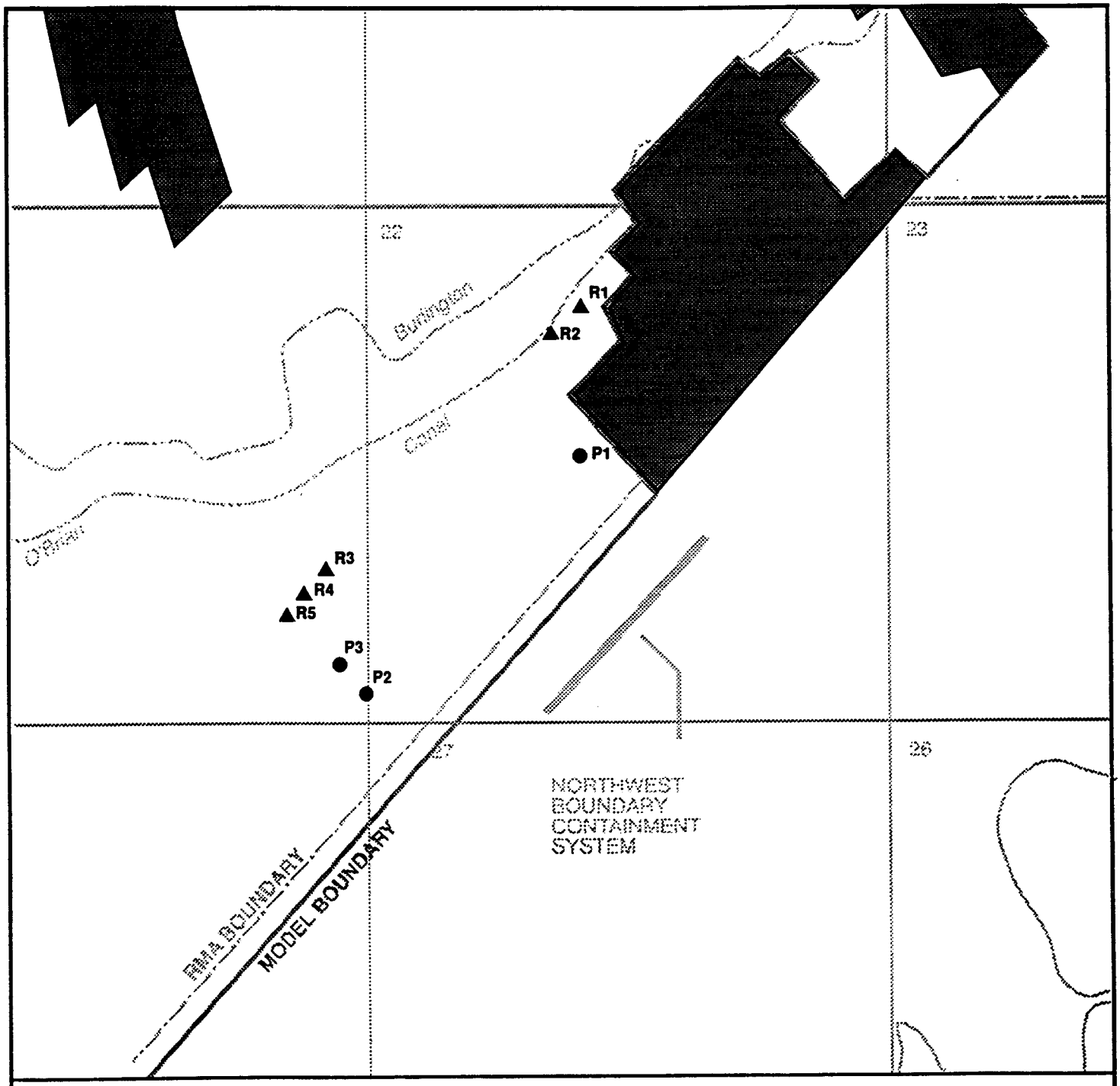
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 3.5.1.6-1

ALTERNATIVE NO. N-6:
EXPANSION 2 TO INTERIM RESPONSE ACTION A



Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 3.5.2.4-1

ALTERNATIVE NO. NW-4:
NORTHWEST PLUME GROUP
EXTRACTION/RECHARGE SYSTEM

TECHNICAL SUPPORT FOR ROCKY MOUNTAIN ARSENAL

Offpost Operable Unit
Endangerment Assessment/Feasibility Study

Final Report

Volume VII of VIII
(FS Appendixes)

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PREPARED BY

Harding Lawson Associates

PREPARED FOR

PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL

THIS DOCUMENT IS INTENDED TO COMPLY WITH THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969.

THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATION RECORD FOR THIS CERCLA OPERABLE UNIT.

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Appendix A

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS ANALYSIS

1.0 INTRODUCTION

Appendix A describes the procedures used to identify and evaluate applicable or relevant and appropriate requirements (ARARs) for the Offpost Operable Unit (OU) at Rocky Mountain Arsenal (RMA). Based on the results of the Development and Screening of Alternatives (DSA), a total of six remedial alternatives were retained for detailed evaluation during the Detailed Analysis of Alternatives (DAA) (Section 5.0). These six alternatives were evaluated for ARARs.

The ARARs evaluation was performed in a manner consistent with U.S. Environmental Protection Agency (EPA) guidance, including the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) found in 40 Code of Federal Regulations (CFR) Part 300, the NCP preamble found in 55 Federal Register 8666 (March 8, 1990), and the "CERCLA Compliance With Other Laws Manual: Parts I and II" (Office of Solid Waste Emergency Response [OSWER] Directives 9234.1-01 and 9234.1-02) (Compliance Manual).

Section 2.0 of Appendix A presents a general discussion of ARARs, including the legal and regulatory framework and how the requirements are generally identified and applied. This discussion is followed by an identification of the pool of potential ARARs for the Offpost OU. The usefulness of potential ARARs is then evaluated and those ARARs that will pertain to the recommended remedy are identified. Sections 3.0, 4.0, and 5.0 of this appendix discuss potential chemical-, location-, and action-specific ARARs for the Offpost OU, respectively.

2.0 IDENTIFICATION AND EVALUATION OF ARARS

This section describes the procedures used in the identification and evaluation of ARARs. Specifically, this section (1) summarizes the definitions and procedures used to evaluate the applicability or relevance and appropriateness of potential ARARs, (2) identifies potential ARARs associated with state authorized programs, and (3) discusses the limitations of the ARARs evaluation and the assumptions used in developing this Appendix A. The guidance documents and other sources of information used in performing the ARARs evaluation and the procedures used to identify potential ARARs are also discussed in this section.

2.1 DEFINITION AND EVALUATION OF APPLICABILITY OR RELEVANCE AND APPROPRIATENESS

Remedial actions selected under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) must attain a degree of cleanup that, at a minimum, assures protection of human health and the environment (42 United States Code [USC] 9621[d][1]). When a hazardous substance remains onsite, CERCLA requires that remedial actions meet a level or standard of control that at least attains standards, requirements, or limitations under any federal, or stricter state environmental law, if such requirements are legally applicable or relevant and appropriate under the circumstances (42 USC 9621[d][2]).

The NCP (40 CFR Section 300.5) defines "applicable" and "relevant and appropriate" requirements as follows:

> Applicable requirements mean those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.
>
> Relevant and appropriate requirements mean those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

The terms "applicable" and "relevant and appropriate" are mutually exclusive. Therefore, a requirement under environmental laws may be either "applicable" or "relevant and appropriate," but not both (Compliance Manual at xiii). For a requirement to be "applicable," the remedial action or the circumstances at the site must satisfy all the jurisdictional prerequisites for the requirement. If a requirement is not applicable, it nonetheless may still be relevant and appropriate.

In deciding whether a requirement is relevant and appropriate, the following factors, found in 40 CFR Section 300.400(g)(2), are evaluated: (1) the purpose of the requirement; (2) the media regulated or affected by the requirement; (3) the substances regulated by the requirement; (4) the action or activity regulated by the requirement; (5) the variances, waivers, or exemptions to the requirement; (6) the type of physical location regulated or affected by the requirement; (7) the type and size of structure or facility regulated or affected by the requirement; and (8) the requirement's consideration of use or potential use of affected resources.

The evaluation of relevance considers the above factors with respect to whether a requirement addresses problems or situations sufficiently similar to the circumstances of the contemplated remedial action. If the requirement is relevant, the evaluation of appropriateness will consider the above factors with respect to whether the requirement is well suited to the particular site (55 Federal Register 8743).

The degree to which ARARs must be met varies. Applicable requirements must be met to the full extent required by the law. However, portions of a requirement may be relevant and appropriate even if the entire requirement is not. Once it is determined that a requirement is both relevant and appropriate, it must be complied with as if it were applicable.

In addition to ARARs, EPA has developed a separate category of information that does not meet the ARAR definition. This category of "to be considered" (TBC) information includes advisories, criteria, or guidance that were developed by EPA, other federal agencies, or states that may be useful in developing CERCLA remedies (40 CFR Section 300.400[g][3]). TBCs, therefore,

are nonpromulgated advisories that are not legally binding but may be considered with ARARs in determining the level of cleanup necessary for protection of human health or the environment.

EPA has determined that CERCLA response actions should be subject only to substantive, not administrative, requirements (55 Federal Register 8758). Substantive requirements are those that pertain directly to actions or conditions in the environment, such as concentration-based standards, technology-based standards, and restrictions upon activities in certain special locations. Administrative requirements, on the other hand, are those mechanisms that facilitate the implementation of the substantive requirement and include the approval of or consultation with administrative bodies, issuance of permits, documentation, and reporting and recordkeeping (55 Federal Register 8758 and Compliance Manual at 1-11).

CERCLA expressly provides for state standards to be ARARs at a site. However, only those standards that are more stringent than federal requirements may be considered. In addition, the state standards must be promulgated (i.e., the requirement must be of general applicability and legally enforceable). Finally, the requirements must be identified in a timely manner by the particular state (40 CFR 300.400[g][4]).

EPA has divided ARARs into three groups: chemical-, location-, and action-specific ARARs. Chemical-specific ARARs set health-, risk-, or technology-based concentration limits for various constituents that may be found in or discharged to various environmental media. Location-specific requirements set restrictions on activities, depending on the characteristics of a site or its immediate environs. In contrast, action-specific ARARs set controls or restrictions on particular kinds of activities related to management of hazardous substances, pollutants, or contaminants.

2.2 POTENTIAL ARARS ASSOCIATED WITH STATE AUTHORIZED PROGRAMS

For those federal environmental statutes that the State of Colorado is fully authorized to operate, the equivalent state regulations represent the potential ARAR. This approach is based on guidance presented in the Compliance Manual (vol. I, p. 2-11), which states that "If the CERCLA site is located in a State with an authorized RCRA program, the State's promulgated RCRA

requirements will replace the equivalent Federal requirements as potential ARARs." The Compliance Manual (vol. II, p. 7-7) further states that "For the purposes of identification and communication of State ARARs, the authorized state requirement is to be documented as the potential ARAR (as it is regarded as the requirement that is in effect)." Finally, the Compliance Manual (vol. II, p. 7-7) states that "If authorization for operating a Federal Program has been acquired by a State, it can be seen that the requirements of the State program are at least as stringent as or more stringent than those requirements of the parallel Federal law or regulation. Therefore, a side-by-side comparison of Federal and State provisions is not necessary."

Based on the above referenced guidance cited in the Compliance Manual, the approach taken in this ARARs evaluation is to identify both the federal and equivalent state requirements. For those requirements that the State of Colorado is fully authorized to implement, the associated state requirements are considered as potentially applicable or appropriate, and the federal regulations would not be applicable or appropriate. For regulations that the State of Colorado is only partially authorized to implement, the portions of the state regulations that Colorado is authorized to implement will be considered applicable or appropriate. For those portions of the regulations that the state is not authorized to implement, the specific portions of the federal regulations will be evaluated as potential ARARs.

Authorized state programs include the Resource Conservation and Recovery Act (RCRA) and Clean Air Act (CAA). An example of a program that Colorado is only partially authorized to implement or where Colorado has yet to adopt recent changes in federal regulations is the Safe Drinking Water Act (SDWA).

2.3 LIMITATIONS AND ASSUMPTIONS OF ARARS EVALUATION

Several limitations and assumptions affected the scope of the ARARs evaluation. The first limitation is that specific conditions, media, or actions only included within the Offpost OU will be addressed. Requirements that may be applicable or relevant and appropriate to media within the scope of other OUs at RMA are not addressed in this evaluation unless they also relate to an action or condition associated with this OU.

The second limitation of the scope of the ARARs evaluation relates to chemical-specific requirements associated with specific actions. Any assessment of the applicability or relevance and appropriateness of chemical-specific requirements that necessitates an understanding of the purpose, objectives, and scope associated with an action would be a potential action-specific requirement rather than a chemical-specific requirement. For example, the Colorado Department of Health (CDH) regulations promulgated under the Colorado Air Quality Act contain standards and limitations associated with specific chemicals and therefore could possibly represent potential chemical-specific ARARs. However, air and landfill gases are not included within the media associated with the Offpost OU and therefore are neither applicable nor relevant. However, if air emissions result from any remedial action that may be undertaken for the Offpost OU, CDH air quality regulations may include potential action-specific ARARs.

The third limitation of the scope of the ARARs evaluation relates to certain Federal Acts described below.

Paragraph 44.2 of the Federal Facility Agreement (FFA) provides that wildlife habitat(s) shall be preserved and managed as necessary to protect endangered species of wildlife to the extent required by the Endangered Species Act (ESA) (16 USC Sections 1531 to 1544), migratory birds to the extent required by the Migratory Bird Treaty Act (MBTA) (16 USC Sections 701 to 701h), and bald eagles to the extent required by the Bald Eagle Protection Act (BEPA) (16 USC Sections 668 to 68d).

The Endangered Species Act (ESA), MBTA and Bald and Golden Eagle Protection Act (BGEPA) apply to the Rocky Mountain Arsenal. The Army shall establish remediation goals for site contaminants to maintain and enhance healthy populations of the species subject to the ESA, MBTA, and BGEPA and their habitats at the Arsenal.

For the Offpost Operable Unit, remediation goals for offpost contamination that meet the requirements of the ESA, MBTA, and BGEPA have been established in coordination with the U.S. Fish and Wildlife Service. These will be included as enforceable remediation levels in the Proposed Plan and the Record of Decision.

For the Onpost Operable Unit, remediation goals for soils and sediments that are consistent with the ESA, MBTA, and BGEPA will be established using a methodology agreed to by the Army, Shell, and EPA in consultation with the U.S. Fish and Wildlife Service. The Army will also consult with the Fish and Wildlife Service to determine whether any of the CERCLA activities or remedial alternatives might have a short term impact on a subject species or its habitat. If a determination is made that the Army's activities or remedial alternatives could have an impact on a subject species or its habitat, the Army will consult with the Fish and Wildlife Service to determine whether the activity should proceed and what, if any, mitigation measures are necessary in light of any long-term benefits to protection of populations of the subject species.

The organizations expressly reserve their rights to assert their respective positions concerning the ESA, MBTA, and BGEPA as ARARs in the future.

Although this FFA provision is not an ARAR, it must be complied with for purposes of implementing an alternative. The Army believes that the alternatives will have no adverse impact on any endangered species or migratory birds or on the protection of wildlife habitats. Coordination will be maintained with the U.S. Fish and Wildlife Service to ensure that no such adverse impact results from implementation of the alternatives. As a result, the ESA, MBTA, and BEPA are not addressed further in this appendix.

3.0 POTENTIAL CHEMICAL-SPECIFIC APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

According to the Compliance Manual, chemical-specific potential ARARs include health- or risk-based narrative standards, numerical values, or methodologies that when applied to site-specific conditions establish the acceptable amount or concentration of a chemical that may be detected in or can be discharged to the environment. This section discusses chemical-specific requirements that are potentially applicable or relevant and appropriate to the Offpost OU.

3.1 PRELIMINARY LIST OF POTENTIAL CHEMICAL-SPECIFIC ARARS

The NCP and Compliance Manual identify federal standards developed under RCRA, SDWA, and the CWA as potential chemical-specific ARARs. These potential ARARs include the following:

- SDWA Maximum Contaminant Levels (MCLs): 40 CFR Sections 141.11 to 141.16, 141.61 to 141.63, 141.88
- SDWA Maximum Contaminant Level Goals (MCLGs): 40 CFR Sections 141.50 to 141.51
- CWA Water Quality Criteria (WQC): 33 USC Section 1313
- RCRA Groundwater Protection Standard: 40 CFR Sections 264.92 to 264.96

With respect to state laws, potential chemical-specific ARARs include the following:

- Colorado Primary Drinking Water Regulations: 5 Code of Colorado Regulations (CCR) 1003-1
- Colorado Water Quality Control Act: 5 CCR 1002-8, Colorado Revised Statutes (CRS) 25-8-101 to 25-8-103, and corresponding regulations
- Colorado Hazardous Waste Management Regulations: 6 CCR 1007-3

These potential chemical-specific ARARs are discussed in this section to assess the potential applicability or relevance and appropriateness to the Offpost OU. During this assessment, the regulations were reviewed with regard to site conditions, particularly the chemicals that have been detected in samples collected from the OU.

3.2 SAFE DRINKING WATER ACT MAXIMUM CONTAMINANT LEVELS

The federal SDWA, 42 USC Section 300f, establishes standards for public drinking water systems. These standards, which are known as MCLs, are defined as the maximum permissible level of a contaminant in water that is delivered to the free flowing outlet of the ultimate user of a public water system (40 CFR Section 141.2). "Public water systems" are those systems that provide piped water for human consumption to at least 15 service connections or an average of at least 25 persons daily for at least 60 days of the year (40 CFR Section 141.2). MCLs can be found at 40 CFR Section 141.11-.16 and 141.60-63. MCLs, therefore, will be applicable if MCLs are exceeded at the free flowing outlet of a public water supply system.

MCLs are not applicable to the remedial action at the Offpost OU because, to date, EPA has not identified any exceedances of MCLs at the "tap" (55 Federal Register 8750). Of course, if any exceedance is discovered in the future, the standards may become applicable. MCLs are, however, potentially relevant and appropriate for conditions at the site. The confined flow system (CFS) and the unconfined flow system (UFS) groundwater beneath the Offpost OU are currently used to supply a "public water system." Therefore, although SDWA MCLs are not applicable, they are potentially relevant and appropriate to the Offpost OU.

Secondary MCLs are also potential ARARs. These levels are designed to control contaminants in drinking water that primarily affect the aesthetic qualities relating to public acceptance of drinking water (40 CFR Section 143.1). Like MCLs, secondary MCLs apply to public water systems and are measured at the tap of a user. Secondary MCLs are nonenforceable limits intended as guidelines for use by states in regulating water supplies.

Secondary MCLs are potential state ARARs for states that have adopted the levels as additional drinking water standards (Compliance Manual at 4-8). Colorado has established secondary MCLs. As a result, the state standards are potential chemical-specific ARARs for the Offpost OU and are discussed in Section 3.7.

3.3 SAFE DRINKING WATER ACT MAXIMUM CONTAMINANT LEVEL GOALS

In addition to MCLs, EPA has promulgated MCLGs, which are the maximum levels of contaminants in drinking water at which no known or anticipated adverse effects on the health of persons would occur, with an adequate margin of safety (40 CFR Section 141.2). MCLGs are found at 40 CFR Section 141.50-52. Unlike MCLs, MCLGs are nonenforceable health-based goals. Consequently, MCLGs are never applicable requirements at CERCLA sites because they are not enforceable standards or levels of control; however, MCLGs may be relevant and appropriate at a site.

Section 121 of CERCLA provides that remedial actions must at least attain MCLGs where such goals are relevant and appropriate (42 USC Section 9621[d][2][A]). According to the NCP, EPA requires that MCLGs set at levels above zero be attained where relevant and appropriate. Where MCLGs are set at zero, the MCL will generally be the potentially relevant and appropriate requirements (40 CFR Section 300.430[e][2][i][B] and [C]).

Because the UFS and CFS groundwater beneath the Offpost OU is a source of drinking water, non-zero MCLGs are potentially chemical-specific relevant and appropriate requirements.

3.4 CLEAN WATER ACT WATER QUALITY CRITERIA

Section 304 of the federal CWA requires that EPA develop and publish criteria for water quality accurately reflecting the latest scientific knowledge on the effects on health and welfare, the concentration and dispersal of pollutants, and the effects of pollutants on biological community diversity, productivity, and stability (33 USC Section 1314[a]). Therefore, the federal WQC are nonpromulgated guidelines that are used by states to develop water-quality standards. Although compliance with WQC is not legally required at CERCLA sites, and they are not "applicable" requirements, WQC may be relevant and appropriate. According to CERCLA Section 121, every remedial action must require a level or standard of control that at least attains WQC where such criteria are relevant and appropriate (42 USC Section 9621[d][2][A]).

In determining whether WQC are relevant, the primary factors to consider are the designated or potential uses of the water, the media affected, and the purposes for which the potential requirements are intended.

Because the UFS and CFS groundwater is used as a drinking water source, WQC developed for protection of public health related to consumption of water and fish are considered to be potentially relevant to the Offpost OU. WQC developed for protection of public health associated with consumption of fish are relevant to the Offpost OU because groundwater discharges to First Creek and fish are found in Barr Lake, which is a drainage to First Creek. Similarly, to the extent surface water is on the Offpost OU or such waters are impacted, WQC for protection of adequate life are potentially relevant and appropriate in the Offpost OU.

According to EPA guidance, however, WQC should be used to set cleanup standards for groundwater only if the groundwater is a current or potential source of drinking water, and other cleanup standards for drinking water are not available (ARARs Q's A's: Compliance with Federal Water Quality Criteria, dated June, 1990 [OSWER Directive 9234.2-09]/FS). Consequently, WQC are not relevant and appropriate to the Offpost OU because MCLs, non-zero MCLGs, and state standards are available as described in Table 2.5.2-1 in Volume V of the Feasibility Study.

3.5 RESOURCE CONSERVATION AND RECOVERY ACT GROUNDWATER PROTECTION STANDARD

The RCRA Groundwater Protection Standard (GPS) (40 CFR Sections 264.92 to 264.96) is designed to ensure that hazardous constituents entering groundwater from a regulated unit do not exceed the concentration limits in the uppermost aquifer underlying the waste management area beyond the point of compliance during the compliance period.

Part of the jurisdictional prerequisites for application of the RCRA concentration limits are that a RCRA-regulated unit be subject to a RCRA permit requirement and receive RCRA-regulated hazardous wastes after July 26, 1982. Because the Offpost OU is not a permitted RCRA-regulated unit and did not receive RCRA-regulated hazardous wastes after July 26, 1982, the RCRA concentration limits are not applicable chemical-specific requirements. However, they

may be potentially applicable action-specific requirements if a RCRA-equivalent unit is constructed and operated as part of the remedial action for the Offpost OU. This issue is discussed further in Section 5.0.

RCRA may be relevant and appropriate when a waste is similar in composition to a RCRA hazardous waste (44 Federal Register 8673). Wastes found at the Offpost OU (e.g., contaminated environmental media) are potentially similar to RCRA hazardous wastes. Therefore, RCRA GPS may be potentially relevant. Because implementation of these portions of the RCRA regulations has been delegated by EPA to the State of Colorado, the equivalent state regulations discussed in Section 3.8 are potentially appropriate, not the federal requirements.

3.6 COLORADO PRIMARY DRINKING WATER REGULATIONS

The Colorado Primary Drinking Water Regulations (5 CCR 1003-1) establish health-based standards for public water systems. As was discussed in conjunction with the SDWA MCLs (see Section 3.2), the primary drinking water regulations are not applicable to the unconfined flow system and confined flow system groundwater systems. However, because the groundwater in the vicinity of the Offpost OU is used as a drinking water source, the primary Colorado drinking water regulations are considered to be potentially relevant. Because the state has primary enforcement responsibility for drinking water regulations in Colorado, the state regulations are considered to be potentially appropriate to the extent that the standards established under the Colorado Primary Drinking Water Regulations are the same or more stringent than the SDWA MCLs.

3.7 BASIC REGULATIONS FOR GROUNDWATER

Regulations promulgated pursuant to the Colorado Water Quality Control Act (CRS Sections 25-8-101, et seq.) establish the Colorado Basic Standards for Groundwater (5 CCR 1002-8, Section 3.11.0). These regulations establish a system for classifying groundwater and adapting water quality standards (including secondary drinking water standards) for such

classifications to protect existing and potential beneficial uses of groundwater. The regulations (5 CCR 1002-8, Section 3.11.4[A]) established the following classifications for groundwater:

- Domestic use - quality
- Agricultural use - quality
- Surface-water quality protection
- Potentially usable quality
- Limited use and quality

Because the groundwater in the vicinity of the Offpost OU has not been classified and because implementation of this portion of the regulation does not automatically cover all groundwater in the state (5 CCR 1002-8, Section 3.11.7[A]), standards associated with such classifications (including secondary drinking water standards) are not currently enforceable and therefore cannot be state ARARs.

In addition to establishing a system for groundwater classification and water quality standards for such classifications, the Colorado Basic Standards for Groundwater also establish statewide groundwater quality standards that apply to all state groundwater unless alternative site-specific standards have been adopted. These statewide standards (5 CCR 1002-8, Section 3.11.5[C]) include interim standards for organic pollutants.

The Colorado Basic Standards for groundwater were promulgated in order to protect deterioration of groundwater quality (5 CCR 1002-8, Section 3.11.10[A]). Regulations like this are viewed as antidegradation provisions. EPA guidance clearly states that such requirements are not considered cleanup criteria (ARARs Q's + A's: State Ground-Water Antidegradation Issues, date July, 1990 [OSWER Directive 9234.2-11/FS]).

Furthermore, in adopting statewide standards, the Colorado Water Quality Control Commission (Commission) addressed the potential usefulness of these standards at CERCLA sites, such as RMA. Specifically, the Commission added a new subsection, 3.11.5(C)(5), relating to CERCLA. Specifically, the section states that:

> Nothing in this regulation shall be interpreted to preclude... an agency responsible for implementation of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 42 U.S.C. 9601, et seq., as amended, from selecting a remedial action and a point of compliance that are more or less stringent than would be achieved by compliance with the statewide numerical standards established in this subsection, or alternative site-specific standards adopted by the Commission, where a determination is made that such a variation is authorized pursuant to the applicable provisions of CERCLA...

Section 3.11.5(C)(5) shows that the Commission did not intend to impose the interim organic standards in Table A as cleanup standards. According to the regulations, the standards automatically apply on a statewide basis, except at CERCLA sites, RCRA corrective action sites, and underground storage tank remediation sites. At these sites, "certain federal program regulatory determinations regarding groundwater quality would not be superseded by the Commission's standards" (Section 3.11.10[B]). In writing the exemption, the Commission recognized that implementing agencies are more familiar with site-specific conditions and are in better position to determine the proper cleanup standards. By not imposing unnecessarily stringent application of the interim organic standards, the Commission sought to show "explicit deference to certain federal regulatory programs which may apply different standards" (Section 3.11.10[H]). Because the interim organic standards are not cleanup standards, they are not potential ARARs.

3.8 COLORADO RULES AND REGULATIONS PERTAINING TO HAZARDOUS WASTE

The Colorado Hazardous Waste Regulations (6 CCR 1007-3) implement the Colorado Hazardous Waste Management Act (CHWMA) (CRS Sections 25-15-301 to 313). The only potential chemical-specific ARARs contained in the Colorado Hazardous Waste Regulations are the RCRA concentration levels for groundwater protection. However, as discussed in Section 3.5, the requirements are not applicable or relevant and appropriate because the Offpost OU is not a RCRA regulated facility, and no such facility is envisioned in the preferred alternative.

3.9 SUMMARY OF CHEMICAL-SPECIFIC ARARs EVALUATION

Table A1 summarizes the evaluation of potential chemical-specific requirements for the Offpost OU.

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4.0 POTENTIAL LOCATION-SPECIFIC ARARs

Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because of where they are located or occur.

4.1 PRELIMINARY LIST OF POTENTIAL LOCATION-SPECIFIC ARARs

The Compliance Manual identifies the following federal laws as potential location-specific ARARs:

- RCRA location requirements: 40 CFR Section 264.18
- National Historic Preservation Act of 1966 (NHPA): 16 USC Section 470
- Archaeological and Historic Preservation Act (AHPA): 16 USC Section 469
- Historic Sites, Buildings, and Antiquities Act (HSBAA): 16 USC Sections 461 to 467
- Fish and Wildlife Coordination Act (FWCA): 16 USC Sections 661 to 666c
- Clean Water Act: 33 USC Section 1344
- 40 CFR Part 6 Appendix A (addressing Executive Orders on floodplain management and wetlands protection)
- Wilderness Act: 16 USC Section 1131
- Wild and Scenic Rivers Act: 16 USC Sections 1271 to 1287
- Coastal Zone Management Act: 16 USC Sections 1451 to 1464

Because no wilderness areas or wilderness study areas are in the vicinity of the site, the site is not located near any wild or scenic rivers, and the site is not located near a coastal area, the requirements associated with the Wilderness Act, the Wild and Scenic Rivers Act, and the Coastal Zone Management Act will not be considered further.

The following state laws were also identified as potential location-specific ARARs:

- Colorado Hazardous Waste Management Regulations: 6 CCR 1007-3
- Colorado Regulations Pertaining to Solid Waste Disposal Sites and Facilities: 6 CCR 1007-2
- Colorado Nongame, Endangered, or Threatened Species Conservation Act: CRS Sections 33-2-101 to 108

Based on the review of ARARs evaluations performed for other NPL sites in Colorado, the requirements associated with the Colorado State Historical Society are also included in this report as potential location-specific ARARs.

Each of the potential location-specific ARARs associated with the acts listed above is evaluated in this section to assess their potential applicability or relevance and appropriateness. In conducting this assessment, the requirements associated with these acts were reviewed with regard to site conditions.

4.2 RESOURCE CONSERVATION AND RECOVERY ACT LOCATION REQUIREMENTS

RCRA identifies several limitations pertaining to where onsite hazardous waste treatment, storage, or disposal may occur (40 CFR Section 264.18). Specifically, RCRA prohibits the placement of new treatment, storage, and disposal (TSD) facilities within 200 feet of a fault displaced in Holocene time (40 CFR Section 264.18[a]). The Colorado Hazardous Waste Regulations impose a more strict standard of within 1000 feet of a fault displaced in Holocene time (see Section 4.10). Because no such faults are identified on any published geologic maps for the Offpost OU and none of the remedial investigation (RI) work has indicated the presence of a fault in this area, this requirement is not considered to be a potential ARAR for the Offpost OU.

In addition, RCRA requires that any facility located within a 100-year floodplain be designed, constructed, operated, and maintained to avoid washout (40 CFR Section 264.18[b]). However, because the Offpost OU is not a RCRA-regulated unit, the floodplain requirement is not considered applicable to the current situation. Nevertheless, because of the potential for release of substances due to flooding, the floodplain requirements are considered to be potentially relevant to the Offpost OU.

The North Boundary Containment System (NBCS), Northwest Boundary Containment System (NWBCS), and Interim Response Action A (IRA A) treatment facilities are not located within the 100-year floodplain. The floodplain regulations are potentially applicable to the design, construction, operation, and maintenance of any new TSD facilities that may be constructed or operated

within the 100-year floodplain associated with the site. However, because the RCRA program has been delegated to the state, the state requirements contain the potential location-specific ARARs.

The RCRA Land Disposal Restrictions (LDRs) also prohibit placement of hazardous wastes in salt domes, salt bed formations, and underground mines or caves (42 USC Section 6924[b]). None of these formations is present at the site. Therefore, these requirements are not considered potential location-specific ARARs.

4.3 NATIONAL HISTORIC PRESERVATION ACT OF 1966

The NHPA (16 USC Section 470) requires that any alteration of terrain that may cause irreparable harm, loss, or destruction of significant artifacts or prehistorical, historical, or archaeological data be required to recover and preserve the artifacts and/or data. No significant artifacts, prehistorical, historical, or archaeological data were identified at the Offpost OU. In addition, no national historic landmarks or properties included or eligible for inclusion on the National Register of Historic Places have been identified in the areas where treatment facilities might be sited at the Offpost OU. As a result, the requirements associated with NHPA are not considered to be potential location-specific ARARs.

4.4 ARCHAEOLOGICAL AND HISTORIC PRESERVATION ACT

The AHPA (16 USC Sections 469 to 469c-1) establishes procedures for preserving historical and archaeological data that might be destroyed through alteration of terrain as a result of a federal construction project or a federally licensed activity or program. If remedial action is conducted under federal lead or through the use of mixed funding provisions under CERCLA, the requirements of AHPA are potentially applicable. If no federal funding is involved, these requirements are potentially relevant and appropriate because their intent is to preserve historical or archaeological data. However, because historical or archaeological data have not been identified at the site, the requirements associated with AHPA are not considered to be potential location-specific ARARs.

4.5 HISTORIC SITES, BUILDINGS, AND ANTIQUITIES ACT

The HSBAA (16 USC Sections 461 to 467) requires that the existence and location of landmarks on the National Registry of Natural Landmarks be considered to avoid undesirable impacts on such landmarks. Because no landmarks on the National Registry have been identified in the Offpost OU, the requirements associated with HSBAA are not considered potential location-specific ARARs.

4.6 FISH AND WILDLIFE COORDINATION ACT

The FWCA (16 USC Sections 661 to 666c) requires that actions be taken to protect fish and wildlife that may be affected by diversion, channeling, or other activities that modify a river or stream (16 USC Section 662). The requirements associated with the FWCA are considered potential location-specific ARARs if remedial actions occur in perennial streams.

4.7 CLEAN WATER ACT

Section 404 of CWA prohibits discharge of dredged or fill materials into a wetland without a permit (33 USC Section 1344). Wetlands have been identified along First Creek (see Appendix B for U.S. Fish and Wildlife wetlands evaluation of the First Creek drainage). Onsite CERCLA activities are exempt from permit requirements. Therefore, permitting requirements associated with Section 404 of CWA are not considered potential location-specific ARARs. However, if the proposed remedial alternatives for the Offpost OU involve dredging or filling of wetlands, the substantive requirements associated with Section 404 will be potentially relevant and appropriate.

Although it is unlikely that wetlands will be adversely affected, the Army will coordinate its activities with the U.S. Fish and Wildlife Service concerning possible impacts.

4.8 EXECUTIVE ORDER 11988 - FLOODPLAIN MANAGEMENT

Executive Order 11988 (40 CFR Section 6.302[b] and Appendix A) directs federal agencies to avoid long- and short-term adverse impacts associated with occupancy and modification of floodplains. Agencies responsible for providing federal assistance for construction and improve-

ments and for conducting programs affecting land use should take actions to accomplish the following:

- Reduce risk of flood loss
- Minimize the impacts of floods on human safety, health, and welfare
- Restore and preserve the natural and beneficial values served by floodplains

These requirements are potentially applicable because federal funds are being used in the evaluation of remedial alternatives for of the Offpost OU. Floodplains have been delineated by the Federal Emergency Management Agency at the site. Because Executive Order 11988 intended "to minimize the impacts of floods on human safety, health, and welfare," these requirements also are considered potentially relevant and appropriate.

Most of the requirements associated with the Executive Order are set forth in the Floodplain Management Guideline published February 10, 1978, by the Water Resource Council to aid federal agencies in complying with the Executive Order. These guidelines include alternative evaluation, impact assessment and mitigation, and public involvement, all of which are already incorporated into the FS. The only additional substantive requirement contained within these guidelines is that certain projects or portions may be designated as a critical action, which is any activity for which even a slight chance of flooding would be too great. In the case of critical actions, the area requiring consideration is expanded from the 100-year to the 500-year floodplain. EPA indicated in the CERCLA/SARA Environmental Review Manual (January 1988) that all CERCLA/Superfund Amendments and Reauthorization Act (SARA) actions are to be considered critical actions; therefore, the 500-year floodplain is considered potentially relevant and appropriate.

4.9 EXECUTIVE ORDER 11990 - PROTECTION OF WETLANDS

Executive Order 11990 (40 CFR Section 6.302[a] and Appendix A) directs federal agencies to take actions to minimize the destruction, loss, or degradation of wetlands; to preserve and enhance the natural and beneficial values of wetlands; and to consider factors relevant to the

survival and quality of the wetlands. Because wetlands have been identified along First Creek (Appendix B), the requirements associated with this Executive Order may be potential location-specific ARARs. These requirements include assessing the impacts of any proposed actions on the wetlands, evaluating alternatives and their potential effects on the wetlands, and identifying mitigative measures to minimize potential harm to the wetlands. These requirements are included within the FS and therefore do not result in any additional requirements.

4.10 COLORADO RULES AND REGULATIONS PERTAINING TO HAZARDOUS WASTE

Colorado Hazardous Waste Regulations (6 CCR 1007-3, Section 264.18[a]) include restrictions on the location of hazardous waste TSD facilities. Specifically, TSD facilities cannot be located within 1000 feet of a fault that was displaced in Holocene time. However, because no Holocene faults have been identified at the Offpost OU or in the surrounding area, this requirement is not appropriate.

The Colorado Hazardous Waste Disposal Site Regulations (6 CCR 1007-2 Part II, Section 2.5.3) require that the geologic and hydrologic conditions of a hazardous waste site assure that waste is isolated from exposure pathways for 1000 years. Because the Offpost OU is not a RCRA regulated unit, the requirement is not applicable. However, because wastes similar to RCRA hazardous wastes may be at the site, this requirement is considered a potentially location-specific relevant and appropriate requirement if a hazardous waste disposal facility is planned as part of a remedial action.

4.11 COLORADO REGULATIONS PERTAINING TO SOLID WASTE DISPOSAL SITES AND FACILITIES

The Colorado Solid Waste Regulations (6 CCR 1007-2, Sections 1.3.2, 2.1, 2.2, 2.4, 4.1, and 6.1) require, among other things, that the siting of a solid waste disposal facility maximize wind protection and minimize upstream drainage. In addition, solid waste disposal cannot occur within the 100-year floodplain. Disposal into or below surface water or groundwater is prohibited. The regulations also control the design of impoundments based on a site's location relative to the uppermost aquifer and the water quality of that aquifer. These requirements are potentially

applicable to the design, construction, and operation of any disposal unit for management of solid waste resulting from implementation of remedial actions for the Offpost OU.

4.12 COLORADO NONGAME, ENDANGERED, OR THREATENED SPECIES CONSERVATION ACT

The Colorado Nongame, Endangered, or Threatened Species Conservation Act (CRS Sections 33-2-101 to 108) requires the state to "manage all nongame wildlife, recognizing the private property rights of individual property owners, for human enjoyment and welfare, for scientific purposes, and to insure their perpetuation as members of ecosystems." The Act further requires "that species or subspecies of wildlife indigenous to this State, which may be found to be endangered or threatened within the State should be accorded protection in order to maintain and enhance their number to the extent possible." Pursuant to this Act, regulations have been established by the Colorado Division of Wildlife defining nongame species and subspecies and threatened or endangered wildlife, their protection, and limitations on their harassment, taking, or possession.

Because remedial alternatives anticipated for the OU are primarily subsurface in nature and do not entail harassing, taking, or possession of nongame species or subspecies, including threatened or endangered wildlife, these regulations are not applicable or relevant to the Offpost OU.

4.13 COLORADO STATE HISTORICAL SOCIETY

Sections 24-80-401 to 411 and 24-80-501 to 502 of the CRS require the preservation of the historic character of state or federal historic preservation areas. Because no historic preservation areas are currently in the vicinity of the site, these requirements are not considered potential location-specific ARARs.

4.14 SUMMARY OF LOCATION-SPECIFIC ARARs EVALUATION

Table A2 summarizes the evaluation of potential location-specific ARARs for the Offpost OU.

5.0 POTENTIAL ACTION-SPECIFIC ARARs

Action-specific requirements are technology- or activity-based requirements or limitations on actions taken with respect to hazardous substances, pollutants, and contaminants. Potential action-specific requirements that may be applicable or relevant and appropriate to these remedial actions include (1) design standards affecting the construction of a remedy; (2) performance standards affecting operation of a remedy, specifically, treatment requirements and management of residuals; and (3) discharge standards.

Potential federal ARARs relating to these types of activities include the following:

- Resource Conservation and Recovery Act: 42 USC Sections 6901 to 6992k
- Safe Drinking Water Act Underground Injection Control Program: 42 USC Sections 300h to 300h-7
- Federal Water Pollution Control Act as modified by CWA: 33 USC Sections 1251 to 1387
- Clean Air Act: 42 USC Sections 7401 to 7626

Potential state ARARs affecting the design, operation, performance, and disposal activities associated with the various potential remedial alternatives include the following:

- Colorado Hazardous Waste Management Regulations: 6 CCR 1007-3
- Colorado Water Quality Control Act: CRS Sections 25-8-101 to 25-8-703 and corresponding regulations (5 CCR 1002-8)
- Colorado Air Quality Control Act: CRS Sections 25-7-101 to 25-7-806 and corresponding regulations (5 CCR 1001-3 to 1001-10)
- Colorado Solid Waste Disposal Sites and Facilities Act: CRS Sections 30-20-101 to 30-20-119 and corresponding regulations (6 CCR 1007-2)

Each of the potential action-specific ARARs is discussed below.

5.1 RESOURCE CONSERVATION AND RECOVERY ACT

EPA has established the following three sets of regulations pursuant to RCRA that may contain potential action-specific ARARs:

- Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR Part 264)

- Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR Part 265)
- Land Disposal Restrictions (40 CFR Part 268)

5.1.1 Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities

EPA has established standards for hazardous waste TSD facilities (40 CFR Part 264). The Compliance Manual indicates that the requirements of Subtitle C of RCRA will apply to groundwater that is withdrawn only if the groundwater is a listed or characteristic hazardous waste and the remedial activity at the CERCLA site constitutes treatment, storage, or disposal as defined by RCRA.

For these standards to be potentially applicable action-specific requirements, waste generated, handled, or resulting from activities associated with the remedial action has to meet the requirements for "characteristic" or "listed" hazardous wastes as defined in 40 CFR Part 261 Subparts C and D, respectively. For groundwater withdrawn to be a "characteristic" waste, it must exhibit one or more of the following characteristics: ignitability, corrosivity, reactivity, or toxicity (40 CFR Sections 261.21 to 261.24, respectively). Based on the data available from the RI, no ignitable, corrosive, reactive, or toxic waste has been identified at the Offpost OU. In addition, no listed hazardous waste has been identified at the Offpost OU. Therefore, RCRA requirements for TSD facilities (40 CFR Part 264) are not applicable at the Offpost OU. However, if groundwater extracted in the final remedy meets the requirements of a characteristic hazardous waste and is removed for treatment, storage, or disposal, the requirements will be applicable.

Because the State of Colorado has been delegated the hazardous waste management program in Colorado in accordance with RCRA Section 3006 and 42 USC Section 6926, the Colorado Hazardous Waste Management Regulations (6 CCR 1007-3) corresponding to 40 CFR Part 264 contain the potentially applicable requirements. These are discussed later in Section 5.6 of this ARARs analysis. However, two subparts of 40 CFR Part 264 have not been delegated to the State of Colorado: Subparts AA, Air Emission Standards for Process Vents and Subpart BB, Air

Emissions Standards for Equipment Leaks. With respect to these two subparts, the federal requirement is the potential ARAR.

5.1.1.1 Air Emission Standards for Process Vents

The regulations found in 40 CFR Part 264 Subpart AA apply to process vents associated with distillation, fractionation, thin-film evaporation, solvent extraction, or air or steam stripping operations at TSD facilities that manage hazardous wastes with organic concentrations of at least 10 parts per million by weight (ppmw) (40 CFR Section 264.1030). These regulations only apply if the operations are conducted in units subject to hazardous waste permits under 40 CFR Part 270 and hazardous waste recycling units at permitted facilities. Because any onsite TSD facility constructed and operated in conjunction with remedial actions for the Offpost OUs is not subject to permits, these requirements are not applicable. Moreover, as currently envisioned, none of the process vents specified in the regulations are included as part of preferred remedy. Therefore, these requirements are not relevant and appropriate.

5.1.1.2 Air Emission Standards for Equipment Leaks

The regulations found in 40 CFR Part 264 Subpart BB apply to equipment in permitted units or recycling units located at permitted facilities that contain or contact hazardous wastes with organic concentrations of at least 10 percent by weight (40 CFR Section 264.1050). Because these requirements apply only to permitted TSD units or recycling units at permitted facilities, they are not applicable action-specific requirements. In addition, because they only apply to units containing or contacting wastes with organic contents of 10 percent by weight or more, they are not relevant action-specific requirements. In addition, none of the treatment processes currently envisioned as part of any of the preferred remedial alternative is anticipated to result in a ten-fold or greater increase in organic concentrations.

5.1.2 Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities

EPA has also established standards for interim status TSD facilities (40 CFR Part 265). In general, these regulations closely parallel the regulations for permitted TSD facilities (40 CFR Part 264). However, two parts of these regulations have not been promulgated under 40 CFR Part 264. These are the standards for thermal treatment (40 CFR Subpart P) and the standards for chemical, physical, and biological treatment (Subpart Q).

Because the Offpost OU will not involve thermal treatment or chemical, physical, and biological treatment as described in the regulations, 40 CFR Part 265 is not a potential action-specific ARAR.

5.1.3 Land Disposal Restrictions

In the 1984 Hazardous and Solid Waste Amendments (HSWA) to RCRA, the U.S. Congress enacted certain restrictions on land disposal of hazardous wastes (42 USC Sections 6924[d]-[g]). These restrictions prohibit continued land disposal of hazardous wastes beyond specified dates unless (1) it has been demonstrated "to a reasonable degree of certainty that there will be no migration of hazardous constituents from the disposal unit or injection zone for as long as the wastes remain hazardous" or (2) the waste meets promulgated treatment standards (42 USC Sections 6924 [d][1], [e][1], [f][2], and [g][5]). Congress has defined the term "land disposal" to include "any placement of such hazardous waste in a landfill, surface impoundment, waste pile injection well, land treatment facility, salt dome formation, or underground mine or cave" (42 USC Section 6924[k]).

Congress directed EPA to promulgate LDRs and treatment standards simultaneously by imposing various deadlines for five categories of hazardous wastes. These categories are (1) certain solvent and dioxin wastes that are land disposed by methods other than deep injection, (2) certain wastes known as "the California list wastes" that are land disposed by methods other than deep injection, (3) hazardous wastes other than the solvents and dioxins and the California list wastes that are listed or identified as of November 8, 1984, (4) hazardous wastes listed or

identified after November 8, 1984, and (5) solvents and dioxins and the California list wastes that are land disposed by deep injection (42 USC Sections 6924[d] through [g]).

In 40 CFR Part 268, EPA identified hazardous wastes that are restricted from land disposal and defined the limited circumstances when an otherwise prohibited waste may continue to be land disposed. Specifically, these regulations established prohibitions and treatment standards for certain wastes as set forth in 40 CFR Part 268 Subpart D.

In setting treatment standards, EPA derived treatment levels for waste groups on the basis of past performances of existing technologies known as best demonstrated available technologies (BDAT) (51 Federal Register 40574). EPA interprets RCRA to authorize treatment standards expressed either as concentration-based performance standards or as a specific treatment method. Wastes must be treated according to the appropriate standard before wastes or the treatment residuals of wastes can be disposed of in or on the land.

The three requirements for the LDRs to be applicable are as follows:

1. The restrictions apply only to RCRA hazardous waste.
2. The wastes must be land disposed or placed in land-based units.
3. The land disposal of the waste must occur after the date for which disposal of the waste is prohibited.

Based upon offpost sampling process knowledge and EPA guidance concerning the Land Disposal Restrictions (LDRs) under RCRA, the Army has no reason to believe there is any listed or characteristic hazardous waste in the Offpost OU or that construction of any alternative would involve placement of a listed or characteristic hazardous waste. If it is determined that a listed or characteristic hazardous waste is present and that placement of such a waste would occur, LDRs will be ARARs, and the Army will act in a manner consistent with EPA guidance for the management of such wastes in the context of a CERCLA response action.

As with the RCRA standards for TSD facilities, the State of Colorado operates the hazardous waste management program in Colorado, including the RCRA LDRs. Therefore, the Colorado

Hazardous Waste Management Regulations (6 CCR 1007-3) corresponding to 40 CFR Part 268 contain the potentially applicable requirements. These are discussed in Section 5.5.

5.2 SAFE DRINKING WATER ACT UNDERGROUND INJECTION CONTROL PROGRAM

The Underground Injection Control (UIC) Program regulates the underground injection of fluids through wells (40 CFR Sections 144-147). The UIC program controls the construction, operation, maintenance, and closure of five distinct classes of injection wells. The class-specific controls serve to prevent and respond to contamination of underground sources of drinking water that could potentially cause either SDWA MCL noncompliance or other adverse human health effects.

Underground injection wells are divided into five general classes of wells for permitting and regulatory purposes. According to 40 CFR Section 144.3, a well is defined as a bored, drilled, or driven shaft, or a dug hole having a depth greater than the largest surface dimension.

The classifications are in part based on the relationship of the injection well to an underground source of drinking water. According to 40 CFR Section 146.3, an underground source of drinking water is defined as any aquifer or its portion that (1) supplies any public water supply or contains a sufficient quantity of water to supply a public water system, and currently supplies drinking water for human consumption or contains fewer than 10,000 milligrams per liter (mg/l) total dissolved solids and (2) is not an exempted aquifer according to 40 CFR Section 146.4.

The applicable UIC technical and procedural standards and criteria vary according to the class of well. The five classes of wells are as follows:

- Class I wells are used to inject industrial, hazardous, and municipal wastes beneath the lowermost formation containing, within 1/4 mile of the well bore, an underground drinking water source.
- Class II wells are used to dispose fluid that is brought to the surface in connection with oil and gas production, to inject fluid for the enhanced recovery of oil or gas, or to store liquid hydrocarbons.
- Class III wells are those used to inject fluid for the extraction of minerals.
- Class IV wells are used to inject hazardous waste or radioactive waste into or above a formation that, within 1/4 mile of the well, contains an underground drinking water

source. Operation or construction of Class IV wells is prohibited and allowed only for the reinjection of treated wastes as part of a CERCLA or RCRA cleanup action.

- Class V wells include all wells not incorporated in Classes I through IV. Typical examples of such wells are recharge wells, septic system wells, and shallow industrial (nonhazardous disposal wells).

Requirements associated with Class II and Class III wells are not applicable or relevant and appropriate to the Offpost OU in general. Class I and Class IV wells entail injection of hazardous or industrial wastes, the distinction between the two being the location and existing quality of the aquifer above, into, or below which the wastes will be injected. The operation or construction of Class IV wells, wells in which hazardous wastes are disposed into or above an underground source of drinking water, are prohibited, and such wells are only allowed to reinject treated groundwater into the same formation from which it was withdrawn as part of a CERCLA cleanup or a RCRA corrective action (40 CFR Section 144.13). A Class V well would be used to reinject wastewater from a CERCLA cleanup that is not defined as hazardous.

There is a general requirement associated with all injection wells and specific requirements associated with Class I wells. The general requirement is that a well must be constructed, operated, and maintained in a manner that does not result in contamination of an underground source of drinking water at levels that violate MCLs or otherwise affect the health of persons (40 CFR Section 144.12).

Disposal of hazardous wastes in a Class I well would entail BDAT requirements or be subject to one of several variances promulgated by or after the time injection begins.

Additional requirements associated with Class I wells include both corrective action (40 CFR Section 264.101) and closure plan (40 CFR Section 144.28[c]) requirements. In addition, Class I wells are subject to the following additional UIC requirements:

- Construction requirements. Various requirements are specified for the construction of Class I wells, including the type of casing and cementing for the well, appropriate geophysical well logging, and other test requirements (40 CFR Section 146.12).

- Operating requirements. The operation of Class I wells is subject to specific operating requirements, including use of approved fluid surrounding the outermost casing and maintenance of injection pressure (40 CFR Sections 144.28[f] and 146.13).

- Monitoring requirements. At a minimum, monitoring requirements for Class I wells include analysis of the injected fluid; installation and use of continuous recording devices to monitor injection pressure, flow rate and volume, and pressure on the annulus; demonstration of mechanical integrity (in accordance with 40 CFR Section 146.8) at least every five years; and use of monitoring wells in the area of review to monitor migration of fluid into and pressure in underground sources of drinking water (40 CFR Section 146.13[b]). As part of the suggested coordination between CERCLA remedial project managers and UIC program (EPA regional and/or state) personnel, monitoring results should be provided to the appropriate UIC program office.

Class IV wells that would be used for reinjection of contaminated groundwater are also subject to BDAT requirements. Closure plan requirements for Class IV wells are provided in 40 CFR Section 144.23(b).

UIC program requirements that must be met, whether the program is run by the state or EPA, are specified in 40 CFR Part 144.26 as follows: "Owners and operators of all injection wells authorized by rule shall submit inventory information to the director." For certain Class V wells regulated pursuant to an EPA program, 40 CFR Section 144.26(b)(2) details specific inventory reporting requirements. Such reporting requirements apply to the following Class V wells:

1. Sand or other backfill wells (Section 146.5[e][8])
2. Radioactive waste disposal wells (Section 146.5[e][11])
3. Geothermal energy recovery wells (Section 146.5[e][12])
4. Brine return flow wells (Section 146.5[e][14])
5. Wells used in experimental technologies (Section 146.5[e][15])
6. Municipal and industrial disposal wells other than Class I
7. Any other Class V wells at the discretion of the regional administrator

The preferred remedy includes the discharge of treated groundwater back into the aquifer. Therefore, the substantive requirements of the UIC regulations may potentially be applicable requirements if wells are used for reinjection, or UIC regulations may potentially be relevant and appropriate if some other method is used for subsurface discharge of treated water.

5.3 THE FEDERAL WATER POLLUTION CONTROL ACT AS AMENDED BY THE CLEAN WATER ACT

The objective of the Federal Water Pollution Control Act (FWPCA) as amended by CWA is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. This objective is achieved through the control of discharges of pollutants to navigable waters. This control is implemented through the application of federal, state, and local discharge standards.

The CWA prohibits the unpermitted discharge of any pollutant or combination of pollutants to waters of the United States from any point source. A point source is defined as

> ...any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, ...from which pollutants are or may be discharged. (40 CFR Section 122.2)

A pollutant is defined for regulatory purposes to include

> ...dredged spoil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewer sludges, munitions, chemical wastes, ...and industrial, municipal, and agricultural waste discharged into water. (40 CFR Section 122.2)

All pollutants are regulated under the CWA. For the purpose of regulation, CWA Section 301(b)(2) divides the pollutants into the following three categories:

- Priority pollutants: the 126 individual toxic pollutants contained in 65 toxic compounds or classes of toxic compounds adopted by EPA pursuant to CWA Section 307(a)(1) including, for example, asbestos, benzene, and chloroform
- Conventional pollutants: pollutants classified, pursuant to CWA Section 304(a)(4), as biochemical oxygen demanding, total suspended solids, fecal coliform, oil and grease, and pH
- Nonconventional pollutants: any pollutants not identified as either priority or conventional (i.e., ammonia nitrogen, chemical oxygen demand, total organic carbon, total solids, and nonpriority toxic pollutants) (40 CFR Section 122.21[1][2])

Three sets of requirements established under CWA may contain potential action-specific ARARs if treated water from the Offpost OU is directly discharged to surface water. These requirements are as follows:

1. Criteria and Standards for the National Pollutant Discharge Elimination System (40 CFR Part 125)

2. Toxic Pollutant Effluent Standards (40 CFR Part 129)

3. Water Quality Standards (40 CFR Part 131).

Treated groundwater will not be directly discharged to surface water. Therefore, the programs in the CWA described above are not action-specific applicable or relevant and appropriate requirements.

5.4 CLEAN AIR ACT

The Clean Air Act (CAA) regulates emissions into the air to promote and maintain public health and welfare. Controls on stationary and mobile sources of emissions are implemented through combined federal, state, and local programs. Pursuant to CAA, EPA has promulgated National Ambient Air Quality Standards (NAAQSs), National Emissions Standards for Hazardous Air Pollutants (NESHAPs), and New Source Performance Standards (NSPSs). Potential ARARs associated with each of these requirements are described below.

5.4.1 National Ambient Air Quality Standards

Pursuant to Section 109 of CAA, EPA has promulgated NAAQSs for six pollutants, called "criteria pollutants" (40 CFR Part 50). EPA has developed both primary and secondary standards for protection of public health and welfare (wildlife, climate, recreation, transportation, and economic values), respectively.

Under Section 107 of CAA, each state has the primary responsibility for assuring attainment of NAAQSs. This is done through the submission and approval of a State Implementation Plan (SIP). Upon EPA approval, the SIP becomes federally enforceable.

Application of the NAAQSs varies depending on whether the source is located in an attainment area (an area designated as being in attainment of the NAAQSs for criteria pollutants) or a nonattainment area. However, only "major sources" are subject to the Prevention of Significant Deterioration (PSD) requirements for attainment areas or lowest achievable emission rate requirements for nonattainment areas. Under the PSD program, major sources are defined as those expected to emit 250 tons or more per year of any regulated pollutant unless the site contains

certain specific types of facilities, such as an incinerator or chemical processing plant, in which case the threshold is 100 tons per year. For nonattainment areas, major sources are defined as those facilities emitting 100 tons or more per year of the pollutant for which the area is designated nonattainment.

As stated in the Compliance Manual, "In general, emissions from CERCLA activities are not expected to qualify as major." In the case of the Offpost OU, the potential remedial alternatives currently envisioned center around treatment of groundwater with granular activated carbon. The remedial alternative with the largest flow rate envisioned in the Draft Final Feasibility Study (FS) is expected to include extraction and treatment of approximately 900 gallons per minute (gpm) of groundwater. At an average concentration of less that 1 mg/l, which is an overestimate of the anticipated total volatile organic compound (VOC) content of the combined extraction stream, the total amount of VOCs in the waste stream would be less than 2.0 tons per year.

The NAAQSs requirements are not applicable to the Offpost OU. In addition, many of the criteria pollutants are not present in the groundwater or are present only in trace amounts. Therefore, the NAAQSs requirements are not considered relevant or appropriate.

5.4.2 National Emission Standards for Hazardous Air Pollutants

Pursuant to CAA Section 112, EPA identifies pollutants that cause or contribute to air pollution that may reasonably be anticipated to result in an increase in mortality or in serious irreversible, or incapacitating reversible, illness. EPA first "lists" a pollutant as hazardous and then establishes emissions standards for source types (i.e., industrial categories) that emit that pollutant, known as NESHAPs. NESHAPs have been promulgated for specific source types emitting the following pollutants: arsenic, asbestos, benzene, beryllium, mercury, radionuclides, and vinyl chloride (40 CFR Part 61).

NESHAPs, like NSPSs, are promulgated for emissions of particular air pollutants from specific sources. NESHAPs are not generally applicable to Superfund remedial activities because CERCLA sites do not usually contain one of the specific source categories regulated. Moreover,

NESHAPs as a whole are generally not relevant and appropriate because the standards of control are intended for the specific type of source regulated and not all sources of that pollutant.

Based on a review of the NESHAPs, these standards are not action-specific ARARs for the remedial action at the Offpost OU.

5.4.3 New Source Performance Standards

Under Section 111 of CAA, EPA promulgates NSPSs for certain classes of new stationary sources of air pollution (40 CFR Part 60). Section 111(d) of CAA, however, requires that, for designated pollutants, individual states must regulate existing sources. The NSPSs limit the emissions of several different pollutants, including the six criteria pollutants and the following three designated pollutants: fluorides, sulfuric acid mist, and total reduced sulfur (including H_2S).

Because NSPSs requirements are source-specific requirements, they are not applicable or relevant and appropriate to the remedial alternatives currently under consideration for the Offpost OU.

5.5 COLORADO HAZARDOUS WASTE REGULATIONS

The State of Colorado operates the hazardous waste management program in accordance with RCRA Section 3006 (42 USC Section 6926). For the most part, the Colorado Hazardous Waste Regulations (6 CCR 1007-3) parallel the RCRA regulations. Substantive requirements of Colorado Hazardous Waste Regulations are potentially applicable if a hazardous waste TSD facility is constructed and operated as part of the remedial action for the Offpost OU.

5.5.1 Part 264 - Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities

The preferred remedy includes extraction and treatment of groundwater. However, no listed or characteristic hazardous wastes have been identified at the Offpost OU. Nevertheless, substantive requirements of Part 264 relating to handling and treatment of hazardous liquid may be potentially applicable for the remedy if groundwater exhibits the toxicity characteristic. In addition, substantive requirements of Part 264 relating to handling and storage of hazardous

wastes may also be applicable. Finally, if hazardous waste residues are produced from the treatment processes and disposed of onsite, substantive requirements of Part 264 relating to disposal may also be applicable. If the groundwater extracted and treated as part of any remedial effort is not a characteristic hazardous waste, the substantive requirements of Part 264 may still be relevant and appropriate if the extracted wastes are sufficiently similar to hazardous wastes.

5.5.2 Part 265 - Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities - Subpart P: Thermal Treatment and Subpart Q: Chemical, Physical, and Biological Treatment

As was previously discussed (see Section 5.1.2) the substantive requirements of Part 265 Subparts P and Q of the Colorado Hazardous Waste Regulations are not potentially action-specific ARARs for the Offpost OU.

5.5.3 Part 268 - Land Disposal Restrictions

RCRA LDRs restrict certain types of hazardous waste from being land disposed only if

1. An extract of the waste or of the treatment residue developed using the TCLP does not exceed the value shown in Table CCWE of Section 268.41, with some exceptions noted in Subpart D, Section 268.40(a)
2. It has been treated with the treatment technology specified under Section 268.42(a) or an equivalent
3. The constituent concentrations in the waste or treatment residue do not exceed the values shown in Table CCW of Section 268.43

Based upon offpost sampling process knowledge and EPA guidance concerning the LDRs under RCRA, the Army has no reason to believe there is any listed or characteristic hazardous waste in the Offpost OU or that construction of any alternative would involve placement of a listed or characteristic hazardous waste. If it is determined that a listed or characteristic hazardous waste is present and that placement of such a waste would occur, LDRs will be ARARs and the Army will act in a manner consistent with EPA guidance for the management of such wastes in the context of a CERCLA response action.

5.6 COLORADO WATER QUALITY CONTROL ACT

Regulations promulgated pursuant to the Colorado Water Quality Control Act (WQCA) include three requirements that may be potential ARARs for discharge of water from treatment facilities to surface water. The state requirements incorporate the requirements of the federal CWA. The state requirements include the Basic Standards and Methodologies for Surface Water, the Classification and Numeric Standards for the South Platte River Basin, and Regulations for Effluent Limitations (5 CCR 1002-8). Treated groundwater will not be directly discharged to surface water. Therefore, the requirements of the Colorado WQCA are not action-specific ARARs at the Offpost OU.

5.7 COLORADO AIR QUALITY ACT

CDH has enacted the Colorado Air Quality Control Regulations pursuant to the Colorado Air Quality Act (CRS Sections 25-7-101 to 25-7-806). Several of the specific regulations may contain potential action-specific ARARs for the Offpost OU, including the following:

Regulation No.	Title
1	Emission Control Regulations for Particulates, Smokes, Carbon Monoxide, and Sulfur Oxides for the State of Colorado
2	Odor Emission Regulations
7	Regulation to Control Emissions of Volatile Organic Compounds
8	The Control of Hazardous Air Pollutants (Part A, including beryllium, mercury, vinyl chloride, lead, benzene, and hydrogen sulfide)

5.7.1 Emission Control Regulations for Particulates, Smokes, Carbon Monoxide, and Sulfur Oxides

The requirements of 5 CCR 1001-3 Section III.D of Regulation 1 address fugitive particulate emissions and, therefore, contain requirements that could be potential action-specific ARARs for the Offpost OU. Specifically, Section III.D.1 addresses general requirements, including requirements related to fugitive particulate emission control plans. Section III.D.2.b contains general requirements, applicable emission limitations guidelines, and control measures and operating

procedures for construction activities. If any construction conducted in conjunction with the remedial action for the Offpost OU will disturb more than 1 acre of land (because RMA is in a PM-10 nonattainment area), the requirements associated with this section of regulations would be applicable.

5.7.2 Odor Emissions Regulations

Regulation 2 sets limits on emission of odorous air contaminants from any single source (5 CCR 1001-4). For the Offpost OU, where the current adjacent land use is primarily agricultural and open space, the regulations require that odors cannot be detected when any odorous air has been diluted with 15 or more volumes of fresh air. This regulation is potentially applicable to remedial actions for the Offpost OU.

5.7.3 Regulation to Control Emissions of Volatile Organic Compounds

Regulation 7 applies to sources within a nonattainment area with the potential to emit more than 100 tons per year of VOCs (5 CCR 1001-9). Because the Denver metropolitan area is a nonattainment area for ozone, this regulation may potentially be applicable. However, as discussed in Section 5.5, the preferred remedial action for the Offpost OU is envisioned to emit considerably less than 100 tons per year of VOCs. Therefore, these requirements would not be applicable to remedial actions for the Offpost OU.

Although this regulation is not applicable, it is intended to control emissions of ozone-creating VOCs. Therefore, the substantive requirements associated with this regulation may potentially be relevant to remedial actions for the Offpost OU. Much of this regulation pertains to specific types of industrial sources, which generally are not sufficiently similar to the conditions anticipated in conjunction with CERCLA remediation of the Offpost OU for these requirements to be appropriate. However, some portions of the general requirements are potentially appropriate. The portions of Regulation 7 that may be potentially relevant and appropriate include the following:

Specific Sections of Regulation 7 That May Be Potentially Relevant and Appropriate	Description
II(C)(2)	General Emissions Limitations - requires reasonably available control technology (RACT) for all new sources
III	General requirements for storage and transfer of VOCs
V	Disposal of VOCs

5.7.4 Regulation for the Control of Hazardous Air Pollutants

Regulation 8 applies to any stationary source that emits an air pollutant that is toxic or hazardous (5 CCR 1001-10). These regulations apply to specific types of plants that produce these chemicals or other stationary sources or activities. They do not apply to remedial actions and, therefore, are not applicable requirements. In addition, because these regulations apply only to specific types of industrial facilities, which are not similar to CERCLA remediation for the Offpost OU, these requirements are generally not considered to be relevant.

5.8 SOLID WASTE DISPOSAL SITES AND FACILITIES ACT

Colorado has promulgated regulations pertaining to solid waste disposal sites and facilities (6 CCR 1007-2) pursuant to the Solid Wastes Disposal Sites and Facilities Act (CRS Sections 30-20-101 to 30-20-119). Several sections of these regulations may be potentially applicable action-specific requirements for the Offpost OU. Specifically Section 5 of these regulations, which establishes the standards for new solid waste disposal facilities (landfills), will be applicable if a landfill cell is specifically constructed onsite to manage solid waste residuals resulting from remedial action for the Offpost OU. Similarly, the substantive requirements contained in Section 6 for design, construction, and operation of new surface impoundments that store, treat, or dispose of liquid, semisolid, or solid wastes would also be applicable if such a facility is constructed and operated in conjunction with remedial action for the Offpost OU. Finally, the substantive requirements contained in Section 12 of the regulations pertaining to

design, construction, and operation of water treatment plant sludge facilities may also be potentially applicable action-specific requirements.

5.9 SUMMARY OF ACTION-SPECIFIC ARARs EVALUATION

Table A-3 summaries the evaluation of potential action-specific ARARs for the Offpost OU.

Table A1: Summary Evaluation of Potential Chemical-specific Applicable or Relevant and Appropriate Requirements for the Offpost Operable Unit
(Page 1 of 3)

Standard, Requirement Criteria, or Limitation	Citation	Description	Potentially Applicable/ Relevant and Appropriate Chemical-specific Requirements	Comment
Federal ARARs				
Resource Conservation and Recovery Act	40 CFR Section 264.94	Concentration limits for hazardous constituents in groundwater beneath TSD facilities.	No/No	Because this portion of the RCRA regulations is implemented by the State of Colorado, the state regulations are potentially appropriate.
Safe Drinking Water Act	40 CFR Part 141	Establishes primary MCLs for public water-supply systems.	No/Yes	Groundwater in the vicinity of the site is being used or may be used as a source of water for a public water system or private supply wells. Therefore, those primary MCLs that are more stringent than the Colorado Primary Drinking Water Regulations (because Colorado has primary enforcement authority) are potentially relevant and appropriate.
	40 CFR Part 143	Establishes nonenforceable secondary MCLs for public water-supply systems.	No/No	Groundwater in the vicinity of the site is being used or may be used as a source of water for a public water system or private supply wells. Colorado has adopted secondary MCLs and, therefore, federal secondary MCLs are not potential chemical-specific ARARs.
	40 CFR Sections 141.50 and 141.51	Establishes MCLGs (nonenforceable health goals) for public water systems.	No/Yes	Groundwater in the vicinity of the site is being used or may be used as a source of water for a public water system or private supply wells. Therefore, in accordance with the NCP, non-zero MCLGs are considered to be potentially relevant and appropriate.

Table A1: Summary Evaluation of Potential Chemical-specific Applicable or Relevant and Appropriate Requirements for the Offpost Operable Unit
(Page 2 of 3)

Standard, Requirement Criteria, or Limitation	Citation	Description	Potentially Applicable/ Relevant and Appropriate Chemical-specific Requirements	Comment
Clean Water Act Water Quality Criteria	33 USC Section 1313	Nonenforceable guidelines to be used in conjunction with the designated uses of stream segments to establish water quality standards.	No/No	Surface water is not included within the scope of the Offpost OU. Onsite surface water is not used for drinking water or other beneficial uses and does not contain fish. Finally, other requirements (i.e., MCLs and Colorado Basic Standards for Groundwater) exist that more fully match the circumstances associated with the Offpost OU.
State ARARs				
Colorado Primary Drinking Water Regulations	5 CCR 1003-1	Establishes primary MCLs for public water systems.	No/Yes	Groundwater in the vicinity of the site is being used or may be used as a source of water for a public water system or private supply wells. Colorado has primary enforcement authority for MCLs. Therefore, Colorado primary MCLs are potentially relevant and appropriate.
Colorado Basic Standards for Groundwater	5 CCR 1002-8 Sections 3.11.-5(A) and (B)	Establishes a system for classifying groundwater and sets water quality standards for such classifications.	No/No	These standards apply to groundwater that has been classified by the Colorado Water Quality Control Commission. The groundwater beneath the Offpost OU has not been classified. Because standards associated with classification are not enforceable in the absence of a classification, the standards are not a state ARAR.
	5 CCR 1002-8 Section 3.11.6(C) Table A	Establishes statewide interim organic standards for groundwater.	No/No	These standards are not potential ARARs.

Table A1: Summary Evaluation of Potential Chemical-specific Applicable or Relevant and Appropriate Requirements for the Offpost Operable Unit
(Page 3 of 3)

Standard, Requirement Criteria, or Limitation	Citation	Description	Potentially Applicable/ Relevant and Appropriate Chemical-specific Requirements	Comment
Colorado Hazardous Waste Management Regulations - Groundwater Protection Standard	6 CCR 1007-3 Section 264.94	Concentration limits for hazardous constituents in groundwater beneath TSD facilities.	No/No	No TSD facility is planned at the Offpost OU. Therefore, the standards are not applicable or relevant and appropriate.

ARAR = applicable or relevant and appropriate requirement
CCR = Code of Colorado Regulations
CFR = Code of Federal Regulations
MCL = Maximum Contaminant Level
MCLG = Maximum Contaminant Level Goal
NCP = National Contingency Plan
OU = operable unit
RCRA = Resource Conservation and Recovery Act
TSD = treatment, storage, and disposal
USC = United States Code

Table A2: Summary Evaluation of Potential Location-specific Applicable or Relevant and Appropriate Requirements for the Offpost Operable Unit
(Page 1 of 3)

Standard, Requirement Criteria, or Limitation	Citation	Description	Potentially Applicable/ Relevant and Appropriate Location-specific Requirements	Comment
Federal ARARs				
Resource Conservation and Recovery Act	40 CFR Section 264.18	Siting is restricted in vicinity of recent faulting. No hazardous waste disposal can occur in a 100-year flood plain. Disposal into or below surface water and groundwater is prohibited.	No/No	Not applicable or relevant and appropriate because the RCRA program in Colorado has been delegated to the state.
National Historic Preservation Act	16 USC Section 470 40 CFR Section 6.301(b) 36 CFR Part 800	Requires federal agencies to take into account the effect of any federally assisted undertaking or licensing on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register of Historic Places.	No/No	The remedy does not effect any district, site, building, structure, or object listed or eligible for the National Register.
Archaeological and Historic Preservation Act	16 USC Section 469 40 CFR Section 6.301(c)	Establishes procedures to provide for preservation of historical and archaeological data that might be destroyed through alteration of terrain as a result of a federal construction project or a federally licensed activity or program.	No/No	No historical or archeological data have been identified at the site.
Historic Sites, Buildings and Antiquities Act	16 USC Sections 461 to 467 40 CFR Section 6.301(a)	Requires federal agencies to consider the existence and location of landmarks on the National Registry of Natural Landmarks to avoid undesirable impacts on such landmarks.	No/No	The remedy does not affect any natural landmark.
Fish and Wildlife Coordination Act	16 USC Sections 661 to 666c	Requires actions to be taken to protect fish and wildlife that may be impacted by a diversion, channeling, or other activities to modify a river or stream.	No/No	Activities at the Offpost OU are not expected to impact streams or rivers. However, the requirements are potentially applicable if the remedy requires remedial actions affecting First Creek.

Table A2: Summary Evaluation of Potential Location-specific Applicable or Relevant and Appropriate Requirements for the Offpost Operable Unit
(Page 2 of 3)

Standard, Requirement Criteria, or Limitation	Citation	Description	Potentially Applicable/ Relevant and Appropriate Location-specific Requirements	Comment
Clean Water Act, Section 404	33 USC Section 1344	Prohibits discharge of dredged or fill materials into wetlands without a permit.	No/No	Onsite CERCLA activities are exempt from permit requirements. It is unlikely that activities at the Offpost OU will involve placing dredged or fill materials into wetlands. However, substantive requirements may be potentially relevant and appropriate if dredging or filling is to be conducted along First Creek.
Executive Order 11988 - Flood Plain Management	40 CFR Part 6, Appendix A	Directs federal agencies to avoid long- or short-term impacts associated with occupancy and modification of a floodplain.	Yes/No	Requires a 500-year floodplain to be identified and considered in scoping any remedial actions.
Executive Order 11990	40 CFR Part 6, Appendix A	Minimizes the destruction, loss, or degradation of wetlands.	Yes/No	Requirements associated with this order would be potentially applicable to any remedial actions that could affect the existing wetlands.
State ARARs				
Colorado Rules and Regulations Pertaining to Hazardous Waste	6 CCR 1007-2, Part II	Geologic and hydrologic conditions of a hazardous waste site must assure that waste is isolated from exposure pathways for 1000 years.	No/No	No TSD facilities are planned for the Offpost OU.
	6 CCR 1007-3, Section 264.18(a)	No hazardous waste disposal can occur within 1000 feet of a fault that has had displacement during Holocene time.	No/No	Considered to be potentially relevant if an onsite hazardous waste disposal facility is planned as part of remedial action; however, not considered to be appropriate as Holocene faults have not been identified at the site or in the surrounding area.

Table A2: Summary Evaluation of Potential Location-specific Applicable or Relevant and Appropriate Requirements for the Offpost Operable Unit
(Page 3 of 3)

Standard, Requirement Criteria, or Limitation	Citation	Description	Potentially Applicable/ Relevant and Appropriate Location-specific Requirements	Comment
Regulations Pertaining to Solid Waste Disposal Sites and Facilities	6 CCR 1007-2, Sections 1.3.2, 2.1, 2.2, 2.4, 4.1, and 6.1	Siting must maximize wind protection and minimize upstream drainage area. No solid waste disposal can occur in a 100-year flood plain. Disposal into or below surface water and groundwater is prohibited. Impoundment design is controlled by a site's location in relation to the uppermost aquifer and by water quality in that aquifer.	No/No	A solid waste disposal facility is not envisioned in the preferred alternative.
Colorado Nongame, Endangered, and Threatened Species Conservation Act	CRS Sections 33-2-101 to 10	Prohibits harassment, taking, or possession of nongame species or subspecies, including threatened or endangered wildlife.	No/No	Remedial alternatives for the Offpost OU are primarily subsurface actions and do not entail harassment, taking, or possession of nongame species or subspecies, including threatened or endangered wildlife.
Colorado State Historical Society	CRS and Sections 24-80-501 to 502 Sections 24-80-401 to 411	Sites within state or federal historic preservation areas will be required to preserve historic character.	No/No	There are no regulated sites in the area.

ARAR = applicable or relevant and appropriate requirement
CCR = Code of Colorado Regulations
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CFR = Code of Federal Regulations
CRS = Colorado Revised Statutes
OU = operable unit
RCRA = Resource Conservation and Recovery Act
TSD = treatment, storage, and disposal
USC = United States Code

Table A3: Summary Evaluation of Potential Action-specific Applicable or Relevant and Appropriate Requirements for the Offpost Operable Units

Standard, Requirement Criteria, or Limitation	Citation	Description	Potentially Applicable/ Relevant and Appropriate Action-specific Requirement	Comment
Federal ARARs				
Resource Conservation and Recovery Act	42 USC Sections 6901-6992			
- Standards for Owners and Operators of Hazardous Waste TSD Facilities	40 CFR Part 264 Subparts AA and BB	Emission standards for process vents (Subpart AA) and air emissions standards for equipment leaks (Subpart BB)	No/No	In general, the RCRA regulations are not applicable or relevant and appropriate as the implementation and enforcement has been delegated to the State of Colorado. However, Colorado's hazardous waste regulations have not incorporated these two subparts. These subparts are not applicable as they only apply to permitted units for facilities. Subpart AA is not relevant and appropriate because characteristic wastes are not treated by one of the specified technologies. Subpart BB is not relevant because it only applies to highly concentrated ($\geq$10 percent) organic wastes.
- Interim Status Standards for Owners and Operators of Hazardous Waste TSD Facilities	40 CFR Part 265, Subparts P and Q	Standards for thermal treatment (Subpart P) and the standards for chemical, physical, and biological treatment (Subpart Q)	No/No	In general, 40 CFR 264 would be the more relevant requirement; however, these two subparts have not been adopted in 40 CFR 264. Because the state has responsibility for implementation and enforcement of RCRA in Colorado, the equivalent state regulations are more appropriate.
- Land Disposal Restrictions	40 CFR Part 268	Establishes prohibitions on land disposal unless treatment standards are met or a "no migration variation" is granted	No/No	The equivalent state regulations are the applicable requirements.

Table A3: Summary Evaluation of Potential Action-specific Applicable or Relevant and Appropriate Requirements for the Offpost Operable Units
(Page 2 of 5)

Standard, Requirement Criteria, or Limitation	Citation	Description	Potentially Applicable/ Relevant and Appropriate Action-specific Requirement	Comment
Safe Drinking Water Act	42 USC Sections 300h to 300h-7			
- Underground Injection Control Regulations	40 CFR Parts 144 to 147	Establishes standards for construction and operation of injection wells	Yes/No	Potentially applicable if reinjection wells are used for discharge of treated water; potentially relevant and appropriate if some other method of reinjection is used.
Federal Water Pollution Control Act as amended by the Clean Water Act	33 USC Sections 1251 to 1387			
- Criteria and Standards for NPDES	40 CFR Parts 122 to 125	Establishes a program for issuing, monitoring, and enforcing permits for direct discharge	No/No	Implementation and enforcement of NPDES has been delegated to the state.
- Toxic Pollutant Effluent Standards	40 CFR Part 129	Establishes pollutant effluent standards for six groups of toxic pollutants	No/No	The preferred remedy does not require discharge of treated water to surface water.
- Water Quality Standards	40 CFR Part 131	Requires NPDES permits to include effluent limitations and requires states to promulgate water quality standards	No/No	These requirements are promulgated through state regulations.
Clean Air Act	42 USC Sections 7401 to 7626			
- National Ambient Air Quality Standards	40 CFR Part 50	Establishes standards for protection of public health and welfare for six "criteria pollutants"	No/No	The pollutants regulated by the requirements are not present or present only in trace amounts in the Offpost OU.

Table A3: Summary Evaluation of Potential Action-specific Applicable or Relevant and Appropriate Requirements for the Offpost Operable Units

Standard, Requirement Criteria, or Limitation	Citation	Description	Potentially Applicable/ Relevant and Appropriate Action-specific Requirement	Comment
- National Emission Standards for Hazardous Air Pollutants	40 CFR Part 61	Establishes emission standards for hazardous air pollutants from specific sources	No/No	The specific sources and pollutants covered by these regulations are generally not related to the Offpost OUs. Because the implementation of the program has been delegated to the state, the equivalent Colorado regulations are more appropriate.
- New Source Performance Standards	40 CFR Part 60	Establishes performance standards for new stationary sources of air pollution	No/No	The regulated sources are not related to the Offpost OUs.
State ARARs				
Colorado Hazardous Waste Management Regulations	6 CCR 1007-3			
- Standards for Owners and Operators of Hazardous Waste TSD Facilities	Part 264	Establishes standards for the design and operation of hazardous waste TSD facilities	No/No	The requirements are only applicable to TSD facilities. The preferred remedy does not include an onsite TSD facility.
- Interim Status Standards for Hazardous Waste TSD Facilities	Part 265, Subparts P and Q	Establishes design and operation standards for thermal treatment (Subpart P) other than incineration and chemical, physical, and biological treatment	No/No	The requirements are only applicable to interim status TSD facilities. The preferred remedy does not include a TSD facility.
- Land Disposal Restrictions	Part 268	Establishes prohibitions on and treatment standards for certain types of hazardous wastes	No/No	The preferred remedy does not include land disposal of restricted hazardous waste.

Table A3: Summary Evaluation of Potential Action-specific Applicable or Relevant and Appropriate Requirements for the Offpost Operable Units
(Page 4 of 5)

Standard, Requirement Criteria, or Limitation	Citation	Description	Potentially Applicable/ Relevant and Appropriate Action-specific Requirement	Comment
Colorado Water Quality Control Act	CRS Sections 25-8-101 to 25-8-703			
- Basic Standards and Methodologies for Surface Water	5 CCR 1002-8 Section 3.1.0	Establishes basic standards, an antidegradation rule, and a system for classifying surface water of the state, assigning standards and granting variances	No/No	Remedy does not include discharge to surface water.
- Classification and Numeric Standards for the South Platte River	5 CCR 1002-8 Section 3.8	Establishes numeric standards for the South Platte River Basin on the basis of use classifications	No/No	Remedy does not include discharge to surface water.
- Regulation on Effluent Limitations	5 CCR 1002-3 Section 10.1	Establishes specific limitations on point source discharges of wastewater into state water and specifies sampling and analytical requirements	No/No	Remedy does not include discharge to surface water.
Colorado Air Quality Standards	CRS Sections 25-7-101 to 25-7-806			
- Emission Control Regulations	Colorado Air Quality Control Regulations No. 1	Establishes standards for emissions of particulates, smoke, carbon monoxide, and sulfur oxide	No/No	A source of these is not anticipated as part of the remedial alternatives for the Offpost OU.
- Odor Emission Regulations	Colorado Air Quality Control Regulation No. 2	Sets limits on emission of odorous air contaminants	Yes/No	Potentially applicable to remedial action for the Offpost OU.
- Regulation to Control Emissions of Volatile Organic Compounds	Colorado Air Quality Control Regulation No. 7	Establishes standards for sources within a non-attainment area with the potential to emit more than 100 tons per year of VOCs	No/Yes	Because significant amounts of VOC, but less than 100 tons/year could be emitted, the remedial action portions of these regulations are potentially relevant and appropriate.

Table A3: Summary Evaluation of Potential Action-specific Applicable or Relevant and Appropriate Requirements for the Offpost Operable Units
(Page 5 of 5)

Standard, Requirement Criteria, or Limitation	Citation	Description	Potentially Applicable/ Relevant and Appropriate Action-specific Requirement	Comment
- Regulations for Control of Hazardous Air Pollutants	Colorado Air Quality Control Regulations No. 8	Establishes emissions limits for hazardous air pollutants from stationary sources which emit more than 100 tons/year	No/No	The proposed remedial alternatives are not expected to emit 100 tons/year of any of the pollutants covered by these regulations.
Colorado Solid Waste Disposal Sites and Facilities Act	CRS Sections 30-20-101 to 119			
- Regulations Pertaining to Solid Waste Disposal Sites and Facilities	6 CCR 1007-2	Establishes standards for new solid waste disposal facilities (Section 5); design, construction, and operation of surface impoundments (Section 6); and design construction and operation of water treatment plant sludge facilities	No/No	A solid waste disposal facility is not envisioned as part of the preferred alternative.

ARAR = applicable or relevant and appropriate requirement
CCR = Code of Colorado Regulations
CFR = Code of Federal Regulations
CRS = Colorado Revised Statues
NPDES = National Pollutant Discharge Elimination System
OU = operable unit
RCRA = Resource Conservation and Recovery Act
TSD = treatment, storage, and disposal
USC = United States Code
VOC = volatile organic compound
$\geq$ = greater than or equal to

Appendix B

WETLAND DELINEATION AND ASSESSMENT

In October, 1991, the U.S. Fish and Wildlife Service (USFWS) conducted a wetland investigation of the First Creek drainage north of Rocky Mountain Arsenal (RMA). The purpose of the investigation, requested by the Program Manager for the Rocky Mountain Arsenal, was to assess potential impacts to wetlands associated with the Offpost Remedial Investigation/Feasibility Study (RI/FS) in the Offpost Operable Unit (OU) (Volume I, Figure 2). The following wetland delineation and assessment are based on the investigation conducted by USFWS.

Delineation

Wetlands can best be described as transitional lands between terrestrial and aquatic systems where the water table is usually at or near the ground surface. Wetlands serve as nature's natural filters, effectively filtering out many contaminants. Once wetlands are destroyed, they are very difficult to replace or reclaim. Wetlands serve as critical habitat for many species of wildlife, including migratory waterfowl.

Three basic elements are examined in a wetlands classification: (1) hydrology, (2) vegetation present, and (3) soils. A representative from the USFWS National Wetlands Office previously delineated wetlands in the First Creek drainage north of RMA from aerial photos and site observation. The USFWS RMA Field Office reviewed this delineation and conducted further evaluation of the First Creek drainage. On the basis of these evaluations, the USFWS determined that First Creek has all the components necessary to classify it as a jurisdictional wetland, an area which is regulated as "water of the United States" under Section 404 of the Clean Water Act. The USFWS provided the plates following this assessment, which delineate the wetlands in the First Creek drainage.

First Creek, in the proposed area of construction of the groundwater treatment system (Interim Response Action A, Alternative No. N-4), is compromised of seasonally flooded to semipermanently flooded wetlands with emergent aquatic vegetation as indicated on the National Wetland Inventory (NWI) maps of the Brighton and Sable quadrangles, included in this appendix. Approximately 250 to 300 acres of wetlands are located along First Creek from the north

boundary of RMA to O'Brian Canal. Figure B1 shows the delineation of First Creek wetlands with respect to the proposed response action.

Assessment

A description of alternatives for groundwater remediation of the Offpost OU is provided in Volume VI, Section 3.5. The identification of groundwater alternatives is divided into two sections corresponding to the North and Northwest Plume Groups identified in Volume VI, Figure 3.2.1-1. Six alternatives for the remediation of groundwater within the North Plume Group are described in Volume VI Section 3.5.1.

Alternative No. N-4 is the preferred alternative for groundwater remediation in the North Plume Group. Under this alternative, the North Boundary Containment System (NBCS) will continue to operate, and the Groundwater Intercept and Treatment System North of RMA will be constructed. The system would remove, contain, treat, and recharge affected groundwater in the First Creek and northern paleochannels downgradient of the NBCS. The discussion presented in this wetland assessment is limited to proposed action in the First Creek paleochannel because no jurisdictional wetlands are present in the vicinity of the northern paleochannel.

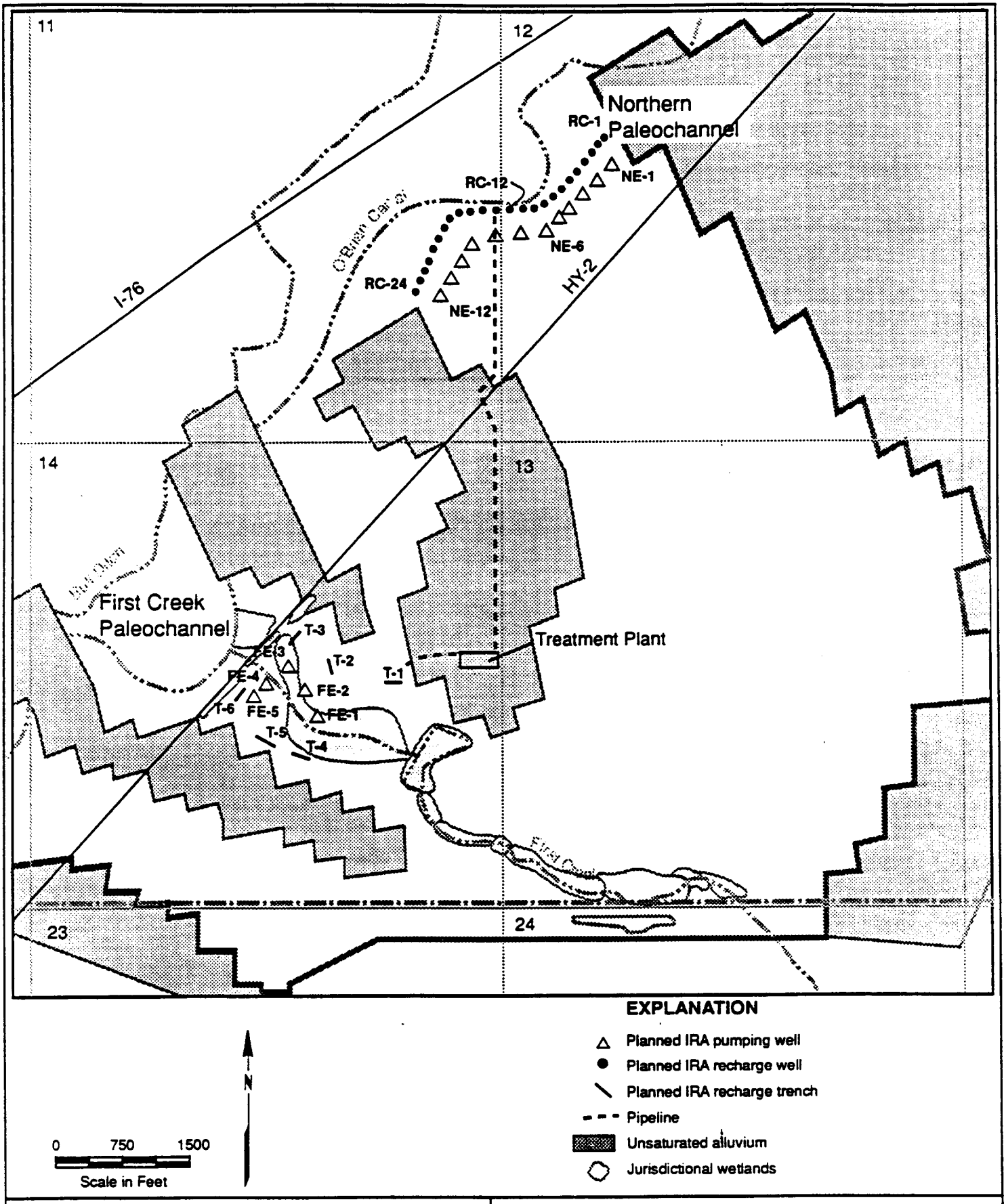
The major components of Alternative No. N-4 include removal of contaminated groundwater using extraction wells, carbon adsorption treatment, and recharge of treated groundwater via wells and trenches. A total of five extraction wells will be placed at the leading edge and along the First Creek paleochannel axis, pumping a total of approximately 180 gpm to the treatment plant through polyvinyl chloride (PVC) pipelines. A pipeline will be constructed beneath First Creek by placing a pipe encased in concrete 5 feet below the creek bed. This work will be accomplished between July and September when First Creek flows are lowest. Dewatering will be required for excavation of recharge trenches and conveyance pipeline trenches to below the static groundwater level.

A total of six recharge trenches will be placed both downgradient of the extraction wells and along the outer boundaries of the First Creek paleochannel. Each recharge trench will be 250 feet long and will be excavated to the bedrock surface or to 24 feet, whichever is shallower. Trenches

will be between 1 and 3 feet wide. Trenches will be backfilled with drain rock up to a depth of 18 inches below ground surface. In this manner, the recharge trenches will provide both lateral hydraulic containment of the First Creek paleochannel and water flushing for enhancing the removal of containment of the First Creek paleochannel and water flushing for enhancing the removal of containments.

Construction of this system began in November 1991 and will be completed by approximately January 1993. There will likely be a short-term impact to the wetlands due to dewatering during construction of wells and trenches. The sporadic drawdown will cause some changes in wetland delineation as water is taken from some areas and added to others. Results of groundwater modeling presented in the IRA A Final Implementation Document (HLA, 1991b) for the implementation of Alternative No. N-4 indicated expected drawdowns of approximately 5 feet in the extraction wells with an approximate radius of influence ranging from 50 to 400 feet. Over the long term, the wetland area will remain approximately the same. In addition to maintaining the wetlands area, the wetlands will be improved because of improved water quality resulting from the remediation of groundwater.

Activities that cause hydrologic changes along First Creek will impact the wetlands. Some disturbance is inevitable. Every effort will be made to minimize actual onsite disturbances during the construction process. The Army will consult with USFWS concerning possible impacts.



Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

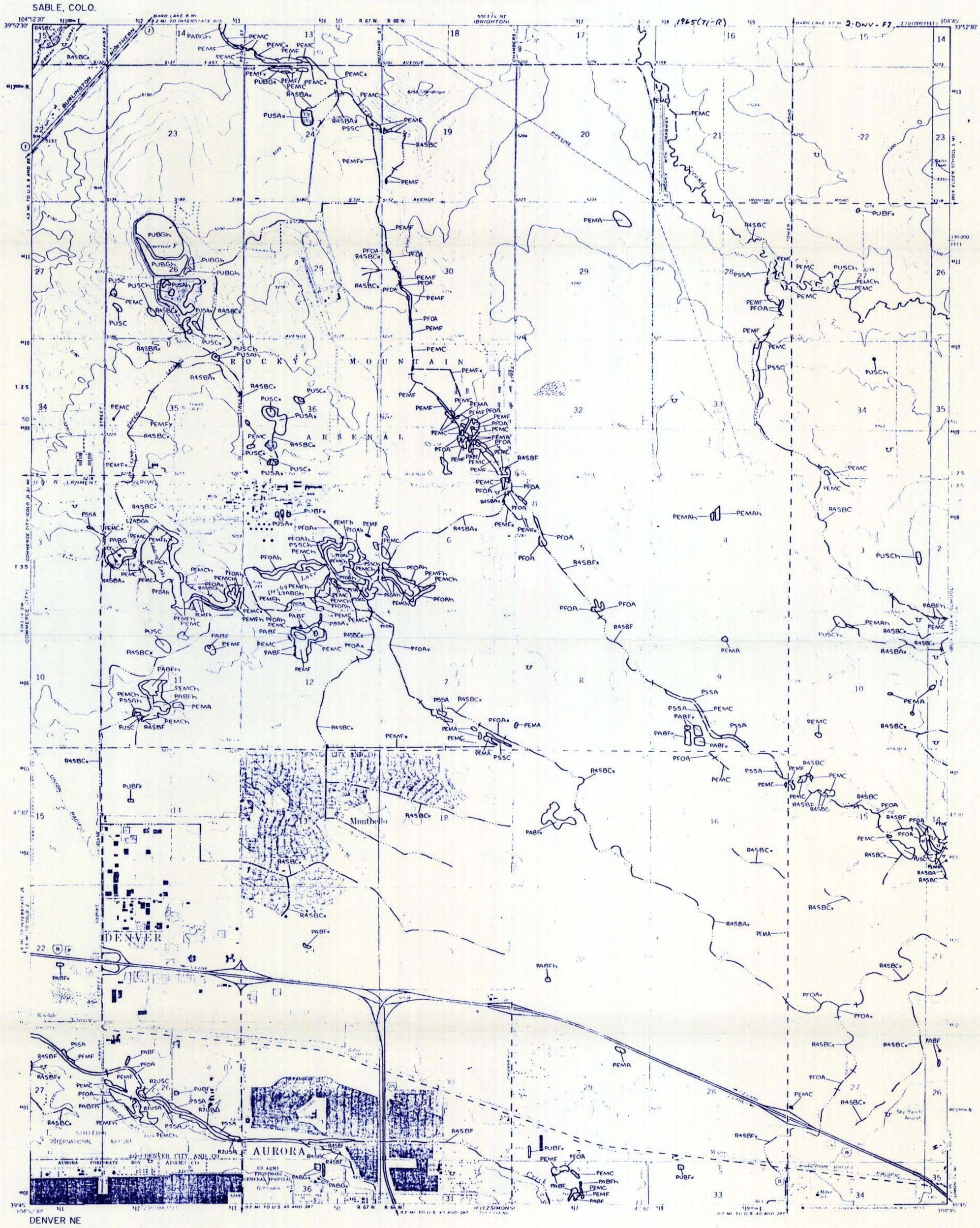
Figure B1

JURISDICTIONAL WETLAND DELINEATION AND ALTERNATIVE NO. N-4 REMEDIAL SYSTEM

NATIONAL WETLANDS INVENTORY

UNITED STATES DEPARTMENT OF THE INTERIOR

SABLE, COLO.



SCALE 1:24 000

1 acre — 10 acres — 20 acres

ACREAGE GUIDE

Other information including a narrative report concerning the wetland resources depicted on this document may be available. For information, contact:

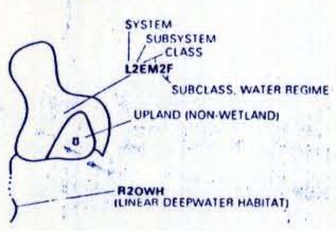
Regional Director (ARDE) Region VI
U.S. Fish and Wildlife Service
P.O. Box 2548, Denver Federal Center
Denver, Colorado 80225

SPECIAL NOTE

This document was prepared primarily by stereoscopic analysis of high altitude aerial photographs. Wetlands were identified on the photographs based on vegetation, visible hydrology, and geography in accordance with **Classification of Wetlands and Deepwater Habitats of the United States** (FWS/OBS - 79/31 December 1979). The aerial photographs typically reflect conditions during the specific year and season when they were taken. In addition, there is a margin of error inherent in the use of the aerial photographs. Thus, a detailed on the ground and historical analysis of a single site may result in a revision of the wetland boundaries established through photographic interpretation. In addition, some small wetlands and those obscured by dense forest cover may not be included on this document.

Federal, State and local regulatory agencies with jurisdiction over wetlands may define and describe wetlands in a different manner than that used in this inventory. There is no attempt, in either the design or products of this inventory, to define the limits of proprietary jurisdiction of any Federal, State or local government or to establish the geographical scope of the regulatory programs of government agencies. Persons intending to engage in activities involving modifications within or adjacent to wetland areas should seek the advice of appropriate Federal, State or local agencies concerning specified agency regulatory programs and proprietary jurisdictions that may affect such activities.

SYMBOLOGY EXAMPLE



NOTES TO THE USER

- Wetlands which have been field examined are indicated on the map by an asterisk (*)
- Additions or corrections to the wetlands information displayed on this map are solicited. Please forward such information to the address indicated.
- Subsystems, Classes, Subclasses, and Water Regimes in *italics* were developed specifically for NATIONAL WETLANDS INVENTORY mapping.
- Some areas designated as R4SB, R4SBW, OR R4SBJ (INTERMITTENT STREAMS) may not meet the definition of wetland.
- This map uses the class Unconsolidated Shore (US). On earlier NWI maps that class was designated Beach/Bar (BB), or Flat (FL). Subclasses remain the same in both versions.

AERIAL PHOTOGRAPHY

DATE 10/84 SCALE 1:58 000 TYPE CIR

DATE / / SCALE / TYPE /

U.S. DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Prepared by National Wetlands Inventory

1991

SYSTEM: M — MARINE

SUBSYSTEM	1 — SUBTIDAL					2 — INTERTIDAL				
CLASS	RB — ROCK BOTTOM	UB — UNCONSOLIDATED BOTTOM	AB — AQUATIC BED	RF — REEF	OW — *OPEN WATER/ Unknown Bottom*	AB — AQUATIC BED	RF — REEF	RS — ROCKY SHORE	US — UNCONSOLIDATED SHORE	
Subclass	1 Bedrock 2 Rubble	1 Cobble Gravel 2 Sand 3 Mud 4 Organic	1 Algal 3 Rooted Vascular 5 *Unknown Submergent*	1 Coral 3 Worm		1 Algal 3 Rooted Vascular 5 *Unknown Submergent*	1 Coral 3 Worm	1 Bedrock 2 Rubble	1 Cobble Gravel 2 Sand 3 Mud 4 Organic	

SYSTEM: E — ESTUARINE

SUBSYSTEM	1 — SUBTIDAL					2 — INTERTIDAL							
CLASS	RB — ROCK BOTTOM	UB — UNCONSOLIDATED BOTTOM	AB — AQUATIC BED	RF — REEF	OW — *OPEN WATER Unknown Bottom*	AB — AQUATIC BED	RF — REEF	SB — STREAMBED	RS — ROCKY SHORE	US — UNCONSOLIDATED SHORE	EM — EMERGENT	SS — SCRUB SHRUB	FO — FORESTED
Subclass	1 Bedrock 2 Rubble	1 Cobble Gravel 2 Sand 3 Mud 4 Organic	1 Algal 3 Rooted Vascular 4 Floating Vascular 5 Unknown Submergent 6 Unknown Surface	2 Mollusk 3 Worm		1 Algal 3 Rooted Vascular 4 Floating Vascular 5 Unknown Submergent 6 Unknown Surface	2 Mollusk 3 Worm	1 Cobble Gravel 2 Sand 3 Mud 4 Organic	1 Bedrock 2 Rubble	1 Cobble Gravel 2 Sand 3 Mud 4 Organic	1 Persistent 2 Nonpersistent	1 Broad Leaved Deciduous 2 Needle Leaved Deciduous 3 Broad Leaved Evergreen 4 Needle Leaved Evergreen 5 Dead 6 Deciduous 7 Evergreen	1 Broad Leaved Deciduous 2 Needle Leaved Deciduous 3 Broad Leaved Evergreen 4 Needle Leaved Evergreen 5 Dead 6 Deciduous 7 Evergreen

SYSTEM: R — RIVERINE

SUBSYSTEM	1 — TIDAL		2 — LOWER PERENNIAL		3 — UPPER PERENNIAL		4 — INTERMITTENT		5 — UNKNOWN PERENNIAL
CLASS	RB — ROCK	UB — UNCONSOLIDATED BOTTOM	*SB — STREAMBED	AB — AQUATIC BED	RS — ROCKY SHORE	US — UNCONSOLIDATED SHORE	**EM — EMERGENT		OW — *OPEN WATER/ Unknown Bottom*
Subclass	1 Bedrock 2 Rubble	1 Cobble Gravel 2 Sand 3 Mud 4 Organic	1 Bedrock 2 Rubble 3 Cobble Gravel 4 Sand 5 Mud 6 Organic 7 Vegetated	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*	1 Bedrock 2 Rubble	1 Cobble Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated		2 Nonpersistent	

*STREAMBED is limited to TIDAL and INTERMITTENT SUBSYSTEMS and comprises the only CLASS in the INTERMITTENT SUBSYSTEM

**EMERGENT is limited to TIDAL and LOWER PERENNIAL SUBSYSTEMS. The remaining CLASSES are found in all SUBSYSTEMS

SYSTEM: L — LACUSTRINE

SUBSYSTEM	1 — LIMNETIC				2 — LITTORAL					
CLASS	RB — ROCK BOTTOM	UB — UNCONSOLIDATED BOTTOM	AB — AQUATIC BED	OW — *OPEN WATER Unknown Bottom*	RB — ROCK BOTTOM	UB — UNCONSOLIDATED BOTTOM	AB — AQUATIC BED	RS — ROCKY SHORE	US — UNCONSOLIDATED SHORE	EM — EMERGENT	OW — *OPEN WATER Unknown Bottom*
Subclass	1 Bedrock 2 Rubble	1 Cobble Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*		1 Bedrock 2 Rubble	1 Cobble Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*	1 Bedrock 2 Rubble	1 Cobble Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	2 Nonpersistent	

SYSTEM: P — PALUSTRINE

CLASS	RB — ROCK BOTTOM	UB — UNCONSOLIDATED BOTTOM	AB — AQUATIC BED	US — UNCONSOLIDATED SHORE	ML — MOSS LICHEN	EM — EMERGENT	SS — SCRUB SHRUB	FO — FORESTED	OW — *OPEN WATER/ Unknown Bottom*
Subclass	1 Bedrock 2 Rubble	1 Cobble Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*	1 Cobble Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	1 Moss 2 Lichen	1 Persistent 2 Nonpersistent	1 Broad Leaved Deciduous 2 Needle Leaved Deciduous 3 Broad Leaved Evergreen 4 Needle Leaved Evergreen 5 Dead 6 *Deciduous* 7 *Evergreen*	1 Broad Leaved Deciduous 2 Needle Leaved Deciduous 3 Broad Leaved Evergreen 4 Needle Leaved Evergreen 5 Dead 6 *Deciduous* 7 *Evergreen*	

MODIFIERS

In order to more adequately describe wetland and deepwater habitats one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy. The farmed modifier may also be applied to the ecological system.

WATER REGIME

Non-Tidal:
- A Temporarily Flooded
- B Saturated
- C Seasonally Flooded
- D Seasonally Flooded/ Well Drained
- E Seasonally Flooded/ Saturated
- F Semipermanently Flooded
- G Intermittently Exposed

Tidal:
- H Permanently Flooded
- J Intermittently Flooded
- K Artificially Flooded
- W Intermittently Flooded/ Temporary
- Y Saturated/ Semipermanent/ Seasonal
- Z Intermittently Exposed/ Permanent
- U Unknown

- K *Artificially Flooded*
- L Subtidal
- M Irregularly Exposed
- N Regularly Flooded
- P Irregularly Flooded
- *S Temporary Tidal
- *R Seasonal Tidal
- *T Semipermanent Tidal
- *V Permanent Tidal
- U Unknown

*These water regimes are only used in tidally influenced freshwater systems

WATER CHEMISTRY

Coastal Halinity:
- 1 Hyperhaline
- 2 Euhaline
- 3 Mesohaline (Brackish)
- 4 Polyhaline
- 5 Mesohaline
- 6 Oligohaline
- 0 Fresh

Inland Salinity:
- 7 Hypersaline
- 8 Euhaline
- 9 Mesosaline
- 0 Fresh

pH Modifiers for all Fresh Water:
- a Acid
- i Circumneutral
- s Alkaline

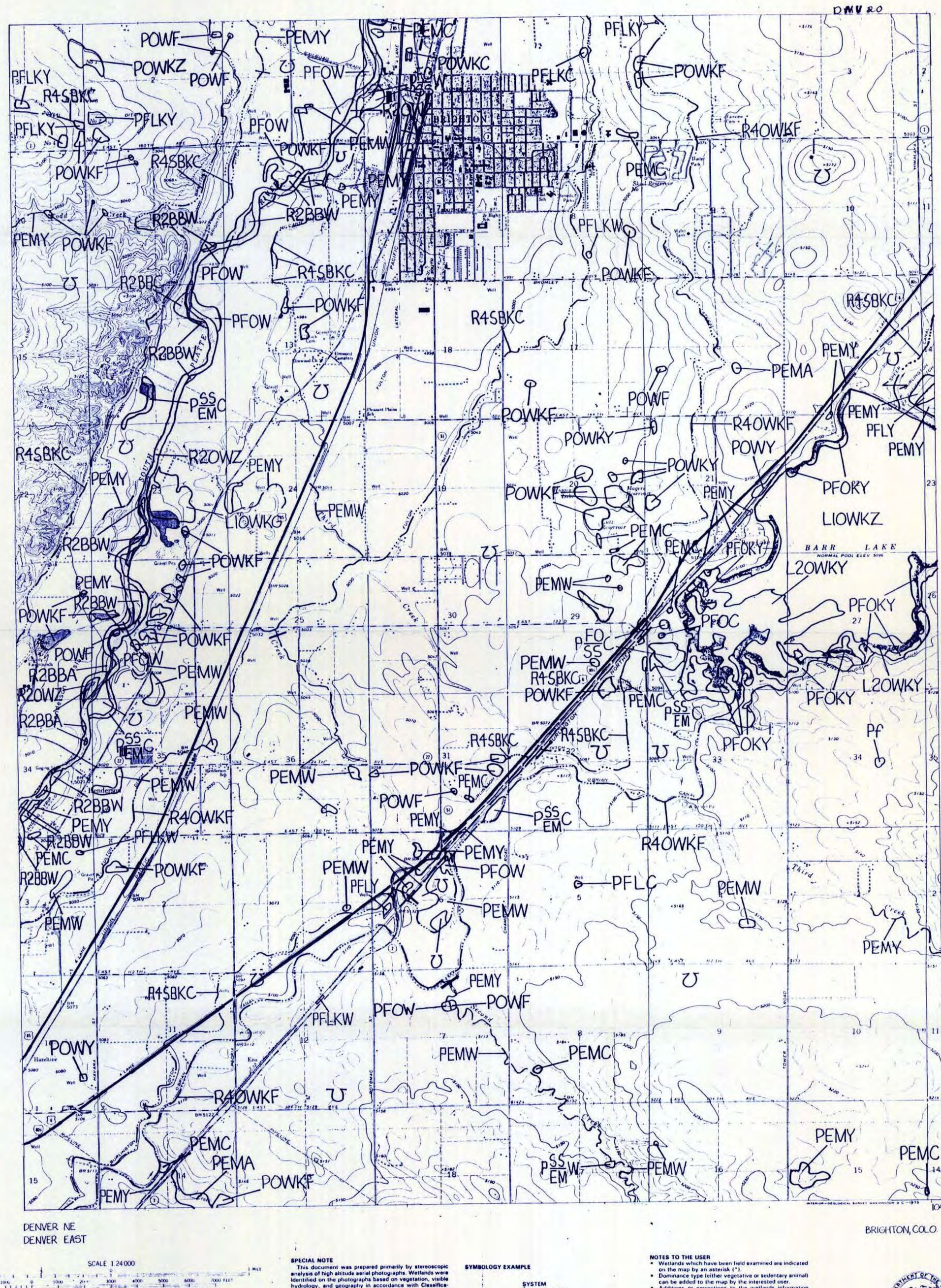
SOIL
- g Organic
- m Mineral

SPECIAL MODIFIERS
- b *Beaver*
- d *Partially Drained/ Ditched*
- f Farmed
- h *Diked/ Impounded*
- r Artificial Substrate
- s *Spoil*
- x Excavated

NATIONAL WETLANDS INVENTORY

UNITED STATES DEPARTMENT OF THE INTERIOR

DMV 20



DENVER NE
DENVER EAST

BRIGHTON, COLO.

SCALE 1:24000

Other information concerning the wetland resources depicted on this document may be available. For information, contact:

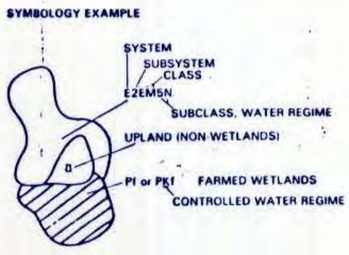
Regional Director (ARDE) Region VI
U.S. Fish and Wildlife Service
P.O. Box 2548, Denver Federal Center
Denver, Colorado 80225

SPECIAL NOTE

This document was prepared primarily by stereoscopic analysis of high altitude aerial photographs. Wetlands were identified on the photographs based on vegetation, visible hydrology, and geography in accordance with **Classification of Wetlands and Deep-Water Habitats of the United States** (An Operational Draft), Cowardin, et al, 1977. The aerial photographs typically reflect conditions during the specific year and season when they were taken. In addition, there is a margin of error inherent in the use of the aerial photographs. Thus, a detailed on the ground and historical analysis of a single site may result in a revision of the wetland boundaries established through photographic interpretation. In addition, some small wetlands and those obscured by dense forest cover may not be included on this document.

Federal, State and local regulatory agencies with jurisdiction over wetlands may define and describe wetlands in a different manner than that used in this inventory. There is no attempt, in either the design or products of this inventory, to define the limits of proprietary jurisdiction of any Federal, State or local government or to establish the geographical scope of the regulatory programs of government agencies. Persons intending to engage in activities involving modifications within or adjacent to wetland areas should seek the advice of appropriate Federal, State or local agencies concerning specified agency regulatory programs and proprietary jurisdictions that may affect such activities.

SYMBOLOGY EXAMPLE



NOTES TO THE USER

- Wetlands which have been field examined are indicated on the map by an asterisk (*).
- Dominance type (either vegetative or sedentary animal) can be added to the map by the interested user.
- Additions or corrections to the wetlands information displayed on this map are solicited. Please forward such information to the address indicated.
- Some areas designated R4SB, R4SBW, or R4SBJ (intermittent streams) may not meet the definition of wetlands.

AERIAL PHOTOGRAPHY

DATE: 6/75
SCALE: 1:80000
TYPE: B-W
DATE: / /
SCALE: _____
TYPE: _____
DATE: / /
SCALE: _____
TYPE: _____

U.S. DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Prepared by Office of Biological Services for the National Wetlands Inventory

WETLAND LEGEND

U – Primarily represents upland areas, but may include unclassified wetlands such as man-modified areas, non photo-identifiable areas and/or unintentional omissions.

ECOLOGICAL SYSTEM

E – ESTUARINE

Ecological Subsystem

1 – Subtidal: RB – ROCK BOTTOM (1 Bedrock, 2 Boulder); UB – UNCONSOLIDATED BOTTOM (1 Cobble/Gravel, 2 Sand, 3 Mud, 4 Organic); AB – AQUATIC BED (1 Submergent Algal, 2 Submergent Vascular, 3 Floating leaved, 4 Floating, 5 Unknown Submergent, 6 Unknown Surface); RF – REEF (2 Mollusc, 3 Worm); OW – OPEN WATER/Unknown Bottom

2 – Intertidal: AB – AQUATIC BED (1 Submergent Algal, 2 Submergent Vascular, 6 Unknown Submergent, 7 Unknown Surface); RF – REEF (2 Mollusc, 3 Worm); FL – FLAT (1 Cobble/Gravel, 2 Sand, 3 Mud, 4 Organic, 5 Vegetated Pioneer, 6 Vegetated Non pioneer); SB – STREAMBED (1 Cobble/Gravel, 2 Sand, 3 Mud, 4 Organic); RS – ROCKY SHORE (1 Bedrock, 2 Boulder, 6 Vegetated Non pioneer); BB – BEACH/BAR (1 Cobble/Gravel, 2 Sand); EM – EMERGENT (1 Persistent, 2 Nonpersistent, 3 Narrow leaved Nonpersistent, 4 Broad leaved Nonpersistent, 5 Narrow leaved Persistent, 6 Broad leaved Persistent); SS – SCRUB/SHRUB (1 Broad leaved Deciduous, 2 Broad leaved Evergreen, 3 Needle leaved Evergreen, 4 Needle leaved Evergreen, 5 Dead, 6 Deciduous, 7 Evergreen); FO – FORESTED (1 Broad leaved Deciduous, 2 Broad leaved Evergreen, 3 Needle leaved Evergreen, 4 Needle leaved Evergreen, 5 Dead, 6 Deciduous, 7 Evergreen)

M – MARINE

Ecological Subsystem

1 – Subtidal: RB – ROCK BOTTOM (1 Bedrock, 2 Boulder); UB – UNCONSOLIDATED BOTTOM (1 Cobble/Gravel, 2 Sand, 3 Mud, 4 Organic); AB – AQUATIC BED (1 Submergent Algal, 2 Submergent Vascular, 8 Unknown Submergent); RF – REEF (1 Coral, 3 Worm); OW – OPEN WATER/Unknown Bottom

2 – Intertidal: AB – AQUATIC BED (1 Submergent Algal, 2 Submergent Vascular, 8 Unknown Submergent); RF – REEF (1 Coral, 3 Worm); FL – FLAT (1 Cobble/Gravel, 2 Sand, 3 Mud, 8 Vegetated Non pioneer); RS – ROCKY SHORE (1 Bedrock, 2 Boulder, 8 Vegetated Non pioneer); BB – BEACH/BAR (1 Cobble/Gravel, 2 Sand)

P – PALUSTRINE

No Subsystem

RB – ROCK BOTTOM (1 Bedrock, 2 Boulder); UB – UNCONSOLIDATED BOTTOM (1 Cobble/Gravel, 2 Sand, 3 Mud, 4 Organic); AB – AQUATIC BED (1 Submergent Algal, 2 Submergent Vascular, 3 Submergent Moss, 4 Floating leaved, 5 Floating, 6 Unknown Submergent, 7 Unknown Surface); FL – FLAT (1 Cobble/Gravel, 2 Sand, 3 Mud, 4 Organic, 5 Vegetated Pioneer, 6 Vegetated Non pioneer); ML – MOSS/LICHEN (1 Moss, 2 Lichen); EM – EMERGENT (1 Persistent, 2 Nonpersistent, 3 Narrow leaved Nonpersistent, 4 Broad leaved Nonpersistent, 5 Narrow leaved Persistent, 6 Broad leaved Persistent); SS – SCRUB/SHRUB (1 Broad leaved Deciduous, 2 Needle leaved Deciduous, 3 Broad leaved Evergreen, 4 Needle leaved Evergreen, 5 Dead, 6 Deciduous, 7 Evergreen); FO – FORESTED (1 Broad leaved Deciduous, 2 Needle leaved Deciduous, 3 Broad leaved Evergreen, 4 Needle leaved Evergreen, 5 Dead, 6 Deciduous, 7 Evergreen); OW – OPEN WATER/Unknown Bottom

L – LACUSTRINE

1 – Limnetic: RB – ROCK BOTTOM (1 Bedrock, 2 Boulder); UB – UNCONSOLIDATED BOTTOM (1 Cobble/Gravel, 2 Sand, 3 Mud, 4 Organic); AB – AQUATIC BED (1 Submergent Algal, 2 Submergent Vascular, 3 Submergent Moss, 4 Floating leaved, 5 Floating, 6 Unknown Submergent, 7 Unknown Surface); OW – OPEN WATER/Unknown Bottom

2 – Littoral: RB – ROCK BOTTOM (1 Bedrock, 2 Boulder); UB – UNCONSOLIDATED BOTTOM (1 Cobble/Gravel, 2 Sand, 3 Mud, 4 Organic); AB – AQUATIC BED (1 Submergent Algal, 2 Submergent Vascular, 3 Submergent Moss, 4 Floating leaved, 5 Floating, 6 Unknown Submergent, 7 Unknown Surface); FL – FLAT (1 Cobble/Gravel, 2 Sand, 3 Mud, 4 Organic, 5 Vegetated Pioneer, 6 Vegetated Non pioneer); RS – ROCKY SHORE (1 Bedrock, 2 Boulder); BB – BEACH/BAR (1 Cobble/Gravel, 2 Sand); EM – EMERGENT (2 Nonpersistent, 3 Narrow leaved Nonpersistent, 4 Broad leaved Nonpersistent); OW – OPEN WATER/Unknown Bottom

R – RIVERINE

Ecological Subsystem

1 – Tidal: EM – EMERGENT(1) (2 Nonpersistent, 3 Narrow leaved Nonpersistent, 4 Broad leaved Nonpersistent)

2 – Lower Perennial: RB – ROCK BOTTOM (1 Bedrock, 2 Boulder); UB – UNCONSOLIDATED BOTTOM (1 Cobble/Gravel, 2 Sand, 3 Mud, 4 Organic); AB – AQUATIC BED (1 Submergent Algal, 2 Submergent Vascular, 3 Submergent Moss, 4 Floating leaved, 5 Floating, 6 Unknown Submergent, 7 Unknown Surface)

3 – Upper Perennial: FL – FLAT (1 Cobble/Gravel, 2 Sand, 3 Mud, 4 Organic, 5 Vegetated Pioneer, 6 Vegetated Non pioneer)

4 – Intermittent: SB – STREAMBED (1 Cobble/Gravel, 2 Sand, 3 Mud, 4 Organic); RS – ROCKY SHORE (1 Bedrock, 2 Boulder); BB – BEACH/BAR (1 Cobble/Gravel, 2 Sand)

5 – Unknown Perennial: OW – OPEN WATER/Unknown Bottom

(1) EM – EMERGENTS are only found in the Riverine Tidal and Riverine Lower Perennial Ecological Subsystem. All other classes are found in all Riverine Ecological Subsystems.

MODIFYING TERMS

In order to more adequately describe wetland and aquatic habitats one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy. The farmed modifier may also be applied to the ecological system

WATER REGIME(1)

Non-Tidal: A Temporary; B Saturated; C Seasonal; D Seasonal-Well drained; E Seasonal-Saturated; F Semipermanent; G Intermittently Exposed

Tidal: H Permanent; J Intermittently Flooded; K Artificial; Z Intermittently Exposed-Permanent; W Intermittently Flooded-Temporary; V Saturated-Semipermanent-Seasonal; U Unknown

Non-Tidal: L Subtidal; M Irregularly Exposed; N Regular; P Irregular

Tidal: R Seasonal Tidal; S Temporary Tidal; T Semipermanent Tidal; V Permanent Tidal; U Unknown

WATER CHEMISTRY

Coastal Salinity: 1 Hyperhaline; 2 Euhaline; 3 Mixohaline (Brackish); 4 Polyhaline; 5 Mesohaline; 6 Oligohaline; 0 Fresh

Inland Salinity: 7 Hypersaline; 8 Eusaline; 9 Mixosaline; 0 Fresh

pH Modifiers for all Fresh Water: a Acid; c Circumneutral; i Alkaline

SOIL

o Organic; n Mineral

SPECIAL MODIFIERS

b Beaver; d Partially Drained/Ditched; f Farmed; h Diked/Impounded; r Artificial; s Spoil; x Excavated

(1) Information on the water regime modifiers found on this legend, but not found in the classification system, may be obtained from the above listed source

Appendix C

DERIVATION OF HEALTH-BASED CRITERIA AND ECOLOGICAL CRITERIA

HUMAN HEALTH

Relevant EPA guidance was observed in deriving groundwater chemical-specific health-based criteria (Volume V, Table 2.5.4.3.-1) for the Feasibility Study (FS). Guidance included the Risk Assessment Guidance for Superfund (EPA, 1989b), the revised National Contingency Plan (EPA, 1990), the Role of the Baseline Risk Assessment in Superfund Remedy Selection Decision (EPA, 1991), and the Superfund Public Health Evaluation Manual (EPA, 1986). According to guidance, chemical-specific ARARs are considered protective. If there are extenuating circumstances, such as exposure to multiple chemicals or pathways of exposure, ARARs must be used with health-based criteria (HBC). In addition, the guidance states that reasonable maximum exposure (RME) risks between 10^{-4} and 10^{-6} are protective. This Appendix shows that the HBC and preliminary remediation goals (PRGs) selected in the FS are protective at the 1×10^{-4} carcinogenic risk level, considering multiple chemicals present in the Offpost Operable Unit (OU). The procedures involved in HBC development are described below.

Part A: Carcinogens

Residential PRGs

To assess the health risks associated with the PRGs, it was necessary to process the groundwater PRGs via the Automated Risk Evaluation System (ARES); the software used to compute risks for the Offpost OU. Appendix C Table C1 lists carcinogenic risks associated with the groundwater PRGs. The cumulative carcinogenic risk is 1.3×10^{-4}. Possible carcinogenic risk from EPA Category C carcinogens atrazine and 1,3-dichlorobenzene was not included because of only limited animal and no human evidence of carcinogenicity. The largest fraction of the 1.3×10^{-4} risk is contributed by arsenic (5.6×10^{-5}, or 43 percent). This is significant given that

- The PRG is established at the certified reporting limit (CRL)
- Naturally-occurring arsenic contributes a risk of approximately 4×10^{-5} using an UL95 concentration of 1.86 micrograms per liter (μg/l) (Volume III, Section 4.1.1.1).
- Subtracting the naturally occurring arsenic UL95 concentration from the exposure point concentrations (Volume II, Tables 2.4.2.5-1 through 2.4.2.5-6) yields a range from less than zero to a maximum 1.34 micrograms per liter (μg/l). Exposure point concentrations for arsenic are probably biased high because of low frequency of detections and

substitution of one-half the CRL for below CRL data. Conservatively using 1.34 μg/l as a proxy for the PRG yields a risk of 3.1 x 10^{-5}. If this risk level is inserted for arsenic into Table C1, the resulting summary risk for groundwater is approximately 1 x 10^{-4}.

If arsenic is completely deleted from the PRG list, the risk associated with groundwater PRGs is reduced to 7.4 x 10^{-5}. This is also supportable, because the arsenic PRGs is established at the lowest limit of detection (CRL) and because nearly all the arsenic in offpost groundwater is due to background sources.

The net carcinogenic risk range associated with the groundwater medium for the residential scenario is as follows .

1. 7.4 x 10^{-5} if arsenic is deleted as a groundwater PRG based on heavy contribution from background sources.
2. 1 x 10^{-4} if arsenic is maintained and the PRG is established at the maximum incremental concentration above background (1.34 μg/l).
3. 2 x 10^{-5} or 3 x 10^{-5} if risk associated with cases a and b, respectively, is reduced by an overconservatism factor of 3 as derived from the uncertainty analysis and summarized in Volume III, Section 4.0.

In summary, the carcinogenic risk associated with the residential scenario groundwater PRGs is approximately 1 x 10^{-4} and may be lower, based on the uncertainty analysis.

Commercial/Industrial/PRGs

Table C1 also illustrates the risks associated with groundwater ingestion and inhalation (during showering) for groundwater PRGs. This risk is 1.3 x 10^{-4}. However, the commercial/ industrial scenario assumed one-half the residential drinking water ingestion rate and shower exposure rate and no food chain exposure, hence these risks are reduced to much less than 6.5 x 10^{-5}. In summary, the groundwater commercial/industrial PRGs provide protection at a carcinogenic risk level of 6.5 x 10^{-5}.

Part B: Noncarcinogens

All receptor PRGs and HBCs

This section describes how PRGs and HBCs were calculated for noncarcinogens given the number of chemicals affecting a target organ, the number of pathways, and media.

Step 1: Determination Acceptable Intakes

Initially, each chemical was evaluated for noncarcinogenic effects. For noncarcinogens,the chronic acceptable intake is the EPA reference dose (RfD). The rationale is that these intakes constitute a level of exposure that would not cause unacceptable chronic adverse effects.

Step 2: Determination Pathway-Specific HBCS

In Step 2 of developing HBC, the intake equations used in the Endangerment Assessment (EA) (Section 2.0) were rearranged. First, the intake term was replaced with the acceptable intake calculated in Step 1. Next, the equation was solved for the concentration in groundwater. The intake for ingestion of groundwater was determined as follows

$$\text{Intake } (mg/kg^{-bw}/day) = \frac{C_{gw} * IR * EF * ED}{AT * BW} \quad (1)$$

where:

C_{gw} = chemical concentration in groundwater

IR = ingestion rate of water

EF = exposure frequency

ED = exposure duration

AT = averaging time

BW = body weight

Replace intake with acceptable intake from step one:

$$\text{Acceptable intake } (mg/kg^{-bw}/day) = \frac{C_{gw} * IR * EF * ED}{AT * BW}$$

Solve equation for the concentration in groundwater (C_{gw})

$$C_{gw} \text{ (mg/l)} = \frac{\text{(Acceptable intake)} * AT * BW}{IR * EF * ED} \quad (3)$$

Step 3: Determine Groundwater HBC

The steps were applied for each chemical of concern and exposure pathway in groundwater. To calculate a single HBC for groundwater, the pathway-specific HBCs were normalized to account for the relative importance of each pathway. This is accomplished by the following equation (Dacre, 1980) (4)

$$HBC(gw) = \frac{1}{\frac{1}{HBC_1} + \frac{1}{HBC_2} + \frac{1}{HBC_3} + \ldots + \frac{1}{HBC_n}}$$

Where HBC_n, is the number of exposure pathways associated with the groundwater medium.

At this point, an HBC was developed for a given medium based on parameters protective of human health and pathways of exposure.

The HBC methodology was used for two different exposure scenarios (EA Section 2.0): residential and commercial/industrial (C/I). The EA contains information on the exposure pathways specific to each scenario. Briefly, the major difference among the scenarios is that the residential scenario includes agricultural pathways (e.g., crops, beef) and the C/I does not.

The exposure parameters used in the HBC calculation were based on EPA guidance and other references where EPA guidance does not exist (EA Section 2.0). Reasonable Maximum Exposure (RME) estimates were developed for each exposure parameter. The RME is the maximum value that is expected to occur (95th percentile). The most likely exposure (MLE) is considered the value that is most likely to occur (50th percentile).

Step 4: Adjust for Multiple Chemicals Within the Groundwater Medium

To compensate for the presence of multiple chemicals, as required by guidance, an adjustment was made for the number of chemicals (n) in groundwater. Each noncarcinogen acts on specific organs (target organs) or tissues in the body. If more than one chemical with the same target organ (e.g., liver) is present in a given medium, it is necessary to adjust the HBC to remain protective of the target organ. The adjustment is similar to the carcinogenic chemicals in that the

individual HBC for a given medium is divided by the number of chemicals with the same target organ in that medium. For example, if groundwater contains five chemicals that affect the liver, dividing the HBC by five will be protective of the liver. A hazard index (HI) level of 0.1 was selected as a cutoff to account for the cumulative effect of multiple chemicals and to delete chemicals with very small HIs for the calculation. Chemicals with HIs >0.1 were used to determine the number of noncarcinogens used in the adjustment. That is, if the HI for a given chemical was less than 0.1, its contribution to health effect was not deemed significant, hence, it was not used in the HBC adjustment. For example, if there were four chemicals that had the liver as a target organ and only two had HIs greater than 0.1, the HBC was divided by two.

To adjust for the number of media (m), the noncarcinogenic HBC or PRGs are divided by m if the COC appears in m media. For residential zones 1, 2, and 6, none of the HBCs listed in Table 2.5.4.2-1 occurs in more than one medium.

The above approach has been verified by generating HBC risks using the EA software applications. As expected for each medium, the HI for chemicals with the liver as the target organ was <1.0.

DERIVATION OF ECOLOGICAL-BASED CRITERIA

SURFACE WATER AND SEDIMENT

On the basis of the ecological risk assessment, there were no exceedances calculated for the organochlorine pesticides in the aquatic food web. Therefore, ecological criteria for upper trophic level species were not derived on the basis of MATC or TRV values.

SOIL

The method chosen to derive soil remediation criteria protective of the sensitive ecological receptors was based on the soil COCs that bioaccumulate, basically, the organochlorine pesticides (OCPs).

The hazard quotient (HQ) of one served as the point of departure for the determination of ecological criteria. The results of the ecological risk assessment (Volume III, Section 5.0 of the EA) indicate that HQ exceedances for the OCPs occurred only for the great horned owl and American kestrel for endrin on the basis of comparing the predicted tissue concentration to the maximum allowable tissue concentration (MATC) value. No HQ exceedances for the OCPs occurred when soil and dietary intakes were compared to the toxicity reference values (TRVs); however, the American kestrel did have a TRV-HQ equal to one for endrin.

The American kestrel was selected as the primary receptor to derive ecological criteria for the following reasons

- HQs equal to and greater than one for endrin
- Year-round presence in the Offpost OU
- Presence of suitable habitat in Offpost OU
- Limited home range compared to the bald eagle
- Less uncertainty associated with the TRV and MATC values
- The American kestrel's diet includes small birds, small mammals, and insects

Other receptors were not selected for various reasons, including one or more of the following: HQs less than one, lack of suitable habitat offpost (e.g., great horned owl), very large home range or spatial adjustment factor (e.g., bald eagle), and lack of a TRV or MATC value.

Two approaches were selected to derive ecological criteria, MATC-based and TRV-based. Both approaches incorporate the species-specific spatial adjustment factor (SAF). The MATC-based approach is identical to that presented in the Biota RI (ESE, 1989), in which the criterion is derived based on the species-specific MATC and total biomagnification factor (BMF) for a particular OCP. The MATC is based on the lowest observed effect level (LOEL) obtained from the scientific literature for the target organism or a similar species (ESE, 1989). The MATC is considered to be protective of the target receptor organism, and other similar species. A description of the MATC is in Volume II, Section 3.0 of the EA and in the Biota RI (ESE, 1989). Data used to estimate the BMF values for biota in the terrestrial or aquatic ecosystems were

obtained from the scientific literature and selected based on scientific judgement (Volume IV, Appendix H). The MATC-based soil criteria are determined as follows

$$\text{Soil Criteria (ug/kg)} = (\text{MATC/BMF}) \times 1/\text{SAF}$$

The TRV-based approach derives a soil concentration that when factored into the terrestrial food web model (Volume IV, Appendix H, Table H2-2) and total daily uptake equation (Volume III, Section 5.0, pages III-5-24 and III-5-25, and Tables 5.3.1-1 through 5.3.1-3) does not result in an HQ greater than one.

Initially, for the TRV-based method, a soil concentration is estimated by a simple ratio comparison as follows:

$$HQ/EPC_s = 1/EC_s$$

where:

HQ = calculated HQ from ecological assessment

EPC_s = soil exposure point concentration used in the ecological assessment

1 = target risk level (i.e., HQ = 1)

EC_s = estimated soil ecological criteria

Next, the estimated value is verified by entering the concentration into the terrestrial food web model to determine predicted tissue concentrations for the COC in each of the receptor's prey items and the daily uptake equation for final comparison to the appropriate TRV. If the resulting HQ derived from the estimated soil ecological criteria is approximately one (i.e., 0.9 to 1.1), the value is accepted. If the value is not approximately one because of influence from surface water ingestion (usually a minor contributor to total intake), the value is adjusted until the modelling efforts result in a HQ equal to one.

The soil ecological criteria derived for the American kestrel are depicted in Table C2. The results indicate the two methods basically support each other as they are in reasonable agreement. Except for endrin, all the criteria values are greater than the geometric mean soil exposure point concentrations used in the ecological assessment (Volume III, Section 5.0, Table 5.2.3-1). The

TRV-based endrin soil criteria value is equal to the geometric mean soil exposure point concentration. The MATC-based endrin value is less than the CRL of 6 μg/kg for endrin; therefore, it is appropriate to exclude the MATC-based criterion and select the TRV-based value.

Table C1: Carcinogenic Risks Associated with Residential Preliminary Remedial Goals
(RMA ARES: Carcinogenic Risks for Exposures to Groundwater PRGs)

		Pathway							
		Inhalation		Oral					
		Medium							
Analyte (weight of evidence)		Ground-water	Total	Dairy Products	Ground-water	Meat	Vegetables	Total	Grand Total
Aldrin	(B2)				1.0E-05			1.0E-05	1.0E-05
Arsenic, total	(A)			6.3E-07	4.8E-05	7.5E-07	6.6E-06	5.6E-05	5.6E-05
Benzene	(A)	1.6×10^{-6}	3.6E-07	2.3E-09	3.6E-07	5.4E-10	6.5E-08	4.3E-07	2×10^{-6}
Carbon tetrachloride	(B2)	6.2E-07	6.2E-07	2.9E-08	1.5E-06	7.3E-09	4.6E-07	2.0E-06	2.6E-06
Chlordane, total	(B2)			2.0E-08	1.5E-06	4.4E-09	2.9E-07	1.8E-06	1.8E-06
Chloroform	(B2)	1.4E-05	1.4E-05	1.6E-09	1.1E-06	3.5E-10	1.8E-07	1.3E-06	1.6E-05
DDE, p,p'-	(B2)			1.3E-07	2.2E-07	3.5E-08	7.6E-08	4.6E-07	4.6E-07
DDT, p,p'-	(B2)				2.0E-07			2.0E-07	2.0E-07
Dibromochloropropane	(B2)	5.5E-09	5.5E-09	5.0E-09	3.2E-06	1.1E-09	5.0E-07	3.7E-06	3.7E-06
Dichloroethane, 1,2-	(B2)	1.2E-06	1.2E-06	3.6E-09	1.2E-06	7.8E-10	1.7E-07	1.3E-06	2.5E-06
Dieldrin	(B2)			9.1E-06	9.4E-06	2.6E-06	9.2E-06	3.0E-05	3.0E-05
Tetrachloroethene	(B2)	1.1E-07	1.1E-07	5.3E-08	3.0E-06	1.3E-08	8.7E-07	3.9E-06	4.0E-06
Trichloroethene	(B2)	8.6×10^{-7}	1.5E-07	2.1E-09	9.8E-08	5.4E-10	3.3E-08	1.3E-07	1×10^{-6}
	TOTAL	1.8×10^{-5}	1.7E-05	1.0E-05	8.0E-05	3.4E-06	1.8E-05	1.1E-04	1.4E-04

Table C2: Soil Ecological Criteria (μg/kg)
American Kestrel

	Aldrin	Dieldrin	Endrin	DDE	DDT
MATC-based	424	424	2	16	16
TRV-based	120	124	8.5	34	33

μg/kg = micrograms per kilogram
MATC = Maximum Allowable Tissue Concentration
TRV = Toxicity Reference Value

This appendix presents a summary of the second level screening of process options presented in Section 2.7. Process options retained were screened on the basis of effectiveness, implementability, and cost. Table D1 presents the screening of selected groundwater process options.

Table D1: Evaluation and Screening of Selected Groundwater Process Options
(Page 1 of 11)

Groundwater General Response Action	Technology Type	Process Option	Effectiveness	Implementability	Cost	References
No Further Action	No Further Action	None	Contaminant reduction is limited to natural attenuation and degradation processes	No remedial actions implemented	Low	
Institutional Controls	Access Restrictions	Land use/deed restrictions	Access restrictions interrupt several exposure pathways: contaminant reduction is limited to natural attenuation and degradation processes	Requires legal action and authority	Low	
		Fencing and warning signs	Very effective in preventing trespassers if properly maintained; contamination reduction is limited to natural attenuation and degradation processes	Implementable but could require land acquisition over much of the Offpost Operable Unit	Low capital, low Operation and Maintenance	
		Land acquisition	May be required to implement other remedial actions	Implementability would depend on willingness of landowners to sell property	Cost depends on the amount of land acquired and the current market value	
	Alternative Water Supplies	Bottled water, uncontaminated wells, connection to municipal supply, formation of water districts	Effective; eliminates risk associated with use of contaminated groundwater for affected residents	Readily implementable; already implemented for some residents on Offpost Operable Unit	Low to high capital; low to high Operation and Maintenance, depending on specific process option	

Groundwater General Response Action	Technology Type	Process Option	Effectiveness	Implementability	Cost	References
	Monitoring	Groundwater monitoring	Effective for documenting and tracking plume development and remediation effects; contamination reduction is limited to natural attenuation and degradation processes	Already implemented (i.e., Comprehensive Monitoring Program); expansion and continuation of monitoring program is readily implementable	Low capital; low to moderate Operation and Maintenance depending on sampling frequency and analytical costs	
Removal	Groundwater Extraction	Well points	Ineffective for extraction of water at depths greater than 22 feet; only effective for low capacity extraction	Not implementable; the majority of contamination on the Offpost Operable Unit is at depths greater than 22 feet	Low to moderate capital; low Operation and Maintenance	3
		Extraction wells	Effective and reliable; extraction wells already operating onpost and will be utilized offpost for Interim Response Action A	Readily implementable; conventional, commercially available	Low to moderate capital; low Operation and Maintenance	3
		Subsurface drains	Effective and reliable	Difficulty of implementation depends on depth and length of drain	Moderate to high capital; low Operation and Maintenance	3
	Water Flushing	Injection	Effective; requires filtration of injected water to prevent clogging of pores	Readily implementable; already implemented onpost for disposal of treated water; high permeability alluvial aquifer is amenable to injection	Moderate Operation and Maintenance; low Operation and Maintenance	3
		Flooding/ infiltration	Effective but difficult to control flushing path	Difficult to implement due to large areas required; may have seasonal difficulties in winter months due to freezing and in summer months will have losses to evaporation; may require land acquisition	Moderate capital; low Operation and Maintenance	8

Groundwater General Response Action	Technology Type	Process Option	Effectiveness	Implementability	Cost	References
Disposal of Treated and Contaminated Groundwater	Pump back of contaminated groundwater to boundary containment systems	Pump back to Northwest Boundary Containment System or North Boundary Containment System	Effective means of disposing of contaminated groundwater. Treatment at system would achieve remedial action objectives	Implementable; would require coordination with system operators and may require facility expansion and land acquisition	Moderate capital, moderate Operation and Maintenance	
	Deep Well Injection	Onsite injection of contaminated groundwater	Effective means of disposal and reduces risk of human exposure to contaminated groundwater	Not implementable; past deep well injection practices caused earthquakes; difficult to obtain permit; agency and public acceptance may be difficult to obtain	Moderate capital; low Operation and Maintenance	3
Disposal of Treated and Contaminated Groundwater (continued)	Deep Well Injection (continued)	Onsite injection of treated groundwater	Not applicable; no reason to isolate treated groundwater to prevent human and/or wildlife exposure; treated groundwater is a valuable resource and should be disposed in a manner that provides for future use	Not implementable; treated groundwater poses no risk to human health or the environment	Moderate capital; low Operation and Maintenance	3
		Offsite (RCRA-treatment, storage, and disposal facility) injection of contaminated groundwater	Effective means of disposal and reduces risk of human exposure to contaminated groundwater	Not implementable; not practical to transport large volumes of groundwater; water rights may require replacement of extracted groundwater	Low capital; high Operation and Maintenance	
		Offsite (RCRA-treatment, storage, and disposal facility) injection of treated groundwater	Not applicable; no reason to isolate treated water to prevent human and/or wildlife exposure; treated water is a valuable resource and should be disposed in a manner that provides for future use	Not implementable; not practical to transport large volumes of groundwater; water rights may require replacement of extracted groundwater	Low capital; high Operation and Maintenance	

Groundwater General Response Action	Technology Type	Process Option	Effectiveness	Implementability	Cost	References
	Shallow Aquifer Injection of Contaminated Groundwater	Injection wells and trenches	Ineffective; does not reduce mobility, toxicity, or volume of waste; may increase mobility of contaminants and increase the volume of affected media	Not implementable; difficult to obtain permits; may increase volume of affected media	Low capital; low Operation and Maintenance	3
	Shallow Aquifer Injection of Treated Groundwater	Injection wells and trenches	Effective method of treated groundwater disposal; aids in site reclamation by replacing contaminated groundwater with treated water; can also act as a component of water flushing operations	Readily implementable; already implemented onpost at the North Boundary Containment System, Northwest Boundary Containment System, and Irondale Containment System; will be implemented at Interim Response Action A	Low capital; low Operation and Maintenance	3
Disposal of Treated and Contaminated Groundwater (continued)	Aboveground Discharge	Discharge of contaminated groundwater to publically-owned treatment works	Moderate effectiveness; depends on treatment facility's ability to handle Offpost Operable Unit contaminants	Not implementable; publically-owned treatment works are unwilling to accept water containing RMA contaminants; contaminated groundwater may not meet pretreatment requirements	Low to moderate capital; low Operation and Maintenance	
		Discharge of treated groundwater to publically-owned treatment works	Effective	Implementable; water rights may require replacement of extracted groundwater	Low to moderate capital; low Operation and Maintenance	
		Discharge of contaminated groundwater to surface water	Not effective; does not reduce mobility, toxicity, or volume of contamination; may contaminate receiving water body, biota, and sediments	Not implementable; public and agency approval unlikely; fugitive emissions problem from volatile contaminants; does not comply with Clean Water Act	Low capital; low Operation and Maintenance	

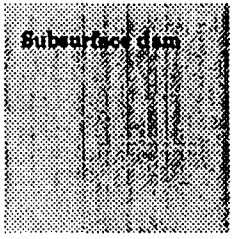
Groundwater General Response Action	Technology Type	Process Option	Effectiveness	Implementability	Cost	References
		Discharge of treated groundwater to surface water	Effective	Not implementable; impacts to surface water body, violation of water rights, and obtaining National Pollutant Discharge Elimination System permit is not likely for water containing Rocky Mountain Arsenal contaminants	Low capital; low Operation and Maintenance	
		Discharge of contaminated groundwater to infiltration basins	Low effectiveness; contaminants removed by volatilization, adsorption to soil, and biodegradation	Not implementable; fugitive emissions problems from volatile contaminants; may contaminate adjacent groundwater and soil	Moderate capital; low Operation and Maintenance	8
		Discharge of treated groundwater to infiltration basins	Effective; may also act as a component of water flushing operations and replaces extracted groundwater	Difficult to implement; requires larger areas, freezing problems in winter, excessive evaporation in summer	Moderate capital; low Operation and Maintenance	8
In-Vessel Treatment	Chemical Inorganics Treatment	Chemical precipitation	Potentially effective for the removal of inorganic contaminants; not effective for organic contaminant removal	Implementable; sludge requires subsequent treatment and disposal	Moderate capital; moderate to high Operation and Maintenance	3, 5, 16, 17
In-Vessel Treatment (continued)	Solids Removal	Sedimentation	Effective for removal of suspended solids; not required as a primary treatment process	Readily implementable as a pretreatment process	Low capital; low Operation and Maintenance	3
		Filtration	Effective for removal of suspended solids; not required as a primary treatment process	Readily implementable as a pretreatment process	Low capital; low Operation and Maintenance	3
	Membrane Separation	Reverse osmosis	Effective for removal of many inorganic contaminants; moderately effective for removal of some organic contaminants; would require treatability study	Moderately implementable; may require pretreatment; reject stream requires treatment	Moderate to high capital; moderate to high Operation and Maintenance	1, 3, 16

Groundwater General Response Action	Technology Type	Process Option	Effectiveness	Implementability	Cost	References
		Electrodialysis	Moderately effective for removal of inorganic anions and cations; not effective for organic contaminants	Implementable; may require pretreatment; concentrate stream requires treatment	Moderate to high capital; moderate to high Operation and Maintenance	5,16
	Phase Separation	Air stripping	Effective for removal of volatile organic compounds with a Henry's Law constant, H>0.03 (atm m^3/mol); non-volatile contaminants not removed	Readily implementable; offgas treatment likely to be required	Low to moderate capital; low to moderate Operation and Maintenance	1, 3, 5
		Steam stripping	Effective for the removal of volatile organic compounds and some semivolatile organic compounds; nonvolatile contaminants not removed	Difficult to implement; more difficult to operate than air stripping; requires steam generation facility; contaminated condensate would require treatment	Moderate to high capital; moderate to high Operation and Maintenance	1, 5
		Distillation	Effective for the removal of volatile organic compounds and semivolatile organic compounds; potential for recovery of some organic contaminants	Implementable; labor intensive operation and maintenance requirements; still bottoms and condensate require treatment	Moderate to high capital; high Operation and Maintenance	1, 5, 12
In-Vessel Treatment (continued)	Sorption	Granular activated carbon	Effective for the removal of a broad range of organic compounds; demonstrated effective for removal of onpost groundwater contaminants, including DIMP, dieldrin, and dibromochloropropane	Readily implementable; already implemented onpost for the treatment of contaminated groundwater at the Northwest Boundary Containment System, North Boundary Containment System, and Irondale Containment System facilities; will be implemented on the Offpost Operable Unit as part of Interim Response Action A	Moderate capital; moderate Operation and Maintenance	3

Groundwater General Response Action	Technology Type	Process Option	Effectiveness	Implementability	Cost	References
		Resin adsorption	Effective for removal of some organic compounds; removal of all organic contaminants may require more than one resin	Difficult to implement; regenerant solution requires treatment; limited demonstration in hazardous waste treatment; may require more than one resin	Moderate capital; moderate Operation and Maintenance	1
		Ion exchange	Potentially effective for removal of inorganic contaminants; effective removal of inorganics may require more than one ion exchange material; not effective for organic contaminants	Implementable; demonstrated; may require more than one ion exchange material; regenerant solution requires treatment	Moderate capital; moderate Operation and Maintenance	1, 3, 16, 17
		Activated alumina adsorption	Potentially effective for removal of some inorganic contaminants; not effective for organic contaminant removal	Implementable; demonstrated for removal of fluoride and arsenic; regenerant solution requires treatment	Low to moderate capital, moderate Operation and Maintenance	17, 18
	Oxidation	Ozone oxidation	Moderately effective for the oxidation of some organic compounds; potential for the formation of hazardous incomplete oxidation byproducts	Implementable; oxidation by-products may require further treatment	Moderate capital; moderate Operation and Maintenance	5
		Hydrogen peroxide oxidation	Moderately effective for the oxidation of some organic compounds; potential for the formation of hazardous incomplete oxidation byproducts	Implementable; oxidation by-products may require further treatment	Moderate capital; moderate Operation and Maintenance	5
In-Vessel Treatment (continued)	Oxidation (continued)	Ultraviolet light/ Ozone/hydrogen peroxide	Effective for many organic contaminants; effectiveness may be improved by pH adjustment and/or catalyst addition	Implementable; may require pretreatment	Moderate capital; moderate to high Operation and Maintenance	5

Groundwater General Response Action	Technology Type	Process Option	Effectiveness	Implementability	Cost	References
	Radiation	Electron beam	Potentially effective for removal of some organic contaminants; demonstrated effective for treatment of municipal wastewater and sludge; documented removal of chloroform and trichloroethene at bench and pilot scale	Difficult to implement; limited experience in treatment of hazardous waste; availability of equipment and trained personnel is limited	High capital; high Operation and Maintenance	13, 14
		Gamma irradiation	Potentially effective for removal of some organic contaminants	Difficult to implement; limited experience in treatment of hazardous waste; availability of equipment and trained personnel is limited	High capital; high Operation and Maintenance	13, 14
	Biological Treatment	Includes activated sludge, rotating biological contactors, powder activated carbon treatment, sequence batch reactors, trickling filters, anaerobic digestors, and submerged fixed film reactors	Not effective for the treatment of DIMP and dieldrin; moderately effective for other organic compounds	Difficult to implement; organic content of groundwater is likely too low to sustain microbial population; substrate addition required; further treatment required	Low to high capital; low to high Operation and Maintenance, depending on specific process option	1, 5, 10
In-Situ Treatment	Physical/Chemical Treatment	Water flushing	Potentially effective for enhancing rate of contaminant removal	Readily implementable; high permeability alluvial aquifer is amenable to water flushing	Moderate capital; low Operation and Maintenance	3, 5
In-Situ Treatment (continued)	Enhanced Biological Treatment	Aerobic degradation	Not effective due to low concentration of contaminants and biorefractory nature of DIMP and dieldrin	Implementability depends on volume requiring remediation	Low capital; low to moderate Operation and Maintenance	1, 3, 5, 6

Groundwater General Response Action	Technology Type	Process Option	Effectiveness	Implementability	Cost	References
	Enhanced Biological Treatment (continued)	Anaerobic degradation	Not effective due to low concentration of contaminants and biorefractory nature of DIMP and dieldrin	Difficult implementation; difficult to maintain anaerobic environment	Low capital; low to moderate Operation and Maintenance	3, 5
Containment	Subsurface Barriers	Slurry wall	Effective for containing groundwater and reducing contaminant mobility when combined with upgradient extraction; demonstrated effective for containment of onpost groundwater at the North Boundary Containment System, and Northwest Boundary Containment System facilities	Implementable; slurry walls already implemented onpost at the North Boundary Containment System and Northwest Boundary Containment System facilities	Moderate capital; low Operation and Maintenance	3
		Grout curtain	Moderately effective for groundwater containment; generally not as effective as slurry walls; no reduction in contamination	Implementable; but difficult to achieve construction of continuous barrier, especially in deep applications; compatibility of grout with contaminants would have to be verified	High capital; low Operation and Maintenance	3
		Hydraulic gradient control	Effective for groundwater containment and contaminant removal; demonstrated effective for containment of onpost groundwater at the North Boundary Containment System, Northwest Boundary Containment System, and Irondale Containment System facilities; no reduction in contamination	Readily implementable; already implemented onpost in association with the North Boundary Containment System, Northwest Boundary Containment System, and Irondale Containment System facilities; chosen as containment process option on the Offpost Operable Unit for Interim Response Action A; extracted groundwater will require treatment	Low to moderate capital; moderate Operation and Maintenance	3

Groundwater General Response Action	Technology Type	Process Option	Effectiveness	Implementability	Cost	References
Containment (continued)	Subsurface Barriers (continued)	Subsurface dam 	Effective for groundwater containment and associated reduction in contaminant mobility; should be combined with upgradient extraction to prevent contaminant bypass; no reduction in contamination	Difficult to implement; problems associated with construction in unconsolidated alluvium include sidewall instability and large volumes of groundwater inflow	High capital; low Operation and Maintenance	3

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▒ = Technologies eliminated due to effectiveness, implementability, or cost considerations.

Appendix E

GROUNDWATER MODELING RESULTS SUMMARY

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1.0 INTRODUCTION

Two numerical models were prepared to simulate groundwater flow and dissolved chemical transport in the Offpost operable unit (OU) north and northwest, respectively, of Rocky Mountain Arsenal (RMA). The models were used to evaluate the relative merits of some of the remedial alternatives evaluated in the Offpost Feasibility Study (FS). This appendix discusses the scope of the modeling effort, the approach and procedures applied, values of model parameters, and a cursory evaluation of each remedial alternative.

1.1 PURPOSE

Groundwater flow and chemical transport phenomena in the Offpost OU north and northwest of RMA are strongly affected by hydrogeologic properties that can vary significantly. Observations of offpost flow and contaminant distributions indicate that dissolved chemical transport is affected by an array of physical-chemical variables and processes. Some of the strongest influences appear to be spatially variable permeability, saturated thickness, and contaminant dilution due to recharge from canal losses and irrigation water. The models discussed herein were developed to capture the general effects of these influences to the extent that reasonable comparisons of proposed remedial alternatives could be made.

The effectiveness of proposed remedial schemes was judged largely on the basis of model-computed remediation time estimates. Thus, a primary objective of the modeling effort was to produce transport model results in a form that show approximated cleanup times.

1.2 MODEL AREAS

Two flow and transport model areas were selected for evaluation of proposed remedial alternatives. The first model, referred to as the North Model, comprised the region lying north of the North Boundary Containment System (NBCS). The second, the Northwest Model, encompassed a region lying west-northwest and north of the Northwest Boundary Containment System (NWBCS). The respective boundaries of the two models are shown in Figure E1.

The decision to develop two models, rather than one comprehensive model, was primarily based on computational efficiency and other concerns regarding numerical simulation of chemical transport. It was necessary for the modeling to cover a large region, extending from the RMA north and northwest boundaries to the South Platte River, while still using sufficiently small model elements, to minimize numerical dispersion and numerical oscillations. On the basis of estimated values of transport model parameters (i.e., pore velocity, dispersivities) and the type of numerical model selected for the simulations, it was concluded that the maximum characteristic dimension of each element comprising the model should not exceed 400 feet. Taking into account this constraint and the computing facilities on which the modeling would be conducted, the decision was made to produce two separate models. Further rationale for developing two models rather than one was that existing contaminant plumes in the North Model area appear to be distinctly separate from those in the Northwest Model area. Accordingly, it was unlikely that remedial schemes in one area would show an effect on the other model.

The model areas illustrated in Figure E1 reflect several concerns that were addressed during initial stages of model design. The model area features and some of the concerns dealt with in selecting model boundaries are:

- The upstream model boundaries coincide roughly with recharge well lines associated with the boundary containment systems.
- Downstream model boundaries are aligned with the South Platte River, which is assumed to be a groundwater discharge area.
- With one exception, the lateral boundaries of each model are composed of no-flow boundaries formed either by zones where the elevation of the top of the Denver Formation is greater than the local water-table elevation or by streamlines defined by the average potentiometric surface. The exception occurs in the Northwest Model where northwest- to north-moving groundwater from recharge operations at the Irondale Containment System (ICS) necessitate that boundary inflow be prescribed along a small portion of a lateral boundary near the model's southwest corner.
- Several zones within the interior of the models are also characterized by shallow Denver Formation materials that rise above the water table. These areas, delineated in Figure E1 and referred to as zones of unsaturated alluvium, are treated as impermeable. The irregular shapes of these areas in Figure E1 results from selection of several trapezoidal shaped elements in the models to represent the impermeable zones.
- The two major groundwater flow and transport pathways north of the NBCS in the North Model (i.e., Northern and First Creek Pathways), are separated by zones of unsaturated

alluvium. An additional elongated zone of unsaturated alluvium helps to define a third pathway emanating from the west end of the NBCS. Inclusion of all three pathways in the North Model makes it possible to assess inter-pathway effects of any remedial schemes that may be implemented immediately north of the NBCS.

- Lateral model boundaries aligned with streamlines rather than the water-table/Denver Formation contact are located considerable distances away from existing contaminant plumes. This step was taken so that remedial schemes based on pumping and injection would not be influenced by these portions of the lateral boundaries and to minimize the possibility that lateral dispersion would permit model-computed plumes to reach these lateral boundaries. As a result of this design approach, the two model areas overlap each other.

1.3 SCOPE AND APPROACH

The models prepared for this FS analysis are approximate in nature. Because comparative evaluation of each remedial alternative does not require highly accurate models, attempts have been made to produce models that incorporate general, rather than specific, features of groundwater flow and associated transport phenomena in the Offpost OU. Nonetheless, the resulting models are sufficiently detailed that simulated flow and chemical transport phenomena appear reasonable relative to historical and current hydrogeologic data in the Offpost OU as well as to the limited information on contaminant plume behavior. Due to the approximate nature of the models, and because the Offpost OU is characterized by considerable conceptual model and parameter uncertainty, none of the modeling results should be construed as accurate predictions of future contaminant distribution or cleanup times. Rather, the models and modeling results should be viewed as tools for assessing the relative merits of suggested remedial alternatives.

The North and Northwest Models have been constructed using general, conceptual models of groundwater flow and transport in the Offpost OU. To capture the effects of the most influential processes occurring in this area, realistic values of hydrogeologic and chemical transport parameters developed in previous studies have been applied. Where feasible, the spatial variability of these properties has been taken into account.

1.3.1 Calibration Methodology

The groundwater flow portions of the North and Northwest Models are based on time-averaged conditions. That is, the flow models are calibrated so that the water-table configurations

produced by each model approximate the average water levels observed in the Offpost OU during the past several years. Inherent in this approach is the assumption that water levels during recent years (i.e., the 1980s and early 1990s) have remained relatively constant despite seasonal and short-term variations in water-table elevations and the processes that affect them. Under this approach, the groundwater flow system in the Offpost OU is considered to exist in a state of dynamic equilibrium (Freeze, 1969), and the flow portions of the North and Northwest Models are called "steady-state" models. The assumption of steady-state flow conditions during recent years has also been made for other models of RMA (Konikow, 1977; Robson, 1977; Warner, 1979; Environmental Science and Engineering, Inc. [ESE] and others, 1988; ESE and others, 1989; Harding Lawson Associates [HLA] and Ebasco, 1990; Morrison-Knudsen Engineers, Inc. [MKE], 1989; Woodward-Clyde Consultants [WCC], 1991).

Time-averaged water-table configurations have been developed mostly from water levels collected during the years 1981-1987. This is the same period used to develop a time-averaged water-table map in the Final Water Remedial Investigation Report (FWRIR) (Ebasco and others, 1989). However, because earlier and more recent data have been collected from wells in the Offpost OU where water-level data has traditionally been sparse, these additional data have also been employed to produce a water-table map representative of "average" conditions. This approach assumes that water-level measurements from a specific point in time do not vary much from average conditions during the 1980s. Sources of relatively recent water-level data are mentioned in the Section 1.3.2 of this appendix. Discussion of some of the pre-1981 water-level data used to construct the 1981-1987 water-table map included in the Final Water RI (Ebasco and others, 1989) is presented in a regional groundwater flow modeling investigation by HLA and Ebasco (1990).

Questions may be raised regarding the validity of assuming steady-state conditions in the Offpost OU during the years 1981 to 1987. The Offpost RI (ESE and others, 1988) indicates that water-table elevations near the RMA north and northwest boundaries have declined an average of 1 to 2 feet during this period. These declines, which are thought to be attributable to decreased

recharge from upgradient onpost sources (e.g., water storage in Basin C up to the early 1970s), are based on water-level hydrographs from wells located a short distance downgradient of the RMA boundary. Because the hydrographs show seasonal fluctuations of 1 to 2 feet, discernible steady declines in the water table of these regions is not entirely evident.

More valid evaluations of possible trends in water levels can be derived by comparing time-averaged 1981 to 1987 mean water-table elevations with water-table maps that are based on recent data. For example, the IRA A study (HLA and Malcolm-Pirnie, Inc. [MP], 1990) indicates that the potentiometric surface north of the RMA north boundary during 1988 to 1990 was very close in magnitude to the mean 1981 to 1987 water levels shown in the FWRIR (Ebasco and others, 1991) for this area. Similarly, water-level maps presented by WCC (1991) and MK-Environmental Services (MKES) (1990) show that recent (1989-1990) water-table elevations downgradient of the RMA northwest boundary are very close in value to 1981 to 1987 mean water-table elevations presented for this area.

The above discussion suggests that a flow model based on 1981 to 1987 mean water-table elevations should be capable of representing current conditions. This approach also appears valid in light of the fact that the models are intended only to be approximate simulators of actual conditions.

A thorough calibration of the chemical transport portions of the North and Northwest Models was not attempted. This step was avoided primarily because of limited historical data regarding offpost contamination and potential contaminant sources. Although the transport models were not calibrated, preliminary simulations with the North Model were made to assess the general ability of the models to approximate plume movement during the last few years. For the few cases in which such preliminary runs have been made, the combined hydrogeologic and transport parameters selected appeared reasonable for simulating plume configurations over a span of a few years.

1.3.2 Information Sources

Previous modeling efforts under the Final Offpost RI (ESE and others, 1988) and the Draft Final Offpost EA/FS (ESE and others, 1989) have covered either portions or most of the area encompassed by the North and Northwest Models produced in this study. However, since 1989, considerable amounts of new information affecting flow and transport processes in the Offpost OU have been collected and interpreted. The two models developed under this FS have incorporated as much of this new information as possible with the intent of producing more realistic model predictions. In fact, the decision was made to develop new models rather than to rely on previous offpost models to evaluate FS remedial alternatives because updated information is available.

Most of the hydrogeologic data used to construct the flow portions of the North and Northwest Models were taken from information provided in the FWRIR (Ebasco and others, 1989) and the Final Offpost RI (ESE and others, 1988). An additional source of hydrogeologic information was a series of maps by Konikow (1975) depicting hydrologic boundaries, bedrock configuration, water-table levels, geologic descriptions, and hydraulic properties of shallow alluvium in the region. Estimates of recharge from a variety of sources were given in a report by MKE (1987).

Findings from earlier modeling efforts at RMA have also been quite useful. These efforts include the previously mentioned modeling projects associated with the Final Offpost RI (ESE and others, 1988) and the Draft Final Offpost EA/FS (ESE and others, 1989), the chloride transport model by Konikow (1977), an analyses of DIMP transport by Robson (1976; 1977), an investigation of operational management of the NWBCS by Warner (1986), an assessment of flow conditions near the NBCS by Carr (1987), and a regional flow modeling investigation by HLA and Ebasco (1990).

A study that has proved particularly useful in updating the hydrogeologic database for the North Model is the IRA A investigation (HLA and MP, 1990) for the region lying between RMA's north boundary and Burlington Ditch. Updated information regarding groundwater levels,

bedrock topography, saturated thickness, areas of unsaturated alluvium, hydraulic conductivity, and groundwater flow rates have been taken from this study. A related report by HLA and Lee and Ro (1990) documenting the design of groundwater intercept and treatment systems in flow pathways north of RMA has also been helpful in assessing the relative success of pump-and-treat remedial schemes for this area.

Several recent reports lend insight into groundwater hydraulics and contaminant transport processes occurring in the Northwest Model area. MKE (1989) performed a steady-state groundwater flow modeling study of the western portion of RMA and adjoining offpost areas adjacent to and downgradient of the ICS. In addition to containing information on water levels, bedrock topography and hydraulic conductivity distributions, the MKE (1989) model also provided estimates of groundwater flow for locales near the upstream boundary of the Northwest Model. Projects involving recent assessments of the NWBCS include a field study by MKES (MKES, 1990) and the NWBCS Long-Term Improvements IRA (WCC, 1991). These investigations identify paleochannels in the vicinity of the NWBCS, discuss local contaminant distributions, provide information on flow rates, and contain summaries of local and updated findings on the hydrogeology.

A recent laboratory study by Deeley and Western (1990) concerning the sorptive properties of dieldrin on RMA soils was reviewed for the purpose of estimating a range of sorption coefficients of this contaminant. However, examination of the historical movement of dieldrin in groundwater has shown that this contaminant is generally transported at a considerably faster rate than was indicated in the above-mentioned laboratory investigation. Possible explanations for this apparent discrepancy between laboratory and field observations are presented in Section 2.2.4 of this appendix.

1.4 MODEL UNCERTAINTY AND LIMITATIONS

As previously stated, the North and Northwest Models are only intended to be approximate simulators of groundwater flow and contaminant transport in the Offpost OU. Like all mathematical models, they are subject to error and limitations. Much of the model error can stem from

the fact that the conceptual model upon which the mathematical simulator is based does not account for all processes occurring in a groundwater system. This is particularly true for transport modeling because many processes potentially affecting contaminant fate and transport (e.g., transformations, degradation) are poorly understood. Transport processes may be so uncertain that the modeler chooses to ignore them rather than represent them poorly. Model error also occurs partly because measurement of parameters affecting flow and transport is subject to error and partly because data measurements are too limited to characterize a groundwater system adequately. Other problems are encountered when attempting model calibration, the procedure whereby input parameters are adjusted until model-computed water levels and contaminant concentrations approximate, as closely as possible, observed values of these variables. Methods of adjusting parameters vary from automated procedures to traditional, ad hoc, trial-and-error approaches. Regardless of the calibration procedures used, usually several combinations of model parameters result in equally good approximations of observed water levels and/or contaminant distributions. Thus, a model that is "calibrated" tends to be "nonunique." Accordingly, one version of a model cannot be relied upon to be any more accurate than another.

Because of uncertainty and nonuniqueness issues and the fact that the models discussed herein are intended only to be approximate indicators of remedial scheme effectiveness, model results should not be construed as accurate predictions of contaminant transport. The North and Northwest Models are subject to a great deal of uncertainty, particularly in areas where data remains very limited (e.g., north of the O'Brian Canal and the Burlington Ditch). Efforts are made throughout this report to discuss uncertainties in the models and to emphasize that model accuracy may be affected by those uncertainties.

2.0 CONCEPTUAL MODELS

2.1 GROUNDWATER FLOW

The conceptual model upon which the flow portions of the North and Northwest numerical models are based is a simplified version of the conceptual flow model presented in the FWRIR (Ebasco and others, 1989). Notable features of the groundwater flow conceptual model used in this study, including simplifications that have been adopted, are mentioned in the following paragraphs.

2.1.1 Unconfined Alluvial Flow System

The flow modeling is limited to simulation of groundwater movement in unconsolidated materials comprising the uppermost water-bearing unit in the Offpost OU. Although made up of both eolian and alluvial deposits, these unconsolidated materials are generally grouped under the general category of alluvium. Aquifer tests in the alluvium indicate that these deposits frequently respond to pumping as if they were confined by overlying fine-grained silts and clays. Despite such responses, the shallow aquifer comprising the alluvium is commonly referred to as the unconfined flow system (Ebasco and others, 1990), and the potentiometric surface measured within it is called the water table. For purposes of the modeling, the shallow alluvial aquifer is herein referred to as the unconfined alluvial flow system (UAFS).

Examination of geologic maps, boring logs, and geologic cross-sections (e.g., ESE and others, 1988; HLA and MP, 1990; MKES, 1990; WCC, 1991) indicates that both the thickness of the UAFS and the materials comprising it vary considerably. Accordingly, much of the modeling effort focused on capturing the spatial variability of both aquifer thickness and material heterogeneity. Aquifer materials are observed to vary both areally and vertically. Examples of vertical heterogeneity are typically shown in cross-sections where alternating lenses or continuous layers of fine-grained alluvial materials are observed. Frequently, layers of silt- and clay-bearing soils are found in the upper 10 to 30 feet of the vertical column. In many cases, these layers help to

create confined flow and anoxic groundwater conditions, factors which potentially play a role in contaminant transport.

Clay and silt layers appear to be present in both paleochannels and interfluvial zones. In fact, it is relatively common to see distinct lenses of fine-grained material near the deepest portions of what otherwise is considered a paleochannel consisting of clean sands and gravels. These latter occurrences of silty and clayey materials are significant because dissolved contaminants can accumulate and linger within them relative to the rapid rate of cleanup in coarser materials (Mackay, 1988; Mackay and Cherry, 1989).

Previous descriptions of shallow groundwater flow at RMA had included portions of the shallow, weathered part of the Denver Formation, which underlies the alluvium, as part of the unconfined flow system (Ebasco and others, 1989). Included under this designation were areas where the top of the Denver Formation exceeds water-table elevation (i.e., in areas of unsaturated alluvium). Although several modeling projects have treated the interface between the alluvium and the Denver Formation as impermeable (e.g., Konikow, 1977; Warner, 1986; ESE and others, 1988; MKE, 1989), some recent models (HLA and Ebasco, 1990; WCC, 1991) have elected to include simulation of flow in the upper Denver Formation. The reason for including this unit is that some data indicate that weathered Denver Formation materials may be permeable and may be capable of transporting groundwater contaminants.

Data characterizing the upper Denver Formation in areas of unsaturated alluvium in the Offpost OU are very limited. Consequently, the hydrogeology of these areas remains very uncertain in comparison to the current understanding of groundwater flow in the UAFS. Given this uncertainty and the objective of developing approximate models for this FS evaluation, the decision was made to limit flow and transport simulations to the alluvium (i.e., UAFS), thus neglecting groundwater flow and transport processes in the shallow Denver Formation. This step helped to simplify model development and calibration.

2.1.2 Boundary Processes

The upstream boundaries of each model were treated as areas of prescribed inflow. In the case of the North Model, this prescribed flow component represented the effluent being recharged to the UAFS from injection wells at the NBCS. Due to the lack of pertinent data, no attempt was made to account for other possible groundwater sources in this vicinity, such as potential leakage beneath the NBCS slurry wall in shallow Denver Formation sands. Prescribed inflows along the upstream boundary of the Northwest Model represented (1) recharge from injected effluent at the NWBCS, (2) groundwater inflows to the RMA northwest boundary from the south, (3) groundwater flow emanating from the injection system of the ICS near the model's southwest corner, and (4) groundwater inflow from the westernmost pathway leading from the NBCS.

The downstream boundaries of the models, which are roughly aligned with the South Platte River, were treated as prescribed head boundaries. Hydraulic heads (i.e., water-table elevations) at these boundaries were fixed at the approximate corresponding river elevations under the assumption that the river acts as a groundwater discharge site. Because head losses from groundwater moving vertically upward to the river may be substantial, actual vertically-averaged heads beneath and near the river may be somewhat greater than the corresponding river elevations. However, because the models are considered to be approximate, this method of handling downstream boundaries was considered acceptable.

As stated earlier, the lateral boundaries of both models, with the exception of a small portion of one of the lateral boundaries of the Northwest Model, were treated as no-flow boundaries.

2.1.3 Groundwater-Surface Water Exchange

The surface-water bodies that were considered to play roles in the hydrogeology of both offpost models included O'Brian Canal, Burlington Ditch, and Fulton Ditch. In addition, the influences of First Creek were accounted for in the North Model.

For modeling purposes, all of the irrigation canals were assumed to be losing waterways that contribute sizeable quantities of water to the UAFS. This assumption was supported by previous analyses of groundwater/surface-water relationships (Ebasco and others, 1989; HLA and

Ebasco, 1990). First Creek was also assumed to be a net losing waterway, although some studies have indicated that portions of the reach of the creek between RMA's North Boundary and O'Brian Canal act as groundwater discharge sites. The decision to handle this reach of First Creek as a net losing stream was based primarily on recent data collected along First Creek (Ebasco and others, 1989).

Recharge to the UAFS from canals and streams was handled as prescribed inflow. This method of simulating groundwater/surface-water exchange is identical to the method applied for groundwater/surface-water interaction in the models of others like Konikow (1977) and MKE (1989) and is simpler than the head-dependent stream-seepage algorithm that was invoked in a previous regional groundwater flow modeling investigation (HLA and Ebasco, 1990). The relatively simple method of prescribing inflow from stream losses is considered adequate for the approximate models produced in this study.

2.1.4 Agricultural Irrigation Recharge

Much of the area between the Burlington Ditch and South Platte River is irrigated for agricultural purposes. Although most of the irrigation water is derived from annual river diversions to irrigation canals in the Offpost OU, approximately 8 percent (Konikow, 1977) is taken from irrigation wells.

To account for the influence of agricultural irrigation recharge in the North and Northwest Models, an estimate was made of the quantity of water that infiltrates and eventually seeps beyond the root zone of the crops being irrigated. As in the studies of Konikow (1977) and MKE (1987), it was assumed that 45 percent of the applied water recharges the UAFS. To be conservative, it was further assumed that another 8 percent of the applied recharge water was removed from the groundwater system by irrigation wells and, therefore, was not available for long-term dilution of contaminants in the area. This approach was advantageous in that it removed the need to estimate the locations and groundwater withdrawal rates of irrigation wells in the model areas. Estimation of current irrigation well pumping rates was considered infeasible for this modeling investigation because data for the irrigation wells are scarce.

2.1.5 Other Hydraulic Processes Considered

Recharge from sources other than surface waterways and agricultural irrigation were considered. These additional sources included (1) infiltration of precipitation that does not necessarily collect as runoff, (2) lawn watering in residential areas, and (3) leaky sewers and storm drains. As discussed in previous assessments of recharge components in the RMA region (MKE, 1987; HLA and Ebasco, 1987), these sources either appear to be minor in quantity or are very difficult to estimate reliably. For these reasons, and because the North and Northwest models are intended to be approximate, recharge from these additional sources was excluded from the models.

Another flow process that was ignored in the models was that of groundwater exchange between the UAFS and the underlying Denver Formation. Previous investigations (e.g., MKE, 1989; HLA and Ebasco, 1990) have suggested that updip flows along bedding planes in the Denver Formation may contribute water to the UAFS. However, in most cases, this water source appears to be exert very minor influence on the UAFS, except in locales where flow in the UAFS is already quite low (HLA and Ebasco, 1990). Thus, the effects of omitting Denver Formation contributions are generally expected to be insignificant. One area where Denver Formation updip flow may play a noticeable role in UAFS groundwater movement is located on the downstream side of the NBCS, particularly toward the west end of the containment system.

Numerous irrigation wells lie within the portions of the Offpost OU covered by the models. However, due to a paucity of pumping information for these wells, they have not been accounted for directly in the models. As previously stated, their influence is taken into account indirectly by reducing the net irrigation recharge by an amount estimated by Konikow (1977) to equal the irrigation pumping component.

Pumping from domestic wells has been ignored in the North and Northwest Models, primarily because the well locations are largely unknown and the well extraction rates are minimal. The models presented in Konikow (1977), the Offpost RI (ESE and others, 1988) and MKE (1989) also ignored domestic pumping.

Finally, the groundwater extraction from a municipal supply well owned by South Adams County Water and Sanitation District (SACWSD) was also neglected in the model. The effects of omitting this well, which is located close to the Northwest Model's western lateral boundary, were considered insignificant because of the large distance between the well and observed contaminant plumes.

2.2 CHEMICAL TRANSPORT

Transport of contaminants within the UAFS was assumed to be described by the two-dimensional form of the advective-dispersive equation (Voss, 1984). Because simulations were limited to two dimensions in the horizontal plane, the concentrations predicted by the models at any location were considered to be vertically averaged values of concentration. In addition to accounting for dissolved chemical transport by advection and dispersion, the models simulated sorption on the porous medium, mass addition due to water sources, and mass removal by pumping.

2.2.1 Effects of Heterogeneity

Fine-grained aquifer materials in parts of both model areas were perceived to play significant roles in the transport of dissolved contaminants. As has been inferred in field studies (Roberts and others, 1986), including groundwater elution tests at RMA (Mackay, 1988), contaminants tend to remain in fine-grained silt- and clay-bearing materials for considerably longer periods of time than occurs in the coarser alluvial sediments (i.e., sands and gravels) comprising an aquifer. This phenomenon occurs partly because the rates at which contaminants either flow or diffuse out of layers of fine-grained sediments after a plume leaves an area are as slow as the rates of influx into these layers when the plume first encountered local sediments. This may help to explain why some offpost monitoring wells continue to show lingering contaminant concentrations when neighboring wells exhibit relatively rapid cleanup. Such persistence in relatively high contaminant concentrations has been observed in parts of the northern and First Creek paleochannels. Similar examples of variable rates of transport in heterogeneous systems have been

discussed by others (Domenico and Schwartz, 1990). It is the intent of the transport modeling generally to capture such effects where possible.

The heterogeneity of materials comprising the UAFS also suggests that macrodispersion (Gelhar and others, 1985; Domenico and Schwartz, 1990) plays a role in contaminant transport in the North and Northwest Models. Accordingly, the dispersivities used in the transport models should be of the same magnitude as those observed at similar length scales in aquifers containing materials like those in the UAFS.

2.2.2 Contaminant Dilution

Past and current plume maps indicate that recharge of surface water is very effective in diluting concentrations of contaminants. Most of the dilution appears to occur in the vicinity of the O'Brian Canal and Burlington Ditch, where water losses from the ditches are the apparent sources of dilution water. It is also likely that further dilution is achieved by recharge of irrigation water in agricultural areas located primarily downgradient of the Burlington Ditch. Other potential sources of dilution water include the Fulton Ditch (Figure E1) and recharge from precipitation, although the latter is difficult to estimate.

The apparent importance of contaminant dilution by recharge required that the transport models be constructed with a numerical code that adequately represents the dilution process. Most chemical transport models that provide direct solutions to the equations governing advective-dispersive transport account for the effects of mass loading with clean water indirectly. A code designed to incorporate dilution directly into the transport solution was used for the North and Northwest Models. Utilization of this code was also beneficial for simulating mass loading on the groundwater system contributed by injected effluent (i.e., at the NBCS, NWBCS, and injection wells or trenches associated with other possible pump-and-treat remedial alternatives.)

2.2.3 Boundary Containment System Effectiveness

Examination of organic contaminant plume movement near the NBCS (RLSA and others, 1989; RLSA 1991) indicates that this system did not completely contain organic contaminants

during the years following its installation and only became fully effective at reducing downgradient concentrations in the late 1980s.

The apparent inefficacy of the NBCS in earlier years has bearing on the conceptual transport model for the North Model area. Primarily, the system's apparent previous inability to reduce downgradient concentrations provides an explanation for the presence of organic contaminant concentrations found a short distance north of the NBCS. If the containment system had functioned as intended in the early 1980s, few to no contaminants would be expected in the First Creek and northern paleochannels just north of the NBCS. Thus, other explanations for contaminants persisting in this area, such as zones of low permeability or anomalously high sorption, are not justified. Furthermore, the improvements to the NBCS justify the use of future contaminant levels along the North Model's upstream boundary that are equal in value to current effluent concentrations.

Like the NBCS, the NWBCS has also undergone improvements during the past few years (MKES, 1990; WCC, 1991) in an effort to reduce downgradient contaminant levels to concentrations equal to those of NWBCS effluent. Again, the apparent inability of the containment system to prevent contaminant bypass in the past helps to explain recent plume configuration within the Northwest Model area. Also, the system improvements justify the use of current effluent concentrations in the transport boundary conditions applied along the Northwest Model's southeast boundary.

2.2.4 Sorption

Sorption of hydrophobic contaminants on the porous medium was treated in the transport model as an equilibrium, reversible process. A linear relationship between the sorbed and dissolved quantities of a contaminant was assumed. This method of handling adsorption and desorption of a transported chemical utilizes a distribution coefficient, K_d. The movement of sorbed contaminants is retarded in comparison to contaminants that do not adsorb to the porous medium. The degree to which transport of a chemical is retarded is often described by its retardation factor (R), which is defined as:

$$R = 1 + \frac{\rho_b K_d}{n} \qquad \text{(Equation 1)}$$

where:

ρ_b = dry bulk density of the porous medium [ML^{-3}]

K_d = distribution coefficient [L^3M^{-1}]

n = porosity [dimensionless]

Realistic estimates of retardation parameters were considered very important for the transport modeling because of the profound effect R values have on computed cleanup times. In general, the lower the R value, the more rapid the cleanup. The R values ultimately used in the transport model were estimated by considering a variety of factors that potentially affect sorption of organic contaminants at RMA. This process included an evaluation of historical contaminant plume distributions as well as a critical assessment of methodologies for estimating R. Inspection of several organic contaminant plumes in both the Onpost and Offpost OUs indicated that many of the contaminants have been moving faster than traditional hydrophobic sorption theory (i.e., theory based on the estimation of K_d) predicts. Several potential influences on the sorption processes were examined in an effort to explain this enhanced transport. Some of the more significant factors examined during this process included:

1. Cosolvent effects - Cosolvency refers to the increase in aqueous solubility and decrease in sorption (and, therefore, decrease in R) of an organic solute due to the addition of a cosolvent to the aqueous solution (Rao and others, 1991). Such enhanced transport of a hydrophobic organic contaminant, like dieldrin, normally occurs in areas where much more soluble organic chemicals exist at very high concentrations. Thus, it is likely that cosolvency effects at RMA, if any, have been limited to onpost areas near contaminant sources (e.g., Basins A through F) and to periods during which contaminants were lost to the groundwater system. Accordingly, cosolvency cannot explain the relatively rapid transport of organic solute plumes observed in the Offpost OU.

2. Enhanced/facilitated transport associated with colloids/macromolecules - Colloid-mediated transport refers to the enhanced solubility of hydrophobic organic chemicals that adsorb to colloids moving through an aquifer at or near the same rate as groundwater (McDowell-Boyer, 1986; Backhus and Gaschwend, 1990; Domenico and Schwartz, 1990). In some instances, the mobile colloids exist in the form of clay particles (Ryan and Gaschwend, 1990). In other instances, the colloidal-size particles may form as a result of the aggregation (i.e., macromolecules) of humic materials (Backhus and Geschwend, 1990). In many cases, the dissolved organic carbon (DOC) level in groundwater must be high in order for colloid-facilitated transport to occur.

Morrison-Knudsen Corporation (1991) indicates that the DOC content in RMA groundwaters is high enough to enhance the transport of hydrophobic chemicals like dieldrin. The origin of such high DOC concentrations is unclear, although the application of organic humate dust-control chemicals represents one possible source. Ryan and Geschwend (1990) have shown that anoxic groundwater (i.e., confined aquifer) conditions are conducive to facilitated transport by clay colloids. As mentioned previously, computed storativities from pump tests performed under the IRA A study (HLA and MP, 1990) have shown the groundwater in both the First Creek and Northern Pathways of the North Model area tends to flow under "confined" conditions. Furthermore, the occasional presence in both of these pathways of silty and clayey materials in the upper several feet of sediment suggests that confined, anoxic conditions are likely. Even in areas where computed storage parameters indicate unconfined aquifer flow, it is still likely that conditions become more anoxic in the deeper portions of the aquifer.

In summary, enhanced/facilitated transport due to sorption of hydrophobic contaminants on mobile colloids appears to be possible at RMA, both in the nearfield adjacent to contaminant source areas, and in the far field, such as the Offpost OU.

3. Nonequilibrium sorption - The possibility exists that the partitioning of organic contaminants on offpost aquifer solids occurs at a slow rate relative to the average linear velocity of groundwater. Under such conditions, sorption may be limited and the assumption of reversible, equilibrium sorption represented by Equation (1) may not be appropriate for simulating transport. However, Deeley and Western (1990) found that 48 hours was sufficient time for dieldrin to adsorb to RMA soils. Thus, it is unlikely that nonequilibrium sorption provides a strong explanation for the rapid movement of dieldrin.

4. Sorption Medium - The retarded transport of hydrophobic organic contaminants is normally associated with adsorption to organic solids in an aquifer. A variety of techniques have been developed (Schwarzenbach and others, 1981) to estimate K_d values using soil organic carbon contents (f_{oc}) and the octanol-water partition coefficient (K_{ow}) for a given chemical. Although the relative ability of a hydrophobic organic solute to adsorb to organic soil materials can vary depending on the contaminant (Domenico and Schwartz, 1990), there is usually a critical level of organic soil content at which sorption to organic and inorganic solids is equal. Below this level, sorption on mineral surfaces tends to control retardation of the contaminant.

   Many of the above-mentioned techniques for estimating K_ds may not apply when the organic carbon content is below 0.1 percent. This has been demonstrated for a variety of contaminated sites through comparisons of K_d values estimated from regression equations with K_ds derived from laboratory tests. Typically, the K_d (or R) values determined from batch equilibrium and column experiments (Curtis and others, 1986; MacIntyre and others, 1991; Priddle and Jackson, 1990) for low organic carbon (< .1 percent) media are larger than those estimated on the basis of hydrophobic sorption theory that accounts for partitioning into organic matter. As a further example of this trend, batch equilibrium experiments (Deeley and Western, 1990) with dieldrin and RMA sediments exhibiting f_{oc}s of less than 0.05 percent resulted in measured K_ds that were as much as an order of magnitude larger than K_ds estimated from hydrophobic sorption theory. Of further interest is the fact that the laboratory-determined K_ds for dieldrin are generally 5 to 40 times larger than those estimated from observed plume movement. These results indicate that low organic carbon contents may help to explain relatively rapid transport of RMA contaminants, but that traditional methods of estimating retardation coefficients on the basis of laboratory experiments and/or f_{oc} measurements for RMA soils may be in error.

Several additional phenomena that were reviewed to assess their influence on sorption in RMA groundwaters included sorption hysteresis (Curtis and others, 1986), K_ds that vary with changing contaminant concentrations, nonlinear sorption, and the effects of material heterogeneity on K_d (Mackay and others, 1988). Although all of these phenomena are possible in the UAFS, none provides a conclusive explanation for the apparent enhanced transport of hydrophobic organic contaminants at RMA.

Despite difficulties in firmly identifying causes for the relatively rapid movement of organic contaminants in the Offpost OU, conclusions were drawn regarding the methods used to estimate retardation factors to be used in the transport models. In particular, the decision was made to estimate R values, when possible, using historical observations of plume movement. In cases where such estimates were not possible, R values derived from RMA-specific laboratory studies and other estimation techniques were used.

2.2.5 Other Transport Processes Considered

No attempt was made in the transport models to account for contaminant decay, biodegradation, or other chemical transformation processes. Uncertainty of the numerous factors that influence potential transformation of RMA groundwater contaminants led to the decision not to account for such processes in the transport simulations. It was believed that this approach would result in conservative predictions of solute transport in that contaminant concentrations would remain higher than if chemical transformations were taken into account.

3.0 MODELING PROCEDURE

3.1 NUMERICAL MODEL

Simulations with the North and Northwest Models have been conducted with SUTRA (Voss, 1984), a finite element code designed to simulate groundwater flow and chemical transport in two dimensions. This code was prepared by the U.S. Geological Survey (USGS) and is publicly available.

The modeling was performed with SUTRA for a variety of reasons, among which are its public status, the ease with which finite elements can be adapted to irregular-shaped areas, and the mathematics upon which the code is formulated. SUTRA is particularly appropriate for offpost modeling due to its governing transport equation that takes into consideration fluid mass balance contributions to the solute balance (Voss, 1984). The fluid mass balance contribution to chemical transport is crucial to an accurate representation of the effects of contaminant dilution by canal losses and irrigation as well as system mass loading from injection of treated groundwater. The reader is referred to the SUTRA user's manual (Voss, 1984) for a detailed discussion of the code's capabilities, the mathematical basis of the code, methods for handling boundary conditions, and the finite element numerical procedures built into it.

The finite element procedure requires that each model area be subdivided into numerous small subregions called elements. The finite element meshes for the North and Northwest Models are shown in Figures E2 and E3, respectively. Both meshes are designed so that elements are oriented primarily in a north to north-northwest direction which is the predominant direction of groundwater flow. As stated earlier, the elements in each model were sized to minimize numerical dispersion and oscillations in computed concentrations during chemical transport simulations. Further discussion of numerical issues considered during the mesh design is provided in a subsequent section regarding input to the transport model.

The North Model consists of 2432 nodes and 2224 quadrilateral elements. The Northwest Model comprises 1760 nodes and 1629 quadrilateral elements.

3.2 MODEL INPUT

3.2.1 Flow Model

3.2.1.1 Water-table Configuration

The numerous recent studies covering offpost areas (MKE, 1989; HLA and MP, 1990; MKES, 1990; and WCC, 1990) have been used to develop an updated map of average water-table elevation previously presented in the FWRIR (Ebasco and others, 1989). This updated map in turn has been used as a calibration target for the steady-state flow models. The resulting average water levels in the North and Northwest Model areas are shown in Figures E4 and E5, respectively.

It should be noted that the configurations shown in these figures may differ slightly from water levels presented in other investigations. Such disparities reflect the fact that some interpretation was applied in developing the water-table configurations for areas where the various reports provided different interpretations.

3.2.1.2 Areas of Unsaturated Alluvium

Areas of unsaturated alluvium along the borders of and within each model have been determined by locating zones where the top of the Denver Formation exceeds the observed water table evaluation. Much of the process of delineating unsaturated alluvium areas was conducted under the FWRIR (Ebasco and others, 1989). However, since the FWRIR, additional water-table and bedrock data have been collected as part of the IRA A investigation (HLA and MP, 1990) and the Offpost RI Addendum (HLA, 1991). These data have helped to better define borders of the unsaturated alluvium zones. The most recent delineation of unsaturated alluvium zones is indicated in Figures E4 and E5 by clusters of elements that are treated as nonactive in the groundwater flow and transport simulations.

3.2.1.3 Base of Unconfined Alluvial Flow System and Saturated Thickness

During the IRA A study (HLA and MP, 1990), new information was gathered regarding the bedrock surface (i.e., top of the Denver Formation) in the First Creek and northern paleochannels

of the North Model. This information has been combined with bedrock-surface data and interpretations previously provided in the FWRIR (Ebasco and others, 1989) and the Offpost RI (ESE and others, 1988) to produce an updated bedrock surface map for the North Model. Similarly, a bedrock-surface map was prepared for the Northwest Model area using data from the FWRIR (Ebasco and others, 1989), the Offpost RI (ESE and others, 1988), the Western Tier modeling investigation by MKE (1989), and the IRA B(ii) Investigation (WCC, 1991). Data from these maps were combined with the previously discussed water-table configurations to determine saturated thicknesses throughout each model area. Computer-generated maps of the resulting saturated thickness distributions in the North and Northwest Models are presented in Figures E6 and E7, respectively.

3.2.1.4 Aquifer Hydraulic Conductivity

Hydraulic conductivities are assigned to each of the elements that comprise the models. Initial estimates of element hydraulic conductivity in the North Model south of O'Brian Canal were taken from recent aquifer test results from the IRA A investigation (HLA and MP, 1990). Initial estimates of hydraulic conductivity for the area north of the O'Brian Canal were derived from zonal hydraulic conductivity maps presented in the FWRIR (Ebasco and others, 1990). Hydraulic conductivity distributions developed during calibration of previous models encompassing the North Model area (ESE and others, 1988; HLA and Ebasco, 1990) were also examined.

The bulk of initial hydraulic conductivity estimates for the Northwest Model were taken from the previously mentioned zonal hydraulic conductivity map prepared as part of the FWRIR (Ebasco and others, 1989) and from several aquifer test results for the northwest portion of the Offpost OU. However, considerable additional hydraulic conductivity information for the southwestern portion of the model was derived from the calibrated model of the western RMA area by MKE (1989). Aquifer tests by MKES (1990) and the modeling investigation by WCC (1991) in the vicinity of the NWBCS were also helpful for estimating initial values of hydraulic conductivity in the upstream portion of the Northwest Model.

Only five values of hydraulic conductivity were used in the original hydraulic conductivity distributions assigned to each model prior to calibration. In the course of calibrating the models, additional values were added. Observed spatial trends in hydraulic conductivity as discussed in the FWRIR (Ebasco and others, 1989) were adhered to throughout the modeling process. In particular, the lowest hydraulic conductivities were assigned primarily to elements located in the upstream portions of each model, whereas the largest conductivity values were associated with South Platte River terrace deposits and the paleochannels that transect them. In general, the coarse-grained fluvial materials located along the axes of paleochannels were characterized by larger conductivities than were the eolian and other fine-grained alluvial deposits found in interfluvial regions.

3.2.1.5 Canal and Stream Losses

Several information sources were examined to derive representative estimates of average irrigation canal loss rates in the Offpost OU. The early model by Konikow (1977) assumed a loss rate for all unlined irrigation canals of 0.40 cubic feet per second per mile (cfs/mi) of canal length. The model produced for the Offpost RI (ESE and others, 1988) used a combined loss rate for the Burlington Ditch and O'Brian Canal that translated into a loss rate for each canal that was about 25 to 50 percent larger than Konikow's (1977) estimated loss rate. Loss rates for Burlington Ditch and O'Brian Canal developed in the RMA regional model (HLA and Ebasco, 1990), which were in large part based on recharge estimates by MKE (1987), appear to range from 1.5 to 2.5 times the Konikow estimated rate. Estimated loss rates in the FWRIR (Ebasco and others, 1989) for the Burlington Ditch and O'Brian Canal for the years 1986 and 1987 suggest that the loss rates may be two to five times the Konikow rate. A value in the middle of this large range of values was chosen for the North and Northwest Models. An average canal loss rate of 1.0 cfs/mi was assigned to the Burlington Ditch and O'Brian Canal. The Fulton Ditch was assigned a loss rate of 0.6 cfs/mi. This latter value was equal to the loss rate applied in the regional flow model developed by HLA and Ebasco (1990). Canal losses were not applied in areas where the canals traverse unsaturated alluvium.

The development of a representative stream loss rate for First Creek between RMA's north boundary and O'Brian Canal was as problematic as estimating canal losses. As previously mentioned, it is not clear on the basis of previous studies whether this reach of First Creek loses water to the UAFS or gains in flow from groundwater discharge during a typical year. Estimates of average stream losses for this reach of First Creek range from 0.43 cfs (HLA and Ebasco, 1990) to 0.15 cfs (Carr, 1987). The latter of these estimated recharge rates is assumed to occur in the First Creek Impoundment. For the purposes of the North Model, the impoundment loss assumed by Carr (1987) was spread uniformly along the full length of First Creek between RMA's north boundary and O'Brian Canal. The resulting loss rate per unit length of stream was 0.1 cfs/mi, which results in a total of 0.15 cfs.

3.2.1.6 Irrigation Recharge Estimates

As previously described, the rate of irrigation recharge was assumed to equal the estimated net recharge rate by Konikow (1977) minus the net withdrawal rate attributed to irrigation wells. The resulting recharge rate of 1.53 feet per year (ft/yr) was assigned to all elements located in the irrigated portions of the model areas. Areas assigned to irrigation were derived largely from figures presented in Konikow (1977). Additional irrigated areas not shown in Konikow's report were approximated using USGS 1:24,000 topographic maps.

3.2.1.7 Prescribed Boundary Flows

Prescribed inflow at the upstream boundary of the North Model was set at 0.49 cfs (220 gallons per minutes [gpm]), which is slightly lower than the average flow rate measured at the NBCS during the years 1984, 1986, and 1987 (Carr, 1987). The inflow is allocated along the many nodes comprising the North Model's upstream boundary roughly in accordance with recharge rates for NBCS injection wells as developed in the modeling investigation of Carr (1987). It should be noted that the spatial distribution of recharge from the NBCS can only be approximated because records of well-specific injection rates are not available. This difficulty is complicated by the fact that injection rates have changed with time due to well clogging problems and periodic well

development to improve recharge efficiency (Carr, 1987). Moreover, the temporal and spatial distribution of recharge of NBCS effluent has changed during recent years as recharge trenches have been incrementally employed in place of recharge wells.

Four components contribute to upstream boundary inflow for the Northwest Model. The first component, injected effluent from the NWBCS, was prescribed in the model at 1.0 cfs. This value represents a recent average recharge rate (550 gpm) from NWBCS operations (WCC, 1991) minus an estimated 100 gpm of recycled water along the southwest portion of the containment system. The second component of boundary inflow was attributed to north- to northwestward-moving groundwater traveling across RMA's northwest boundary southwest of the NWBCS. Using groundwater flow estimates from MKE (1989), this boundary inflow was prescribed at 1.88 cfs. The third boundary inflow component represented north- to northwestward-moving groundwater emanating from recharge operations on the downgradient side of the ICS. Currently, about 2.67 cfs is reinjected into the UAFS after treatment at the ICS (MKE, 1989). On the basis of the observed water-table configuration downgradient of the ICS injection wells, 1.04 cfs was estimated to enter the Northwest Model as a result of ICS operations. This component was treated as prescribed inflow along the lateral boundary of the Northwest Model near its southwest corner. Finally, 0.02 cfs of inflow was prescribed along the upstream portion of the model that receives flow from the westernmost portion of the NBCS.

3.2.1.8 Groundwater Withdrawals

For reasons discussed previously, groundwater withdrawals due to irrigation wells were not accounted for directly in the North and Northwest Models. Instead, the effects of irrigation pumping were incorporated into the estimated rate of recharge attributed to irrigation. Similarly, pumping from domestic wells and a single municipal supply well owned by SACWSD was not taken into account in the models. As a result, the only groundwater pumping simulated with the models was that which occurred as part of suggested remedial alternatives. Discussion of pumping rates under the various remedial schemes is provided in Section 4.0 of this appendix.

3.2.2. Transport Models

Required parameters for the chemical transport portions of the North and Northwest Models were groundwater pore velocity, longitudinal and transverse dispersivities, and sorption distribution coefficients (K_ds). Pore velocities were computed directly in the flow portion of SUTRA (Voss, 1984) using a uniform effective porosity of 30 percent.

3.2.2.1 Dispersion Parameters

In both models, a uniform longitudinal dispersivity of 100 feet was employed. This value was identical to the dispersivity used in the Konikow (1977) and Robson (1977) models and was of the same magnitude as dispersivities compiled by Gelhar and others (1985) for flow system materials similar to those comprising the UAFS.

A uniform transverse dispersivity of 33 feet was used in all transport simulations. Transverse dispersion was assumed to be less than longitudinal dispersion because of the elongated shape of the contaminant plumes in the area. The 3:1 ratio of longitudinal and transverse dispersivity is similar to that used in the Offpost RI (ESE and others, 1988) modeling.

The selection of a longitudinal dispersivity of 100 feet was taken into consideration during the design of the finite element meshes shown in Figures E2 and E3. Guidelines presented in the SUTRA manual (Voss, 1984) and by Campbell and others (1981), for minimizing numerical oscillations suggest that the maximum length of an element side should not be greater than four times the dispersivity. Accordingly, none of the elements comprising the meshes shown in Figures E2 and E3 contain sides with lengths greater than 400 feet.

The finite element meshes selected for the two models were also tested for their ability to minimize numerical dispersion. This was accomplished by conducting preliminary transport runs on portions of the models using computer-generated meshes that had twice the resolution (i.e., elements were made half size) of the meshes shown in Figures E2 and E3. These tests showed that the coarser meshes experienced only minor numerical dispersion and were adequate for FS modeling purposes.

3.2.2.2 Retardation Factors

As discussed previously, some organic contaminants at RMA appear to be transported at a faster rate than predicted by laboratory sorption tests and traditional hydrophobic sorption theory. Examination of factors possibly affecting this enhanced transport suggested that methods of estimating retardation factors (R) using historical plume movement are preferable to other estimation techniques such as those based on regression equations (e.g., Schwarzenbach and Westall, 1981). The procedures used to develop ranges of R values for simulation of DIMP, chloroform, and dieldrin transport are described in the following paragraphs.

The method of estimating R using historical plume movement assumed that the travel distance in the plume reflective of the average contaminant velocity (v_c) could be determined. Allowing for dispersion, the travel distance at a selected time was located upgradient of the plume's leading edge. In the case of pulsed inputs at the contaminant source, the travel distance was identified with the location of plume's center of mass associated with the first pulse input. A range of v_c values was computed by dividing the travel distance by a range of estimated times since the groundwater system was first contaminated.

R values were computed by dividing the average linear groundwater velocity (v_w) by v_c. A range of values for v_w was computed with Darcy's Law (Domenico and Schwartz, 1990) using a representative value of hydraulic conductivity, a measured range of hydraulic gradients and a realistic range of effective porosities. The representative hydraulic conductivity was set equal to the geometric mean of conductivity values determined from aquifer pumping tests (ESE and others, 1988; HLA and MP, 1990) conducted in a contaminant's pathway. The geometric mean hydraulic conductivity has been shown to be most representative of an aquifer's "equivalent" or "average" conductivity, given that most conductivity data sets from aquifers are lognormally distributed (Domenico and Schwartz, 1990).

Computations for estimating the retardation coefficient for DIMP are shown in Table E1. These calculations are based on 1979 DIMP concentration data indicating that the center of mass of the first pulse input of DIMP had migrated at least as far as O'Brian Canal in the First Creek

paleochannel. The assumed source of the DIMP was the northern portion of Basin C. The longest travel time was calculated assuming DIMP was first added to the groundwater system when it was initially manufactured in 1953. The shortest travel time was computed under the assumption that DIMP first become a major source of contamination in 1957, when waste liquids from Basin F were temporarily stored in Basin C (ESE and others, 1988). The range of hydraulic gradients in Table E1 represents recent potentiometric conditions (Ebasco and others, 1989) as well as the average conditions between 1955 and 1971 (Konikow, 1975) when liquid waste and water were added to Basins A through E. On the basis of the computations, R values of 1 (no retardation) and 2 were used in the DIMP transport simulations. These values were believed to be realistic, although an R of 2 is slightly less than the highest R shown in Table E1. The Table E1 estimates are thought to be conservatively large due to evidence that, by 1979, much of the DIMP plume had moved beyond O'Brian Canal in the First Creek paleochannel, where dilution had eradicated much of it.

Retardation factor calculations such as those above were also considered using data from pathways leading to the Northwest Model area. However, reliable computations could not be obtained for this region because northward-moving groundwaters apparently dilute contaminated groundwaters from the Basin A neck before they reach RMA's northwest boundary.

Parameters used to compute retardation factors for dieldrin and corresponding R values are shown in Table E2. The contaminant travel distance in this case represents the distance between the assumed contaminant source (northern portion of Basin F) and the west-central portion of Section 13 in the northern paleochannel, where relatively large concentrations of dieldrin existed as of 1986. The maximum and minimum travel times assume that dieldrin contamination first occurred in 1951 (date of first dieldrin production) and 1956 (date of Basin F completion), respectively. The range of hydraulic gradients represents both recent conditions (Ebasco and others, 1989) and average conditions between 1955 and 1971 (Konikow, 1975). Using these latter computations, R values of 2 to 5 were selected for dieldrin transport simulation. As in the case of

DIMP, dieldrin R values could not be developed from plume data in pathways leading to the RMA northwest boundary because of apparent contaminant dilution.

A range of retardation factors for a third organic contaminant, chloroform, was estimated using K_d values reported in RMA literature. Unfortunately, a limited database of historical chloroform transport prevented calculation of R values using the same methods applied to DIMP and dieldrin. The minimum R value used in the chloroform simulation was 1 (no retardation), which corresponded to a very small K_d derived from laboratory tests on RMA soils (ESE and others, 1987). A maximum R of 4 was employed in chloroform transport modeling. The maximum value was roughly computed using the recommended K_d of 0.47 milliliters per gram (ml/g) for chloroform in the FWRIR (Ebasco and others, 1989), a soil dry bulk density (ρ_b) of 1.85 grams per cubic centimeter (g/cm^3), and an assumed porosity of 30 percent.

Because historical plume configurations for dieldrin and DIMP indicate that transport of both of these organic contaminants is less retarded than predicted by estimated K_d values (Ebasco and others, 1989), chloroform's transport may also be enhanced. Consequently, chloroform model runs based on an R of 1 may be more representative of actual conditions than those using an R of 4.

3.3 FLOW MODEL CALIBRATION

3.3.1 North Model

The flow portion of the North Model was calibrated using a trial-and-error procedure. The parameters adjusted most during the steady-state calibration were element hydraulic conductivities. Saturated thicknesses were also adjusted in a few locations. Prescribed inflows representing recharge at the NBCS and seepage losses from irrigation canals and First Creek were kept constant.

During calibration of the North Model, attempts were made to use relatively uniform values of hydraulic conductivity within distinct flow zones. For example, uniform values of hydraulic conductivity were first assigned to each of the Northern and First Creek paleochannels using average values of hydraulic conductivity derived from IRA A (HLA and MP, 1990) aquifer tests

conducted in these areas. Similarly, a relatively large hydraulic conductivity representative of coarse river terrace sediments was applied in a large zone located in the downstream portion of the model adjacent to the South Platte River. A preliminary calibration was achieved by making only minor adjustments to these initial zonal distributions of conductivity. Calculations were made periodically during the preliminary calibration effort to assure that model-produced flows in the northern and First Creek paleochannels were in relative agreement with flows estimated for these areas during the IRA A investigation (HLA and MP, 1990).

The water-table configuration produced by the calibrated North Model is shown in Figure E8. Hydraulic conductivities used to develop the calibrated model ranged from 25 feet per day (ft/day) to 1500 ft/day. It should be noted that the match between computed and observed water levels just north of the NBCS is not perfect. However, to improve the match would likely require considerable adjustment of prescribed fluxes attributed to NBCS recharge wells. The distribution of NBCS Flux is poorly documented and may still be undergoing change.

3.3.2 Northwest Model

The flow portion of the Northwest Model was calibrated in much the same manner as the North Model. Most of the calibration procedure involved adjustments to the hydraulic conductivity distributions. Minor adjustments were also made in saturated thicknesses and the distributions of canal losses. The hydraulic conductivity values ultimately used in the upstream portion of the model were similar to those reported in the MKE (1989) model of the western RMA area and in the aquifer test results from MKES (1990).

Model-computed steady-state water levels for the calibrated Northwest Model are shown in Figure E9. The hydraulic conductivities in this model range from 25 to 2500 ft/day.

3.4 WATER BUDGETS

The water budgets for the North and Northwest Models are shown in Figures E10 and E11, respectively. Included in the North Model budget are calculated flows at selected locations in the

northern and First Creek paleochannels, as well as in the westernmost pathway leading from the NBCS.

3.5 PRELIMINARY TRANSPORT MODELING

The transport models were not calibrated, primarily because of a lack of needed data, such as contaminant source history and comprehensive and detailed hydraulic head data over time. However, a few preliminary transport model runs were made with the North Model to simulate chloroform plume movement during the late 1980s. These runs were conducted to assess the ability of adopted transport parameters to result in realistic plume movement. Chloroform was selected for these simulations because clear and distinct changes have been observed in the chloroform plume north of RMA's north boundary (RLSA and others, 1989; RLSA, 1991) since concentrations on the downgradient side of the NBCS were reduced in the late 1980s.

Preliminary model runs were made using R values of 1 and 4. Both runs produced reasonable results. The lower R value resulted in concentrations that better represented the tail of the plume, whereas the larger R provided better approximations of plume behavior just south of O'Brian Canal.

4.0 MODEL SIMULATIONS

Transport simulations were conducted for DIMP, chloroform, and dieldrin in the North Model and for dieldrin and chloroform in the Northwest Model. All simulations were carried out over a total period of 30 years using uniform time steps of two months. The two-month step duration complied with recommendations for limiting time steps (Campbell and others, 1981) to prevent problems with numerical oscillations.

Model runs involving extraction and injection wells were assumed to reach steady-state flow conditions within a short period of time. This assumption was appropriate largely because measured storativities from aquifer tests in the vicinity of contaminated areas (Ebasco and others, 1989; HLA and MP, 1990) are often small, which indicates that water levels respond relatively quickly to stresses such as pumping. The presumed cause of these low storativities is shallow, fine-grained deposits that tend to act as confining units for the alluvium. The assumption of steady-state flow conditions was also thought to be reasonable in light of the approximate nature of the models.

The approach taken with the transport simulations was first to examine the effects of continued operation of the NBCS and NWBCS (Alternative Nos. N-2 and NW-2). The ranges of R values previously discussed were applied in these initial simulations with the intent of estimating the possible range of remediation rates that might occur under existing conditions. The initial simulations helped to identify potential problem areas for remediation and provide preliminary indications of alternative remedial strategies that might be needed.

Remedial alternatives were evaluated using graphs of maximum contaminant concentrations versus time. The graphs facilitated comparison of contaminant remediation times to reach established preliminary remediation goals (PRGs) and the relative rates of UAFS remediation provided by the remedial alternatives.

4.1 NORTH MODEL

Remedial action scenarios evaluated with the North Model included:

- Alternative No. N-2: Continued Operation of the NBCS With Improvements as Necessary
- Alternative No. N-4: IRA A
- Alternative No. N-5: Expansion 1 to IRA A
- Alternative No. N-6: Expansion 2 to IRA A

The results of the model simulations for these scenarios are discussed in the following sections.

4.1.1 Alternative No. N-2: Continued Operation of the NBCS with Improvements as Necessary

North Model simulations under Alternative No. N-2 assumed that contaminant concentrations in recharged effluent at the NBCS would remain at the same value as recent average measured effluent concentrations. Dieldrin and chloroform were not detected in the NBCS effluent, and DIMP was detected at low concentrations. Effluent concentrations for dieldrin, DIMP, and chloroform used as input to the model were set at 0.025 micrograms per liter (μg/l) (half the CRL), 3.00 μg/l, and 0.25 μg/l (half the CRL), respectively.

Of the organic contaminants modeled, DIMP is probably the most mobile. To evaluate the movement of DIMP in the North Model under Alternative No. N-2, two model runs, corresponding to two different degrees of sorption, were made. The first run, using an R of 1, was made to examine the movement of DIMP under the assumption that its transport is not retarded. The second simulation, using an R of 2, was made to account for the possibility that DIMP transport might be slightly retarded. Computed R values from some investigations (ESE and HLA, 1987) and observations of historical plumes have indicated that DIMP transport may be mildly retarded due to sorption.

Initial DIMP concentrations in the North Model area are shown in Figure E12. Although this figure only shows areas where DIMP concentrations exceed the PRG of 600 μg/l, the initial conditions used in the model include DIMP concentrations as low as the current CRL (0.4 μg/l).

Simulation results for DIMP under Alternative No. N-2 are presented in Figure E13. As this figure indicates, maximum DIMP concentrations appear to decline rapidly during the first five years of model simulation. The maximum concentration is shown to decrease from 5600 μg/l initially to concentrations ranging from about 300 to 700 μg/l after five years. This rapid decline may not be unrealistic in light of evidence that the NBCS has only recently become effective in reducing concentrations downgradient of the system. Model-estimated times to attain the PRG for DIMP are shown to range from approximately 3 to 7 years for the range of R factors employed in the simulations.

The distribution of chloroform used as initial conditions in the North Model transport runs is illustrated in Figure E14. The PRG of 15 μg/l for chloroform comprises the lowest contour shown on this figure. Model results for Alternative No. N-2 are presented in Figure E15. As this figure shows, the maximum concentration of chloroform declines rapidly within the first five years from approximately 500 μg/l to 50 μg/l when using a R value of 1. As would be expected, the estimated timeframes are much slower when chloroform transport is retarded by a factor of 4. Model results indicate that the estimated times to attain the chloroform PRG range from approximately 10 to 27 years.

Of the three organic contaminants modeled, dieldrin is probably the most heavily sorbed. As discussed previously, R values of 2 and 5 were chosen for simulations of dieldrin transport. Evidence of the greater tendency of dieldrin to be sorbed relative to DIMP and chloroform is illustrated in the initial plume configuration for dieldrin (Figure E16).

Model computed maximum concentrations over time for dieldrin under Alternative No. N-2 are presented in Figure E17. Model-estimated times to attain the dieldrin PRG range from approximately 20 to 30-plus years.

4.1.2 Alternative No. N-4: Interim Response Action A

Contaminant transport runs were performed with the North Model after it had been adjusted to simulate implementation of Alternative No. N-4 (see Figure 3.5.1.4-1). The First Creek paleochannel system includes five extraction wells and six recharge trenches. The estimated flow

rate (HLA and MP, 1990) for the First Creek paleochannel system, 180 gpm, was divided equally among the five extraction wells and six recharge trenches. Consequently, each extraction well was assumed to pump at a flow rate of 36 gpm, and each recharge trench was assumed to receive 30 gpm of treated effluent. Flow rates were assigned to model nodes closest to the respective well or trench locations.

The northern paleochannel system consists of a row of 12 extraction wells and 24 recharge wells (Figure 3.5.1.4-1). The flow rate estimated in the IRA A Implementation Document for the northern paleochannel system was 300 gpm. The flow was divided equally among the extraction and recharge wells, with each extraction well pumping at 25 gpm and each recharge well receiving 12.5 gpm of treated effluent.

In the transport simulations, contaminant concentrations in the treatment plant effluent were set equal to current average concentrations of effluent from the NBCS.

Maximum concentration versus time graphs resulting from modeling runs performed with the simulated implementation of Alternative No. N-4 are presented in Figures E18, E19, and E20 for the contaminants DIMP, chloroform, and dieldrin, respectively; the figures indicate that the most pronounced effect of Alternative No. N-4 is on the cleanup of DIMP. Model results indicate that estimated times to attain the DIMP PRG range from approximately 2 to 3 years. Attainment of the dieldrin PRG is estimated to occur in approximately 15 to 30 years. The model-estimated times to attainment of the chloroform PRG are approximately 10 to 25 years.

4.1.3 Alternative No. N-5: Expansion 1 to IRA A

Alternative No. N-5 consists of two additional extraction wells and four additional recharge trenches in the First Creek paleochannel, and one additional extraction well and two additional recharge trenches in the northern paleochannel (see Figure 3.5.1.5-1) over Alternative No. N-4. For modeling purposes, the extraction wells were designed to pump at 30 gpm each. This would result in a 90 gpm increase to the influent stream for Alternative No. N-5. Recharge trenches are assumed to be approximately 300 feet long each, with each trench receiving approximately 15 gpm. The pumping and recharge rates used under Alternative No. N-5 are believed to be

reasonable approximations, considering the aquifer properties in the vicinity of corresponding extraction well and recharge trench locations. Model-estimated times to attain the DIMP PRG range from approximately 1 to 2 years. Attainment of the dieldrin PRG is estimated to occur in approximately 10 to 20 years. Attainment of the chloroform PRG is estimated to occur in approximately 5 to 20 years.

4.1.4 Alternative No. N-6: Expansion 2 to IRA A

Expansion 2 consists of four additional extraction wells and eight additional recharge trenches in the First Creek paleochannel and three additional extraction wells and five additional recharge trenches in the northern paleochannel (see Figure 3.5.1.6-1) over Alternative No. N-4. The extraction wells and recharge trenches comprising Alternative No. N-5 are included in Alternative No. N-6. The extraction wells are assumed to pump 30 gpm each. The recharge trenches in the First Creek paleochannel are assumed to receive approximately 15 gpm each. The 90 gpm removed by the three extraction wells in the northern paleochannel has been equally divided among the five recharge trenches in this pathway so that each trench receives approximately 18 gpm.

Model-estimated times to attain the DIMP PRG range from approximately 1 to 2 years. Attainment of the dieldrin PRG is estimated to occur in approximately 10 to 20 years. Attainment of the chloroform PRG is estimated to occur in approximately 5 to 15 years.

4.2 NORTHWEST MODEL

Remedial action scenarios evaluated for the Northwest Model include:

- Continued Operation of the NWBCS With Improvements As Necessary (Alternative No. NW-2)
- Northwest Plume Group Extraction/Recharge System (Alternative NW-4)

Modeling simulations were performed for dieldrin and chloroform under Alternative No. NW-2 and for dieldrin only under Alternative No. NW-3. Results from these simulations are discussed in the following sections.

4.2.1 Alternative No. NW-2: Continued Operation of the NWBCS With Improvements As Necessary

Northwest Model simulations under Alternative No. NW-2 were performed for dieldrin and chloroform. This alternative assumes that recent expansions to the northeast and southwest portions of the NWBCS (MKES, 1990) have resulted in the capture and treatment of dieldrin that appeared to previously bypass the system. Because dieldrin in NWBCS effluent has been below the CRL of 0.05μg/l, the concentration of dieldrin in NWBCS effluent was set at 0.025 μg/l for model simulations. For chloroform, the NWBCS effluent concentration was set at 13.8 μg/l, which represents an average of recent concentrations. The initial conditions plume configurations for dieldrin and chloroform in the Northwest Model area are shown in Figures E27 and E28, respectively.

The results for dieldrin of the simulations based on Alternative No. NW-2 are presented in Figure E29. As this figure indicates, estimated times to attain the PRG for dieldrin range from approximately 3 to 8 years. Results for chloroform are presented in Figure E30. As shown in this figure, maximum chloroform concentrations remain approximately equal to the average NWBCS effluent concentrations of 13.8 μg/l, which is below the PRG for chloroform.

4.2.2 Alternative No. NW-4: Northwest Plume Group Extraction/Recharge System

Alternative No. NW-4 consists of a total of three extraction and five recharge wells (see Figure 3.5.2.4-1). Two of the extraction wells and three of the recharge wells are located in a dieldrin plume that resulted from bypass of the NWBCS to the south. The remaining extraction well and two recharge wells are located in the area of a dieldrin plume that resulted from historical bypass of the NWBCS to the north. In the transport model, the extraction wells were designed to pump 50 gpm each. The three recharge wells in the southern dieldrin plume are assumed to receive 33 gpm each of treated effluent, and the two recharge wells in the northern dieldrin plume are assumed to receive 25 gpm each of treated effluent.

Maximum dieldrin concentration versus time graphs for model runs performed with the simulated implementation of Alternative NW-4 are presented in Figure E31. Attainment of the

dieldrin PRG is estimated to occur in approximately 2 to 5 years. The maximum chloroform concentrations (not shown) remain approximately equal to the average NWBCS effluent concentration of 13.8 μg/l, which is below the chloroform PRG.

5.0 SUMMARY AND CONCLUSIONS

Two numerical models were developed to simulate alluvial groundwater flow and dissolved contaminant transport in the Offpost OU for the North and Northwest Plume Groups. The models were used to evaluate the relative merits of remedial alternatives developed in Volume VI, Section 3.0 of the FS.

The two models, referred to as the North and Northwest Models, were constructed using the USGS finite element code SUTRA (Voss, 1984). The North Model, which encompassed the area between the NBCS and the South Platte River, accounted for flow and transport in the First Creek and Northern paleochannels, as well as a third pathway stemming from the west end of the NBCS. The Northwest Model covered the area between RMA's northwest boundary in the vicinity of the NWBCS and the South Platte River. Due to the concerns about lateral dispersion during transport simulation and the potential effects of model boundaries on remedial schemes, the lateral boundaries were located considerable distances away from the plumes being modeled. Consequently, the two model areas overlap each other.

Substantial effort was made during the preparation of each model to assure that numerical problems sometimes associated with finite element simulation of transport (i.e., numerical oscillations and numerical dispersion) were kept to a minimum. Based upon estimated model parameters and guidelines for reducing numerical oscillation and dispersion, the model meshes were designed such that none of the elements contained sides with lengths greater than 400 feet, and time steps were limited to 60 days.

The models prepared for the purposes of the FS analysis are approximate in nature. Because comparative evaluation of the benefits derived from each remedial alternative does not require highly accurate models, attempts have been made to produce models that incorporate general features of groundwater flow and associated transport phenomena in the Offpost OU. Nonetheless, the resulting models are sufficiently detailed that predicted flow and chemical transport phenomena appear reasonable relative to historical and current hydrogeologic data in the Offpost OU as well as the limited information on contaminant plume behavior. Due to the approximate

nature of the models, and because the Offpost OU is characterized by considerable conceptual model and parameter uncertainty, none of the modeling results should be construed as accurate predictions of future contaminant distribution or cleanup times. Rather, the models and modeling results should be viewed as tools for assessing the relative merits of remedial alternatives.

The flow modeling was limited to simulation of groundwater movement in unconsolidated alluvial materials in the Offpost OU. Consequently, regions where alluvial materials are not saturated were excluded from the North and Northwest Models (Figure E1). In the North Model, the exclusion has resulted in the confinement of groundwater flow to distinct and separate pathways.

The upstream boundaries of each model were treated as areas of prescribed inflow. Downstream boundaries, which are roughly aligned with the South Platte River, were treated as prescribed head boundaries. The lateral boundaries of both models, along with the boundaries surrounding areas of unsaturated alluvium, were primarily treated as no-flow boundaries.

In addition to upstream boundaries, sources of recharge to the North and Northwest Models included the O'Brian Canal, Burlington Ditch, Fulton Ditch, and agricultural irrigation. In the North Model, First Creek was treated as a minor source of recharge.

Groundwater flow in the North and Northwest Models was calibrated to the approximate time-averaged water table during the years 1981 to 1987. More recent water-level data from wells installed subsequent to 1987, however, were incorporated into the average water-table surface. Chemical transport was "calibrated" only in a limited sense in the North Model.

Chemical transport of contaminants within the UAFS was simulated with the calibrated flow model using the advective-dispersive transport portion of the SUTRA code. The models simulated the processes of linear equilibrium sorption and desorption, chemical mass addition due to fluid sources, and mass removal by pumping.

The chemicals dieldrin, DIMP, and chloroform were chosen for transport simulations in the North Model. Dieldrin and chloroform transport simulations were performed in the Northwest Model. Extensive research on the sorption characteristics of these chemicals was conducted in an

effort to choose a realistic range of each contaminant's R value. A range of R values was estimated for each chemical based upon a variety of factors that potentially affect sorption of organic contaminants at RMA. Actual observations of plume movement at RMA were generally believed to provide the most realistic estimates of retardation factors and were preferred over laboratory studies and methods based on regression equations.

Chemical transport simulations were performed using dieldrin, DIMP, and chloroform to evaluate the effects of current remedial actions (i.e., the NBCS and NWBCS), as well as potential additional remedial actions (Alternative Nos. N-4, N-5, and N-6). Transport simulation results were compared on the basis of maximum concentration versus time plots. Simulations were conducted using the most recent plume configuration interpretations based on Fall 1989, 1990, and 1991 data as presented in the Proposed Final Offpost RI Addendum Report (HLA, 1992). Simulations were carried out for a period of 30 years.

For the North Model, the following remedial action scenarios were simulated: (1) Continued Operation of the NBCS With Improvements As Necessary (Alternative Nos. N-2), (2) IRA A (Alternative No. N-4), (3) Expansion 1 to IRA A (Alternative No. N-5), and (4) Expansion 2 to IRA A (Alternative No. N-6). The results of these simulations were evaluated on the basis of simulated cleanup times measured on the maximum concentration versus time graphs. The approximate time to cleanup was calculated based upon the PRGs for DIMP, chloroform, and dieldrin presented in Volume V, Table 2.4.3.3-1.

Simulations performed for the North Model show generally decreasing timeframes for attainment of PRGs with increasing complexity of remedial components (Alternative No. N-2 to Alternative No. N-6). Of the three contaminants simulated, remediation times for DIMP are the quickest, while remediation times for dieldrin are the slowest. This difference appears to be related to the lower range of retardation factors for DIMP relative to dieldrin.

For the northwest model, two scenarios were simulated: (1) Continued Operation of the NWBCS With Improvements As Necessary (Alternative No. NW-2) and (2) Northwest Plume Group Extraction/Recharge System (Alternative No. NW-4). Results for chloroform under

Alternative No. NW-2 indicate that maximum concentrations remain close to the average NWBCS effluent concentration of 13.8 μg/l, which is below the chloroform PRG. Results from simulations of Alternative Nos. NW-2 and NW-4 indicate that remediation times for dieldrin decrease from maximums of approximately eight years under Alternative No. NW-2 to five years under Alternative No. NW-4.

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Table E1: Estimated Retardation Factors for DIMP

Geometric Mean Hydraulic Conductivity	=	195 feet/day
Hydraulic Gradient	=	0.0050 - 0.0053
Effective Porosity	=	30 - 35%
Average Linear Velocity, v_w	=	2.78 - 3.38 feet/day
Contaminant Travel Distance	=	14,000 feet
Travel Time	=	22 - 26 years
Average Contaminant Velocity, v_c	=	1.48 - 1.74 feet/day
Retardation Factor, R	=	1.6 - 2.3

Table E2: Estimated Retardation Factors for Dieldrin

Geometric Mean Hydraulic Conductivity	=	275 feet/day
Hydraulic Gradient	=	0.0033 - 0.0043
Effective Porosity	=	30 - 35%
Average Linear Velocity, v_w	=	2.59 - 3.94 feet/day
Contaminant Travel Distance	=	10,500 feet
Travel Time	=	30 - 35 years
Average Contaminant Velocity, v_c	=	0.82 - 0.96 feet/day
Retardation Factor, R	=	2.7 - 4.8

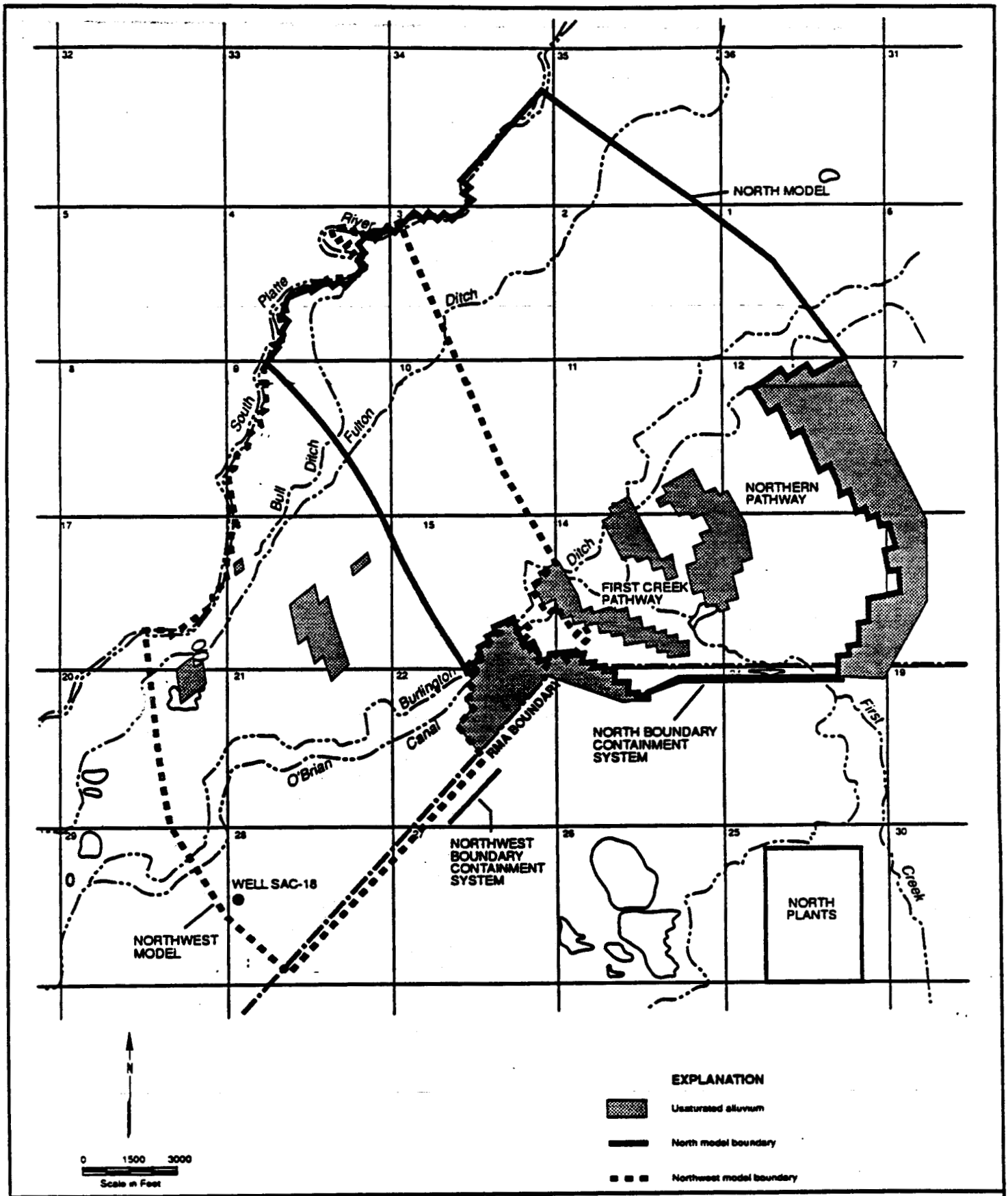

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Figure E1

NORTH AND NORTHWEST MODEL AREAS

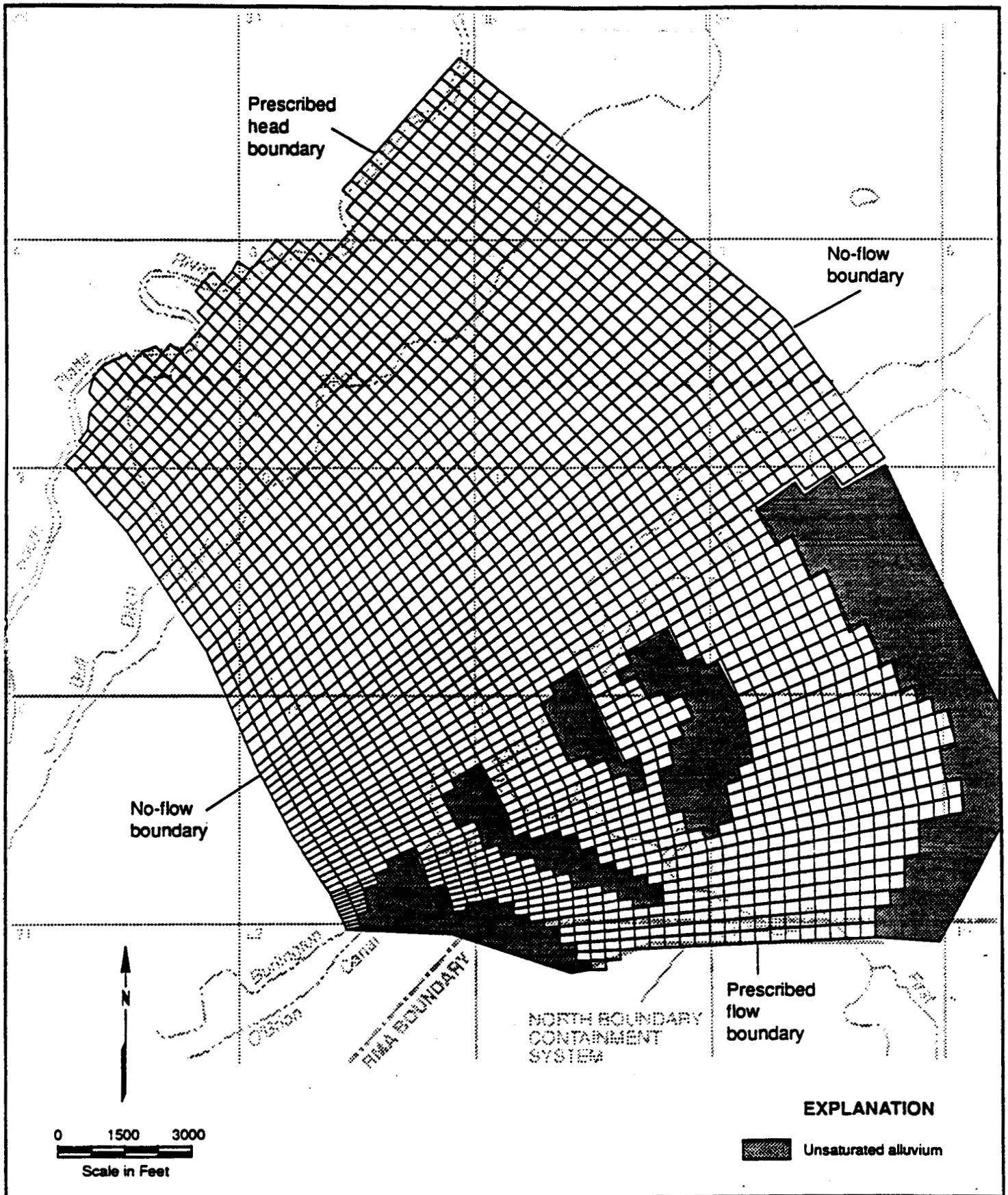

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Figure E2

FINITE ELEMENT MESH AND BOUNDARY CONDITIONS – NORTH MODEL

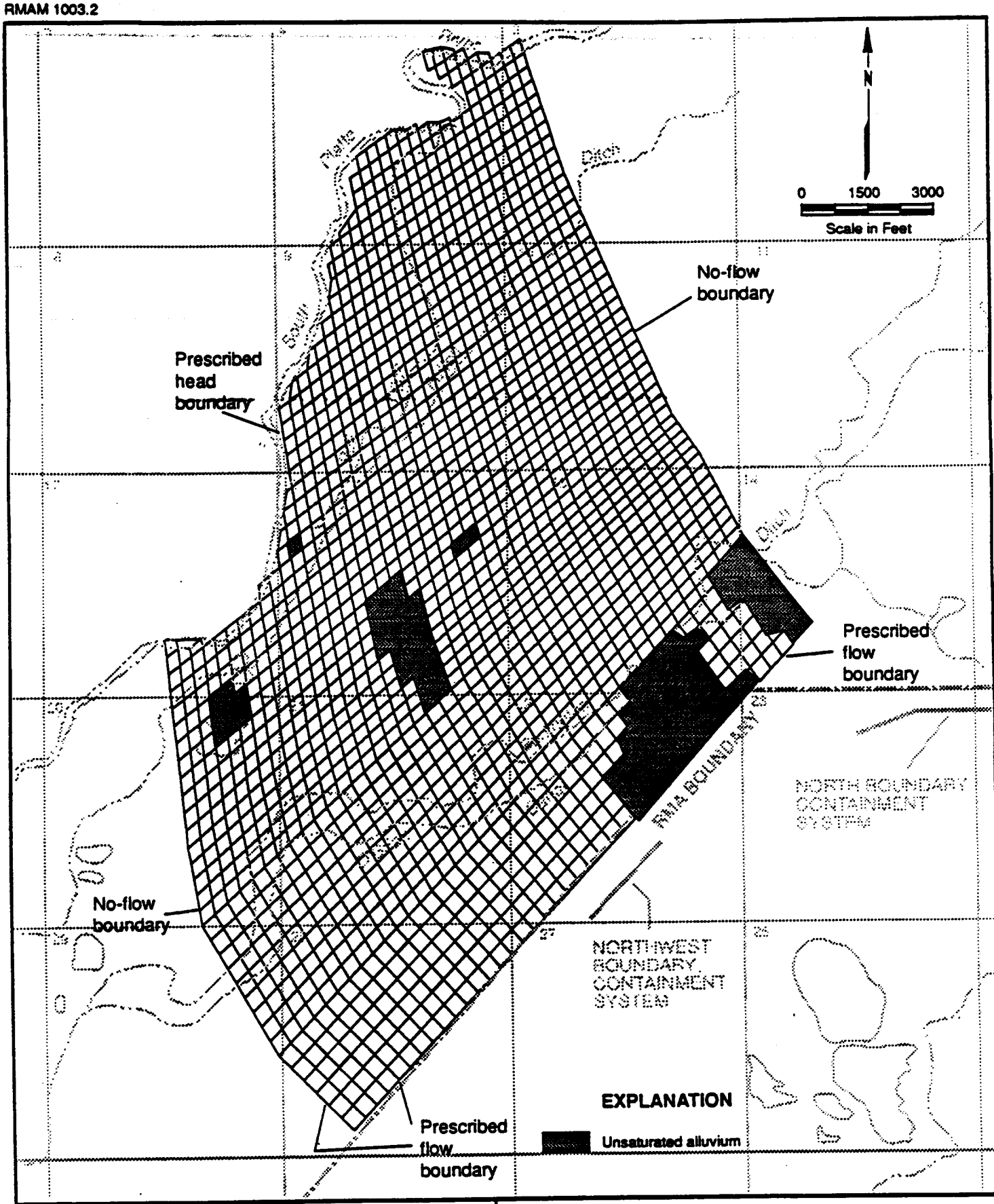

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Figure E3

FINITE ELEMENT MESH AND BOUNDARY CONDITIONS – NORTHWEST MODEL

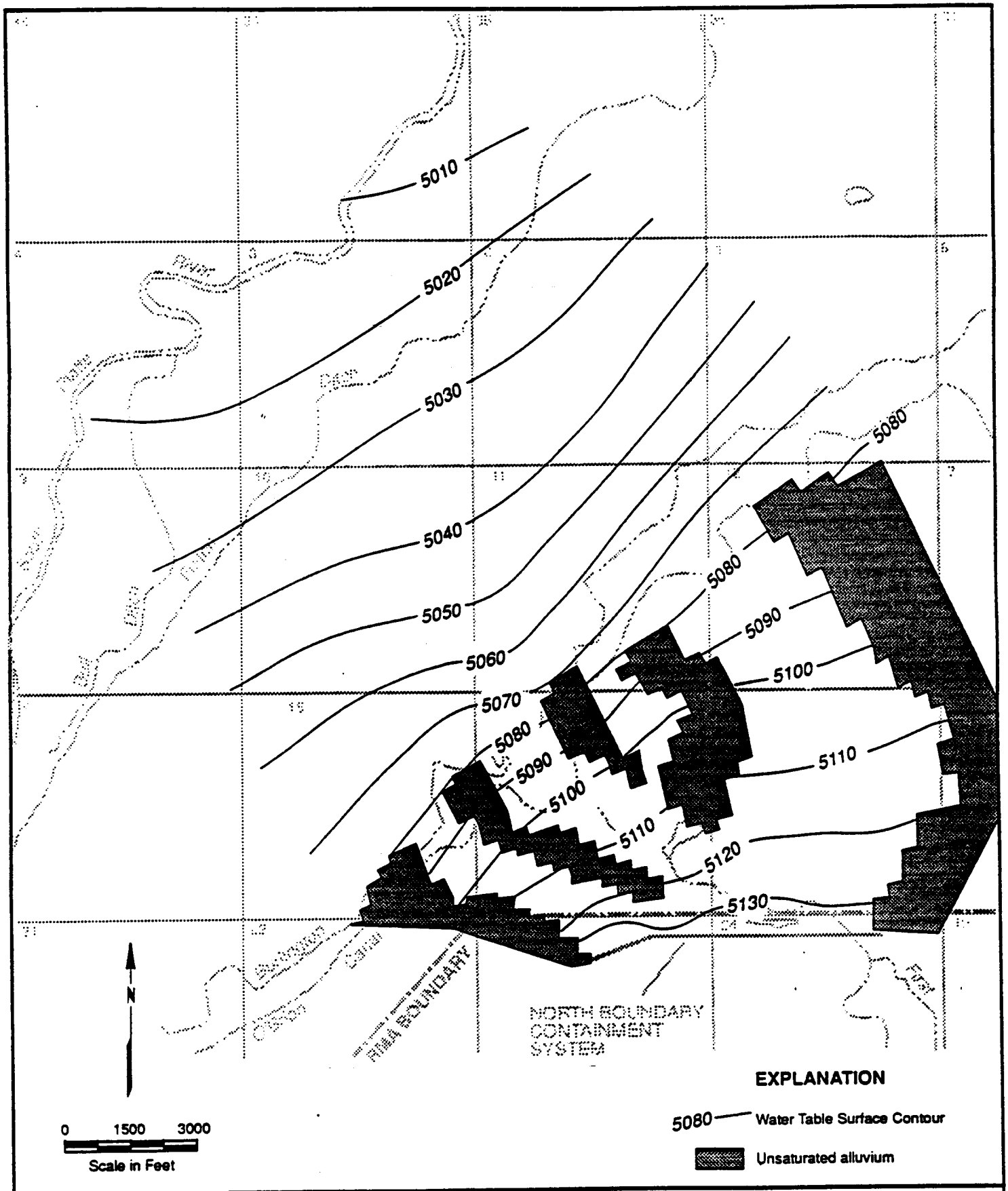

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Figure E4

APPROXIMATE WATER TABLE CONFIGURATION – NORTH MODEL

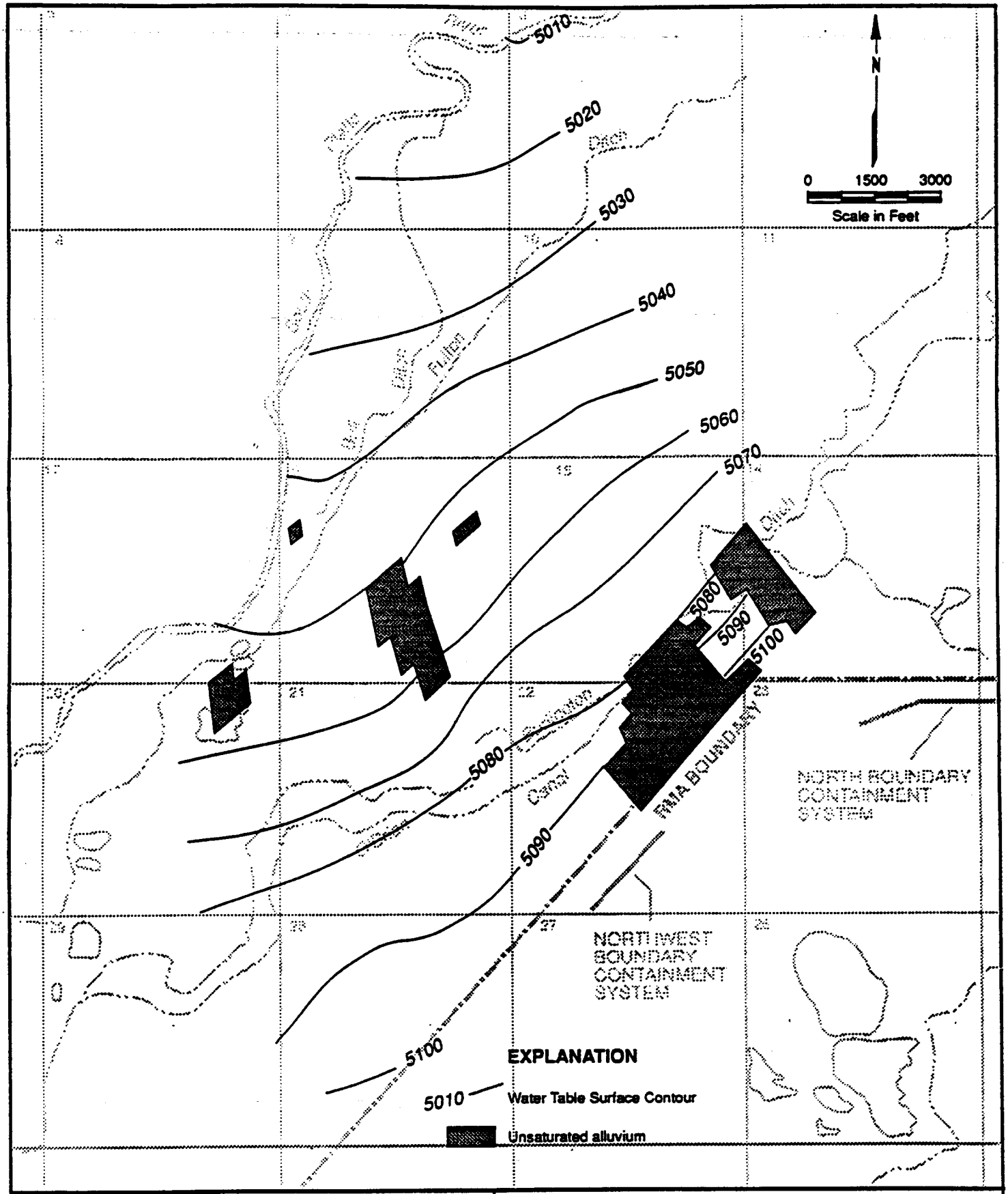

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Figure E5

APPROXIMATE WATER TABLE CONFIGURATION – NORTHWEST MODEL

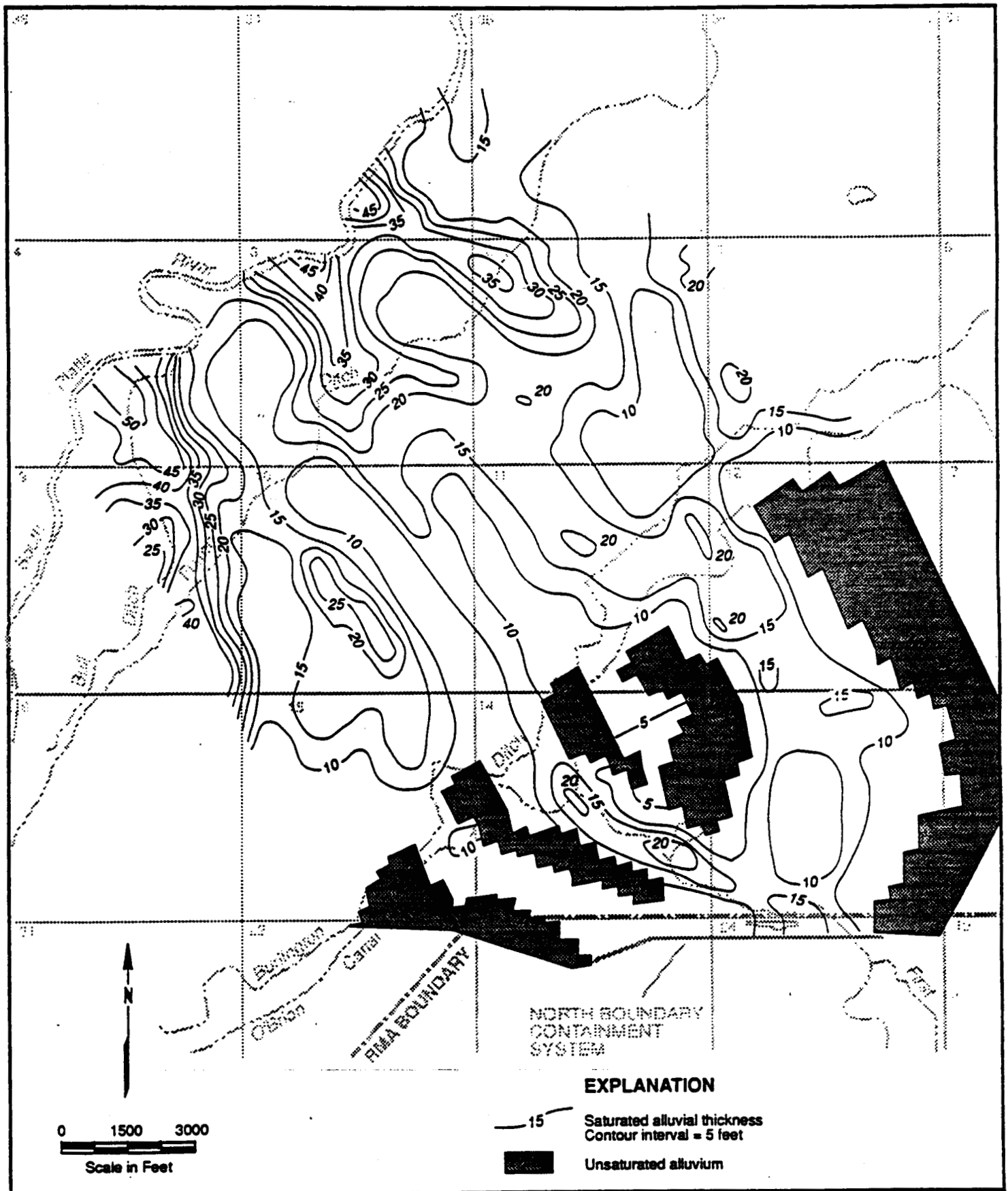

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Figure E6

ALLUVIAL SATURATED THICKNESS – NORTH MODEL

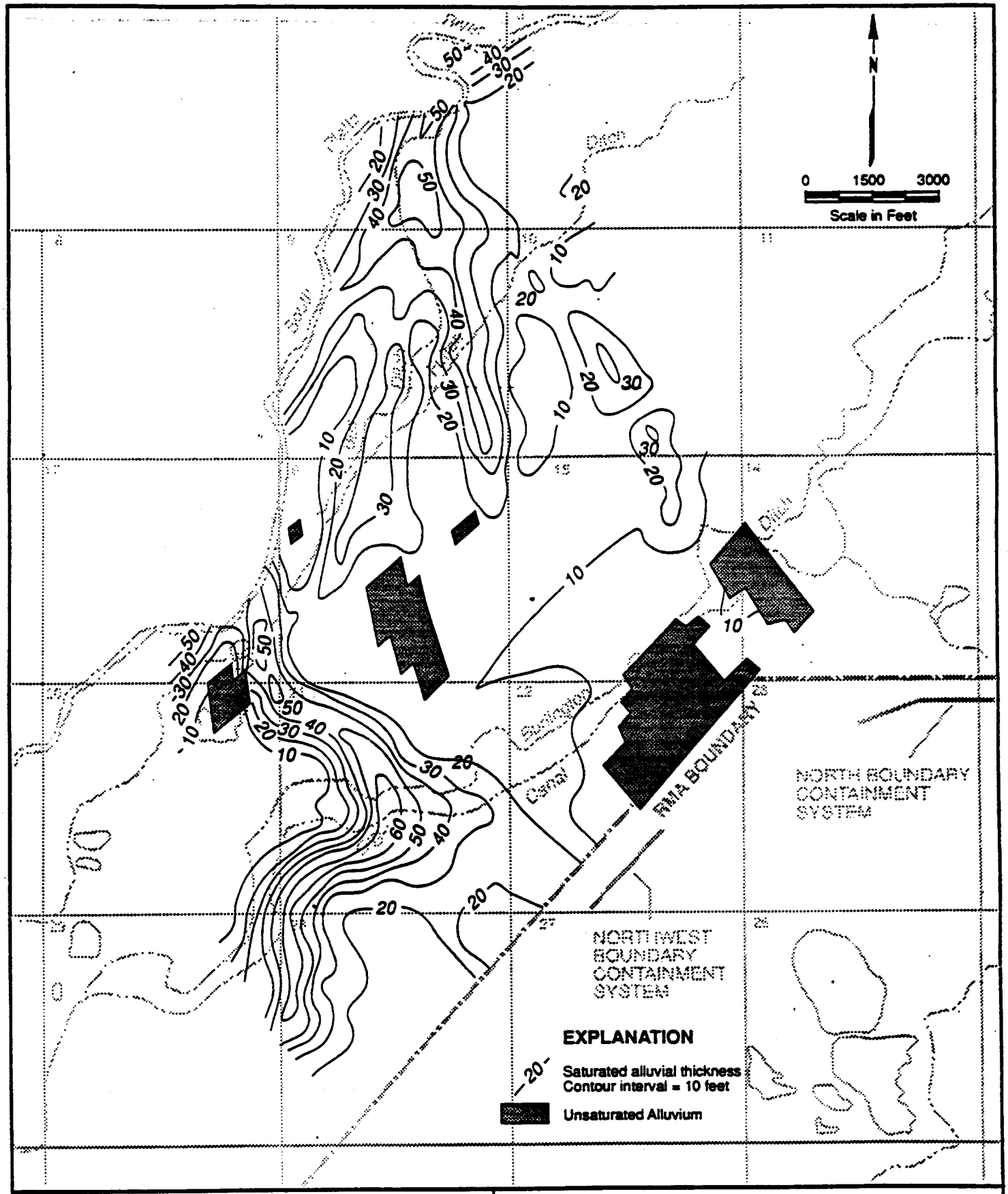

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Figure E7

ALLUVIAL SATURATED THICKNESS – NORTHWEST MODEL

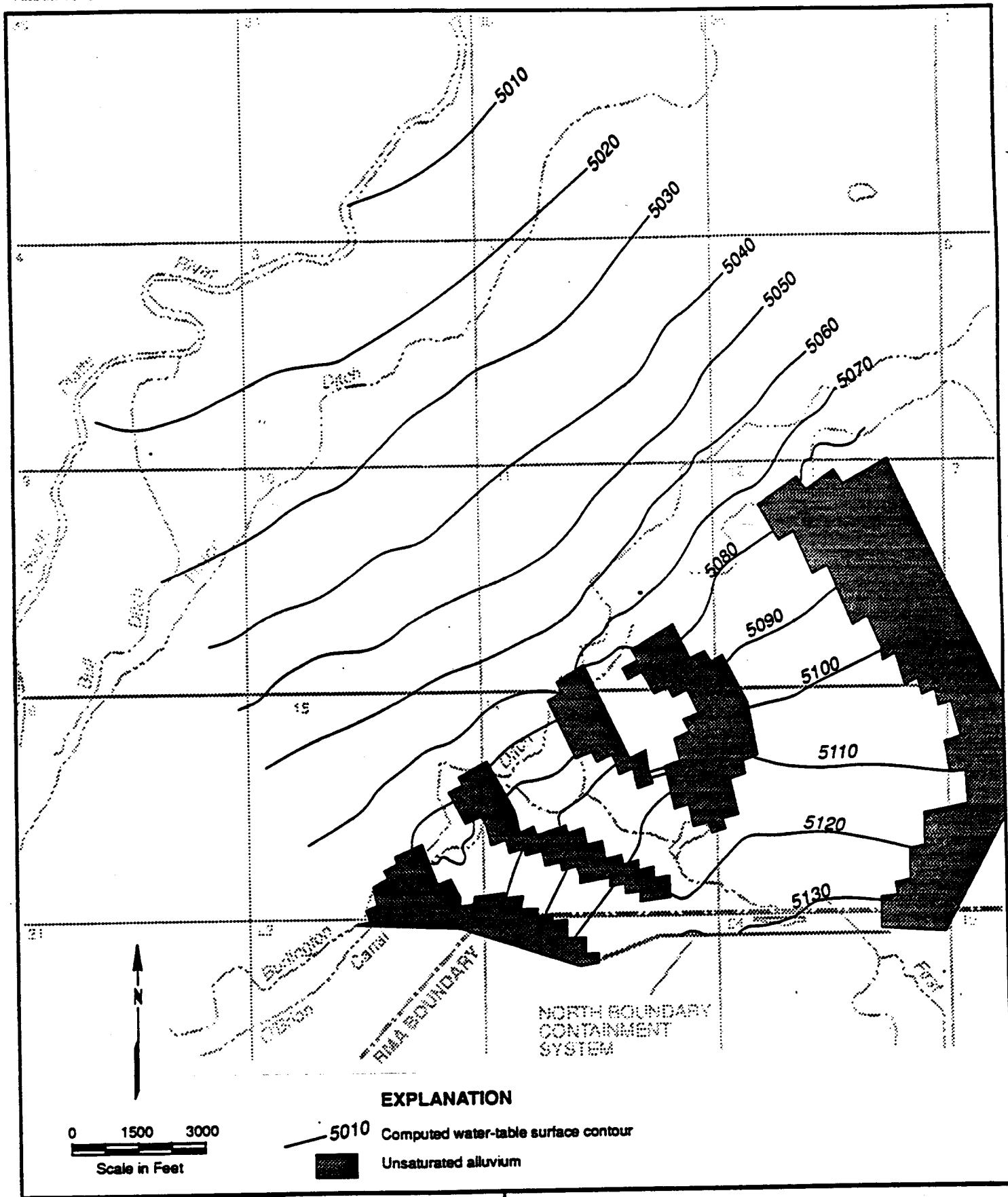

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Figure E8

COMPUTED WATER TABLE – NORTH MODEL

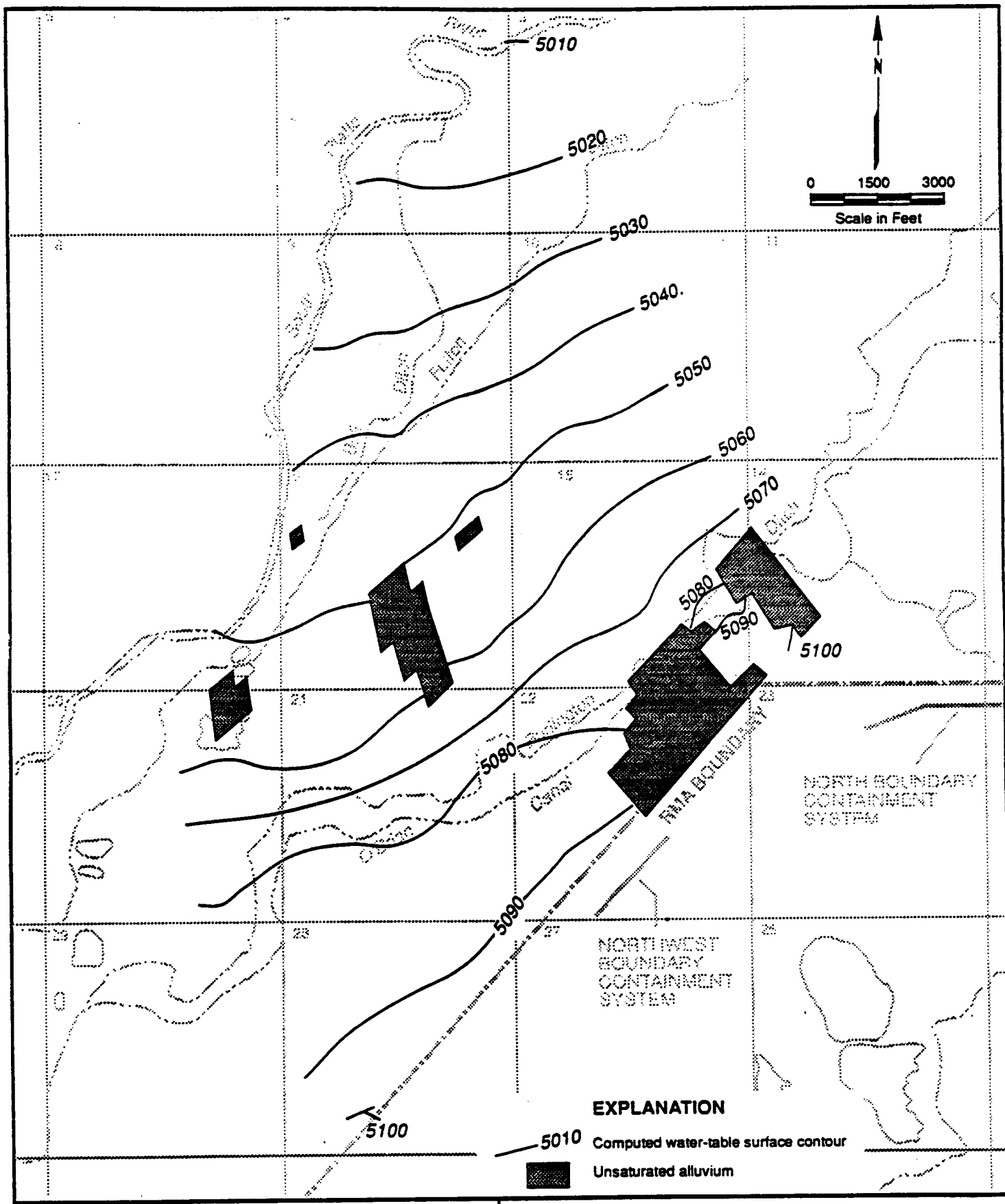

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Figure E9

COMPUTED WATER TABLE – NORTHWEST MODEL

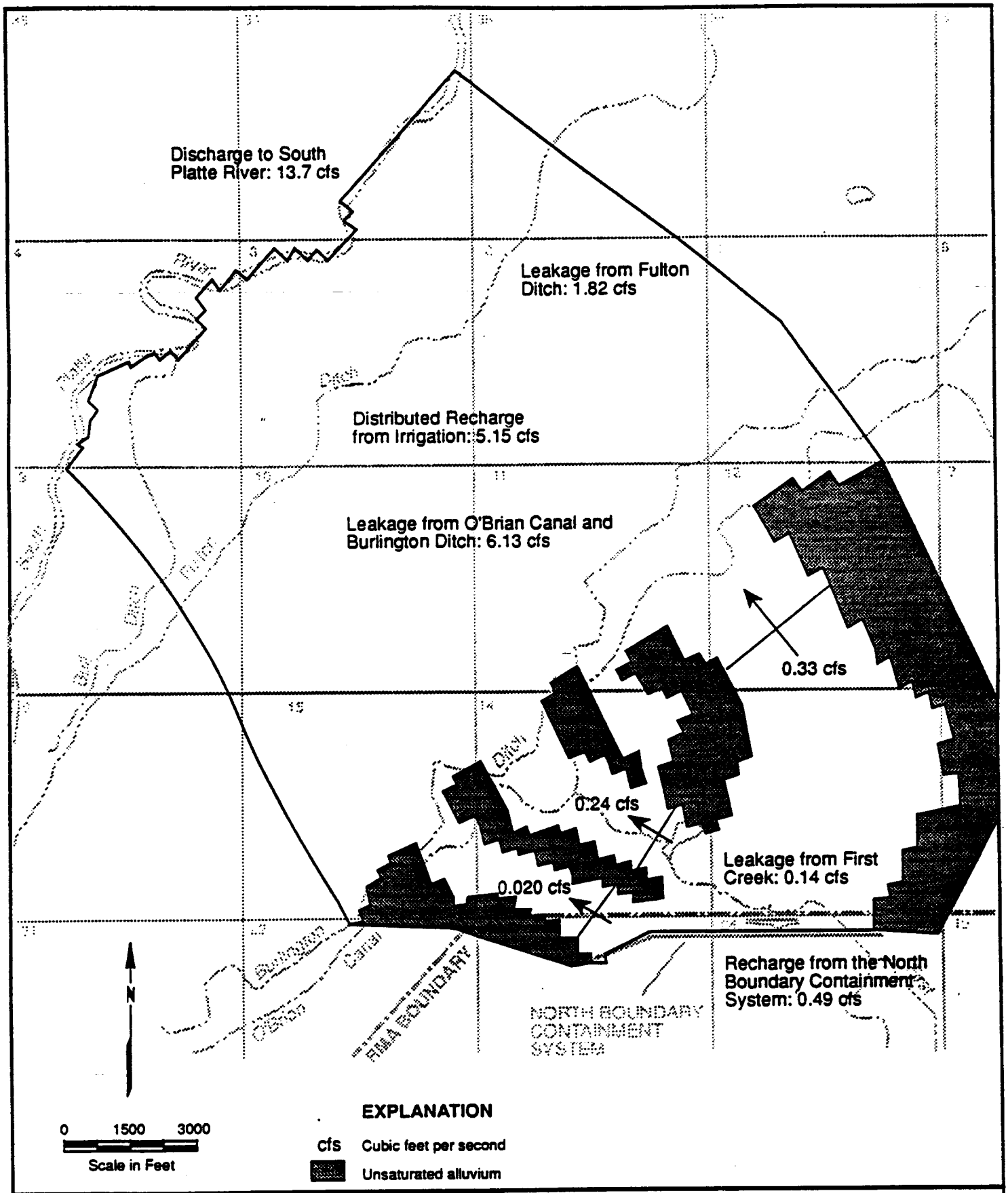

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Figure E10

WATER BUDGET – NORTH MODEL

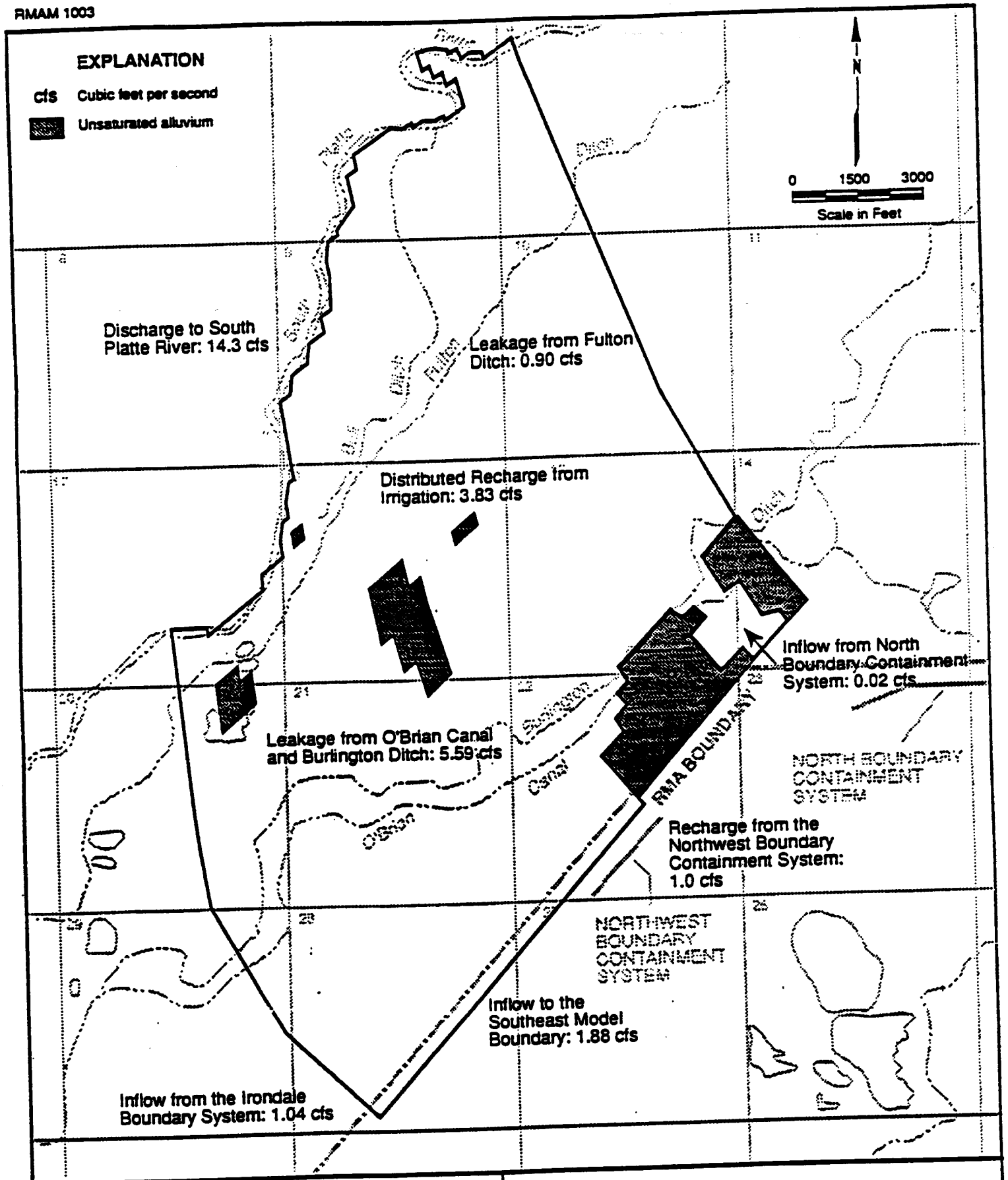

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Figure E11

WATER BUDGET – NORTHWEST MODEL

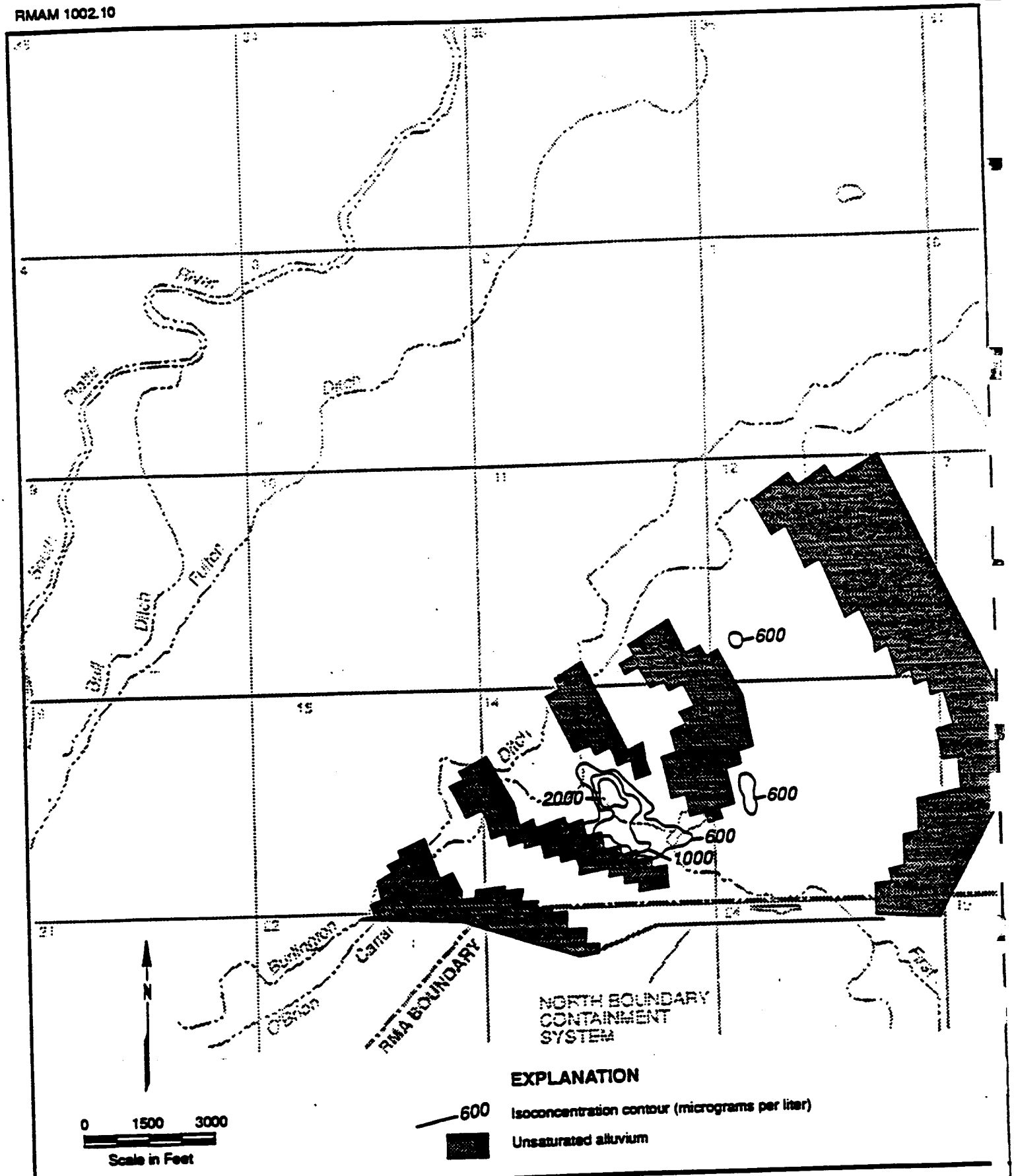

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Figure E12

DIMP INITIAL CONDITIONS – NORTH MODEL

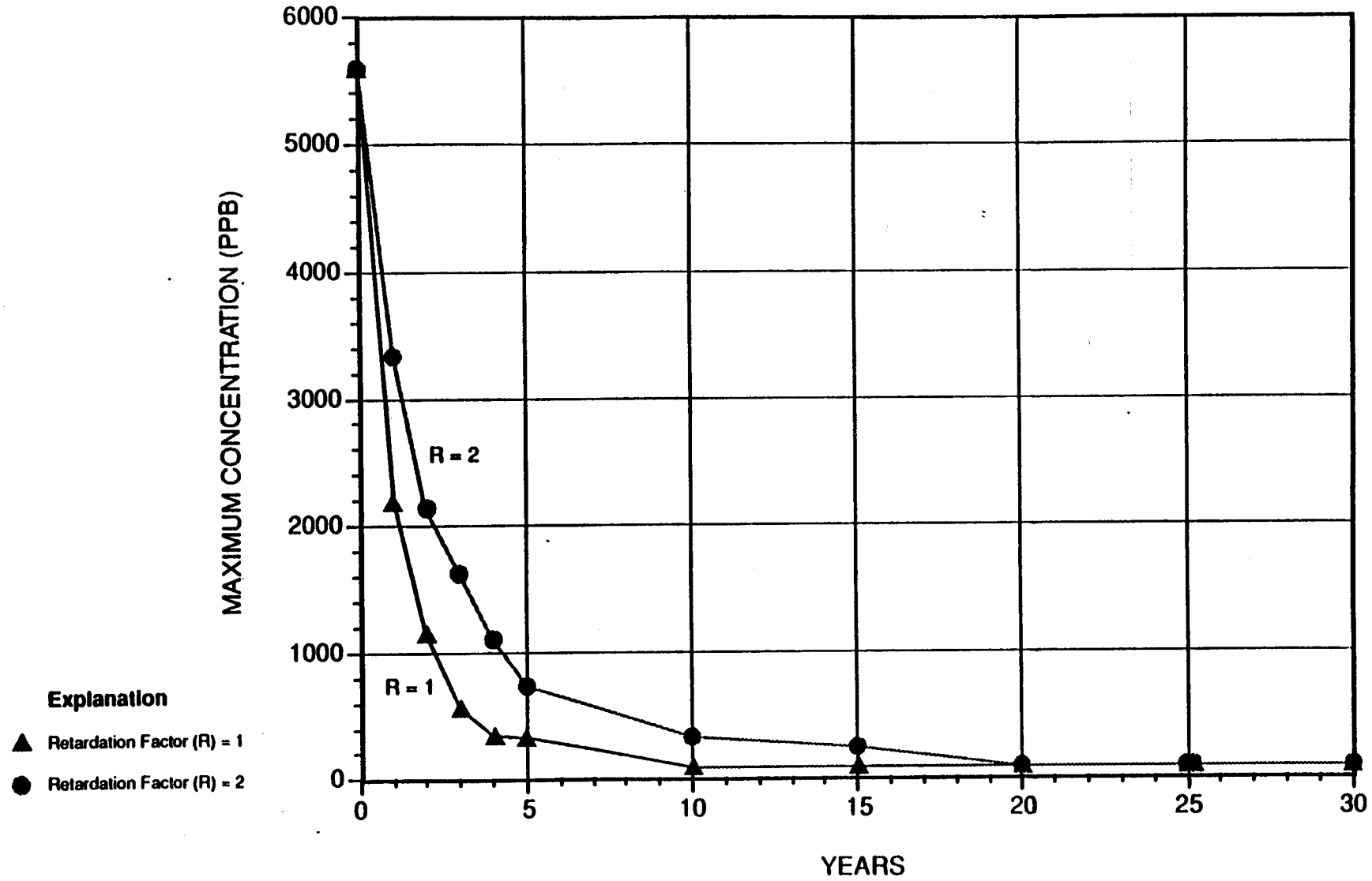

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Figure E13

ALTERNATIVE NO. N-2:
SIMULATED MAXIMUM DIMP CONCENTRATION
VERSUS TIME – NORTH MODEL

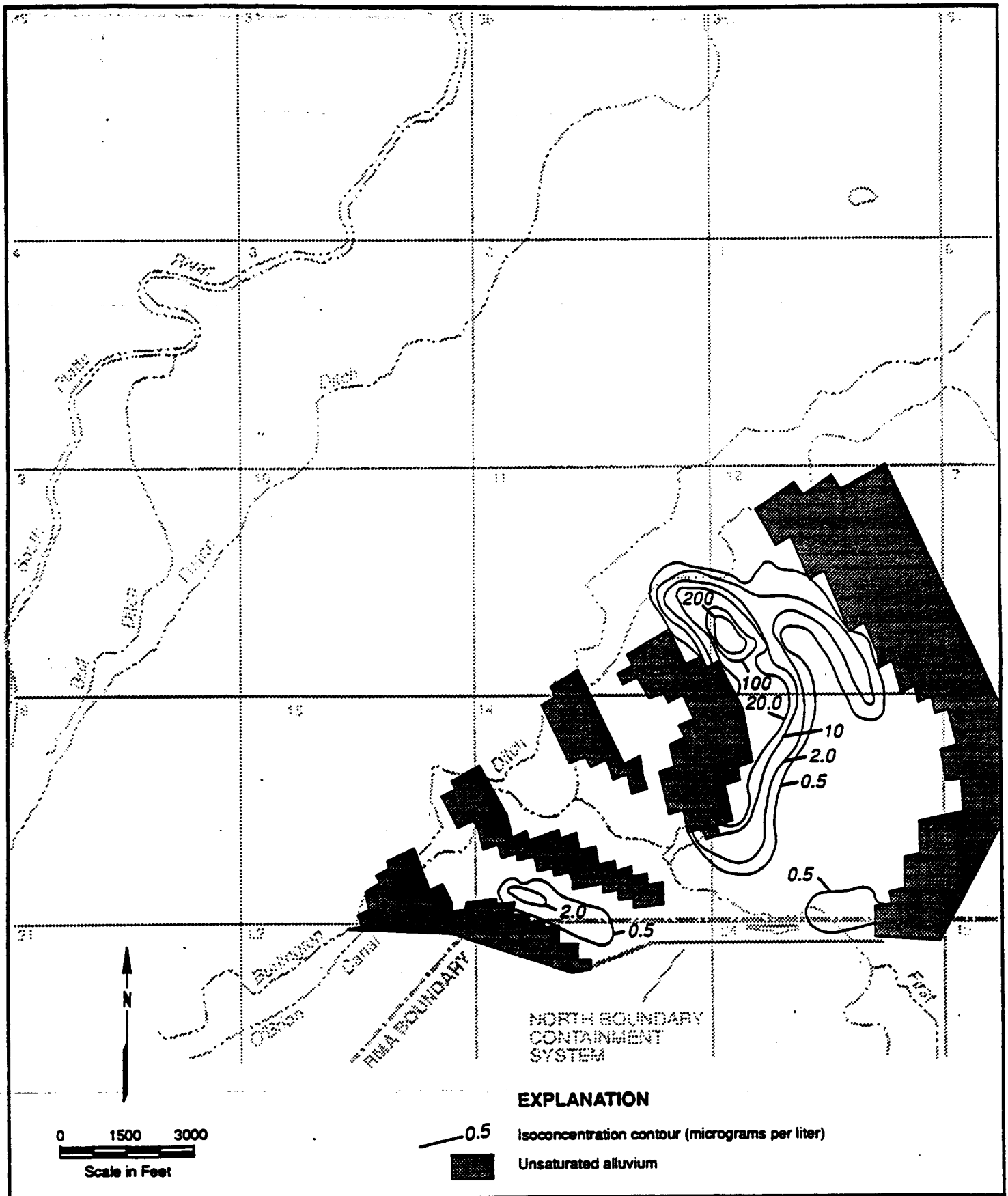

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Figure E14

CHLOROFORM, INITIAL CONDITIONS – NORTH MODEL

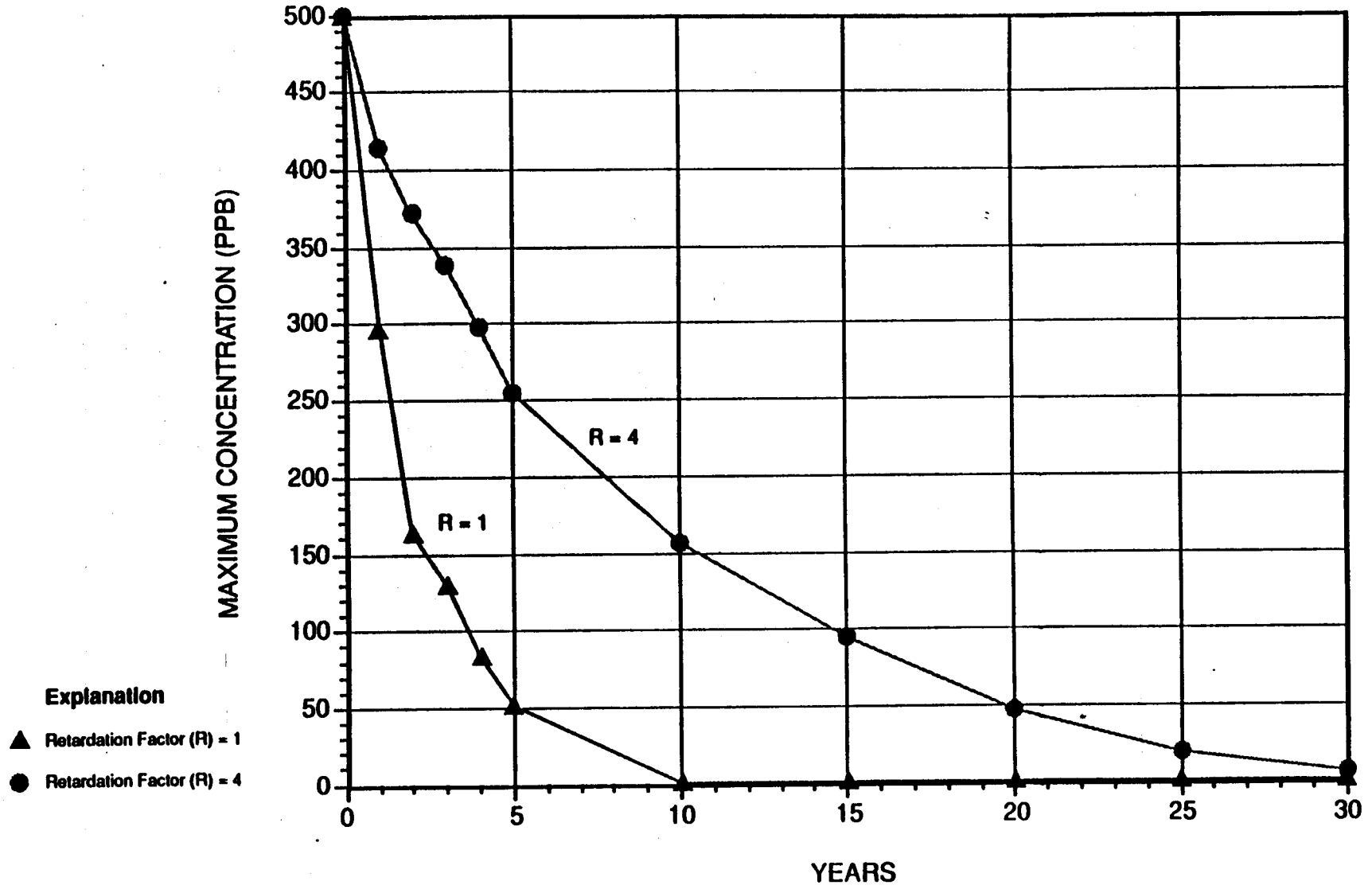

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Figure E15

ALTERNATIVE NO. N-2:
SIMULATED MAXIMUM CHLOROFORM CONCENTRATION VERSUS TIME – NORTH MODEL

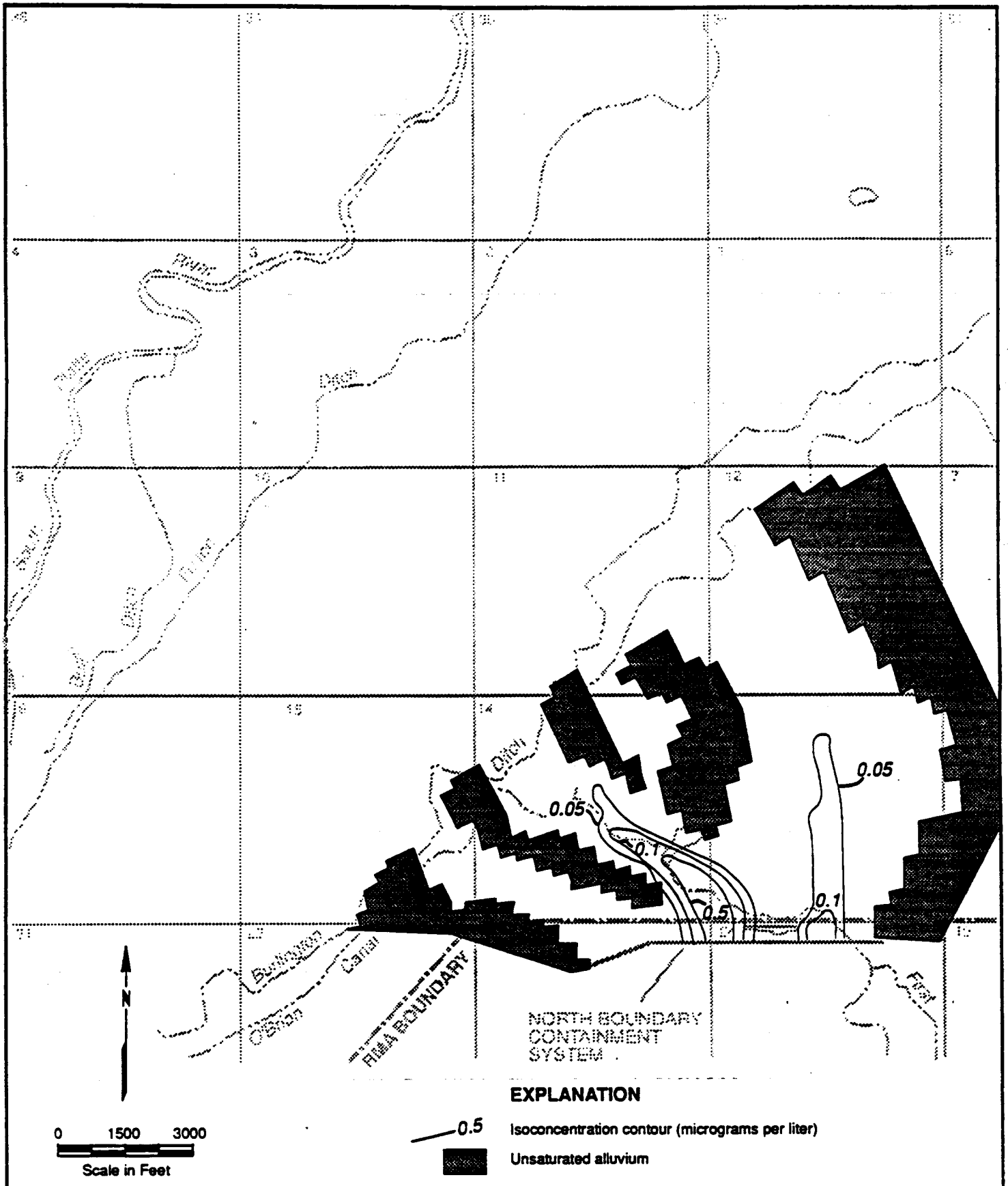

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Figure E16

DIELDRIN INITIAL CONDITIONS – NORTH MODEL

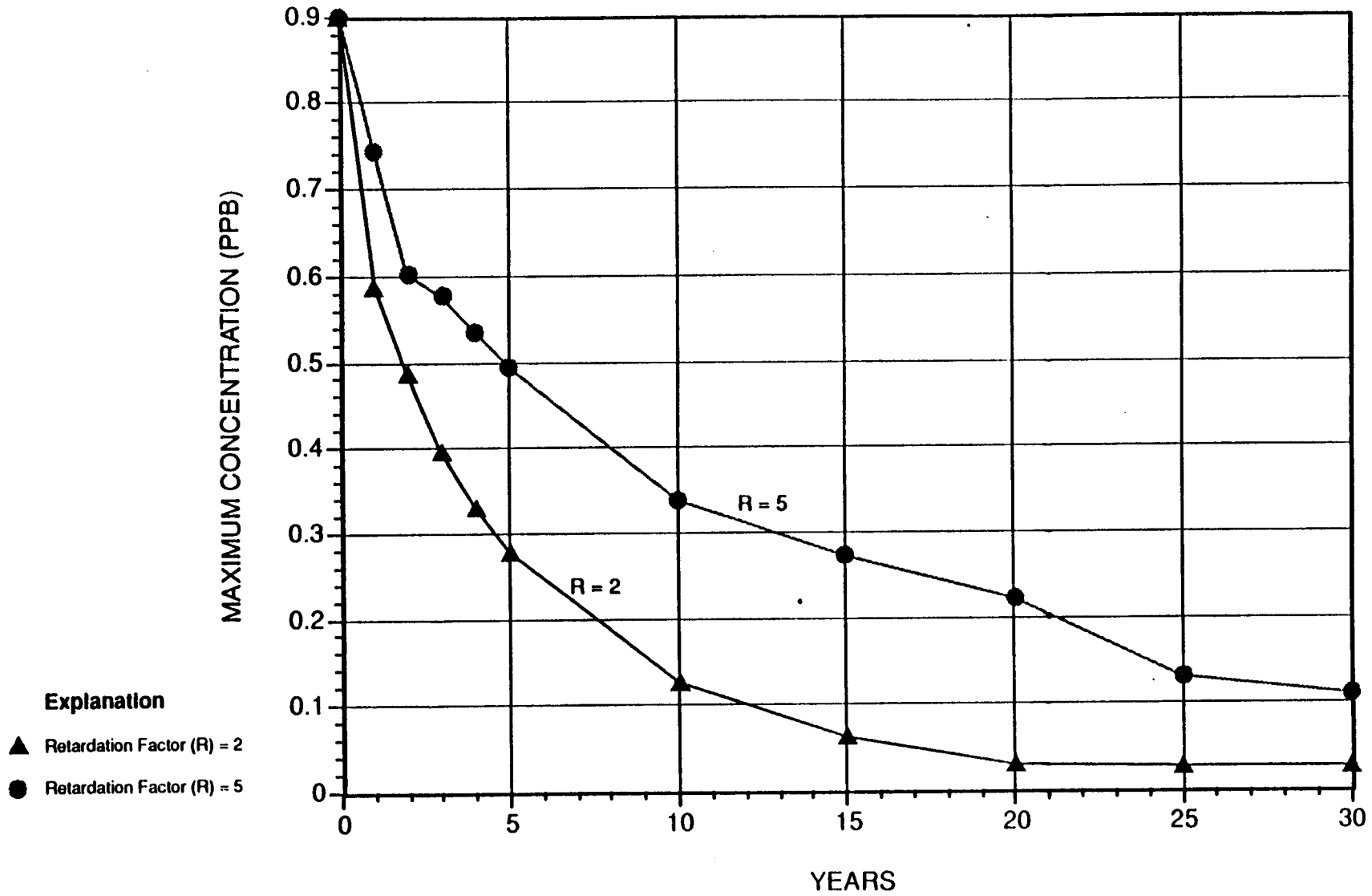

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Figure E17

ALTERNATIVE NO. N-2:
SIMULATED MAXIMUM DIELDRIN CONCENTRATION
VERSUS TIME – NORTH MODEL

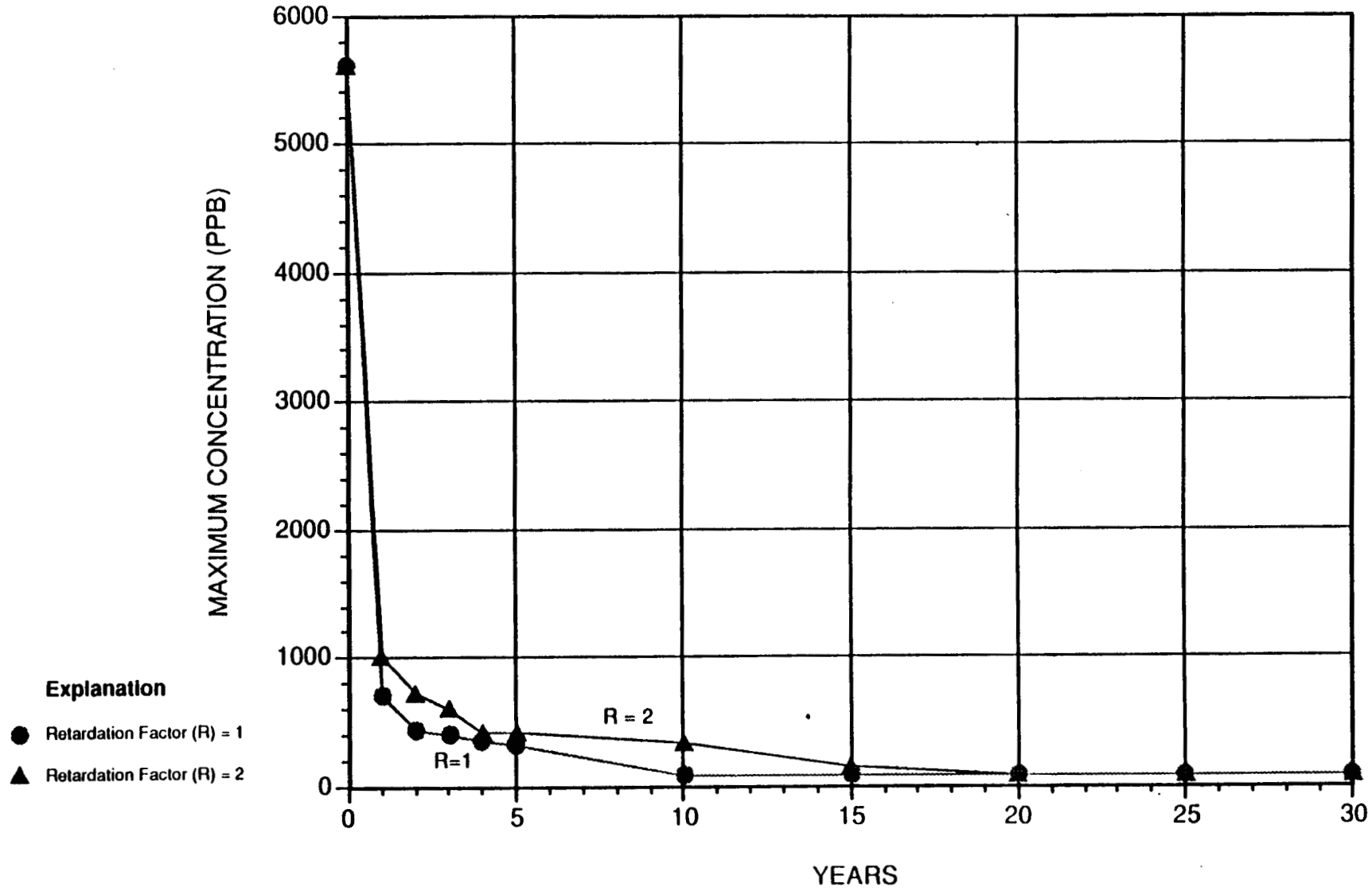

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Figure E18

ALTERNATIVE NO. N-4:
SIMULATED MAXIMUM DIMP CONCENTRATION
VERSUS TIME – NORTH MODEL

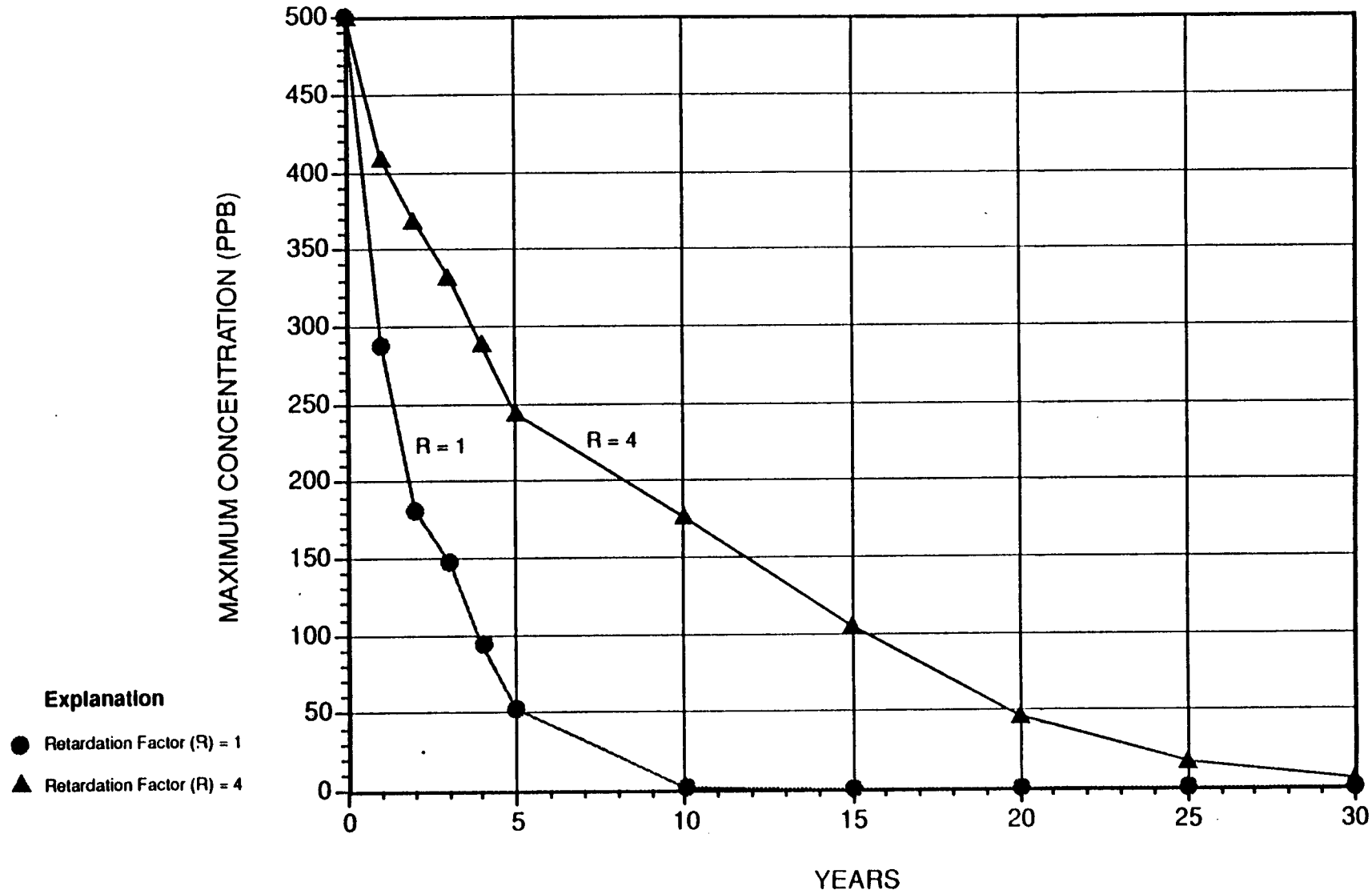

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Figure E19

ALTERNATIVE NO. N-4:
SIMULATED MAXIMUM CHLOROFORM CONCENTRATION
VERSUS TIME – NORTH MODEL

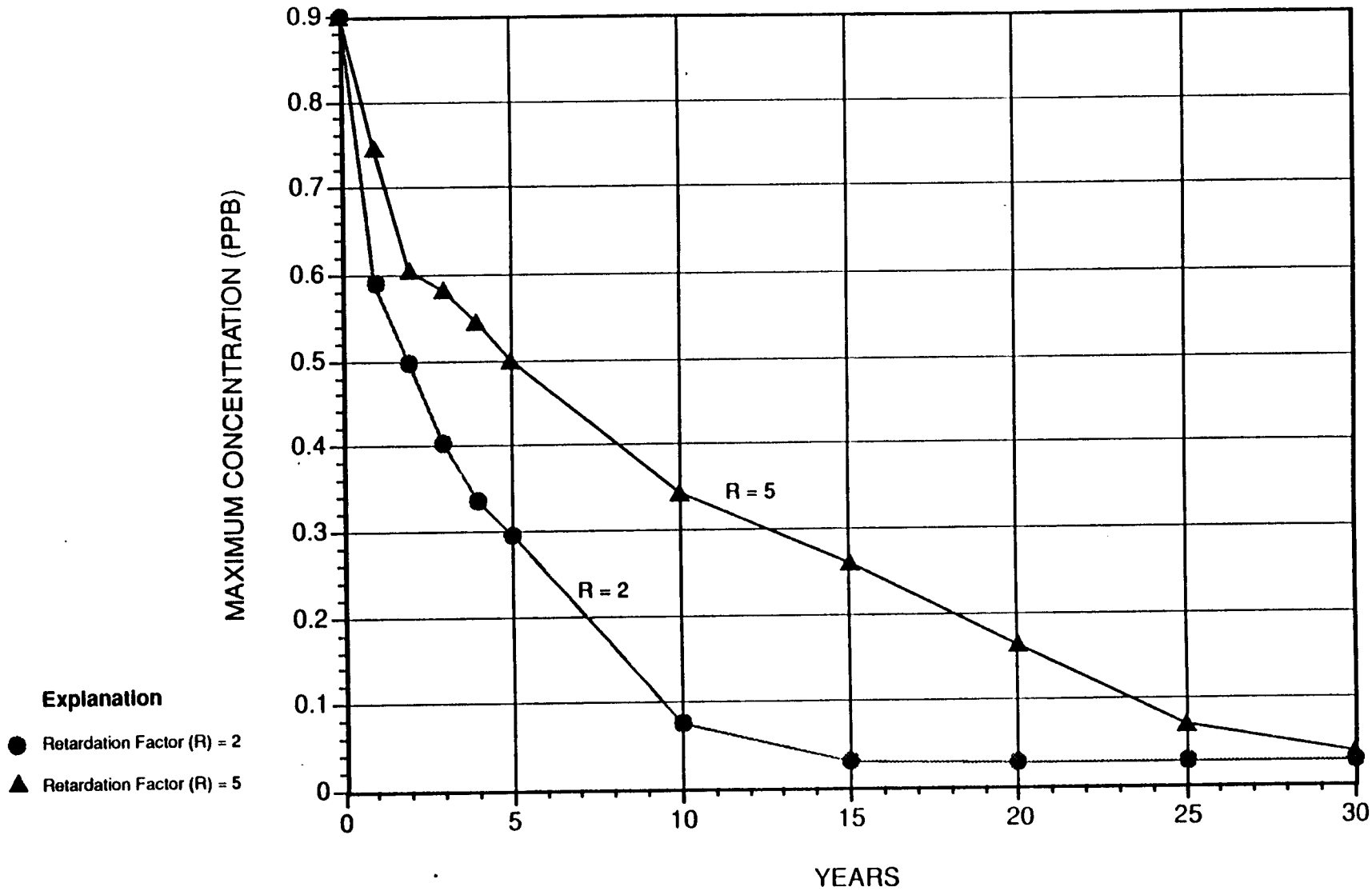

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Figure E20

ALTERNATIVE NO. N-4:
SIMULATED MAXIMUM DIELDRIN CONCENTRATION
VERSUS TIME – NORTH MODEL

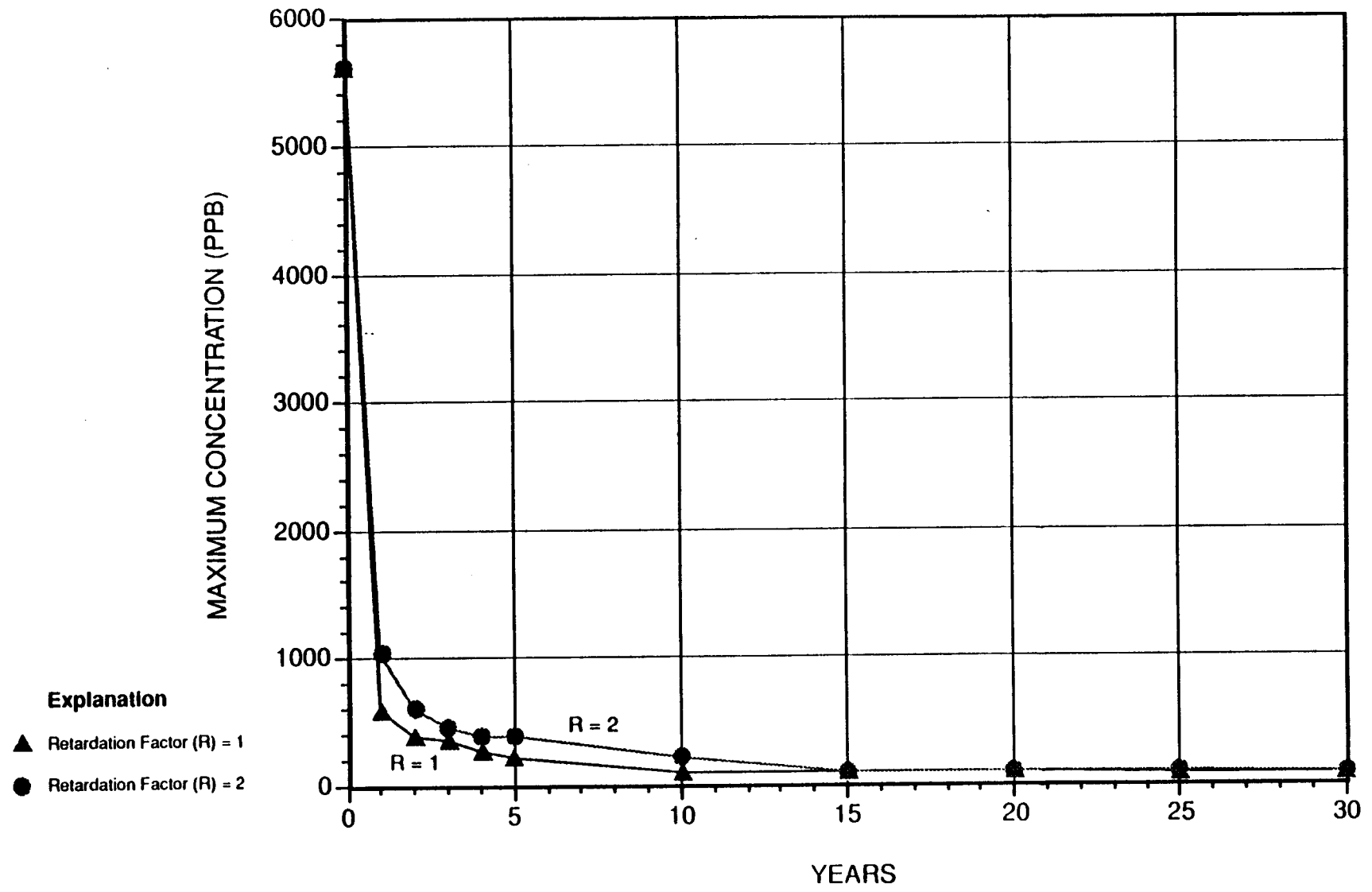

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Figure E21

ALTERNATIVE NO. N-5:
SIMULATED MAXIMUM DIMP CONCENTRATION
VERSUS TIME – NORTH MODEL

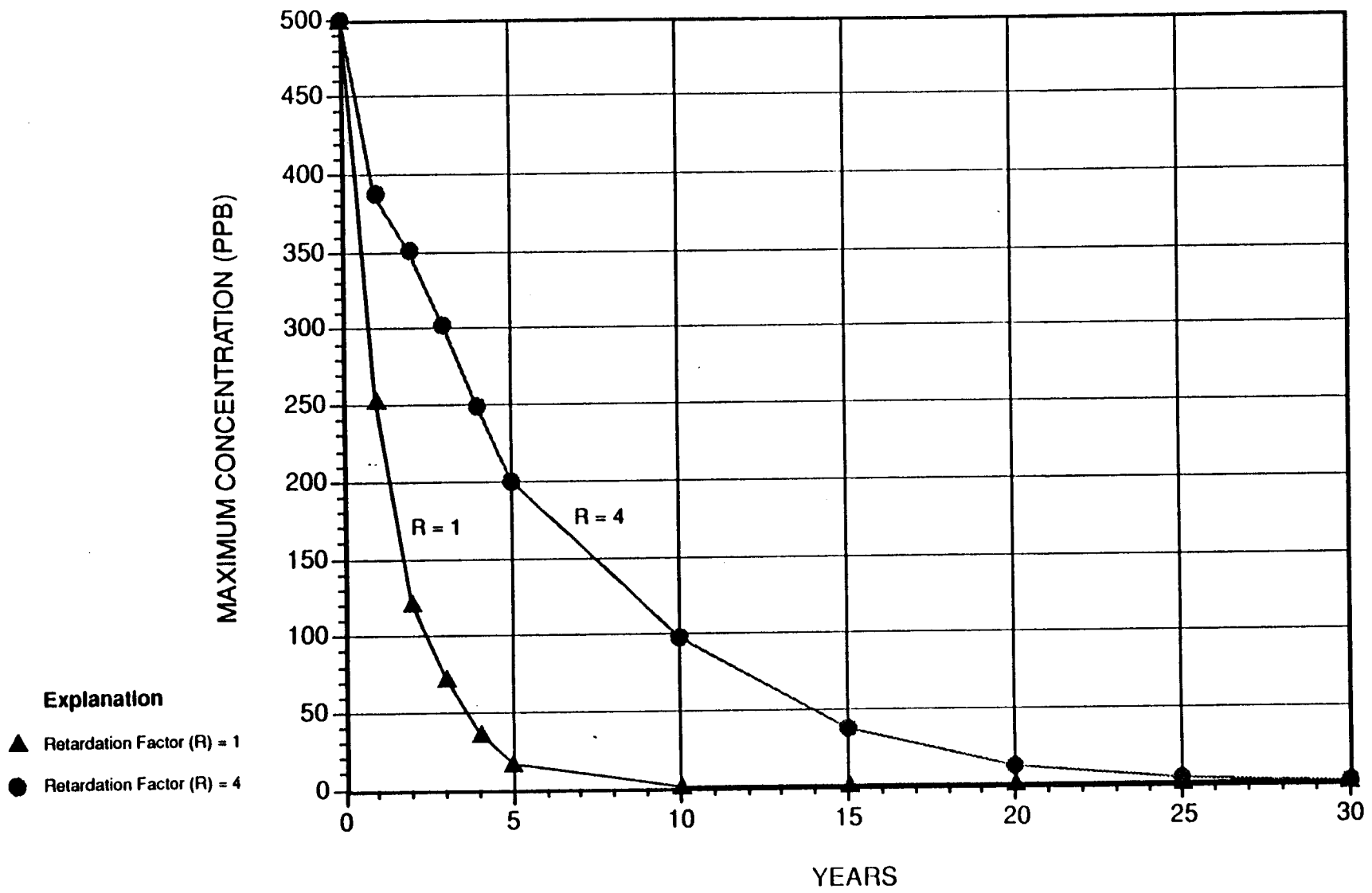

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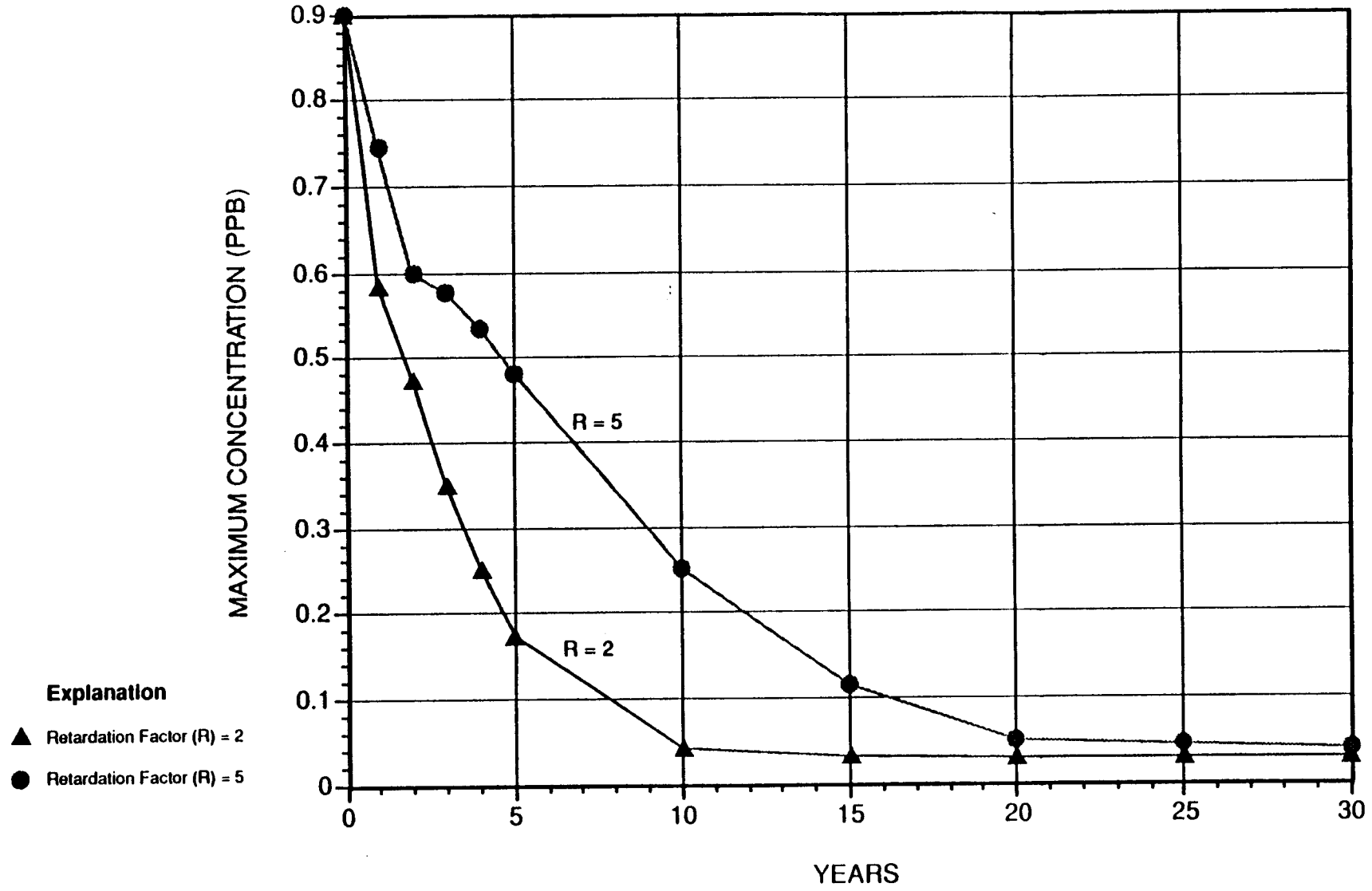
Figure E22

ALTERNATIVE NO. N-5:
SIMULATED MAXIMUM CHLOROFORM CONCENTRATION
VERSUS TIME – NORTH MODEL

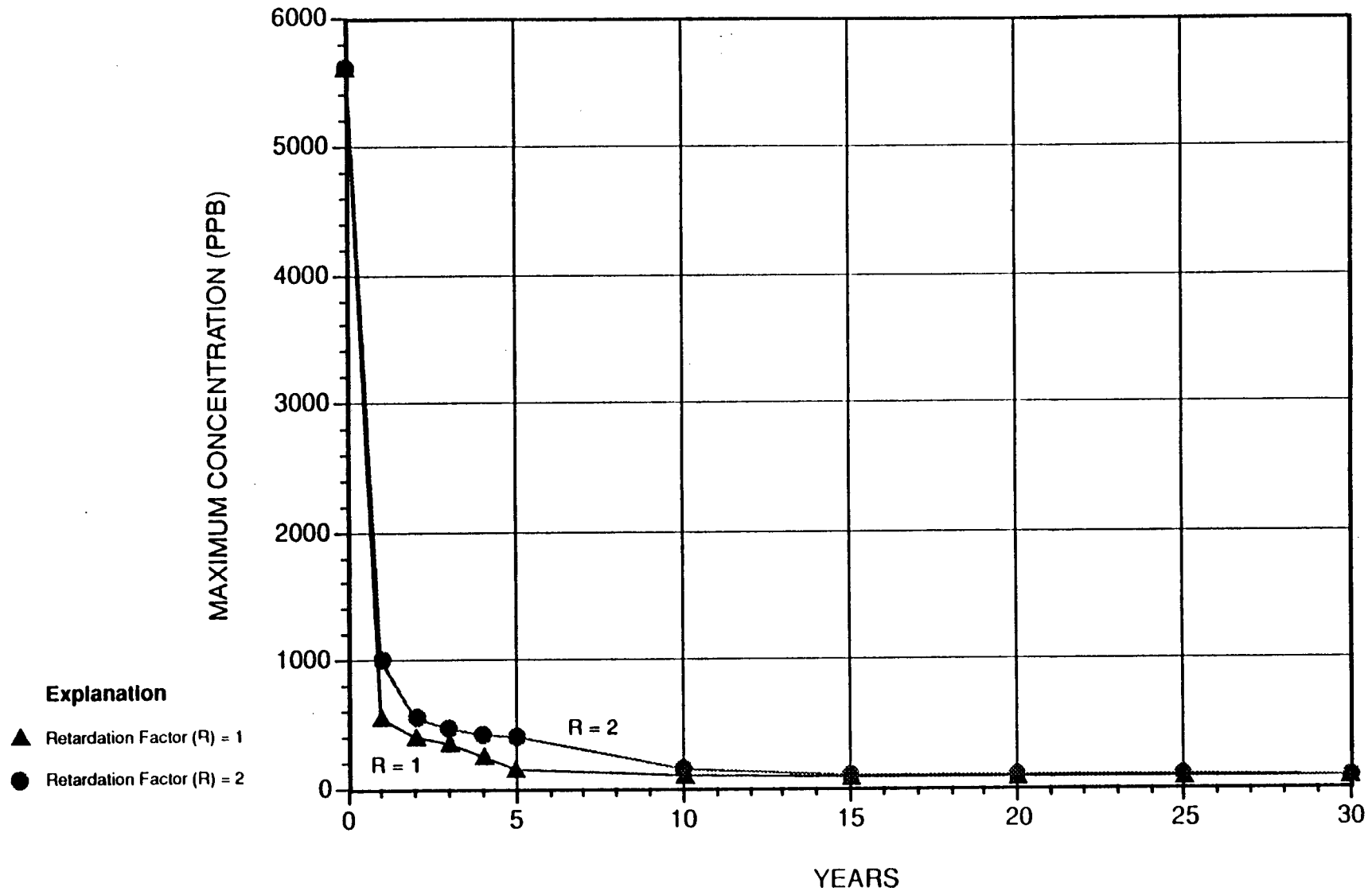


Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure E23

ALTERNATIVE NO. N-5:
SIMULATED MAXIMUM DIELDRIN CONCENTRATION
VERSUS TIME – NORTH MODEL

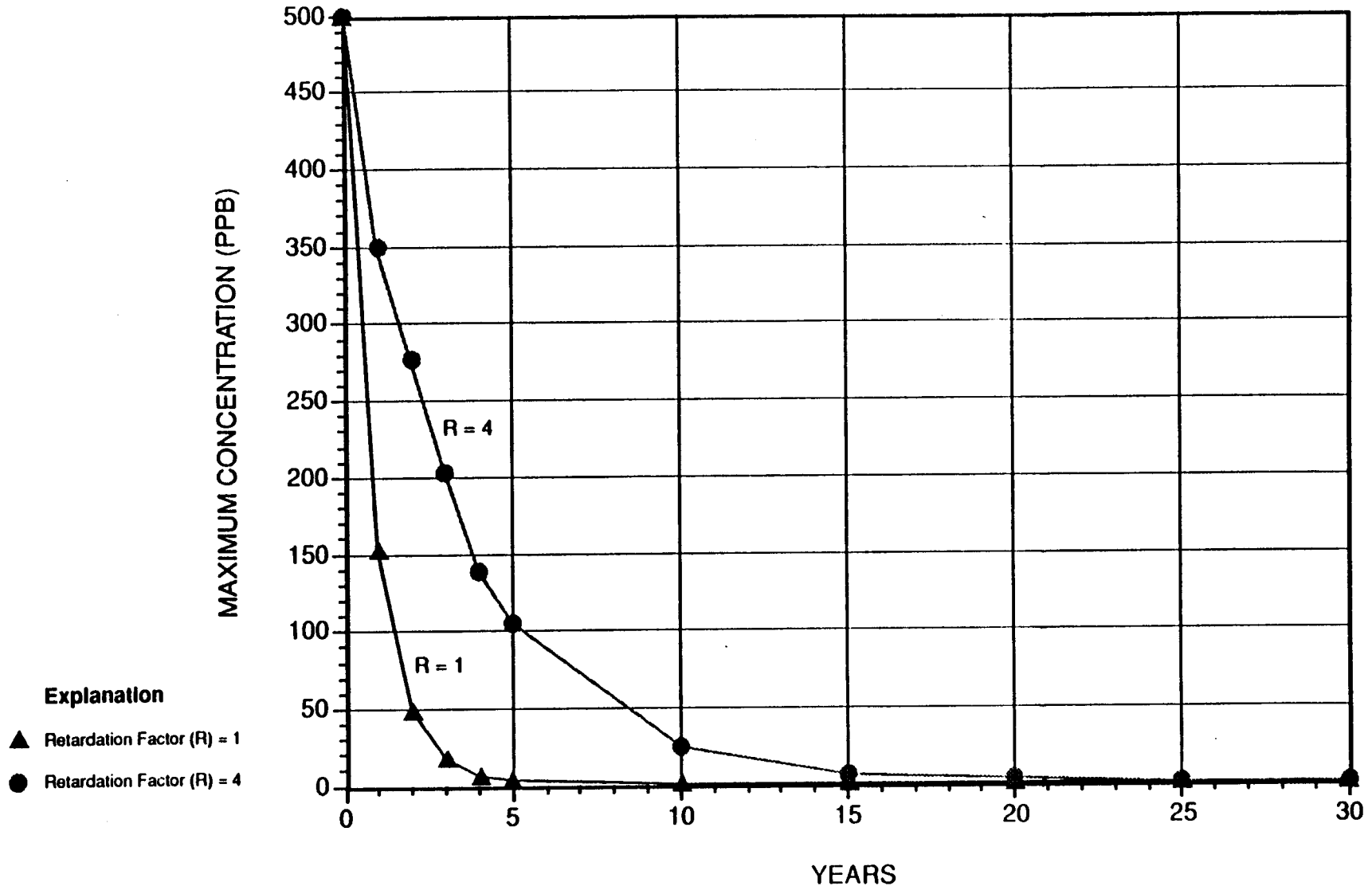


Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure E24

ALTENATIVE NO. N-6:
SIMULATED MAXIMUM DIMP CONCENTRATION
VERSUS TIME – NORTH MODEL



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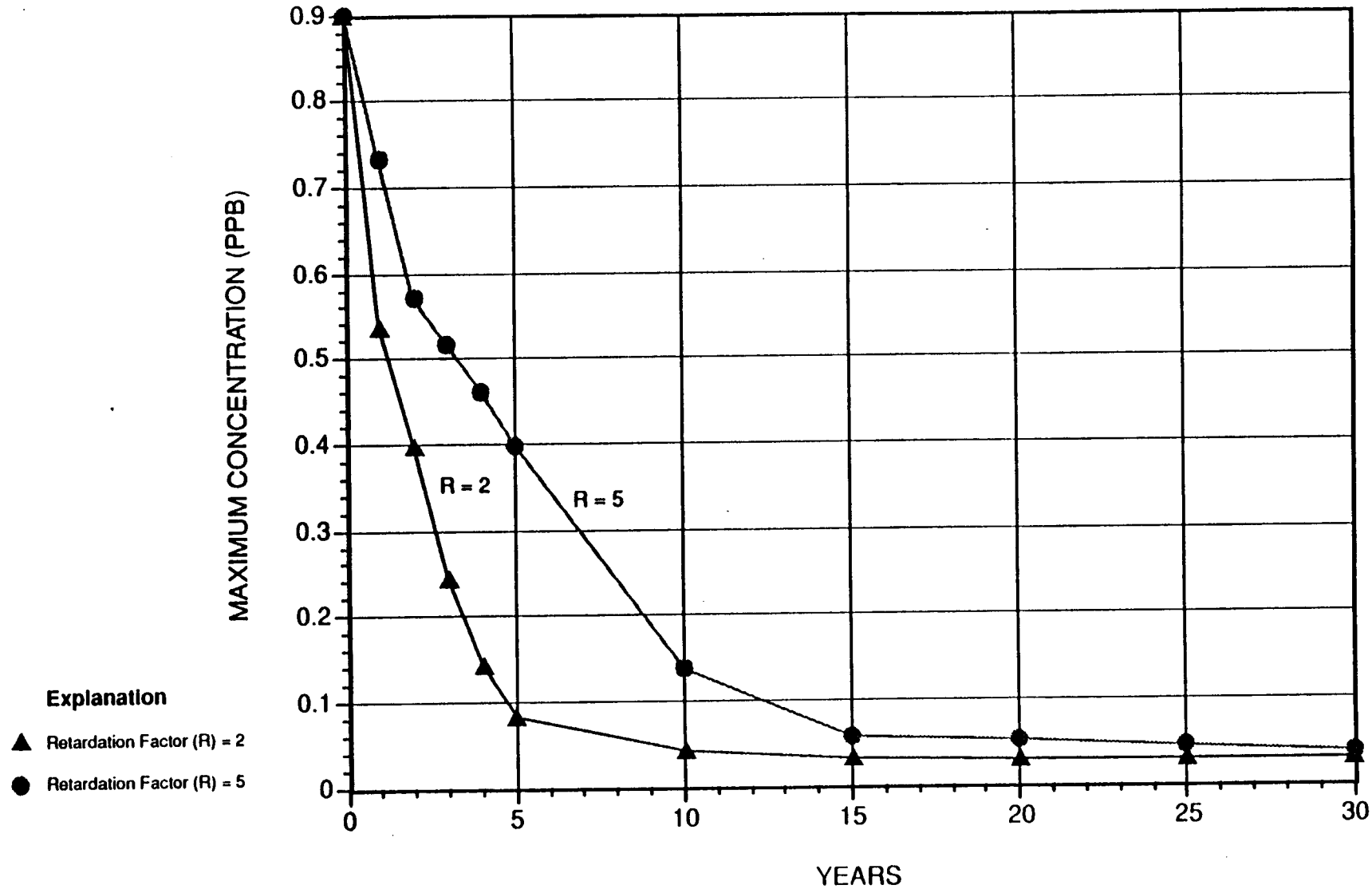
Rocky Mountain Arsenal

Commerce City, Colorado

Figure E25

ALTERNATIVE NO. N-6:
SIMULATED MAXIMUM CHLOROFORM CONCENTRATION
VERSUS TIME – NORTH MODEL



Prepared for:
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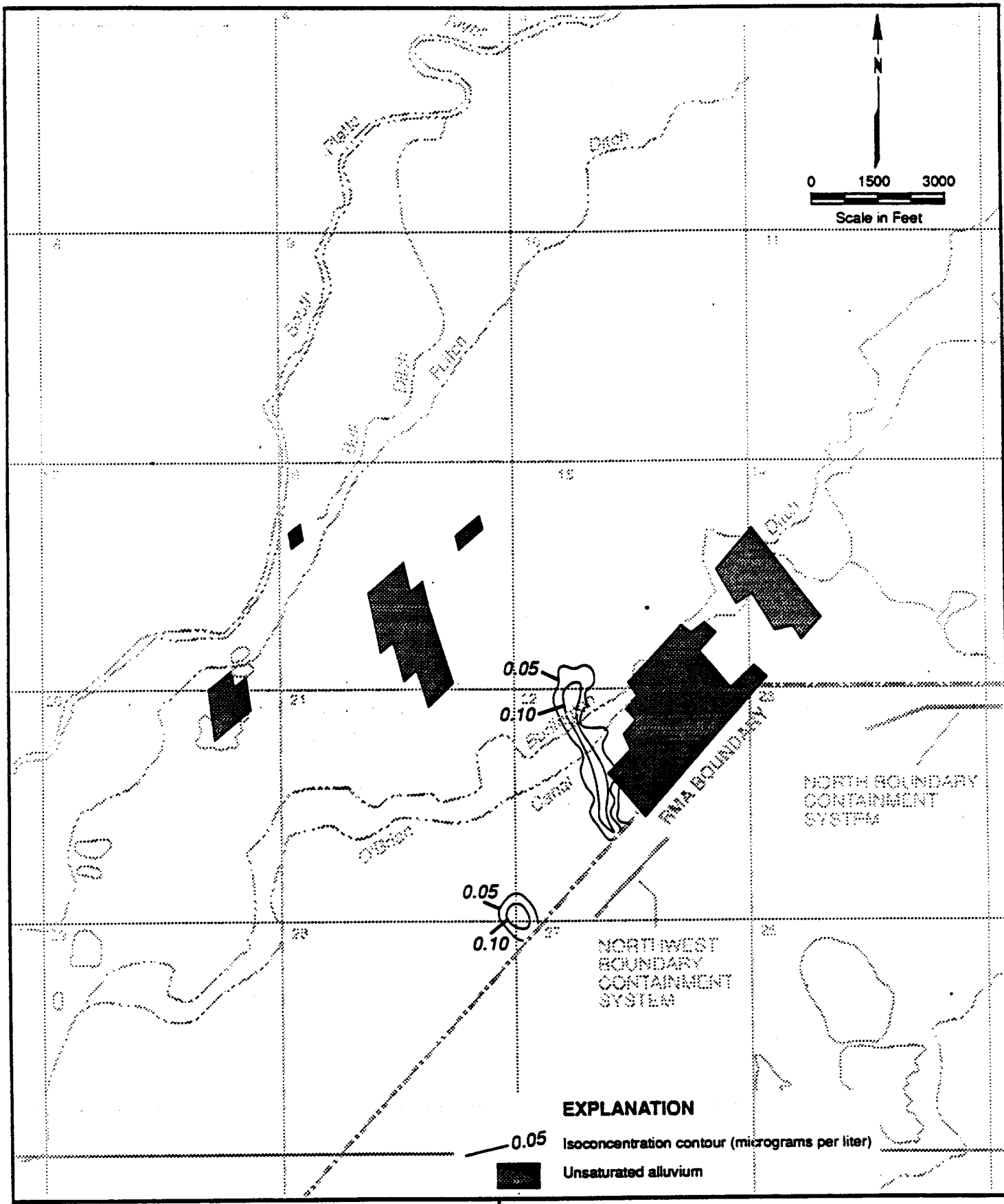
Rocky Mountain Arsenal

Commerce City, Colorado

Figure E26

ALTERNATIVE NO. N-6:
SIMULATED MAXIMUM DIELDRIN CONCENTRATION
VERSUS TIME – NORTH MODEL



Prepared for:
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Rocky Mountain Arsenal

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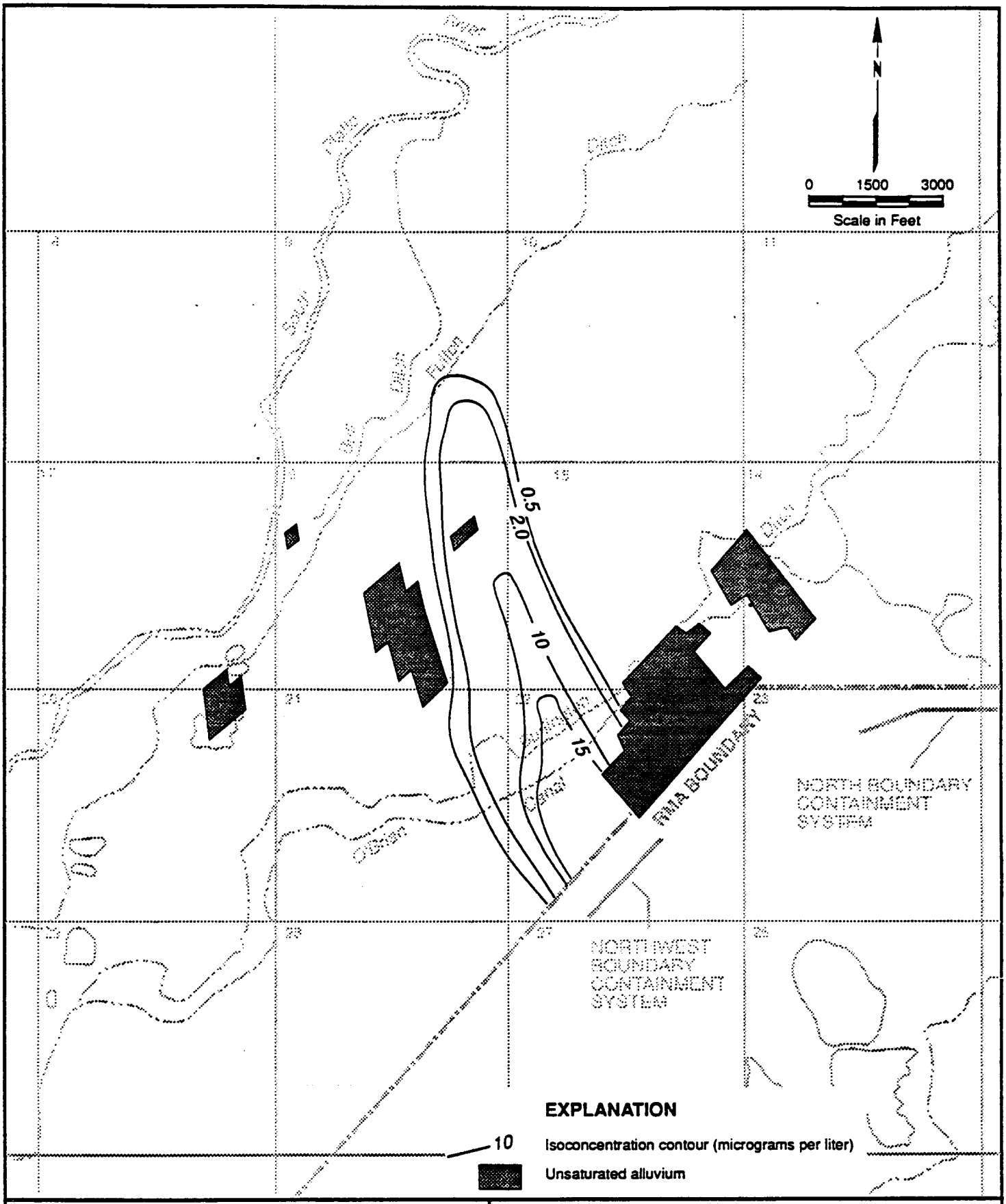
Figure E27

DIELDRIN INITIAL CONDITIONS – NORTHWEST MODEL



Prepared for:
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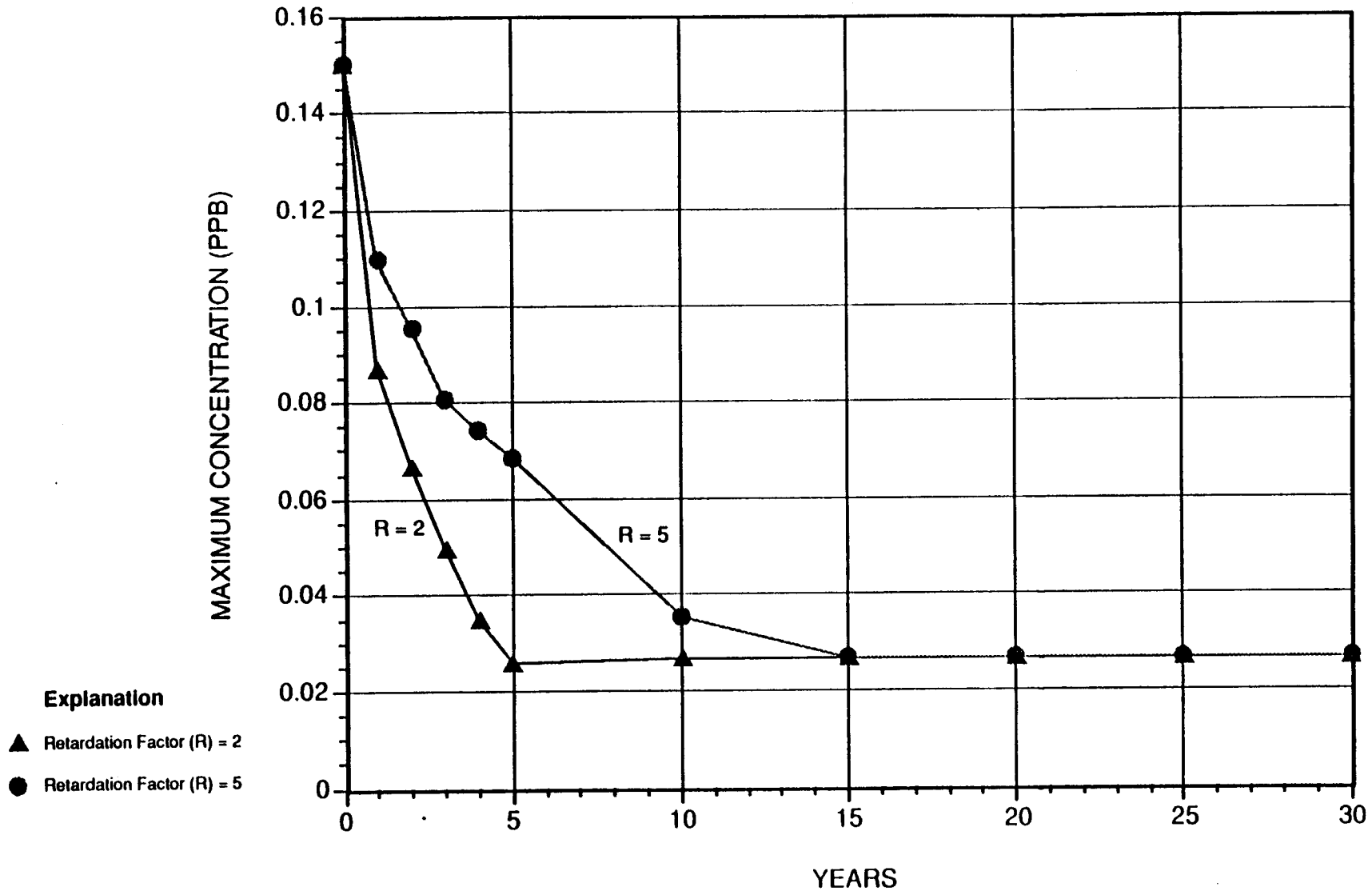
Rocky Mountain Arsenal

Commerce City, Colorado

Figure E28

CHLOROFORM INITIAL CONDITIONS – NORTHWEST MODEL

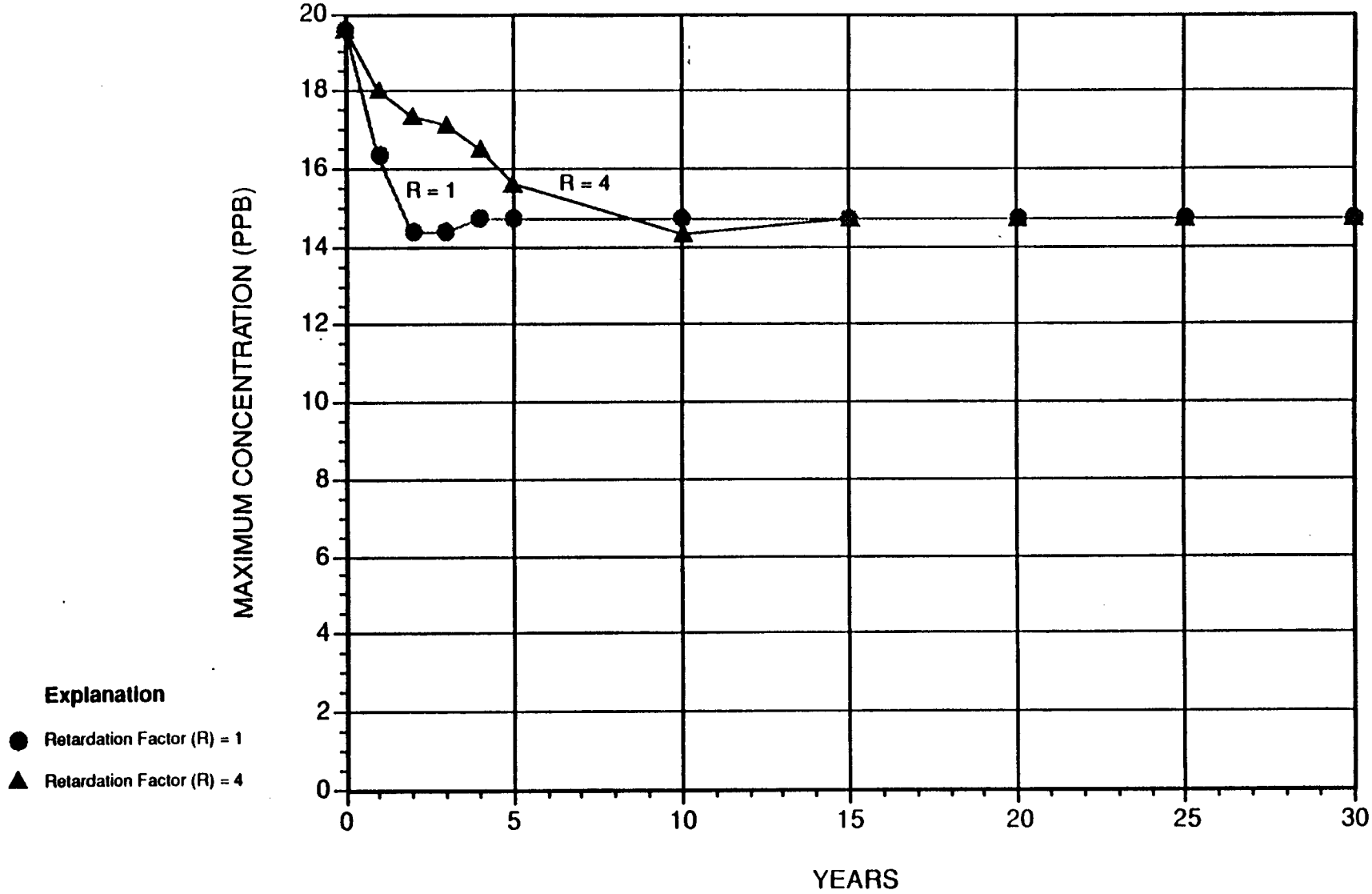


Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure E29

ALTERNATIVE NO. NW-2:
SIMULATED MAXIMUM DIELDRIN CONCENTRATION
VERSUS TIME – NORTHWEST MODEL



Prepared for:
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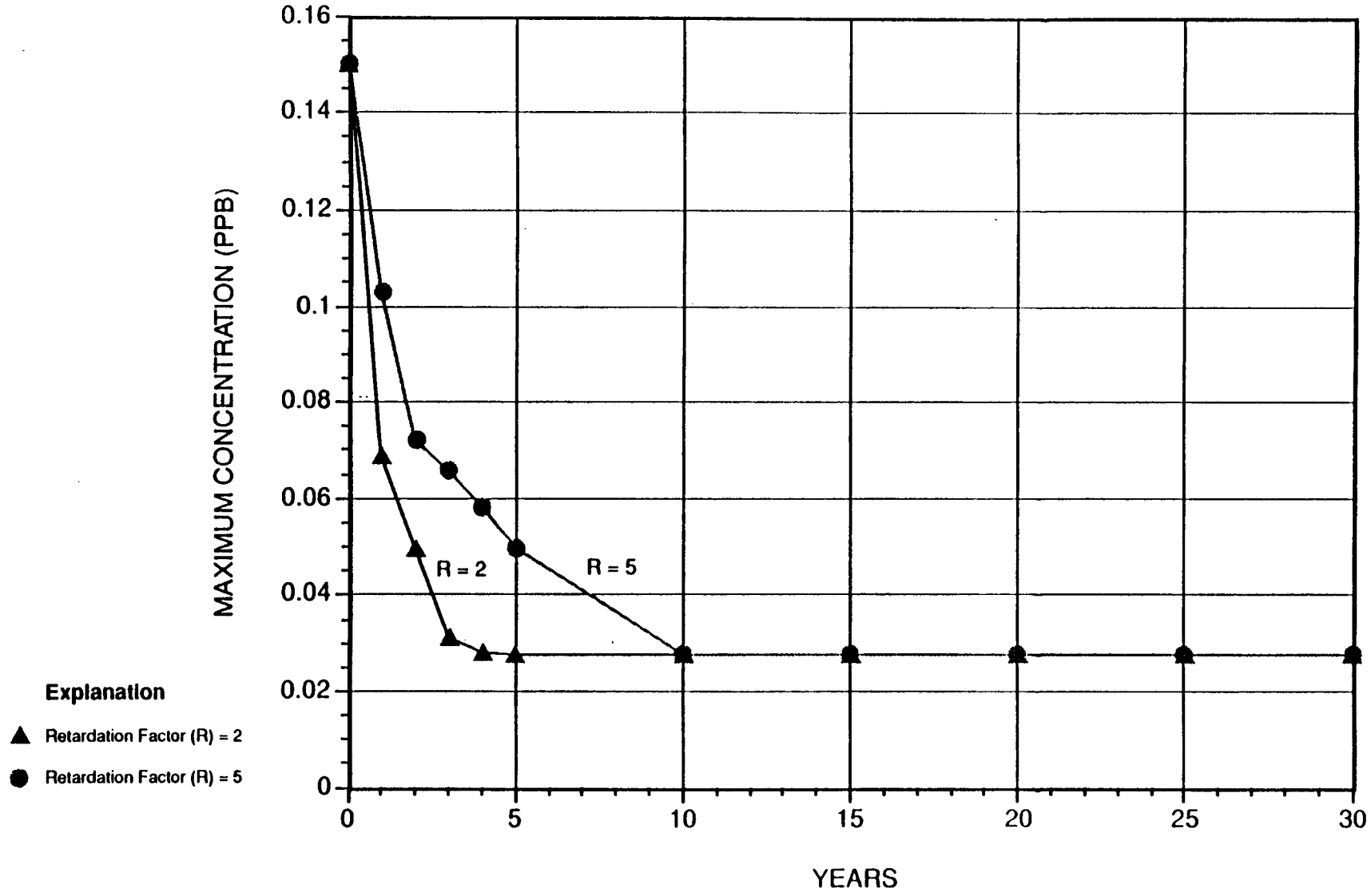
Rocky Mountain Arsenal

Commerce City, Colorado

Figure E30

ALTERNATIVE NO. NW-2:
SIMULATED MAXIMUM CHLOROFORM CONCENTRATION
VERSUS TIME – NORTHWEST MODEL



Prepared for:
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Rocky Mountain Arsenal

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Figure E31

ALTERNATIVE NO. NW-4:
SIMULATED MAXIMUM DIELDRIN CONCENTRATION
VERSUS TIME – NORTHWEST MODEL

Appendix F

COST ESTIMATES

ASSUMPTIONS FOR ALTERNATIVES

The following assumptions were made in developing cost estimates (see Tables F1 through F10) for alternatives and commonalities.

Commonalities of Alternatives

This section describes the assumptions made in developing cost estimates for groundwater alternative commonalities including groundwater monitoring, 5-year site reviews, regulatory oversight, and boundary containment systems.

Groundwater Monitoring

- 2-man crew, 2 trucks
- 2 1/2 wells sampled per day
- Wells selected from GMP Benchmark Water Quality Monitoring Network
- Analytical costs, $3200 per sample
- One review, one document biannually
- Quality control costs are 30 percent of analytical costs
- Sampling twice a year
- Monitoring would continue for the time duration corresponding to the estimated time to achieve PRGs based on groundwater modeling. The range of retardation factors used in the groundwater modeling results in a range in estimated remediation time frames.

5-Year Site Reviews

- Review of analytical data
- Review of land use
- Re-evaluation of exposure point concentrations
- Calculation of exposure and risk
- Document - Limited risk assessment every 5 years
- Site review would continue for the time duration corresponding to the estimated time to achieve PRGs based on groundwater modeling

Regulatory Oversite (EPA and State)

- 150 hours for meetings and document review each year for 30 years
- Regulatory oversite would continue for the time duration corresponding to the estimated time to achieve PRGs based on groundwater modeling

Boundary Containment Systems (NBCS and NWBCS)

- Replacement carbon (carbon usage and carbon replacement costs based on 1990 values)
- O&M parts and supplies (actual 1990 expenditures)
- O&M labor (actual 1990 expenditures)
  - 2 operators
  - 1 support engineer
- Utilities (1990 charges)
  - Gas
  - Electric
  - Phone
- Laboratory analyses (actual 1990 charges for chemical analyses)
- Corps of Engineers (O&M technical support) (1990 values)
- All cost estimates were derived by the Technical Operations Division of the Program Manager for Rocky Mountain Arsenal (PMRMA)
- Projected operational time frame for boundary system is unknown; for the purpose of costing, 30 years of operation was assumed

Groundwater Alternatives

Following are some of the assumptions used in preparing cost estimates and a listing of components included within each alternative.

Alternative No. N-1: No Action

- Groundwater monitoring, 5-year site reviews, and regulatory oversite

Alternative No. N-2: Continued Operation of North Boundary Containment System with Improvements as Necessary

- Groundwater monitoring, 5-year site reviews, regulatory oversite, and continued operation of the NBCS

Alternative No. N-3: Land Acquisition and Use Restriction

- Purchase land (approximately 382 acres) with deed restrictions
- Purchase price of land based on 1990 to 1991 sales records from Adams County assessor from land sold near vicinity of interest
- Legal fees for land acquisition were not included
- Groundwater monitoring, 5-year site reviews, regulatory oversite, and continued operation of the NBCS

Alternative No. N-4: Interim Response Action A

- Extraction and recharge wells - includes well installation, completion, and materials; access roads; fencing; vaults; electrical; instrumentation; and soil waste handling.
- Recharge trenches - includes installation of a 250-foot trench using conventional trenching equipment, materials, access roads, fencing, vaults, electrical, instrumentation and soil waste handling.
- Piping and trenching - includes double-walled pipe with leak detection for untreated water, single-walled pipe for treated water, installation of pipe using one-pass trenching equipment, and dewatering using well points, when necessary.
- Treatment facility - based on site preparation, building construction, materials, carbon adsorption units, pumps, plumbing, controls, and electrical costs.
- Start-up costs - includes surveying, health and safety, contract bonds, home office overhead, and liability insurance.
    - Includes short-term monitoring program-based on sampling 60 wells (24 wells are from the IRA A sampling program and 36 from GMP benchmark water quality monitoring network). In the cost tables that follow, the short-term monitoring cost includes only 24 wells. The intensive short-term monitoring program sampling period is scheduled for 2 years. The additional 36 wells are priced in the groundwater monitoring portion of the cost tables. The assumptions for groundwater monitoring in Appendix F apply to the proposed intensive short-term monitoring program.
- Indirect costs - assumptions are developed under the Indirect Costs subheading below.
- Groundwater monitoring, site reviews, and continued operation of NBCS.
- IRA A treatment facility O&M costs - includes staff, electricity (for building and carbon system), gas (heat), telephone parts and supplies, analytical, and services from the Corps of Engineers. All costs estimates were derived from O&M costs for the boundary systems

provided by the RMA Technical Operations Division, with adjustment for the relative treatment facility differences (i.e., size and flow rate). Operation would continue for the time duration corresponding to the estimated time to achieve PRGs based on the groundwater modeling results.

- Carbon usage rate (CUR) - based on modeling results assuming a retardation factor of 1 for DIMP, the CUR was estimated for the first 3 years of operation, corresponding to an inlet concentration decrease in DIMP from approximately 630 to 80 ppb. The CUR was 3.6 pounds per 1000 gallons. For 3 to 15 years of operation, corresponding to an inlet concentration decrease in DIMP from approximately 80 to 3 ppb, the CUR was calculated to be 1 pound per 1000 gallons. Based on modeling results assuming a retardation factor of 2 for DIMP, the CUR was estimated for the first 5 years of operation corresponding to an inlet concentration decrease in DIMP from approximately 630 to 85 ppb. The CUR was calculated to be 3.6 pounds per 1000 gallons. For 5 to 30 years of operation corresponding to an inlet concentration decrease in DIMP from approximately 85 to 2 ppb, the CUR was 1 pound per 1000 gallons. The estimated concentrations of DIMP from the outlet of the IRA A extraction system were similar to actual DIMP concentrations at the influent to the NBCS carbon adsorption units. The actual CURs from operational data (PMRMA 1985-1989 for the NBCS) were used to estimate CURs for IRA A.

- Carbon replacement - based on using a blend of 50 percent regenerated carbon and 50 percent virgin carbon. Costs include transportation and regeneration of carbon.

Alternative No. N-5: Expansion 1 to Interim Response Action A

- The assumptions used in estimating costs for Alternative No. N-4 apply to this alternative, except the duration of estimated CURs.

- Carbon usage rate - based on modeling results assuming a retardation factor of 1 for DIMP, the CUR was estimated for the first 2 years of operation, corresponding to an inlet concentration decrease in DIMP from approximately 615 to 80 ppb. The CUR was calculated to be 3.6 pounds per 1000 gallons. For 2 to 10 years of operation, corresponding to an inlet concentration decrease in DIMP from approximately 80 to 10 ppb, the CUR was calculated to be 1 pound per 1000 gallons. Based on modeling results assuming a retardation factor of 2 for DIMP, the CUR was estimated for the first 4 years of operation corresponding to an inlet concentration decrease in DIMP from approximately 615 to 80 ppb. The CUR was calculated be 3.6 pounds per 1000 gallons. For the 4 to 20 years of operation corresponding to an inlet concentration decrease in DIMP from approximately 80 to 3 ppb, the CUR was calculated to be 1 pound per 1000 gallons. The estimated concentrations of DIMP from the Expansion 1 to IRA A extraction system were similar to actual influent concentrations to the NBCS carbon adsorption units. The actual CUR from operational data for the NBCS (PMRMA 1985-1989) were used to estimate CURs for IRA A.

- Carbon replacement - based on using a blend of 50 percent regenerated carbon and 50 percent virgin carbon. Costs include transportation and regeneration of carbon.

Alternative No. N-6: Expansion 2 to Interim Response Action A

- All the assumptions used in estimating costs for Alternative No. N-5 apply to this alternative except the duration of estimated carbon usage rates.

- Carbon usage rate - based on modeling results assuming a retardation factor of 1 for DIMP, the CUR was estimated for the first 2 years of operation, corresponding to an inlet concentration decrease in DIMP from approximately 55 to 3 ppb. The CUR was calculated to be 3.6 pounds per 1000 gallons. For the 2 to 10 years of operation corresponding to an inlet concentration decrease in DIMP from approximately 80 to 10 ppb, the CUR was calculated to be 1 pound per 1000 gallons. Based on modeling results assuming a retardation factor of 2 for DIMP, the CUR was estimated for the first 3 years of operation corresponding to an inlet concentration decrease in DIMP from approximately 590 to 80 ppb. The CUR was calculated to be 3.6 pounds per 1000 gallons. For the 3 to 20 years of operation corresponding to an inlet concentration decrease in DIMP from approximately 80 to 3 ppb, the CUR was calculated to be 1 pound per 1000 gallons. The estimated concentrations of DIMP from the IRA A extraction system were similar to actual influent concentrations to the carbon adsorption units at the NBCS. The actual CURs from operational data (PMRMA 1985-1989) for the NBCS were used to estimate CURs for Expansion 2 to IRA A.

- Carbon replacement - based on using a blend of 50 percent regenerated carbon and 50 percent virgin carbon. Costs include transportation and regeneration of carbon.

Alternative No. NW-1: No Action

- Assumptions used in estimating costs for Alternative No. N-1 apply to this alternative.

Alternative No. NW-2: Continued Operation of Northwest Boundary Containment System with Improvements as Necessary

- Groundwater monitoring, site reviews, regulatory oversite, and continued operation of the NWBCS.

Alternative No. NW-3: Land Acquisition and Use Restrictions

- Assumptions used in estimating costs for Alternative No. N-3 apply to this alternative except the land to be purchased would be approximately 150 acres.

Alternative No. NW-4: Northwest Plume Group Extraction/Recharge System

- Extraction and recharge wells - includes well installation, well completion, materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling.

- Recharge trenches - includes installation of a recharge trench using conventional trenching equipment, materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling.

- Piping and trenching - includes double-walled pipe with leak detection for untreated water, single-walled pipe for treated water, installation of pipe using one-pass trenching equipment, and dewatering using well points when necessary.

- Groundwater monitoring, 5-year site reviews, regulatory oversight, and continued operation of the NWBCS.

INDIRECT COSTS

Indirect costs were calculated as a percentage of capital costs as follows:

- Engineering and design is assumed to be 15 percent of the capital costs. This includes the costs for the detailed design of the proposed remediation system.
- Contingency is assumed to be 30 percent of the capital costs. This includes the costs for a potential growth in the project due to unexpected site conditions.
- Resident engineering is assumed to be 25 percent of the capital costs. This includes the cost for construction oversight by the design engineers.
- Regulatory oversite is assumed to be 10 percent of the capital costs. This includes the cost for meetings and document review by EPA and the state.
- Construction management is assumed to be 10 percent of the capital costs. This estimate includes the cost for administration and supervision by the Corps of Engineers.

PRESENT WORTH CALCULATIONS

- There are two categories for present worth costs: nonconservative and conservative. The nonconservative value uses a groundwater modeling timeframe estimate that corresponds to a dieldrin retardation factor of 2, and for the conservative value the timeframe corresponds to a dieldrin retardation factor of 5.
- The capital costs are assumed to be expended in the first 3 years and are not discounted.
- The O&M costs assume a payment made at the end of the period specified using a multiplier at a 5 percent discount rate to arrive at the present worth value.

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
TABLE F1:	ALTERNATIVE No. N-1: NO ACTION						
A. LONG-TERM O&M							
1. Groundwater Monitoring Nonconservative (0 - 15 yrs) Conservative (0 - 30 yrs)	Semi-annual sampling of 36 wells for full analytical suite including sampling, analysis, and documentation costs	2	sample events	$176,000	$352,000	$3,654,000	$5,411,000
2. Site Reviews Nonconservative (0 - 15 yrs) Conservative (0 - 30 yrs)	Review of analytical data and limited risk assessment - 1 every 5 years	1	review/5yr	$150,000	$150,000	$282,000	$417,000
3. Regulatory Oversite Nonconservative (0 - 15 yrs) Conservative (0 - 30 yrs)	Meeting and document review - Agency costs	150	hours	$80	$12,000	$125,000	$184,000
	Total Category Costs					$4,061,000	$6,012,000
	Total Alternative Costs					$4,061,000	$6,012,000

(1) Remediation timeframe corresponds to dieldrin retardation factor of 2 for nonconservative case

(2) Remediation timeframe corresponds to dieldrin retardation factor of 5 for conservative case

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
TABLE F2: ALTERNATIVE No. N-2: CONTINUED OPERATION OF THE NORTH BOUNDARY SYSTEM WITH IMPROVEMENTS AS NECESSARY							
A. LONG-TERM O&M							
1. Groundwater Monitoring Nonconservative (0 - 15 yrs) Conservative (0 - 30 yrs)	Semi-annual sampling of 36 wells for full analytical suite including sampling, analysis, and documentation costs	2	sample events	$176,000	$352,000	$3,654,000	$5,411,000
2. Site Reviews Nonconservative (0 - 15 yrs) Conservative (0 - 30 yrs)	Review of analytical data and limited risk assessment - 1 every 5 years	1	review/5yr	$150,000	$150,000	$282,000	$417,000
3. North Boundary Containment System (0 - 30 yrs)	Labor, carbon, maintenance, and analytical costs	1	annual cost	$1,724,000	$1,724,000	$26,502,000	$26,502,000
4. Regulatory Oversite Nonconservative (0 - 15 yrs) Conservative (0 - 30 yrs)	Meeting and document review - Agency costs	150	hours	$80	$12,000	$125,000	$184,000
	Total Category Costs					$30,563,000	$32,514,000
	Total Alternative Costs					$30,563,000	$32,514,000

(1) Remediation timeframe corresponds to dieldrin retardation factor of 2 for nonconservative case

(2) Remediation timeframe corresponds to dieldrin retardation factor of 5 for conservative case

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
TABLE F3:	ALTERNATIVE No. N-3: LAND ACQUISITION AND USE RESTRICTION						
A. CAPITAL COSTS							
1. Purchase Land	Purchase 382 acres with deed restrictions	382	acres	$10,000	$3,820,000	$3,820,000	$3,820,000
	Subtotal					$3,820,000	$3,820,000
	10 % Regulatory Oversight					$382,000	$382,000
	30 % Contingency					$1,146,000	$1,146,000
	Total Category Costs					$5,348,000	$5,348,000
B. LONG-TERM O&M							
1. Groundwater Monitoring Nonconservative (0 - 15 yrs) Conservative (0 - 30 yrs)	Semi-annual sampling of 36 wells for full analytical suite including sampling, analysis, and documentation costs	2	sample events	$176,000	$352,000	$3,654,000	$5,411,000
2. Site Reviews Nonconservative (0 - 15 yrs) Conservative (0 - 30 yrs)	Review of analytical data and limited risk assessment - 1 every 5 years	1	review/5yr	$150,000	$150,000	$282,000	$417,000
3. North Boundary Containment System (0 - 30 yrs)	Labor, carbon, maintenance, and analytical costs	1	annual cost	$1,724,000	$1,724,000	$26,502,000	$26,502,000
	Total Category Costs					$30,438,000	$32,330,000
	Total Alternative Costs					$35,786,000	$37,678,000

(1) Remediation timeframe corresponds to dieldrin retardation factor of 2 for nonconservative case

(2) Remediation timeframe corresponds to dieldrin retardation factor of 5 for conservative case

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
TABLE F4:	ALTERNATIVE No. N-4: INTERIM RESPONSE ACTION A						
A. CAPITAL COSTS							
1. Monitoring well system							
IRA A Monitoring Wells	Install 75 additional monitoring wells - includes surveying, drilling, well development, and oversight	75	wells	$12,113	$908,000	$908,000	$908,000
2. Capital Costs - First Creek Pathway Extraction/Recharge System							
Extraction Wells	Includes well installation and materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling	5	wells	$54,200	$271,000	$271,000	$271,000
Recharge Trenches	Includes trench installation and materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling	6	trenches	$185,600	$1,114,000	$1,114,000	$1,114,000
Piping and Trenching In and Out of Treatment Facility and Well/Trench Fields for First Creek Paleochannel	Includes double-walled pipe with leak detection, single-walled pipe, installation with dewatered excavations for transmission lines, and connections to wells and recharge trenches	1	lump sum	$538,000	$538,000	$538,000	$538,000
3. Capital Costs - Northern Pathway Extraction/Recharge System							
Extraction Wells	Includes well installation and materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling	12	wells	$57,200	$686,000	$686,000	$686,000
Recharge Wells	Includes well installation and materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling	24	wells	$57,200	$1,373,000	$1,373,000	$1,373,000

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
Piping and Trenching In and Out of Treatment Facility and Well/Trench Fields for Northern Paleochannel	Includes double-walled pipe with leak detection, single-walled pipe, installation for transmission lines, and connections to wells and recharge trenches	1	lump sum	$611,000	$611,000	$611,000	$611,000
4. Treatment Facility	Includes site prep, building construction, materials, carbon adsorption units, pumps, plumbing, electrical, and controls	1	lump sum	$4,106,100	$4,106,000	$4,106,000	$4,106,000
5. Start-up Costs	Miscellaneous start-up costs	1	lump sum	$341,094	$341,000	$341,000	$341,000
	Subtotal					$9,948,000	$9,948,000
15 %	Engineering and Design					$1,492,000	$1,492,000
30 %	Contingency					$2,984,000	$2,984,000
2.5 %	Resident Engineering					$249,000	$249,000
10 %	Regulatory Oversight					$995,000	$995,000
10 %	Construction Management					$995,000	$995,000
	Total Category Costs					$16,663,000	$16,663,000
B. LONG-TERM O&M							
1. Groundwater Monitoring Nonconservative (0 - 15 yrs) Conservative (0 - 30 yrs)	Semi-annual sampling of 36 wells for a full analytical suite including sampling, analysis, and documentation costs	2	sample events	$176,000	$352,000	$3,654,000	$5,411,000
2. Site Reviews Nonconservative (0 - 15 yrs) Conservative (0 - 30 yrs)	Review of analytical data and limited risk assessment - 1 every 5 years	1	review/5yr	$150,000	$150,000	$282,000	$417,000

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
3. Facility O&M Costs Nonconservative (0 - 15 yrs) Conservative (0 - 30 yrs)	Includes building O&M costs such as staff, electric (for building and carbon system), gas (heat), and telephone	1	annual cost	$521,900	$522,000	$5,417,000	$8,023,000
4. Water Treatment	Aqueous Phase Carbon Adsorption						
Carbon Replacement Nonconservative (0 - 3 yrs) Conservative (0 - 5 yrs)	Includes 50% regenerated carbon, 50% virgin carbon, and transportation (with a usage rate of 3.6 lbs/1000 gal)	480	gpm	$1,703	$817,000	$2,226,000	$3,539,000
Carbon Replacement Nonconservative (3 - 15 yrs) Conservative (5 - 30 yrs)	Includes 50% regenerated carbon, 50% virgin carbon, and transportation (with a usage rate of 1 lbs/1000 gal)	480	gpm	$473	$227,000	$1,738,000	$2,507,000
5. North Boundary Containment System (0 - 30 yrs)	Labor, carbon, maintenance, and analytical costs	1	per year	$1,724,000	$1,724,000	$26,502,000	$26,502,000
	Total Category Costs					$39,819,000	$46,399,000
	Total Alternative Costs					$56,482,000	$63,062,000

(1) Remediation timeframe corresponds to dieldrin retardation factor of 2 for nonconservative case

(2) Remediation timeframe corresponds to dieldrin retardation factor of 5 for conservative case

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
TABLE F5:	ALTERNATIVE No. N-5: EXPANSION 1 TO INTERIM RESPONSE ACTION A						
A. CAPITAL COSTS							
1. Remedial Design Investigation	Includes sampling, data management and report	1	lump sum	$50,000	$50,000	$50,000	$50,000
2. Monitoring well system							
IRA A Monitoring Wells	Install 75 additional monitoring wells - includes surveying, drilling, development and oversight	75	wells	$12,113	$908,000	$908,000	$908,000
3. Capital Costs IRA A Groundwater Extraction/Recharge System		1	lump sum	$4,654,000	$4,654,000	$4,654,000	$4,654,000
4. Capital Costs - First Creek Pathway Extraction/Recharge System							
Extraction Wells	Includes well installation and materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling	2	wells	$57,200	$114,000	$114,000	$114,000
Recharge Trenches	Includes trench installation and materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling	4	trenches	$185,600	$742,000	$742,000	$742,000
Piping and Trenching In and Out of Treatment Facility and Well/Trench Fields for First Creek Paleochannel	Includes double-walled pipe with leak detection, single-walled pipe, installation with dewatered excavations for transmission lines, and connections to wells and recharge trenches	1	lump sum	$220,765	$221,000	$221,000	$221,000
5. Capital Costs - Northern Pathway Extraction/Recharge System							
Extraction Wells	Includes well installation and materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling	1	wells	$57,200	$57,000	$57,000	$57,000

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
Recharge Trenches	Includes trench installation and materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling	2	trenches	$185,600	$371,000	$371,000	$371,000
Piping and Trenching In and Out of Treatment Facility and Well/Trench Fields for Northern Paleochannel	Includes double-walled pipe with leak detection, single-walled pipe, installation for transmission lines, and connections to wells and recharge trenches	1	lump sum	$8,025	$8,000	$8,000	$8,000
6. Treatment Facility							
IRA A	Includes site prep, building construction, materials, carbon adsorption units, pumps, plumbing, electrical, and controls.	1	lump sum	$4,106,000	$4,106,000	$4,106,000	$4,106,000
7. Start-up Costs	Miscellaneous start-up costs	1	lump sum	$341,094	$341,000	$341,000	$341,000
	Subtotal					$11,572,000	$11,572,000
15 %	Engineering and Design					$1,736,000	$1,736,000
10 %	Construction Management					$1,157,000	$1,157,000
30 %	Contingency					$3,472,000	$3,472,000
2.5 %	Resident Engineering					$289,000	$289,000
10 %	Regulatory Oversight					$1,157,000	$1,157,000
	Total Category Costs					$19,383,000	$19,383,000
B. LONG-TERM O&M							
1. Groundwater Monitoring Nonconservative (0 - 10 yrs) Conservative (0 - 20 yrs)	Semi-annual sampling of 36 wells for a full analytical suite including sampling, analysis, and documentation costs	2	sample events	$176,000	$352,000	$2,718,000	$4,387,000

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
2. Site Reviews Nonconservative (0 - 10 yrs) Conservative (0 - 20 yrs)	Review of analytical data and limited risk assessment - 1 every 5 years	1	review/5yr	$150,000	$150,000	$210,000	$338,000
2. Facility O&M Costs Nonconservative (0 - 10 yrs) Conservative (0 - 20 yrs)	Includes building O&M costs such as staff, electric (for building and carbon system), gas (heat), and telephone	1	annual cost	$523,900	$524,000	$4,045,000	$6,529,000
3. Water Treatment	Aqueous Phase Carbon Adsorption						
Carbon Replacement Nonconservative (0 - 2 yrs) Conservative (0 - 4 yrs)	Includes 50% regenerated carbon, 50% virgin carbon, and transportation (with a usage rate of 3.6 lbs/1000 gal)	570	gpm	$1,703	$971,000	$1,805,000	$3,442,000
Carbon Replacement Nonconservative (2 - 10 yrs) Conservative (4 - 20 yrs)	Includes 50% regenerated carbon, 50% virgin carbon, and transportation (with a usage rate of 1 lbs/1000 gal)	570	gpm	$473	$270,000	$1,581,000	$2,404,000
4. North Boundary Containment System (0 - 30 yrs)	Labor, carbon, maintenance, and analytical costs	1	annual cost	$1,724,000	$1,724,000	$26,502,000	$26,502,000
	Total Category Costs					$36,861,000	$43,602,000
	Total Alternative Costs					$56,244,000	$62,985,000

(1) Remediation timeframe corresponds to dieldrin retardation factor of 2 for nonconservative case

(2) Remediation timeframe corresponds to dieldrin retardation factor of 5 for conservative case

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
TABLE F6:	ALTERNATIVE No. N-6: EXPANSION 2 TO INTERIM RESPONSE ACTION A						
A. CAPITAL COSTS							
1. Remedial Design Investigation	Includes sampling, data management, and report	1	lump sum	$50,000	$50,000	$50,000	$50,000
2. Monitoring well system							
IRA A Monitoring Wells	Install 75 additional monitoring wells-includes surveying, drilling, development, and oversight	75	wells	$12,113	$908,000	$908,000	$908,000
3. Capital Costs IRA A Groundwater Extraction/Recharge System		1	lump sum	$4,654,000	$4,654,000	$4,654,000	$4,654,000
4. Capital Costs - First Creek Pathway Extraction/Recharge System							
Extraction Wells	Includes well installation and materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling	4	wells	$54,200	$217,000	$217,000	$217,000
Recharge Trenches	Includes trench installation and materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling	8	trenches	$185,600	$1,485,000	$1,485,000	$1,485,000
Piping and Trenching In and Out of Treatment Facility and Well/Trench Fields for First Creek Paleochannel	Includes double-walled pipe with leak detection, single-walled pipe, installation with dewatered excavations for transmission lines, and connections to wells and recharge trenches	1	lump sum	$401,480	$401,000	$401,000	$401,000
5. Capital Costs - Northern Pathway Extraction/Recharge System							
Extraction Wells	Includes well installation and materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling	3	wells	$57,200	$172,000	$172,000	$172,000

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
Recharge Trenches	Includes trench installation and materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling	5	trenches	$119,160	$596,000	$596,000	$596,000
Piping and Trenching In and Out of Treatment Facility and Well/Trench Fields for Northern Paleochannel	Includes double-walled pipe with leak detection, single-walled pipe, installation for transmission lines, and connections to wells and recharge trenches	1	lump sum	$41,280	$41,000	$41,000	$41,000
6. Treatment Facility Expansion							
IRA A Carbon System	Includes site prep, building construction, materials, carbon adsorption units, pumps, plumbing, electrical, and controls	1	lump sum	$4,106,000	$4,106,000	$4,106,000	$4,106,000
Start-up Costs	Miscellaneous start-up costs	1	lump sum	$341,094	$341,000	$341,000	$341,000
IRA A Expansion (Carbon Contactor)	Expansion of IRA A includes additional carbon unit and modifications to plumbing and controls	1	lump sum	$180,550	$181,000	$181,000	$181,000
	Subtotal					$13,152,000	$13,152,000
	15 % Engineering and Design					$1,973,000	$1,973,000
	10 % Construction Management					$1,315,000	$1,315,000
	30 % Contingency					$3,946,000	$3,946,000
	2.5 % Resident Engineering					$329,000	$329,000
	10 % Regulatory Oversight					$1,315,000	$1,315,000
	Total Category Costs					$22,030,000	$22,030,000

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
B. LONG-TERM O&M							
1. Groundwater Monitoring Nonconservative (0 - 10 yrs) Conservative (0 - 20 yrs)	Semi-annual sampling of 36 wells for a full analytical suite including sampling, analysis, and documentation costs	2	sample events	$176,000	$352,000	$2,718,000	$4,387,000
2. Site Reviews Nonconservative (0 - 10 yrs) Conservative (0 - 20 yrs)	Review of analytical data and limited risk assessment - 1 every 5 years	1	review/5yr	$150,000	$150,000	$210,000	$338,000
3. Facility O&M Costs Nonconservative (0 - 10 yrs) Conservative (0 - 20 yrs)	Includes building O&M costs such as staff, electric (for building and carbon system), gas (heat), and telephone	1	annual cost	$525,200	$525,000	$4,055,000	$6,545,000
4. Water Treatment Expansion							
Carbon Replacement Nonconservative (0 - 2 yrs) Conservative (0 - 3 yrs)	Includes 50% regenerated carbon, 50% virgin carbon, and transportation (with a usage rate of 3.6 lbs/1000 gal)	690	gpm	$1,703	$1,175,000	$2,185,000	$3,200,000
Carbon Replacement Nonconservative (2 - 10 yrs) Conservative (3 - 20 yrs)	Includes 50% regenerated carbon, 50% virgin carbon, and transportation (with a usage rate of 1 lbs/1000 gal)	690	gpm	$473	$326,000	$1,913,000	$3,179,000
5. North Boundary Containment System (0 - 30 yrs)	Labor, carbon, maintenance, and analytical costs	1	annual cost	$1,724,000	$1,724,000	$26,502,000	$26,502,000
	Total Category Costs					$37,583,000	$44,151,000
	Total Alternative Costs					$59,613,000	$66,181,000

(1) Remediation timeframe corresponds to dieldrin retardation factor of 2 for nonconservative case
(2) Remediation timeframe corresponds to dieldrin retardation factor of 5 for conservative case

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
TABLE F7:	ALTERNATIVE No. NW-1: NO ACTION						
A. LONG-TERM O&M							
1. Groundwater Monitoring Nonconservative (0 - 3 yrs) Conservative (0 - 8 yrs)	Semi-annual sampling of 13 wells for a full analytical suite including sampling, analysis, and documentation costs	2	sample events	$67,000	$134,000	$365,000	$866,000
2. Site Reviews Nonconservative (0 - 3 yrs) Conservative (0 - 8 yrs)	Review of analytical data and limited risk assessment - 1 every 5 years	1	review/5yr	$150,000	$150,000	$118,000	$210,000
3. Regulatory Oversite Nonconservative (0 - 15 yrs) Conservative (0 - 30 yrs)	Meeting and document review - agency costs	150	hours	$80	$12,000	$125,000	$184,000
	Total Category Costs					$608,000	$1,260,000
	Total Alternative Costs					$608,000	$1,260,000

(1) Remediation timeframe corresponds to dieldrin retardation factor of 2 for nonconservative case

(2) Remediation timeframe corresponds to dieldrin retardation factor of 5 for conservative case

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
TABLE F8: ALTERNATIVE No. NW-2: CONTINUED OPERATION OF THE NORTHWEST BOUNDARY CONTAINMENT SYSTEM WITH IMPROVEMENTS AS NECESSARY							
A. LONG TERM O&M							
1. Groundwater Monitoring Nonconservative (0 - 3 yrs) Conservative (0 - 8 yrs)	Semi-annual sampling of 13 wells for a full analytical suite including sampling, analysis, and documentation costs	2	sample events	$67,000	$134,000	$365,000	$866,000
2. Site Reviews Nonconservative (0 - 3 yrs) Conservative (0 - 8 yrs)	Review of analytical data and limited risk assessment - 1 every 5 years	1	review/5yr	$150,000	$150,000	$118,000	$210,000
3. Northwest Boundary Containment System (0 - 30 yrs)	Labor, carbon, maintenance, and analytical costs	1	annual cost	$769,000	$769,000	$11,821,000	$11,821,000
4. Regulatory Oversite Nonconservative (0 - 15 yrs) Conservative (0 - 30 yrs)	Meeting and document review - agency costs	150	hours	$80	$12,000	$125,000	$184,000
	Total Category Costs					$12,429,000	$13,081,000
	Total Alternative Costs					$12,429,000	$13,081,000

(1) Remediation timeframe corresponds to dieldrin retardation factor of 2 for nonconservative case

(2) Remediation timeframe corresponds to dieldrin retardation factor of 5 for conservative case

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
TABLE F9:	ALTERNATIVE No. NW-3: LAND ACQUISITION AND USE RESTRICTIONS						
A. CAPITAL COSTS							
1. Purchase Land	Purchase 150 acres with deed restrictions	150	acres	$10,000	$1,500,000	$1,500,000	$1,500,000
	Subtotal					$1,500,000	$1,500,000
	30 % Regulatory Oversight					$450,000	$450,000
	10 % Regulatory Oversight					$150,000	$150,000
	Total Category Costs					$2,100,000	$2,100,000
B. LONG-TERM O&M							
1. Groundwater Monitoring Nonconservative (0 - 3 yrs) Conservative (0 - 8 yrs)	Semi-annual sampling of 13 wells for a full analytical suite including sampling, analysis, and documentation costs	2	sample events	$67,000	$134,000	$365,000	$866,000
2. Site Reviews Nonconservative (0 - 3 yrs) Conservative (0 - 8 yrs)	Review of analytical data and limited risk assessment - 1 every 5 years	1	review/5yr	$150,000	$150,000	$118,000	$210,000
3. Northwest Boundary Containment System (0 - 30 yrs)	Labor, carbon, maintenance, and analytical costs	1	annual cost	$769,000	$769,000	$11,821,000	$11,821,000
	Total Category Costs					$12,304,000	$12,897,000
	Total Alternative Costs					$14,404,000	$14,997,000

(1) Remediation timeframe corresponds to dieldrin retardation factor of 2 for nonconservative case

(2) Remediation timeframe corresponds to dieldrin retardation factor of 5 for conservative case

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
TABLE F10:	ALTERNATIVE No. NW-4: NORTHWEST PLUME GROUP EXTRACTION/RECHARGE SYSTEM						
A. CAPITAL COSTS							
1. Purchase Land	Purchase land for siting extraction/recharge wells	70	acres	$15,000	$1,050,000	$1,050,000	$1,050,000
2. Capital Costs - Northwest Plume Group Extraction /Recharge System							
Extraction Wells	Includes well installation and materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling	3	wells	$57,200	$172,000	$172,000	$172,000
Recharge Wells	Includes trench installation and materials, access roads, fencing, vaults, electrical, instrumentation, and soil waste handling	5	wells	$57,200	$286,000	$286,000	$286,000
Piping and Trenching In and Out of Treatment Facility and Well Fields for Northwest Paleochannel	Includes double-walled pipe with leak detection, single-walled pipe, installation with dewatered excavations for transmission lines, and connections to wells and recharge trenches	1	lump sum	$147,500	$148,000	$148,000	$148,000
	Subtotal					$1,656,000	$1,656,000
	15 % Engineering and Design					$248,000	$248,000
	10 % Construction Management					$166,000	$166,000
	30 % Contingency					$497,000	$497,000
	2.5 % Resident Engineering					$41,000	$41,000
	10 % Regulatory Oversight					$166,000	$166,000
	Total Category Costs					$2,774,000	$2,774,000

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE (1991 $)	COST (1991 $)	PRESENT WORTH COST (1) NONCONSERVATIVE (1991 $)	PRESENT WORTH COST (2) CONSERVATIVE (1991 $)
B. LONG-TERM O&M							
1. Groundwater Monitoring Nonconservative (0 - 2 yrs) Conservative (0 - 5 yrs)	Semi-annual sampling of 13 wells for a full analytical suite including sampling, analysis, and documentation costs	2	sample events	$67,000	$134,000	$249,000	$580,000
2. Site Reviews Nonconservative (0 - 2 yrs) Conservative (0 - 5 yrs)	Review of analytical data and limited risk assessment - 1 every 5 years	1	review/5yr	$150,000	$150,000	$118,000	$118,000
3. Northwest Boundary Containment System (0 - 30 yrs)	Labor, carbon, maintenance, and analytical costs	1	annual cost	$769,000	$769,000	$11,821,000	$11,821,000
	Total Category Costs					$12,188,000	$12,519,000
	Total Alternative Costs					$14,962,000	$15,293,000

(1) Remediation timeframe corresponds to dieldrin retardation factor of 2 for nonconservative case
(2) Remediation timeframe corresponds to dieldrin retardation factor of 5 for conservative case

TECHNICAL SUPPORT FOR ROCKY MOUNTAIN ARSENAL

Offpost Operable Unit
Endangerment Assessment/Feasibility Study

Final Report

Volume VIII of VIII
(Responses to Comments)

November 24, 1992
Contract Number DAAA15-88-0021
Task RIFS1 (Delivery Order 0001)

PREPARED BY

Harding Lawson Associates
Environmental Science and Engineering, Inc.

PREPARED FOR

PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL

THIS DOCUMENT IS INTENDED TO COMPLY WITH THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969.

THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATION RECORD FOR THIS CERCLA OPERABLE UNIT.

PREFACE TO VOLUME VIII

This volume presents comments regarding the Offpost OU Endangerment Assessment/ Feasibility Study report and responses prepared by Harding Lawson Associates. Four sets of comments and responses are presented in this volume in the following order:

- Shell Oil Company (Shell)
- U.S. Environmental Protection Agency (EPA)
- U.S. Department of the Interior Fish and Wildlife Service (USFWS)
- Colorado Department of Health (CDH)

Within each set, comments are presented in the same order in which they were received. The comments have not been edited or revised in any way. A Glossary is provided as a list of acronyms and abbreviations used in the responses.

SHELL OIL COMPANY COMMENTS REGARDING THE ENDANGERMENT ASSESSMENT/FEASIBILITY STUDY FOR ROCKY MOUNTAIN ARSENAL OFFPOST OPERABLE UNIT - DISPUTE ISSUES

GENERAL COMMENTS

Comment No. 1 - Inappropriate Land Use Scenario

This EA/FS uses a rural residential (hypothetical subsistence farmer) scenario in its baseline risk assessment. This hypothetical population of residents, i.e., subsistence farmer residents, and the associated land uses do not exist in the RMA Offpost Operable Unit. The rural residential cancer risk estimates and hazard indices are based upon flawed data and faulty assumptions that do not consider realistic, reasonable maximum current and future exposures to compounds of concern as required by the National Contingency Plan (NCP) and EPA guidance. Moreover, due to various factors it is impossible for this scenario to exist in the RMA Offpost Operable Unit at the present time because of the high land values and the over appropriation of alluvial groundwater. Furthermore, due to the planned realignment of 96th Avenue, if adjacent lands are developed, commercial and industrial land use is most likely, as the Army recognizes in the FS.

Response

As a result of dispute resolution, the Organizations agreed to an urban residential scenario for zones 3 and 4, commercial-industrial for zone 5, and rural residential for zones 1, 2, and 6. Attachment A to this set of responses to comments is the dispute resolution agreement letter signed by all parties to the dispute and dated May 5, 1992. Commercial-industrial land use for zone 5 was contingent on the South Adams County Water and Sanitation District's (SACWSD's) certification that it does not plan to use groundwater in this zone during the next 30 years. Attachment B to this set of responses to comments is a letter from SACWSD to the Army, providing documentation that SACWSD does not intend to install water-supply wells in the future in zone 5.

Comment No. 2 - Inadequate Ecotoxicity Assessment

The food web model presented in this EA/FS estimates excess risk to the biota present in the RMA Offpost Operable Unit due to flawed methodologies and errors in logic. The model results are inconsistent with the observation of a healthy wildlife population. Furthermore, the model employs unrealistic and physically impossible parameter values such as those used for bioaccumulation factors, bioconcentration factors, the dietary intake of aquatic food items by the great blue heron, and unrealistically low toxicity reference values. In addition, the uncertainty associated with the food web model is so large that the results are adequate only for screening purposes.

Response

As a result of dispute resolution (see Attachment A), the Organizations agreed to use literature values for bioaccumulation factors (BAFs), bioconcentration factors (BCFs), and home range area. The Army considered literature BAFs less than optimal but an acceptable alternative to onpost calibrate BAFs. The Organizations also agreed to use spatial weighting factors determined on the basis of home range area and to modifications to the toxicity reference value (TRV) derivation process.

Comment No. 3 - Incorrect Groundwater Exposure Point Concentrations

The methodology used in this EA/FS to generate groundwater exposure point concentrations is flawed; therefore, the results are incorrect and inconsistent with the observed contaminant distributions. Furthermore, this EA/FS does not present current and future contaminant exposures for the groundwater compounds of concern, and is therefore inconsistent with the NCP and EPA guidance. Based on Shell's evaluation of the available data, the EA/FS overestimates the groundwater exposure point concentrations several fold in some areas.

Response

Based on dispute resolution (see Attachment A), the Organizations agreed to limit the groundwater database to 1989 to 1991 and to delete gas chromatography/mass spectrometry (GC/MS) and field duplicate data where appropriate (Volume II, Section 2.0). In addition, a future groundwater exposure scenario was evaluated, and groundwater concentrations were reduced as a result of treatment of groundwater by the boundary containment systems over 30 years.

Comment No. 4 - Incomplete Dieldrin Toxicological Profile

This EA/FS fails to include key toxicological information (identified in our comments on the draft of this document) regarding human data in the dieldrin toxicological profile; however, this information was included in the aldrin/dieldrin toxicological profile for the RMA On-Post Final Human Health Exposure Assessment. Furthermore, the inclusion of additional information is preferred per the NCP and EPA guidance, and is important for risk management decisions.

Response

Based on dispute resolution (see Attachment A), the Organizations agreed to include the Shell dieldrin toxicological profile as a separate document in Volume IV, Appendix F of the Endangerment Assessment (EA).

Comment No. 5 - Manganese as a Compound of Concern

Manganese should not be a compound of concern (COC) for the RMA Offpost Operable Unit because there is no known source at RMA, the assessment of the analytical data is flawed, and manganese, if a COC, would be a pollutant or a contaminant, not a hazardous substance under CERCLA. Furthermore, manganese is a naturally occurring constituent of the soils and groundwater.

Response

Based on dispute resolution (see Attachment A), the Organizations retained manganese as a chemical of concern because groundwater monitoring data indicate manganese is associated with RMA.

Comment No. 6 - ARARs

A number of aspects of the ARARs analysis in this EA/FS are inconsistent with the selection criteria of CERCLA or the NCP. Following are some of the more significant matters of concern.

With respect to the ARARs based on the Colorado Basic Standards for Groundwater and the Colorado Basic Standards for Surface Water, the EA/FS does not explain why the standards are applicable or relevant and appropriate. In any event, Shell objects to all state groundwater standards that are more stringent than MCLs on the grounds that the standards were not automatically intended to be ARARs by 5 CCR 1002-8.3.1.11(5). We also note that one of the most important tables, 2.4.3.1-1 of Volume V, is missing from this document.

The EA/FS is inconsistent in its treatment of Land Disposal Restrictions (LDRs). It correctly acknowledges that the reinjection of groundwater does not trigger LDRs because LDRs are superseded by RCRA Section 3020(a). p. VII-A-9. It also states that LDRs are not ARARs because there are no listed wastes from RMA in the Offpost Operable Unit.

p. VII-A-15. Despite these concentrations, the EA/FS then incorrectly states that LDRs have been identified as action-specific ARARs for all treatment alternatives. See p. VII-A-23.

With respect to stormwater discharge regulations, Shell disagrees with the conclusion that the stormwater discharge regulations may be relevant and appropriate, because, among other reasons, the FS alternatives do not involve the discharge of stormwater runoff to surface water.

In certain instances, proposed MCLs have been selected as ARARs rather than TBCs. This is inconsistent with the NCP. Furthermore, additional chemical-specific TBCs which were suggested by Shell have been rejected.

Response

The ARARs analysis presented in Volume VII Appendix A of the Feasibility Study (FS) has been revised to include an explanation for the finding that the Colorado Basic Standards for Groundwater (CBSG) are not applicable or relevant and appropriate. The basis for this finding is in Appendix A and rests primarily on citations from the Statement of Basis and Purpose in the CBSG. The Statement of Basis and Purpose indicates that CDH did not intend that the Table A Interim Organic Standards be applied as cleanup standards for CERCLA, RCRA Subtitle C, or UST actions.

Appendix A of Volume VII has been revised to include the language agreed upon in the May 5, 1992, dispute resolution letter concerning land disposal restrictions under RCRA.

The dispute relative to stormwater discharge regulations was withdrawn.

Appendix A has been revised to include considerations of proposed MCLs as TBCs rather than ARARs.

U.S. ENVIRONMENTAL PROTECTION AGENCY COMMENTS REGARDING THE ENDANGERMENT ASSESSMENT/FEASIBILITY STUDY FOR ROCKY MOUNTAIN ARSENAL OFFPOST OPERABLE UNIT - DISPUTE ISSUES

ENDANGERMENT ASSESSMENT

GENERAL COMMENTS

Comment No. 1 - Development of PRGs

EPA would invoke dispute concerning the effects of multiple chemicals within a medium and effects of COCs in multiple media as presented in the offpost endangerment assessment, and all calculations that utilized the resulting values, for the reasons detailed below, except for the low risk involved in the specific example. In any other instance we would not accept this procedure.

A. Effects of Multiple Chemicals Within A Medium and Effects of COCs in Multiple Media.

Soil HBC/PRGs do not adequately address the cumulative effects of multiple carcinogens in one medium, nor do they provide protection against cumulative effects of COCs in multiple media.

In its response to cover letter comment No. 4 (VIII-4) the Army "agrees that the evaluation of multiple media should be included in the derivation of HBC." However, the response only discusses multimedia adjustments for non-carcinogens, which were ultimately not found to be necessary, and were therefore not made. The document remains silent on the subject of multimedia adjustments for carcinogens. The approaches for carcinogens and noncarcinogens should be consistent. Since the Army proposed to divide PRGs for noncarcinogens by the number of media in which these COC occur, PRGs for carcinogens should also be divided by the number of media in which they occur. Yet, calculated HBC for carcinogens were not adjusted in this manner.

For example, since several carcinogens occur in groundwater as well as in soil in Zones 3 and 4, and commercial/industrial workers are exposed to both, soil PRGs for these carcinogens should have been divided by 2.

However, no adjustments for multimedia effects for carcinogens were made. VII-C-2 describes the derivation of the residential soil PRG for dieldrin which was calculated to be 0.46 µg/kg at the 10^{-6} risk level. Instead of dividing the PRG by 2, the Army chose a concentration associated with a higher risk level (33 µg/kg at the 7 x 10^{-5} risk level) and presented this approach as the adjustment for additive effects of COCs in soil and groundwater. It is unclear to the EPA how the acceptance of the higher risk level could possibly counteract additive effects of COCs in multiple media.

Furthermore, the proportion method does not address the effects of multiple carcinogens within one medium, and no efforts have been made to adjust for this deficiency. EPA calculated that 23% of the soil carcinogenic risk to commercial/industrial workers in Zone 3 is attributable to COCs other than dieldrin, therefore an adjustment to account for the additional risks is necessary.

Response

Volume V, Section 2.2 of the FS has been significantly revised to include additional detail concerning development of PRGs in light of comparison of cumulative Offpost Operable Unit (OU) hypothetical cancer risks to the NCP acceptable risk range. Additional detail is also

presented in this section concerning risk associated with individual media in the Offpost OU, based on the risks presented in Volume III, Section 4.0 of the EA. As discussed in detail in Volume V, Section 2.2, the cumulative Offpost OU hypothetical cancer risk is a maximum of 3×10^{-4}, based on risks presented in the EA. As discussed extensively in Volume V, Section 2.2, Offpost OU remedial action is not warranted because the Offpost OU cumulative risk is within the NCP acceptable risk range. Also as discussed in Volume V, Section 2.2, the Army recognizes that there are several site-specific factors that, when considered in totality, suggest remediation of groundwater is preferable to no action in the Offpost OU. The above referenced sections of text concerning PRG development explicitly state the risks corresponding to the groundwater, soil, surface water, and sediment media. Also, justification is given for the conclusion that soil, surface water, and sediment media do not require development of remedial action goals. Remedial action goals were developed for the groundwater medium as discussed in Volume V, Section 2.2, consistent with the methodology presented in detail in Volume VII, Appendix C. Appendix C explicitly describes the development of PRGs, considering the effects of multiple chemicals within the groundwater medium.

See response to Part 1 given above.

As described in the response to Part 1 given above, soil PRGS were not developed.

See response to Part 1 given above.

The development of PRGs for groundwater medium explicitly accounts for the effects of multiple carcinogens within groundwater. This information is presented in Volume VII, Appendix C.

B. Derivation of PRGs

Some of the soil HBCs differ from those in the draft final text (as shown in Volume V, Table 2.4.5-1). It appears a new methodology has been used for deriving the HBCs of carcinogens (described in Volume II Appendix C). We have difficulty duplicating the new HBC numbers.

PRGs were adjusted based on observed contaminant distribution and with the intent of achieving low aggregate risk (as per footnote to Volume V. Table 2.4.5.5-1, that "some preliminary remediation goals are different than HBC presented in Table 2.4.4-1."). Which PRGs were adjusted, and why?

The soil HBC for the "Adjusted Residential" RME of Aldrin and Dieldrin are 31 ppb and .5 ppb respectively (listed in Volume V Table 2.4.5-1). Since these two compounds are very similar, to make the document more defensible it would help to explain why their HBC differ by such a large amount (a factor of over 60).

To enable the layman reader to better follow the derivations, we suggest that the Army include the following in its final version of the EA/FS:

i. A flow chart showing how the PRGs for each medium was determined.

ii. A complete listing of HBCs for the COCs in each medium.

iii. An addendum or appendix in which the actual step-by-step derivation of the HBCs and PRGs (if different from the HBC) were determined. It should the chemical's slope factor and/or reference dose. It should reflect adjustment effects for multiple media exposure and organ toxicity.

Response

The response to Part A of this comment states that Volume V, Section 2.2 presents justification based on comparison of cumulative site risk and individual media site risk to the acceptable risk range. Development of remedial action objectives and PRGs for soil was warranted.

Selected PRGs differ from HBCs because of the need to consider aggregate risk.

A flow chart showing considerations for selecting PRGs has been included in Section 2.4.5.5 of Volume II. Step-by-step derivation of HBCs is in Appendix C of Volume VII. This appendix accounts for multiple organ toxicity. Slope factors and reference doses are in Tables 3.1-3 and 3.1-4 of Volume II of the EA.

Comment No. 2 - The Use of the 10^{-4} Cancer Risk as a Point of Departure for Determination of HBC

EPA invokes dispute concerning the use of the "10 to the minus four" cancer risk as a point of departure for determination of HBC as presented in the offpost endangerment assessment, and all calculations that utilized the resulting values, for the reasons detailed below. In its response to Cover Letter Comment No. 1 the Army cites the NCP (55FR 8717) which states "Preliminary remediation goals for carcinogens are set at a 10^{-6} point of departure, but may be revised to a different risk level within the acceptable risk range on the basis of the consideration of appropriate factors including but not limited to: exposure factors, uncertainty factors, and technical factors..." The Army used several factors in an attempt to justify the selection of PRGs which present carcinogenic risks exceeding 10^{-6}. For example, the Army discusses only briefly the groundwater CRLs. There is no explanation of how the soil HBCs were derived or why they do not correspond to the PRG point of departure risk level. Groundwater CRLs are extraneous to soils PRGs. A discussion is required to justify the higher risk levels selected for soils in zones 1, 2, 5 and 6.

While EPA agrees that there are many uncertainties in the EA, EPA is not at all convinced that all of the uncertainties can be interpreted to conclude that the results of the EA present an overestimation of risks. EPA believes that problems and uncertainties associated with data representiveness, data quality and the approaches in the EA could also have contributed to an underestimation of risks in the offpost.

Examples of specific issues that may have caused an underestimation were include the following:

A. A key pathway (COC intake via eggs) was not addressed except for one chemical (dieldrin). Had the egg pathway been addressed for all relevant COCs, some HIs would have shown even greater exceedances than they did.

B. Another source of uncertainty is the fact that some groundwater COCs which are currently moving toward the offpost have not been addressed in the EA. These COCs include NDMA. The health risks associated with these chemicals would be additive to those already evaluated in the EA. (EPA still has substantive reservations concerning this issue, and reserves the right to invoke dispute at a later time.)

C. The EA (III 4-7) states that in Zone 1A 70% of the risks are attributable to COC contamination of soil. Most of this risk stems from the uptake of COCs into food materials. The fact that soil concentrations were divided by 5, before COC uptake into vegetables, beef and dairy via soil was assessed, presents a potential for underestimation of risks.

The Army did not discuss the determination of background contamination levels and their incorporation into the development of the appropriate PRGs. A section such be included which discusses the development and incorporation of background values.

Response

As discussed extensively in Volume V, Section 2.2, development of PRGS for the groundwater medium was performed consistent with the methodology described in the NCP. Groundwater HBC were calculated at the 10^{-6} level for carcinogens when ARARs were not available and at a HI of less than 1.0 for noncarcinogens without ARARs. These criteria were used as a basis for developing PRGs for groundwater. The NCP states departure from 10^{-6} may be appropriate considering various factors, including but not limited to exposure factors, uncertainty factors, and technical factors. Exposure factors the Army evaluated in the EA included cumulative effects of multiple contaminants, multiple pathways, population sensitivities, potential impacts on environmental receptors, and cross-media impacts. Additionally, uncertainty factors that evaluate the effectiveness of the alternative, the weight of scientific evidence concerning exposures in cumulative health effects, and the reliability of exposure data were also evaluated by the Army in the EA/FS. Finally, the Army also evaluated technical factors in the selection of PRGs, consistent with the NCP, including detection and quantitation limits, technical limits to the remediation, and the ability to monitor and control movement of the contaminants. In summary, the Army's approach to groundwater PRG development as described in Volume V, Section 2.5 is fully consistent with the approach described in the NCP. As described in the response to EPA Comment No. 1, PRGs were not developed for the soil medium.

A. On the basis of dispute resolution (see Attachment A), EPA agreed that the risk assessment would evaluate only dieldrin for the egg pathway. As stated in Volume II, Section 2.1.1.1, dieldrin was the only chemical of concern (COC) detected above the certified reporting limit (CRL) in an egg sample analyzed from the Offpost OU; therefore, inclusion of other COCs was not indicated.

B. All the groundwater alternatives include a specific component that calls for improvement or modification of the boundary containment systems, as necessary, to address future chemical plume concentrations. This information is in Volume VI, Section 3.0.

C. Without sufficient empirical scientific data, it is difficult to determine whether the division of COC soil concentrations by five actually resulted in an underestimation of risk. The surficial soil concentrations were divided by five to estimate a depth-averaged concentration in the root zone because the soil COCs are strongly adsorbed to soil particles and are unlikely to be readily leached through the soil column. The division of soil concentration by five is discussed further in the response to Comment No. 5.

Background concentration levels were not used in the development of groundwater PRGS.

Comment No. 3 - Land Use

EPA invokes dispute concerning the land use scenarios as presented in the offpost FS, and all sections and calculations that utilized the offpost FS conclusions, for reasons detailed below. The discussion in Volume II demonstrates that there is uncertainty in regard to the land uses offpost. Uncertainty, per the NCP, would require a comparison of land uses, such as residential, commercial-industrial and recreational.

Scenarios for residential land use should be evaluated whenever there are homes on or near the site, or when residential development is reasonably expected in the future. Consideration of historical

land use; suitability for residential development; local zoning; and land use trends should be undertaken. The farm family scenario should be evaluated if it is known that such families reside in the area. EPA's concern is that residential uses were not compared in the Feasibility Study (along with the Commercial-Industrial and Recreational uses). This should be done, given the present level of discussion and the existing situation in the area. Some examples of uncertainty in the discussion are:

A. *PUD is not defined in Figure 7.2.2.1.2-2. A PUD does not support the elimination of residential use between RMA and Route 2, without a specific definition which precludes residential.*

B. *There was not information on the delineation or uses of the wetland in zones 3 and 4 sufficient to eliminate residential use.*

C. *The realignment of 96th Avenue has been presented as speculation. There is no information on whether there are plans to condemn the property for this route, whether land has been dedicated for this route, whether it is on any official planning or transportation plan demonstrating such a project. Further, there is not information sufficient to eliminate residential use along a realigned corridor.*

D. *There was no explanation concerning the format issue of the 1990 Census which was described as helping to define the present use. (P II-2-40)*

E. *There was no discussion sufficient to conclude that Offpost Groundwater IRA would render land Commercial/Industrial. (P II-2-44).*

Presently, it cannot be demonstrated that the likelihood of residential use is small, given the discussion of the circumstances in the Offpost OU, zones 3 and 4. These comments are premised upon page 8710 of the National Contingency Plan (55FR8710, March 8, 1990), Section 6.2.2 of the Risk Assessment Guidance (OSWER Directive 9285.701a; July, 1989), and Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors" (OSWER Directive 9285.6-30, March 25, 1991).

Response

The topic of this comment was addressed during the dispute resolution process. Refer to Attachment A for additional information in the dispute resolution letter. On the basis of dispute resolution, all Organizations agreed to use a single land use scenario for each zone within the Offpost OU. Zones 1, 2, and 6 were classified as rural residential, zones 3 and 4 as urban residential, and zone 5 as commercial/industrial. The land use scenarios and potential exposure pathways were further defined as a result of agreements reached by the Organizations during the dispute resolution process, as follows:

A. Rural Residential (EA/FS zones 1, 2, and 6)

meat* (75 percent)
dairy* (75 percent)
egg (only evaluated dieldrin)
vegetable* (40 percent)
groundwater (ingestion)
groundwater (inhalation)
soil (dermal)
soil (ingestion)

sediments (dermal)
surface water (dermal)

B. Urban Residential (EA/FS zones 3 and 4)

vegetable* (40 percent)
soil (dermal)
soil (ingestion)
sediments (dermal)
surface water (dermal)
groundwater (ingestion)
groundwater (inhalation)

*All percents indicate amount of consumption from local sources.

Risk estimates for Zones 3 and 4 will be presented in two manners:

1. As a baseline risk assessment for all media per EPA guidance. The groundwater portion of the risk assessment will be based on the calculated risks from 1989 to 1991 groundwater data in those zones.

2. The second risk calculations will be based on the continuing beneficial effect of the onpost boundary system operations in a 30-year time. The text will state that these are the expected potential exposures for individuals in those zones and the risks associated with those exposures.

C. Commercial/Industrial (EA/FS zone 5)

soil (dermal)
soil (ingestions)
groundwater (ingestions)
groundwater (inhalation)

If SACWSD provides appropriate documentation indicating that SACWSD is not planning to install future water wells in zone 5 over the next 30 years, the groundwater pathway will be removed from zone 5. Attachment B to this set of responses to comments is a letter from SACWSD to the Army, providing documentation that SACWSD does not intend to install water-supply wells in zone 5 in the future.

Comment No. 4 - Interpretation of Uncertainties Analysis

EPA invokes dispute concerning the interpretation of the uncertainty analysis as presented in the offpost EA/FS, and all sections and calculations that involve this interpretation, for the reasons detailed below. The response to comments on the uncertainty analysis is inadequate to address the agency's concerns, in that it failed to distinguish between propagating variability and critical knowledge uncertainties. The uncertainty analysis is put together in a fashion that renders it, in reality, an analysis of uncertainties. Site-specific parameters, such as exposure point concentrations, were found to contribute little to overall variability (i.e. they were "insensitive parameters") compared to various parameters associated with human behavior (exposure duration, ingestion rates, etc.). This being the case, it is not possible to determine whether the uncertainty analysis over- or underestimates actual exposures which might occur on the site. Stated in another way, any "hypothetical" exposed population in the off-site area may vary considerably from the "typical"

case. The logical conclusion is that there is no way to determine whether the RME estimate or the quantitative uncertainty analysis better represents potential upper range exposures.

The Army maintain that they accept this conclusion, but the document suggests the opposite. The risk assessment concludes that the uncertainty analysis "clearly" shows that the RME overestimates potential exposures and concludes that the risk assessment may be "excessively" conservative. This conclusion is then carried into the Feasibility Study to help justify a target risk substantially higher than 1 x 10^{-6} for PRGs for the residential scenario. Such conclusions and interpretations clearly indicate that the Army accepts the uncertainty analysis as a more "accurate" measure of potential exposures. In view of the lack of knowledge of site-specific exposure parameters in these "hypothetical" populations, and the lack of meaningful discussion on them, EPA cannot accept this interpretation. In fact, the analyses seem to suggest that the appropriate conclusion might be almost the opposite. Agreement within a factor of 3 or so should be viewed as quite good in the face of the many uncertainties which go into risk assessment. EPA feels that the appropriate interpretation is that estimates for maximum exposure are quite reasonable in comparison with those expected in a "typical" community, and that no substantial "overconservatism" has been documented.

In addition, the document does not distinguish between a "sensitive subpopulation" and the "population-at-risk". An example may serve to demonstrate the point. As one moves away from the Arsenal boundary, concentrations of contaminants in soil generally decrease until some "background" is reached. If data from samples taken over this entire area are averaged, many current or future residents on the fringe, or outside of the zone of the higher contamination will be included in the exposure estimates. Since such individuals are not among the "at-risk" population, the result will be an underestimate of exposures. The Army has recognized this in dividing the off-post into zones. However, the document does not recognize that individuals may also be on the fringe in a temporal as well as spatial fashion. As previously affirmed, many individuals in a population may be exposed for such short time periods that they cannot be considered "at-risk." These individuals can reasonably be excluded from a quantitative uncertainty analysis without changing the basic intent to examine a potential (perhaps "hypothetical") range of exposures in the AT-RISK population.

Response

The proposed final EA/FS has been revised in response to this comment. Specifically, the Army has concurred with and added EPA suggested wording regarding the interpretation of the uncertainty analysis results, specifically, in Section 2.6 and 4.4. The distinction between propagation of variability and critical knowledge uncertainties was specifically addressed in the previous draft as well as this draft (see Section 2.4.5.5.3), and the Army fails to appreciate how EPA's previous comments require further elaboration on that issue. The Army agrees that the uncertainty analysis is an analysis of uncertainties. The Army agrees that the uncertainty analysis is prone to share certain categories of errors with the reasonable maximum exposure (RME) analysis. Included among these are:

1. Selection of exposure pathways for quantification: The same pathways are included in both the RME and the uncertainty analysis. Some of these pathways may be incomplete now or in the future. Conversely, some pathways that were not quantified may contribute to exposure and risk, but documentation was provided in Section 2.3.3 (and the response to comments incorporated in the March 17, 1992, proposed final report), supporting the conclusion that pathways not quantified contribute negligibly to exposure.

2. Use of national average statistics rather than site-specific data for exposure factors, such as consumption of homegrown vegetables and duration of residency: Additional discussion has been added to respond to EPA's comment on this issue in Section 2.4.5.4.

Considering these limitations, the primary conclusion that can be drawn from the uncertainty analysis is that consistent selection of upper 90th and 95th percentile values for exposure concentrations, exposure factors, and equilibrium partition coefficients (the procedure used to derive RME intake estimates) tends to compound conservatism to such an extent that the RME intake has a very low probability of exceedance. This finding leads the Army to conclude that selection of a remedial alternative that produces an RME risk near the upper end of the acceptable risk range would be protective of human health per the NCP.

The Army disagrees with EPA's interpretation that "agreement" within a factor of 3 is significant of anything more than careful representation of the distributional inputs to the uncertainty analysis. The inputs were designed to represent the same distributional information used to define the point values (90th or 95th percentile) input to the RME calculation, so "agreement" simply confirms that the distributions were represented in a consistent fashion in both the RME and uncertainty analyses.

EPA's point regarding the difference between a sensitive subpopulation and the "population at risk" is well taken. The distinction is a difficult issue throughout this and numerous other site risk assessments. The sensitive subpopulation upon which the RME is based is assumed to maintain a backyard garden (and domestic animals in some zones). Although it should be clear that not all, and perhaps relatively few, residents would actually fit this profile, the Army and EPA seek to protect such residents' health should they choose to do so. The uncertainty analysis attempts to represent the population at risk, including these relatively highly exposed few. The Army believes that representation of all the individuals within the population at risk enhances our ability to communicate risks to the public in a balanced and meaningful way. Individuals who reside in the offpost area for only one or two years should not be misinformed that their risk is equal to the RME. Contrary to EPA's comment, the document does address this issue through the uncertainty analysis by incorporating a realistic range of exposure durations (all the way from 1 year to 70), and this is clearly one of the reasons why the median exposure is much lower than the RME. As derived from the Exposure Factors Handbook, the median duration of residency at a single residence (nationwide) is approximately 10 years, much lower than the RME estimate of 30 years. The distribution used in the uncertainty analysis also reflects the possibility of exposure durations much greater than 30 years, but the probability of longer exposure durations is very low. The Army sees no compelling reason to exclude either short-duration or unusually long-duration residents from the uncertainty analysis.

Comment No. 5 - Division of Soil Concentrations by 5

EPA would invoke dispute concerning the division of soil concentration values by the factor of 5 as presented in the offpost endangerment and all calculations that used the resulting values, for the reasons detailed below, except for the low risk involved in the specific example. In any other instance we would not accept this procedure. In its response to General Comment No. 24 the Army defends the adequacy of the subsurface soil data set, which was used to assess COC concentrations in subsurface soil. The Army claims that 5 sets of corresponding subsurface and surficial soil data sample points were used for the comparison. However, subsurface sample HA 1261 SO, which is mentioned in the Army's response is not included in RI Figure 2.5 which gives locations for subsurface samples. Furthermore, this sample is neither mentioned in the text, nor are any data included in the relevant Appendix. Since the sample appears to be not documented, it cannot be used for the comparison.

This would appear to leave 4 soil samples for the 0.5 foot depth analysis. Dieldrin was detected in only one of the 4 samples (HA 9085 SO), however, the dieldrin concentration in this sample (70 µg/kg) was higher than that of other surficial soil samples that were collected relatively nearby (HA 1235 Wb, 30 µg/kg, HA 1229 WB, 13 µg/kg, and the "collocated" surficial soil sample HA

0996 WB, 55 µg/kg). Even though dieldrin concentrations were below the detection limit in the 3 other subsurface samples, EPA believes that the data are not sufficient to justify dividing soil concentration by 5 (or by 4).

Furthermore, the text (II-2-77) indicates that most of the surficial soil data are from untilled areas, and that the subsurface soil samples were collected "nearby." It seems inappropriate to measure subsurface soil concentrations in areas which have not been used for agricultural purposes, if these soil concentrations are then used to determine COC uptake into vegetables. It is obvious that in plowed, filled and irrigated soils COCs would more evenly distributed in the subsurface.

Response

Results from sample HA 1261 SO were reported in the remedial investigation (RI) addendum. However, a typographical error in that document resulted in the sample being labelled "HA 1261 S". The results are also part of the Program Manager for Rocky Mountain Arsenal (PMRMA) database where the sample is labelled HA 1261 SO, and that database is part of the administrative record.

EPA appears to be confused that division of concentration by a factor of 5 is somehow related to the fact that five sets of corresponding subsurface and surficial samples were used as supporting documentation. The factor of 5 is derived from the ratio of the depth of the root zone for row crops to the depth interval of surficial samples. At the risk of belaboring our arguments already on the record, we assert that all available evidence supports the conclusion that surficial soil contamination offpost has resulted from deposition of windblown aerosols from onpost sources, that the soil COCs are all organochlorine pesticides that are highly immobile within the soil profile, and consequently that it is likely that untilled soil will contain soil COCs only in the upper one or two inches of the profile. These hypotheses are supported by the fact that detectable concentrations have been observed nearly exclusively in surficial (upper 1 to 2 inches) samples and that nearby samples of the upper 6 inches have lower or nondetectable concentrations. The portions of the Offpost OU where the highest surficial soil concentrations have been found have predominantly not been used for row crop cultivation but rather have been fallow/pastureland. If, under a potential future land use, they were to be cultivated for vegetables, they would be tilled, thus mixing the contaminants presently found in the upper 1 to 2 inches through the root zone, resulting in an average root zone concentration approximately 1/5 of the observed surficial concentrations.

EPA's final paragraph suggesting that samples from untilled land not be considered for the vegetable pathway analysis contradicts related EPA guidance that potential future land uses that might result in RME exposures be evaluated. The Army, following EPA guidance, has conservatively assumed that land not currently in cultivation might be cultivated in the future. Areas currently under cultivation for vegetables have substantially lower concentrations of COCs in soil.

Comment No. 6 - Ecological Risk Assessment

EPA invokes dispute concerning a) the values for bioaccumulation factors (BAF) and biomagnification factors (BMF), and b) the value for dieldrin MATC in top predators (eagle/owl/kestrel/) presented in the off post ecological risk assessment, and all calculations that used these factors, such as ecological PRGs, for the reasons detailed below. (See: Volume III, Section 5.0 et seq., Volume IV, Appendix H, and Volume V, Ecological PRGs, Volume VII, Appendix C.)

In addition, EPA still has substantial reservations concerning the methodology used to derive ecological toxic reference (TRV) values. EPA would invoke dispute on the TRV methodology for dispute at this time; however, since the TRV values were not used to develop ecological PRGs, we

will not dispute at this time. EPA reserves the right to invoke dispute on the TRV methodology should it be used in the onpost ecological assessment.

A. Bioaccumulation factors (BAF) and Biomagnification Factors (BMF)

The values for BAFs and BMFs, and other values calculated from these, cannot be accepted as presented due to serious concerns about the methodology used to derive those BAF/BMFs.

The off post ecological risk assessment (ERA), as currently presented is a deterministic version of the on post ecological risk characterization (ERC) model.

The ERC has not previously been reviewed, and thus constitutes entirely new information. A set of computer disks were provided to EPA on March 19, 1992, containing the post-calibration values for on post biota. No supporting documentation was provided with those disks.

EPA will submit detailed comments concerning the on post biota model under separate cover. A careful review of the available data set was undertaken for study area 1, and indicates that there is no acceptable basis for comparing contaminant concentrations in soil, terrestrial plants, and prairie dogs. Although the sample sizes were reasonably large, at least for soil and prairie dogs, the number of co-located samples that could be compared rigorously is extremely small. Thus, these data cannot be used to estimate BAFs or BMFs. The attempt to do so, based on the entire files of soil and biota data, involves almost exclusively the comparison of non-comparable data.

Response

A. The Army elected to use calibrated onpost data because it felt that site-specific parameters were preferable over literature values that were based on controlled experimental studies or field studies conducted in other geographical regions. The Army felt that BAFs derived from both controlled laboratory studies or other field studies would not reflect influences from environmental/ecological conditions within the Offpost OU. Therefore, the Army concluded the onpost values would be preferable because the offpost is environmentally and ecologically similar to the onpost.

However, the Army acknowledges that because of different scheduling needs, the onpost values were not adequately reviewed by the Organizations and State (OAS) before their use in the draft final ecological assessment. Therefore, the Army has agreed to incorporate the BAF and BCF values derived during the dispute resolution process. The Army still maintains the literature values are not representative of Offpost OU site-specific conditions.

B. Dieldrin MATC in top predators (eagle/owl/kestrel)

The dieldrin MATC value of 1.6 ppm cannot be accepted because it relates to lethality in birds of prey.

The Army selected an MATC value of 1.6 for both aldrin and dieldrin in birds of prey. The value of 1.6 ppm is the average concentration in the carcasses of 101 bald eagles found dead between 1971 and 1974. (K.R. Barbehenn and W.L. Reichel, Organochlorine concentrations in bald eagles: brain/body lipid relations and hazard evaluation. Journal of Toxicological Environmental Health 8:325-330, 1981). The value of 1.6 ppm is neither a safe level nor a minimum level: it is an average level in a collection of birds grouped together for other

reasons. The paper is about the pharmacology of dieldrin in eagles, not about dose-response relationships.

The best experimental data on effects of dieldrin on birds of prey are those of Wiemeyer et al. (DDE, DDT + Dieldrin: Residues in American Kestrels and Relations to Reproduction, 1986). The mean carcass concentrations in birds that died was 1.7 ppm (range, 0.7 - 4.5 ppm). Thus, a carcass concentration of 0.7 ppm is related to lethality, and cannot be indicated as "allowable." To apply these data to other birds of prey, including eagles, would require an additional interspecies uncertainty factor.

Reported cases of dieldrin poisoning in bald eagles from several states (Prouty, R.M. et al, 1977. Residues of organochlorine pesticides and polychlorinated biphenyls and autopsy data for bald eagles, 1973-74.

Pestic. Monitor J. 11:134-137, and Kaiser, T.E. et al, 1980. Organochlorine pesticide, PCB, and PBB residues and necropsy data for bald eagles from 29 states -- 1975-77. Pestic. Monitor. J. 13:145-149) indicate median carcass residues in bald eagles of 0.74, 0.63, 0.60, 0.66, and 0.22 ppm, wet weight. Although it is difficult to use these data to define a minimum or low effect level, it is clear that a population average level of 0.66 ppm is associated with deaths from dieldrin poisoning in some individuals. Therefore, EPA cannot accept the MATC value of 1.6 ppm for dieldrin.

Response

B. The MATC values used in the draft final ecological assessment were obtained from the Onpost Ecological Risk Characterization (ERC). Although these values were not adequately reviewed by the OAS before the release of the draft final ecological assessment, the Army has some serious concerns about the adequacy of the data from the Wiemeyer and others paper cited by EPA for establishing a dieldrin MATC. The Army's concerns include the following: use of a chemical mixture with no single dosing with dieldrin, study not designed to investigate dieldrin toxicity only, the presence of other stressors (e.g., periods of low ambient temperatures and disease episodes of enteritis), study conducted more than 23 years ago, insufficient numbers for an adequate statistical comparison, and the presence of toxicological anomalies. For example, the lowest kestrel carcass concentrations associated with mortality in the low dose groups is 0.7 ppm as cited above by EPA; however, the brain concentration in this kestrel is one of the lowest levels reported, 0.09 ppm, and this animal also has the second highest value reported for carcass lipid percent of dry weight, 36.4 percent. Toxicologically, it is highly unlikely that dieldrin either directly or indirectly caused this animal's death. Additionally, in their summary of dieldrin-related deaths for all study groups, the authors indicate dieldrin was not the cause of death for any animal in the low dosage groups and only contributed to the death of three others. Sixteen birds comprised the low dosage groups. Therefore, the Army cannot accept 0.7 ppm as a suitable MATC.

Following a review of several articles published on dieldrin toxicity during the dispute resolution and a conference call with Dr. Stanley Wiemeyer, the Organizations and Army agreed upon a dieldrin MATC value of 1.1 ppm.

Comment No. 7 - Acceptance of Ecological Hazard Indices that Exceed 1

EPA invokes dispute concerning the acceptance of ecological hazard indices that exceed 1 as presented in the offpost risk assessment, and all calculations that utilized the resulting values, for the reasons detailed below.

A. *The Army justifies the acceptance of high HIs for ecological receptors with the argument that the movement of these receptors to areas outside of Zone 3 will reduce the ecological risk. At the same time the Army dismisses the additional risks that ecological receptors encounter when they move onpost. The Army states (response to General Comment No. 6) that "movement of receptors to the onpost increases exposure that is more appropriately evaluated in the onpost."*

EPA disagrees with this statement. The physical setting of RMA and its surroundings suggests that ecological receptors are more likely to spend time at RMA than in the more developed areas outside of RMA. While EPA does not require the Army to quantitatively address the additional risks that animals residing in the offpost encounter due to movement into the onpost, EPA believes that the additional exposures are a source of uncertainty in the ecological risk assessment, which should not be dismissed. The potential for additional and even greater exposures make the risks associated with Zone 3 very significant, and Hazard Indices above 1 cannot be accepted.

While the Army is correct in stating that the home range of mobile ecological receptors may exceed the size of Zone 3, the Army does not provide any quantitative information on how much time these receptors spend outside of Zone 3, or what percentage of prey is caught outside of Zone 3. The HIs calculated in ecological risk assessments are quantitative estimates based on many considerations and factors. These quantitative data cannot be dismissed based on a completely unquantified assumption. It should also be noted here, that even though several of the calculated HIs are high, EPA has many concerns with the input parameters used to calculate the HIs. If more appropriate parameters were used, resulting HIs would be even higher.

B. *The results of the EA showed that the egg pathway is an important contributor to noncarcinogenic risk. For example, for the child resident in Zone 1C the egg pathway contributes an HI of 3.1×10^{-1} to a total HI of 1.2. The fact that the egg pathway has not bee evaluated for soil COCs other than dieldrin is especially significant in light of the fact the HIs for hepatotoxic effects in children exceed 1 in all zones.*

The soil concentrations for endrin, DDT/DDE and chlordane are similar to those of dieldrin (Table 2.4.2.5-8). Therefore, if the soil to egg partitioning coefficients for these chemicals are similar to the soil/egg partitioning coefficient for dieldrin, chemical concentrations in eggs would be similar to those of dieldrin, and the egg pathway for other soil COCs would contribute greatly to the already existing calculated risk. For example, an estimate shows that the egg pathway for chemicals other than dieldrin might contribute an HI of approximately 0.65 to hepatoxic effects in children in Zone 3.

The Army states that it was unable to quantify the egg pathway for chemicals other than dieldrin, because no literature value for the soil to egg partitioning coefficient could be found for these chemicals. EPA suggested (General Comment No. 26) that a default value for K_{se} similar to that of dieldrin be used to estimate the concentrations of soil chemicals in eggs. In the absence of site-specific data and/or literature data for the K_{se} parameter, the approach recommended by EPA would have been reasonably conservative. To not address potentially important pathways because of the lack of data is unacceptable in a human health risk assessment, when use of parallel information would at least yield qualitative information for the uncertainty analysis.

Response

A. The movement of mobile ecological receptors to onpost areas potentially could result in additional exposure and increased risks; however, the Army cannot quantitatively determine

the additional risk that may occur because the onpost ERC is not yet complete. The HI is the result of a comparison of an estimate close to a benchmark, in this case, a toxicity reference value. A numeric result greater than one does not indicate the potential magnitude or severity of effect, only that the benchmark dose was exceeded. The EPA appears to accept an HI of one as an absolute reference point and any exceedance above one as totally unacceptable. This defies biological reality and the uncertainty associated with biological systems. Compared to the physical sciences, biological outcomes are less predictable, and a range of acceptability is appropriate. Although sufficient monitoring/analytical data are lacking, it is highly unlikely that the HIs, as determined for this ecological assessment, underestimate the potential risk and ecological receptors.

The Army strongly disagrees with the statement, "If more appropriate parameters were used, resulting HIs would be even higher." In fact, on the basis of dispute resolution, the parameters agreed upon by the Army and Organizations resulted in lower HIs. These parameters included a spatial adjustment factor to account for the receptor's dietary intake fraction obtained from zone 3 and/or zone 4 relative to the receptor's home range.

Comment No. 8 - General Comment Concerning ARARs Analysis

EPA invokes dispute concerning the adequacy of the ARAR analysis as presented in the offpost EA/FS, and all calculations and conclusions that utilized the analysis, for the reasons detailed below. The discussion of ARARs in the EA/FS is inadequate. Compliance with ARARs is a threshold requirement for comparing and selecting remedial alternatives, yet the ARAR discussion in Appendix A provides no basis for differentiating alternatives. The ARARs analysis should have considered the universe of ARARs as they applied to each remedial alternative, providing detailed discussion with respect to the preferred alternative. EPA's "CERCLA Compliance with Other Laws Manual," OSWER Dir. 9234.1-01 (August, 1988), specifies the process for completing an ARAR determination. (See CERCLA Compliance with Other Laws Manual, pp 1-55 to 1-56). In addition, Appendix E to EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA," OSWER Dir. 9355.3-01 (October, 1988), provides a suggested format for the summary of ARARs. EPA recommends that this format be used. Even if this format is not followed, a substantively equivalent discussion is required. EPA believes that the EA/FS does not sufficiently address ARARs, and therefore objects to the entire proposed ARAR determination.

It is not sufficient to lump together entire statutes or groups of regulations without analyzing the portions thereof that may be applicable or relevant and appropriate. For example, on p. VII-A-14, the Army's ARAR analysis states: "To the extent that hazardous wastes do exist, 40 CFR Part 264 will be an ARAR." This statement is so vague that it cannot reasonably construed to constitute an analysis. In fact, it is clear that some sections of Part 264 may be ARARs, and some may not. As just one example, 40 CFR Part 264.281 relating to ignitable or reactive wastes is not likely to play a role in this remedial action, but 40 CFR 264.100, which establishes a ground water monitoring program, may well be relevant and appropriate.

In light of the lack of adequate identification and discussion of individual ARARs, EPA is unable to provide a comprehensive list of the deficiencies of Appendix A. Instead, EPA requires that a thorough ARAR analysis be performed taking into account the universe of Federal and State ARARs.

In addition, EPA has disagreed with particular ARAR conclusions that were reached in the Army's Response to Comments. These are described in more detail below.

Response

Volume VII, Appendix A of the FS, ARARs analysis, has been revised to address EPA's concern that sufficient detail was not provided. Specifically, additional detail was provided in the section describing each of the major categories of chemical-specific, action-specific, and location-specific ARARs. Additionally, as requested by EPA, a table summarizing the ARARs analysis was added.

Additional text was added to Volume VII, Appendix A, specifically addressing sections within 40 CFR, Part 264, and discussing which sections of Part 264 may be ARARs.

Additional text has been added to Volume VII, Appendix A, including and addressing the universe of Federal and State ARARs.

A. *Specific Inaccuracies in ARARs Analysis*

EPA invokes dispute concerning specific inaccuracies in ARAR analysis as presented in the offpost EA/FS that EPA can now identify, and all calculations and conclusions that utilized the analysis, for the reasons detailed below.

i. *Response to Comments on Volume VII:*

The portion of this response that states: "ARARs do not discuss surface water and sediments because the preferred alternative does not require remedial action for those specific media," is inconsistent with CERCLA and the NCP. CERCLA requires that remedial action:

attain a degree of cleanup of hazardous substances, pollutants, and contaminants released into the environment and of control of further release at a minimum which assures protection of human health and the environment.

42 U.S.C. s[s]9621(d).

In order to assure that remedies are protective of human health and the environment, section 121 of CERCLA requires that the remedy attain ARARs. If there is any exposure pathway for humans, ARARs must be considered to establish protectiveness. If site conditions do not meet ARARs, remedial alternatives must be developed. Even if surface water and sediment are determined to have no exposure pathway for humans, in light of the Endangered Species Act, the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act, surface water and sediment must be considered as potential exposure pathways for migratory birds and eagles. If ARARs have not been considered for surface water and sediment, the selected remedy cannot be shown to be protective and cannot meet the threshold criteria required for comparison of remedies in the NCP. See 40 CFR § 300.430.

Response

With regard to the EPA inquiry on the Endangered Species Act (ESA), the Bald and Golden Eagle Protection Act (BGEPA), and the Migratory Bird Treaty Act (MBTA), Appendix A in Volume VII has been revised to include in totality the language agreed upon in the dispute resolution process and communicated in a letter from EPA to the other parties, dated September 18, 1992, regarding these three federal acts (see Attachment C).

ii. *Response to Comment No. 17:*

This response states that reports available at EPA or RMA are "publicly available" and may be cited without constraint. EPA disagrees. The Army has relied on old reports that may no longer be available, as well as draft reports that may be subject to privilege. These and any other reports that may not be publicly available, should be included as appendices to the EA, or, at the very least, added in full to the Administrative Record.

Response

The Army stands by its response that reports available at EPA or RMA are "publicly available" and may be cited without constraint. In appropriate appendixes in the Final EA/FS, the Army has included information that is not yet available, e.g., some ecological risk assessment parameters that were obtained from the unfinalized Onpost ERC are in Appendix H.

iii. *Response to Comment No. 25:*

This response is incorrect insofar as it suggests that the Migratory Bird Treaty Act does not require protection of individual birds. 16 U.S.C. s[s] 703 clearly states that it is unlawful to "kill...any migratory bird...or any egg of any such bird..." This statute was amended in 1974 for the specific purpose of changing a reference to "birds" (plural) to "bird" (singular). The language of the statute "makes it clear that killing a single bird is sufficient to create criminal liability..." United States v. Corbin Farm Service, 444 F. Supp. 510 (E.D. Cal. 1978).

For further discussion of the Migratory Bird Treaty Act as an ARAR, see Response to Comment No. 216, below.

Response

Refer to response to A.i. given above, regarding the dispute resolution agreement for the three Federal Acts.

iv. *Response to Comment No. 114:*

This response suggests that EPA may not dispute the values for the chemical-specified absorption factor (ABS) because EPA had previously been informed of these values in a RMA subcommittee meeting and expressed no opposition at that time. This position is insupportable. EPA is in no way bound by its silence at a time when the Agency was under no affirmative duty to raise objections. EPA has not waived its right to pursue dispute resolution on this issue.

Response

Comment acknowledged.

v. *Response to Comment No. 216:*

The response to this comment, which states that the Endangered Species Act, 16 U.S.C. s[s] 1531, et seq., the Bald and Golden Eagle Protection Act, 16 U.S.C. s[s] 668, et seq., and the Migratory Bird Treaty Act, 16 U.S.C. s[s] 701 et seq., are not ARARs is both incorrect and

inadequate. Contrary to assertions made in the Army's response, the Endangered Species Act, the Migratory Bird Treaty Act and Bald and Golden Eagle Protection Act contain substantive requirements applicable to circumstances present at this site.

With respect to the Endangered Species Act, we note that 16 U.S.C. s[s] 1538 (1)(B) states:

> *[i]t is unlawful for any person subject to the jurisdiction of the United States to take any such species within the United States...*
>
> *and "take" is defined at s[s] 1532(19) as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." The Agency interprets "harm" as any harm resulting from contaminant pollution.*

The Migratory Bird Treaty Act states:

> *Unless and except as permitted by regulations made as hereinafter provided in this subchapter, it shall be unlawful at any time, by any means or in any manner, to pursue, hunt, take, capture, kill...any migratory bird, any part, nest, or egg of any such bird...*
>
> *16 U.S.C. s[s] 703.*

The United States Court of Appeals for the Second Circuit has interpreted this statute to apply to a situation in which migratory birds were killed by the release of chemicals into a pond. United States v. FMC Corp., 572 F.2d 902 (2d Cir. 1978).

Similarly, the Bald and Golden Eagle Protection Act makes it unlawful to kill bald or golden eagles by poisoning. See 16 U.S.C. s[s] 668d: "As used in this subchapter..."take" includes also pursue, shoot, shoot at, poison, wound, kill, capture, trap..." (emphasis added).

According to the NCP, ARARs are:

> *[c]leanup standards, standards of control, and **other substantive requirements**, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or **other circumstance found at a CERCLA site.***
>
> *400 CFR § 300.5 (emphasis added).*

The Endangered Species Act, the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act, clearly set up substantive requirements and/or limitations (i.e. protection of certain species) under circumstances that are present at this site. The statement in the ARAR analysis (Appendix A) that "the alternatives will have no adverse impact on any endangered species or migratory birds" is insufficient. Not only are the Endangered Species Act, Bald and Golden Eagle Protection Act and Migratory Bird Treaty Act ARARs, but they must also be used to set standards for remediation that will be protective of endangered species, migratory birds and bald and golden eagles.

Response

Refer to response to Part 1 above regarding the dispute resolution agreement with respect to the three Federal Acts.

Pages VIII-20 through VIII-26 are missing from the original.

FEASIBILITY STUDY

GENERAL COMMENT

Comment No. 1 - Alternative Selection

EPA invokes dispute concerning the groundwater alternative selected in the offpost FS, and all areas of this document and future documents that are effected by the selection, for the reasons detailed below. Since all of the alternatives presented for the remediation of the groundwater (excepting the No-Action alternative) are variations on the configuration of the same technology, the alternatives are essentially equivalent. All of the alternatives evaluate various arrangements of a transverse pump-and-treat system. In order to make the FS comprehensive and in compliance with guidance, axial arrangements should also be evaluated. The Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA states, "For aquifers currently being used as a drinking water source, alternatives should be configured that would achieve ARARs or risk-based levels as rapidly as possible." The Offpost FS has not evaluated configurations that could potentially achieve a more rapid remediation, such as an axial system.

The Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites states, "A rapid remedial alternative generally should be developed for ground water that is a current or potential (emphasis added) source of drinking water. This alternative should achieve the selected cleanup level throughout the area of attainment within the shortest time technically feasible. Additional alternatives should be developed to ensure that a wide range of distinctive hazardous waste management strategies are evaluated at most sites." The FS must be modified to broaden the range of alternatives to include one which would achieve cleanup in the shortest time possible or demonstrate that a more rapid cleanup is not technically feasible.

Response

The Army strongly disagrees with EPA's contention that an aggressive groundwater alternative was not evaluated in the Offpost FS. As discussed in Volume VI, Section 3.0, Development of Remedial Alternatives, and Volume VI, Section 6.0, Detailed Analysis of Remedial Alternatives, the offpost geology, hydrogeologic systems, contaminant distribution, and contaminant transport properties were studied extensively both analytically and using a groundwater numeric model. The modeling effort is described in both Volume VI, Section 3.0 in terms of development of remedial alternatives and extensively in Appendix E of Volume VII.

The results of this analysis are presented in a lengthy discussion in Volume VI, Section 3.0. The controlling hydrogeologic and contaminant transport properties of the Offpost OU groundwater system include (1) groundwater seepage velocity of the First Creek pathway relative to the northern pathway, (2) the distribution of the relatively less mobile compound dieldrin compared to the distribution of more mobile compounds such as DIMP and chloroform, and (3) the controlling transport properties of dieldrin as compared to the transport properties of DIMP and chloroform. As described in Volume VI, Section 3.0, Alternative No. N-4 for the North Plume Group was developed through a combination of analytical well field simulation, knowledge of contaminant distribution and contaminant transport properties, and hydrogeology of the North Plume Group.

A transverse capture system for the northern pathway was chosen to intercept contaminants moving in the northern pathway. An axial system of collection wells and recharge trenches was selected in the First Creek pathway. Alternative No. N-4 consists of a total of 17 walls and 6 trenches with a total extraction flow rate of approximately 480 gpm. Alternative No. N-5 has a total of 20 extraction wells and 12 trenches. Alternative No. N-6 has a total of 4 extraction wells and 19 trenches. The total linear feet of recharge trenches ranges from 1500 feet in Alternative

No. N-4 to approximately 4400 feet in Alternative No. N-6. The total extraction flow rate ranges from 480 gpm in Alternative No. N-4 to a total of 690 gpm in Alternative No. N-6.

The increasing complexity of Alternative Nos. N-5 and N-6 as compared to Alternative No. N-4 was evaluated to assess the impact of adding a number of extraction and recharge trenches in areas where contaminants were remaining in areas of slower relative groundwater velocity and tighter aquifer materials, and to address less mobile contaminants.

The level of aggressiveness of Alternative Nos. N-5 and N-6 reached a practical maximum whereby the maximum practical number of additional extraction wells and recharge trenches was evaluated for remediation timeframe and aquifer drawdown considerations. Model-estimated groundwater mounding and drawdown resulting from the recharge trenches and extraction well arrays reached practical limits in Alternative Nos. N-5 and N-6. The discussion presented in Volume VI, Section 3.0 gives specific information demonstrating the distinct differences in level of complexity and aggressiveness of the remedial alternatives studied in the EA/FS.

SPECIFIC COMMENTS

Comment No. 2

Response to Comment 201

See dispute item number 2 (land use) above.

Response

See response to EPA General Comment No. 3 under Endangerment Assessment.

Response to Comment 202

The response to this comment is inadequate, but EPA will not dispute this issue at this time. However, the document would be more defensible if the following concerns were addressed. The Army has not adequately addressed the remediation of the contaminated surface water. As presented, the FS evaluates only one alternative for the remediation of surface water, which is the remediation of the surface water via source removal, i.e., remediation of the groundwater. The FS Guidance (OSWER Directive 9355.3-01, October 1988, p. 1-8) states, "As practicable, a range of treatment alternatives should be developed, varying primarily in the extent to which they rely on long-term management of residuals and untreated wastes. The upper bound of the range would be an alternative that would eliminate, to the extent feasible, the need for any long-term management (including monitoring) at the site. The lower bound would consist of an alternative that involves treatment as a principal element (i.e., treatment is used to address the principal threats at the site), but some long-term management of portions of the site that did not constitute "principal threats" would be required. Between the upper and lower bounds of the treatment range, alternatives varying in the type and degrees of treatment and associated containment/disposal requirements should be included as appropriate. In addition, one or more containment option(s) involving little or no treatment should be developed as appropriate, and a no-action alternative should always be developed."

The Army has not provided an objective evaluation of possible alternatives for the remediation of the contaminated surface water other than concluding that the remediation of the groundwater would remediate the surface water. The timeframe and costs for remediation of surface water are not identified, even within the context of the remediation of the groundwater, since a portion of

these elements reside in the remediation costs and timeframe for the Onpost OU, for which the FS has not yet been prepared.

Even though the surface water contamination may not constitute a "principal threat" in the Offpost OU, this contaminated media must be evaluated in the FS.

Response

See response to EPA General Comment No. 1 under Endangerment Assessment. Remedial action objectives were not developed for the surface-water medium.

Response to Comment 229

See response to specific comment 202 above.

Response

See response to EPA General Comment No. 1 under Endangerment Assessment.

Response to Comment 230

See response to specific comment 202 above.

Response

See response to EPA General Comment No. 1 under Endangerment Assessment.

Response to Comment 231

See responses to specific comments 202 above.

Response

See response to EPA General Comment No. 1 under Endangerment Assessment.

Response to Comment 242

See responses to specific comments 202 above.

Response

See response to EPA General Comment No. 1 under Endangerment Assessment.

Response to Comment 246

See responses to specific comments 202 above.

Response

See response to EPA General Comment No. 1 under Endangerment Assessment.

U.S. DEPARTMENT OF THE INTERIOR FISH AND WILDLIFE SERVICE COMMENTS REGARDING THE ENDANGERMENT ASSESSMENT/FEASIBILITY STUDY FOR ROCKY MOUNTAIN ARSENAL OFFPOST OPERABLE UNIT - DISPUTE ISSUES

GENERAL COMMENTS

Comment No. 1

The Service is concerned that the Migratory Bird Treaty Act (MBTA) is being treated inconsistently within the Offpost EA/FS process. In response to our General Comment #2 on the Draft Offpost EA/FS, the Army has stated that protection under the MBTA has been included into the screening criteria for biological receptors, however, in the response to Specific Comment #24, the Army states that "there is no need to attempt to protect individual environmental receptors". Additionally, in response to EPA General Comment #23, the Army states that "the Migratory Bird Treat Act does not require protection for individual birds". The Army further states that even humans are not protected at the individual level. While this may be true for humans, federal law does require protection at the individual level for migratory birds.

While protective models may profess to safeguard only the majority of individuals within a population, it is generally recognized that their level of precision may not reflect absolute reality. Conservatism exercised at various steps within modelling efforts may actually come nearer to protecting an entire population than an admission of the imperfection of the process would admit. The Service hopes that through providing its best professional judgement it will protect the welfare of its trust species to the greatest extent practicable. Service trust species must be protected and/or damage assessment for any losses may be initiated.

Response

The Army has derived toxicity factors (TRVs and MATCs) for use in the ecological assessment that at least provide protection to a population of a species and that are highly likely to beeven more protective. It is impossible to state with absolute scientific certainty that all individuals covered by the MBTA will be protected because there is a lack of sufficient chronic toxicity data for the COCs in wildlife species. The Army has incorporated modeling parameters (e.g., BAFs, BCFs, and MATCs) that have been derived on the basis of input from the Organizations, including the professional judgment of the U.S. Fish and Wildlife Service (USFWS). The Army's professional judgment is that these factors are sufficiently conservative to be protective of healthy animals, including healthy sensitive subpopulations. The emphasis is on "healthy" because the Army cannot predict the risk to animals that are affected by environmental stressors beyond the control of the Army (e.g., climatic changes, bacterial and viral infections).

Comment No. 2

Additionally, the Service strongly objects to introducing new information regarding the Food Web Model developed in the Onpost EA without a formal review of that information. Specifically, information is presented in this document regarding the input parameters identified as Maximum Allowable Tissue Concentrations (MATCs), Bioaccumulation Factors (BAFs), Bioconcentration Factors (BCFs), etc. which the Service has not yet had an opportunity to review. Introduction of this material justifies a delay in the finalization of this document until all Food Web Model input parameters and calibration/validation processes have been adequately reviewed and subsequent comments have been addressed.

Response

This comment has been addressed through the dispute resolution process (see Attachment A). The Army and Organizations have agreed to use the revised food web modeling parameters presented in the final EA/FS Ecological Assessment (Volume III, Section 5.0 and Volume IV, Appendix H). The Army agreed to incorporate the values with the understanding that they represent conservative values based on interpretations of literature data and may not be representative of site-specific conditions present in the Offpost OU.

Comment No. 3

Furthermore, in reference to Food Web Model input parameters, the Service has serious concerns regarding the incorporation of some of the proposed MATC and BAF values. In particular, the dieldrin MATC is too high and some of the BAFs have extremely high standard deviations which can encompass a wide range of values. Additionally, the appendices provided in the document are incomplete and therefore the Biomagnification Factors cannot be correctly derived using the available information. The Service will be providing further comment on these concerns at a later date after a thorough review of this information has been completed.

Response

Refer to the response for USFWS Comment No. 2

Comment No. 4

Finally, the Service is concerned that sediment contamination will not be adequately addressed in the Feasibility Study. Specifically, the Service is concerned regarding the high level of dieldrin (370 mg/kg) found at one site along the north boundary of the Arsenal. In response to our Specific Comment #10, the Army states that "this sample was collected from a groundwater seep away from the main channel of First Creek and, as such, is not representative of First Creek sediment". While this may be true, it does not abrogate the potential need for remediation at this site, particularly as it can be attributed to Arsenal contaminants. Other issues regarding sediment which the Service previously commented on in the draft document appear to have been addressed in the response to our comments.

Response

Section 2.2 in Volume V of the EA/FS describes the PRG development methodology and compares both cumulative offpost risks and individual media risk to the acceptable risk range. The risk corresponding to the sediment medium is a maximum of 8×10^{-7}. Remedial action objectives were therefore not developed for the sediment medium. See response to EPA General Comment No. 1 Endangerment Assessment.

COLORADO DEPARTMENT OF HEALTH COMMENTS REGARDING THE ENDANGERMENT ASSESSMENT/FEASIBILITY STUDY FOR ROCKY MOUNTAIN ARSENAL OFFPOST OPERABLE UNIT - DISPUTE ISSUES

GENERAL COMMENTS

Comment No. 1 - Development of PRGs

a) *Use of Health Based Criteria (HBCs) to develop Preliminary Remediation Goals (PRGs).* *The parts of the EA/FS that deal with derivation of PRGs have become even more confusing than in the previous draft. We request that the relevant sections of this document be rewritten to permit public understanding and to enable more focused review by the parties. Despite our basic inability to duplicate or follow the Army's process, the State has managed to glean the following problems with the approach:*

Some (but not all) of the soil HBCs (shown in Volume V, Table 2.4.5-1) are different from those in the draft final text. The Army has used a different methodology for deriving the HBCs of carcinogens (described in Volume II Appendix C) and our efforts to reproduce the Army's new HBC numbers have not been successful.

The soil PRGs are even further complicated by the Army's footnote to Volume V Table 2.4.5.5-1 that "[s]ome preliminary remediation goals are different than HBC presented in Table 2.4.4-1. PRGs were adjusted based on observed contaminant distribution and with the intent of achieving low aggregate risk." The meaning and effect of the second part of the footnote are not clear. Which PRGs received this treatment, how were they adjusted, and why?

The soil HBC listed in Volume V Table 2.4.5-1 for the "Adjusted Residential" RME of Aldrin and Dieldrin are 31 ppb and .5 ppb respectively. The two compounds have very similar transport and toxicological properties. We request an explanation of why their HBC differ by a factor of over 60.

In an effort to make the derivation clearer, we request that the Army include the following in its final version of the EA/FS.

i. *A flow chart detailing the hierarchy of choices and standards which were employed in the derivation of the PRGs for each medium.*

ii. *A complete set of HBC for the COCs in each medium.*

iii. *An appendix in which the actual values are written, detailing step-by-step derivation of the HBC and PRG if different from the HBC. This appendix should start with the chemical's slope factor and/or reference dose and detail the effects of adjustment for multiple media exposure, common organ toxicity, etc. If the method of proportions is used, we request that the details of that step be included, too. We request that this be done for each of the groundwater COCs that do not have ARARs (11 compounds) or have PRGs that are different than ARARs, and the soil COCs (5). We also request that this derivation be detailed for the surface water and sediment PRGs.*

Response

Volume V, Section 2.0 has been significantly revised to include additional detail concerning development of PRGs in light of comparison of cumulative Offpost OU risks to the NCP

acceptable risk range. Additional detail is also presented in this section concerning risk associated with individual media in the Offpost OU, based on the risks presented in Volume III, Section 4.0 of the EA. As discussed in detail in Volume V, Section 2.2, the cumulative Offpost OU hypothetical cancer risk is a maximum of 3×10^{-4} based on risks presented in the EA. As discussed extensively in Volume V, Section 2.2, Offpost OU remedial action is not warranted because the offpost OU cumulative risk is within the NCP acceptable risk range. Also as discussed in Volume V, Section 2.2, the Army recognizes that there are several site-specific factors that, when considered in totality, suggest remediation of groundwater is preferable to no action in the Offpost OU. The above-referenced sections of text concerning PRG development explicitly state the risks corresponding to the groundwater, soil, surface water, and sediment media. Also, justification is given for the conclusion that soil, surface water, and sediment media do not require development of remedial action goals. Remedial action goals were developed for the groundwater medium as discussed in Volume V, Section 2.2, consistent with the methodology presented in detail in Volume VII, Appendix C. Appendix C explicitly describes the development of PRGs, considering the effects of multiple chemicals within the groundwater medium.

See response to Part 1 given above.

As described in the response to Part 1 given above, soil PRGS were not developed.

See response to Part 1 given above.

The development of PRGs for groundwater medium explicitly accounts for the effects of multiple carcinogens within groundwater. This information is presented in Volume VII, Appendix C.

b) *Use of a 10^{-6} Point of Departure. Despite its assertions to the contrary, the Army appears not to have followed the express prescription of the NCP, cited both in the revised document itself and in the Army's responses, that a 10^{-6} point of departure be used in the development of PRGs. In response to State comments, the Army claimed that it had used a 10^{-6} point of departure, but later arrived at a 10^{-4} risk level PRG after reviewing a "number of elements and criteria" related to the selection of health-based criteria and determination of PRGs. (Army response to CDH Cover Letter Comment No. 1; see also Response to CDH Cover Letter Comment No. 3). Unfortunately, there is not enough information presented in either the document or the responses to comments to enable a reviewer to reproduce and understand the Army's analysis and decision making. This omission makes an objective review difficult. The end result, however, indicates that the prescription of the NCP has not been followed.*

The Army states in Volume V of the revised text that "in accordance with the NCP, Section 300.430(e)(1), PRGs were developed considering ARARs, HBC, factors related to technical limitations (e.g. detection limits), background concentrations, land use and ecological criteria." (40 C.F.R. Part 300.430(e)(i)). Absent from the Army's analysis (with the exception of the cursory and confusing treatment of arsenic in Appendix C) is any detailed discussion of the determination of background contamination levels and their incorporation into the development of the appropriate PRGs. In fact, in response to State comments objecting to the determination of background levels in soils and groundwater, the Army specifically assured us that its background estimations would not be used to establish PRGs. (See CDH FS Specific Comment No. 7 and the Army's response to Cover Letter Comment No. 8(d)). This, and other statements, therefore, contradict the assertions in the responses to comments. Please clarify whether the Army's background calculations were used in the derivation of PRGs. The State has previously objected to the Army's locations of background sample sites. (See State comments offpost R.I. as well as prior comments on the proposed offpost EA/FS).

Also absent from the EA/FS is an adequate explanation justifying the deviation from the 10^{-6} point of departure. All that is provided in a cursory discussion of groundwater CRLs. There is no explanation of how the Army arrived at soil HBCs which do not correspond to the PRG point of departure risk level. Since groundwater CRLs are irrelevant to soils PRGs, some explanation is needed to justify the higher risk levels selected for soils in zones 1, 2, 5 and 6.

Response

As discussed extensively in Volume V, Section 2.2, development of PRGs for the groundwater medium was performed consistent with the methodology described in the NCP. Groundwater HBC were calculated at the 10^{-6} level for carcinogens when ARARs were not available and at a HI of less than 1.0 for noncarcinogens without ARARs. These criteria were used as a basis for developing PRGs for groundwater. The NCP states departure from 10^{-6} may be appropriate, considering various factors, including but not limited to exposure factors, uncertainty factors, and technical factors. Exposure factors evaluated by the Army in the EA included cumulative of multiple contaminants, multiple pathways, population sensitivities, potential impacts on environmental receptors, and cross-media impacts. Additionally, uncertainty factors that evaluate the effectiveness of the alternative, the weight of scientific evidence concerning exposures and cumulative health effects, and the reliability of exposure data were also evaluated by the Army in the EA/FS. Finally, the Army also evaluated technical factors in the selection of PRGs, consistent with the NCP, including detection and quantitation limits, technical limits to the remediation, and the ability to monitor and control movement of the contaminants. In summary, the Army's approach to groundwater PRG development, as described in Volume V, Section 2.2, is fully consistent with the approach described in the NCP.

c) *Land Use. It appears that the Army has modified portions of the document addressing the land use issue for zones 3 and 4 of the offpost operable unit area to clarify that it is not basing its decision on the assurances offered by Shell Oil Co; rather, it is relying on land use forecasts contained in the documents cited in response to State FS General Comment No. 1, page 65. The State essentially has two problems with this approach. First, by choosing to remediate only to levels protective of commercial/industrial or recreational uses, the Army is ignoring the fact that current use of the land is, (or would be but for the fact that Shell acquired the property), rural residential. (See also, Figure 2.4.5.5-1, "Offpost Operable Unit Current Land Use Map, 1991" which clearly indicates that, but for the acquisition of land by Shell, the zones are currently used for "General agriculture", "Exclusive Rural Family" "Rural Subdivision (10 acres minimum)" and "Irrigated Farming"). Second, projected uses as forecasted in the cited documents do not define all reasonable potential uses; they merely identify predicted or desired development.*

Regarding the first issue, as previously pointed out, the NCP preamble states that "...the baseline risk assessment should consider both actual risks due to current conditions and potential risks assuming no remedial actions" (55 Fed. Reg. 8710). Potential carcinogenic risks to people living and consuming vegetables in zones 3 and 4 would exceed 1 x 10^{-6}, thereby indicating that soil remediation is appropriate. The Army and Shell, as liable parties, cannot avoid cleanup by merely restricting access to contaminated media.

Regarding the second issue, we believe the Army has misconstrued the intent and language of the NCP addressing future land use. Future land use considerations are not intended to eliminate pathways and reduce exposures; rather, they are mandated so that a remedy selected today will be protective of people exposed, perhaps to a greater degree, in the future. The provision is meant to be inclusive, not exclusive.

Furthermore, the Army does not consider whether rural residential land uses represent "reasonably expected exposures" as required by the NCP, (see 55 Fed. Reg. 8710). Instead, in the Army's own language, they are determined not to be "a likely probability." (See Response to State FS General Comment No. 1.) These are very different tests. Thus, the Army has failed to follow the prescriptions of the NCP regarding utilization of land use forecasts. Factually, the Army's future land use assumptions ignore several important considerations. The first and most obvious consideration is that the land use forecasts relied on by the Army explicitly state that a considerable portion of zones 3 and 4, including section 13, are either currently zoned for residential/agricultural use or are forecasted to be. (Volume V, Figures 2.4.1-2 and 2.4.5.5-1).

The exact basis of the Army's "expectation" that commercial and industrial development will occur in the proximity of the new Denver Airport is also unclear. Stapleton International Airport has an extensive residential community bordering the airport and extending well into the Denver metropolitan area. Roadways leading to and from the airport, through these residential areas, are often four lane divided highways. The Army's basic assumption that a widening of 96th Avenue, coupled with expected commercial development, will prevent residential use in zones 3 and 4 defies simple observation of existing land use conditions around the existing airport.

The Army's suggestion that in the event of residential development, provision of alternative drinking water will eliminate any potential exposure, begs the question of whether residential land use is a reasonable potential use. If so, PRGs must be established accordingly and alternatives developed to meet these PRGs through remediation to the maximum extent practicable.

Response

The topic of this comment was addressed during the dispute resolution process. Refer to Attachment A for additional information contained in the dispute resolution letter. On the basis of dispute resolution, all Organizations agreed to use a single land use scenario for each zone within the Offpost OU. Zones 1, 2, and 6 were classified as rural residential, zones 3 and 4 as urban residential, and zone 5 as commercial/industrial. The land use scenarios and potential exposure pathways were further defined as follows:

A. Rural Residential (EA/FS zones 1, 2, and 6)

meat* (75 percent)
dairy* (75 percent)
egg (only evaluated dieldrin)
vegetable* (40 percent)
groundwater (ingestion)
groundwater (inhalation)
soil (dermal)
soil (ingestion)
sediments (dermal)
surface water (dermal)

B. Urban Residential (EA/FS zones 3 and 4)

vegetable* (40 percent)
soil (dermal)
soil (ingestion)
sediments (dermal)

surface water (dermal)
groundwater (ingestion)
groundwater (inhalation)

*All percents indicate amount of consumption from local sources.

Risk estimates for Zones 3 and 4 will be presented in two manners:

1. As a baseline risk assessment for all media per EPA guidance. The groundwater portion of the risk assessment will be based on the calculated risks from 1989 to 1991 groundwater data in those zones.

2. The second risk calculations will be based on the continuing beneficial effect of the onpost boundary system operations in a 30-year timeframe. The text will state that these are the expected potential exposures for individuals in those zones and the risks associated with those exposures.

C. Commercial/Industrial (EA/FS zone 5)

soil (dermal)
soil (ingestions)
groundwater (ingestions)
groundwater (inhalation)

If SACWSD provides appropriate documentation indicating that SACWSD is not planning to install future water wells in zone 5 over the next 30 years, the groundwater pathway will be removed from zone 5. Attachment A to this set of responses to comments is a letter from SACWSD to the Army, providing documentation that SACWSD does not intend to install water-supply wells in the future in zone 5.

d) *Groundwater PRGs. The State objects to the following PRGs for groundwater:*

Chemical	*PRG*	*Source*	*CBSG*
aldrin	*.05*	*CRL*	*.002*
carbon tetrachloride	*.99*	*CRL*	*.3*
chloroform	*15*	*HBC 6*	
1,2-Dichloroethane	*1.1*	*CRL*	*.4*
dieldrin	*.05*	*CRL*	*.002*
manganese	*200*	*CBSG (agric)*	*50 (secondary drinking)*

(Table 2.4.4.3-1, Offpost PRGs for Groundwater; all values are in micrograms per liter).

i. *Manganese ARAR. This table lists the groundwater PRG for manganese as 200, according to the Colorado Basic Standards for Ground Water (CBSG). While this number is correct for agricultural uses, the CBSG secondary drinking water standard for manganese is 50 ppb. The PRG must be adjusted to reflect this lower number. (5 CCR 1002-8, Part 3.11, Table 2.)*

ii. *Chloroform ARAR. The Army has refused to recognize the State chloroform standard of 6 as an ARAR on the grounds that it is not generally applicable throughout the State since municipalities exceed the standard. The Army is incorrect in its assertion. In promulgating the Basic Standards for Regulation of groundwater, the Water Quality Control Commission was clear in addressing the general applicability of the standards. The Commission stated: "...The purpose of the adoption of the statewide standards is to provide a statewide baseline of protection by establishing standards that will apply broadly to Colorado ground waters, for certain toxic organic pollutants and radioactive materials." (Emphasis added).*

Under 121(d)(4) ARARs may be waived if they are found to be inconsistently applied. (See also 40 C.F.R. §300.430 (f)(1)(ii)(C)(5)). However, according to the NCP, a State standard "is presumed to have been consistently applied unless there is evidence to the contrary". (55 Fed. Reg. 8749.) It is the burden of the President, and not the State, to submit substantial evidence that the State standard has been inconsistently applied. The Army has not met this evidentiary standard with its cursory response to CDH Feasibility Study Comment 4(d) and CDH Appendix A Comment No. 16.

iii. *The other chemicals have PRGs based on the Army's detection limits which are higher than the State's health-based standards. As previously asserted, the State's health-based standards are applicable to the remedial action and must be achieved or waived pursuant to CERCLA 121(d)(4).*

iv. *CRL methodology. The State has at least since 1987 consistently objected to the Army's use of its Certified Reporting Limit (CRL) methodology because it results in detection limits that are higher than EPA method detection limits (MDLs) and, in some instances, exceed health-based levels. The State again raised this issue in its comments on the Offpost Operable Unit RI/EA/FS Workplan, January 26, 1990 in which detection limits for a number of the above-listed chemicals were identified as exceeding health-based levels. With the exception of carbon tetrachloride, it appears that the Army has been unsuccessful at lowering its CRLs. Given the fact that lower detection limits are practicable, the Army has not justified its deviation from a 10^{-6} point of departure based on the limitation of its CRL methodology.*

v. *Arsenic. Arsenic is a unique problem. Although the Army's CRL of 2.35 ug/l does not exceed the MCL this ARAR, as acknowledged in the Army's response to EPA General Comment No. 1, falls outside of the risk range provided for in the NCP. See "EPA Risk Assessment Forum Special Report on Ingested Inorganic Arsenic: Skin Cancer: Nutritional Essentiality," EPA, July 1980. As previously pointed out by the State, a concentration representative of a 10^{-6} risk level would be .023 ug/l (State Comments on Draft ARARs for the NWBS Long-Term Improvements IRA, submitted 03/06/91) which is two orders of magnitude lower than the CRL. Therefore, for this compound, a lower detection limit and PRG is appropriate.*

Response

Response to Comment d) i. - Secondary drinking water standards are nonenforceable standards and are not ARARs.

Response to Comment d) ii. - The ARARs analysis presented in Appendix A of Volume VII describes the ARARs selection process and the treatment of the CBSGs. Based on language presented in the CBSG Statement of Basis and Purpose and on EPA guidance, the CBSGs are not ARARs.

Response to Comment d) iii. - CDH has referred to previous documentation provided by the Army regarding the Army's CRLs as compared to other detection limits.

Response to Comment d) iv. - See response to Comment d) iii presented above.

Response to Comment d) v. - See response to Comment d) iii presented above.

Comment No. 2 - Use of Groundwater Model

The Army's responses to comments on the development, use, and reporting of the groundwater model fail to address the State's concerns regarding the absence of calibration of the transport model, the absence of sensitivity analyses to quantify the model's uncertainties, the omission of the unconfined portion of the Denver Formation, and the poor presentation of the results (no spatial presentation of plumes at different points in time, and no analysis of the removal rates of contaminant mass as a function of each simulated remedy). We, therefore, can have no confidence in the modeled results or in the Army's interpretation of the results; nor are we assured that the optimal injection/ extraction well locations were even considered.

The Army's response was, in essence, that the model was only to be used to estimate the relative effectiveness of the various remedial alternatives and that a rigorous modeling exercise was not justified at this time. The Army further implied that a rigorous modeling exercise is only warranted when data are obtained from the performance monitoring of the installed remedy. A model is useful during performance monitoring to update predictions on the installed remedy's ability to achieve goals within an acceptable timeframe; however, now is the time for a good, sound modeling exercise, before spending millions of dollars on an inappropriate remedy, and before rejecting more aggressive and effective remedies on the basis of projected initial capital outlay.

Response

Calibration of the transport models would require a large amount of data that is not available for the systems studied in the Offpost OU. Specifically, data that would be required include hydraulic heads near the likely sources of contamination at RMA during and soon after the years that contamination occurred and historical information regarding plume configuration as a function of time, covering the period commencing with the years that contamination occurred. The groundwater flow models have been approximately calibrated to time-averaged conditions during the 1980s, long after the major hydraulic effects of recharge in Basins A through F had occurred. This fact is what permits the flow model to be based on hydraulic conditions observed in recent years. The lack of comprehensive head data before the 1980s severely limits the possibility of viable transport model calibration. For sensitivity analyses to be performed effectively, the sensitivities of selected parameters, such as hydraulic heads, to model parameters, such as hydraulic conductivities, should be calculated directly using the calibrated flow model. These sensitivities would be optimally determined through simultaneous application of automatic calibration techniques. As stated in Volume VII, Appendix E, the FS models were intended to be only approximate and, consequently, were not calibrated with an automatic inverse technique.

The Army reconfirms that the groundwater modeling effort conducted is fully sufficient for purposes of analyzing the relative differences between competing groundwater alternatives. As stated in Volume VI, Section 5.2, significant effort has been expended to produce models that incorporate general features of groundwater flow and associated transport phenomena. Nonetheless, the models are sufficiently detailed that predicted flow and chemical transport phenomena in the Offpost OU agree with historical and current hydrogeologic data and observed contaminant distributions.

Maximum concentration versus time plots was used because this approach gives a conservative estimate of remediation timeframes. The location of selected points used at each time step in the graph reflects the maximum concentration observed within the entire model area. Selection of the point with maximum groundwater contamination assures that remediation timeframe estimates are based on a time when no point within the model area exceeds PRGs. This method is fully capable of comparing the relative effectiveness of remedial alternatives, which is the intent of the groundwater modeling.

Comment No. 3 - Use of Cost Analysis to Eliminate Alternatives

The Army's selection of no additional remediation other than the currently planned IRA intercept system is not sufficiently justified in accordance with the selection criteria in the NCP and CERCLA. The improper reliance on land use projections, the inappropriate analysis of cost effectiveness, and the utilization of an inadequate model result in violations of these cleanup prescriptions. The land use and model issues have been addressed in comments 1c and 2 above.

The State has several concerns with the Army's elimination of alternatives based on time and cost considerations. For example, N-6 and N-5 were eliminated because they would require greater initial capital outlay than the selected alternative. This decision failed to consider the fact that the rejected alternatives would be more protective of the environment, provide for a shorter remediation timeframe, and be equally or more cost effective in the long term than the selected alternative.

To emphasize short over long term costs in such a manner is not in accordance with the NCP. In fact, the EPA specifically eliminated language requiring such an analysis from its proposed rule. (55 Fed. Reg. 8728-29). In doing so, the EPA found such an analysis "too narrow" and not reflective of overall effectiveness which "involves a composite of effectiveness factors, i.e. long term effectiveness and permanence, toxicity, mobility or volume reduction through treatment and short term effectiveness." Id. Thus, the Army's elimination of alternative N-6 based on increased capital costs when the total present worth costs are "essentially equivalent" to alternative N-5, and the elimination of alternative N-5 for which total present worth costs are actually less than the selected alternative, contravenes the NCP and CERCLA prescriptions to utilize permanent treatment solutions to the maximum extent possible and be cost effective.

NW-4, an alternative which would provide substantial improvements to the Northwest Boundary Containment System (NWBCS), was also eliminated based on projected remediation timeframes which, by the Army's own admission, were inherently uncertain. By failing to construct a reasonably reliable model at this time, the Army is precluding its ability to perform an accurate and objective cost-effectiveness analysis in accordance with CERCLA and the NCP.

Response

CDH has misinterpreted the analysis of groundwater alternatives presented in Sections 4.0, 5.0, and 6.0, in Volume VI. As presented in these sections of the FS, the analysis and comparison of remedial groundwater alternatives focuses on effectiveness, implementability, remedial time-frames, reduction of toxicity, mobility and volume, compliance with ARARs, overall protection of human health and the environment, and cost considerations. The alternatives studied present a wide range of levels of complexity in terms of remedial components, total flow rate from extraction wells, total numbers of recharge trenches, total linear feet of recharge trenches, and selected location of remedial components with respect to observed plume distribution.

The Army strongly disagrees with EPA's contention that an aggressive groundwater alternative was not evaluated in the Offpost FS. As discussed in Volume VI, Section 3.0, Development of Remedial Alternatives, and Volume VI, Section 6.0, Detailed Analysis of Remedial Alternatives,

the offpost geology, hydrogeologic systems, contaminant distribution, and contaminant transport properties were studied extensively, both analytically and using a groundwater numeric model. The modeling effort is described in both Volume VI, Section 3.0 in terms of development of remedial alternatives and extensively in Appendix E of Volume VII.

The results of this analysis are presented in a lengthy discussion in Volume VI, Section 3.0. The controlling hydrogeologic and contaminant transport properties of the Offpost OU groundwater system include (1) groundwater seepage velocity of the First Creek pathway relative to the northern pathway, (2) the distribution of the relatively less mobile compound dieldrin compared to the distribution of more mobile compounds such as DIMP and chloroform, and (3) the controlling transport properties of dieldrin as compared to the transport properties of DIMP and chloroform. As described in Volume VI, Section 3.0, Alternative No. N-4 for the North Plume Group was developed through a combination of analytical well field simulation, knowledge of contaminant distribution and contaminant transport properties, and hydrogeology of the North Plume Group.

A transverse capture system for the northern pathway was chosen to intercept contaminants moving in the northern pathway. An axial system of collection wells and recharge trenches was selected in the First Creek pathway. Alternative No. N-4 consists of a total of 17 walls and 6 trenches with a total extraction flow rate of approximately 480 gpm. Alternative No. N-5 has a total of 20 extraction wells and 12 trenches. Alternative No. N-6 has a total of 4 extraction wells and 19 trenches. The total linear feet of recharge trenches ranges from 1500 feet in Alternative No. N-4 to approximately 4400 feet in Alternative No. N-6. The total extraction flow rate ranges from 480 gpm in Alternative No. N-4 to a total of 690 gpm in Alternative No. N-6.

The increasing complexity of Alternative Nos. N-5 and N-6 as compared to Alternative No. N-4 was evaluated to assess the impact of adding a number of additional extraction and recharge trenches in areas where contaminants were remaining in areas of slower relative groundwater velocity and tighter aquifer materials, and to address less mobile contaminants.

The level of aggressiveness of Alternative Nos. N-5 and N-6 reached a practical maximum whereby the maximum practical number of additional extraction wells and recharge trenches was evaluated for remediation timeframe and aquifer drawdown considerations. Model-estimated groundwater mounding and drawdown resulting from the recharge trenches and extraction well arrays reached practical limits in Alternative Nos. N-5 and N-6. The discussion presented in Volume VI, Section 3.0 gives specific information demonstrating the distinct differences in level of complexity and aggressiveness of the remedial alternatives studied in the EA/FS.

The Army has not used short-term cost as a basis for rejection of Alternative Nos. N-5 and N-6. As discussed in Volume VI, Section 5.0 and 6.0, the primary reasons for selecting Alternative No. N-4 over Alternative Nos. N-5 and N-6 are summarized below. With respect to long-term effectiveness and permanence, these alternatives are essentially equivalent. All the alternatives would reduce hypothetical risk and address exposure pathways through reducing COC concentrations in the North Plume Group. Due to inherent uncertainties in groundwater modeling, predicted differences between treatment alternatives in the time to achieve PRGs may not be significant.

With respect to reduction in toxicity, mobility, and volume, all the alternatives would reduce the toxicity, mobility, and volume of contaminated groundwater through extraction, treatment, and recharge in the North Plume Group. As stated previously, the uncertainty associated with the remediation timeframes estimated by the groundwater modeling suggests that, in practical terms, the estimated timeframes for the alternatives are equivalent.

With respect to overall protection to human health and the environment, all the alternatives would provide significant protection of human health and the environment by decreasing contaminant concentrations and reducing hypothetical risks within the same approximate time. These alternatives are essentially equivalent with respect to providing protection of human health and the environment because the short-term intensive groundwater monitoring program proposed under Alternative No. N-4 would provide full-scale system performance information that could be used to identify any necessary or beneficial improvements to the system and to provide information on optimal location of these additional systems.

See response to CDH Comment No. 3 Parts 1 and 2, above for information on evaluation of alternatives.

Sections 4.0, 5.0, and 6.0 in Volume VI of the FS present information concerning the relative differences between Alternatives Nos. NW-2 and NW-4. As stated previously, the groundwater model is fully capable of analyzing relative differences between competing alternatives. See responses to Parts 1, 2, and 3 of Comment No. 3, above.

Comment No. 4 - Selection of the N-4 Alternative

The State cannot agree that N-4 is superior to N-5 because N-4's short-term intensive monitoring will "...identify any necessary improvements to the system..." and because "[u]ncertainties inherent in the groundwater modeling results make the prediction of remediation times imprecise." (Section 5.5.1.1). Short-term performance monitoring should logically be a part of any remedy to accomplish the first goal stated above. The short term monitoring program proposed by the Army (See Draft Final Monitoring Plan for the Groundwater Intercept and Treatment System North of the RMA, IRA, February, 1992) should also apply to all of the alternatives selected for evaluation. The State has submitted comments addressing the proposed monitoring plan and incorporates its comments by reference (See CDH Letter from Edson to Blose, March 4, 1992).

The Army's second reason (as stated above) for not selecting remedies more aggressive than N-4 is inconsistent with their response that more aggressive remedies for the DIMP plume along First Creek and the dieldrin plume along the Northern Pathway are not needed because the model predicts that PRGs will be achieved in 5 to 15 years and 30 years, respectively. Either the predicted remedial timeframes are reliable or they are not. The State agrees with the formula statement that acknowledges that the actual timeframes for remediation are unknown. Simple logic, however, suggests that a more aggressive remedy along the plume's axis (N-5 and N-6) will remediate the plume faster and therefore would be a more desirable alternative.

In addition, although the Army adopts 2.35 ug/l as its PRG for arsenic, it is not clear that the selected remedial alternative will achieve this level. Plume maps indicate detections of arsenic along the First Creek pathway exceeding the PRG; however, the chosen carbon filtration treatment technology does not treat arsenic. As arsenic is a major contributor to the carcinogenic risk posed by exposure to this groundwater, treatment alternatives for arsenic must be added to the design of the treatment facility.

Response

See response to CDH Comment No. 3, above.

See response to CDH Comment No. 3, above.

Estimation of anticipated influent concentrations of contaminants for the alternatives studied in the Offpost FS indicate that the PRG for arsenic will not be exceeded in the influent to a treatment plant.

Comment No. 5 - Preferred Alternative for the Northern Plume

As stated in our previous comments, the preferred alternative for the Northern Plume ignores current and forecasted land use in an area that will contain contaminated water exceeding ARARs. The area the plume migrates through is, according to the Army's current and forecasted land use maps, subject to residential use. (See Volume V, Figures 2.4.5.5-1 "Offpost Operable Unit Current Land Use Map, 1991"; and 2.4.1-2 "Offpost Operable Unit Future Land Use" and the corresponding residential zoning designations for section 13). Thus, use of the unconfined alluvial aquifer as a source of domestic water is a reasonable possibility. To suggest, as the Army has in its response to the State's concern, that rapid restoration is unnecessary because contaminated water is not now used as a drinking water source, and because potential future users would be put on alternative water supplies, ignores the prescription of the NCP which requires the rapid restoration of current and potential drinking water sources. (55 Fed. Reg. 8732). Alternatives that would address groundwater remediation within the plume migration area should be considered.

Response

The preferred alternative for the Northern Plume Group is fully consistent with the most likely future land use scenario presented in the Offpost EA/FS. The most likely future land use scenario is rural residential for zones 1, 2, and 6; urban residential for zones 3 and 4; and commercial/ industrial in zone 5. As stated previously in Sections 4.0, 5.0, and 6.0 in Volume VII and in response to Comment Nos. 2 and 3 above, Alternative No. N-4 is demonstrably superior to Alternative No. N-5.

Comment No. 6 - Operable Unit Areas Not Included in EA/FS Evaluations

The Army's response to concerns that a significant portion of the Offpost OU area was not evaluated in the EA/FS was to state that the remaining areas "were not determined to be affected by RMA related contamination" despite the fact that the Offpost OU "as described in the Federal Facility Agreement (FFA), is where hazardous substances, pollutants, or contaminants from RMA are located" (Army responses to CDH Cover Letter Comment No. 3, EPA Cover Letter Comment No. 7, and EPA General Comment No. 1). The Army also pointed out that concentrations detected in these areas were less than one half of the dieldrin PRGs.

No information has been included in the EA/FS (or in the Offpost RI Addendum) discussing or interpreting the existing data to determine the source of contamination. The Army needs to document why it is excluding from the EA/FS process nearly one half of the Offpost OU area. An analysis must be supplied for those areas outside of zones 1 through 6, particularly where the cumulative risks from RMA contaminants exceed a 10^{-6} risk level. Such a presentation is necessary before the State could concur with such conclusions.

The Army's dismissal of dieldrin detections identified by the State on the grounds that they do not exceed the Army's PRG ignores the fact that PRGs are supposed to be developed based on a 10^{-6} point of departure. No justification for deviating from the point of departure is offered; therefore, remedial alternatives must be developed to achieve this risk level in these areas.

Response

The Offpost EA/FS divides the OU into six zones. These zones were delineated on the basis of the known extent of contamination as presented in the Offpost OU RI Addendum report. Section 2.4.1 in Volume II of the EA describes in detail the rationale and the database evaluated in delineating the zones to be studied in the Offpost EA/FS. Each of these zones was delineated on the basis of distinctions in exposure conditions. The primary factor used to define the zones was a pattern of COC concentrations in groundwater. In addition, the spatial pattern of COCs in surficial soil was also used to set zone boundaries. A broad area extending from the north and northwest boundaries of RMA to the South Platte River exhibits varying levels of COCs. The maximum downgradient extent of this contamination area is defined primarily by low levels of DIMP (i.e., DIMP in excess of CRLs). The existing contaminate distribution in groundwater, surface water, and surficial soil, as well as differences in land and water use were considered in mapping six zones where exposures are expected to be distinct from each other. The outermost boundary defining the six zones is the extent of known contamination associated with RMA, which is defined as the Offpost OU by the Federal Facility Agreement.

In response to CDH's contention that no information has been included in the EA/FS discussing or interpreting the existing data to determine the source of contamination, CDH is referred to Section 1.0 of Volume I for an extensive four-page discussion detailing the conceptual site model that delineates the source of contamination to the Offpost OU in groundwater, surface water, soil, and air.

With respect to CDH's comment regarding the aldrin detections, CDH is referred to Section 2.2, which discusses the Offpost OU cumulative risk and risk corresponding to individual media as compared to the NCP-prescribed acceptable risk range. This section of the text describes in detail the rationale for elimination of the soil medium as requiring development of remedial action objectives.

Comment No. 7 - Statistical "Hot Spot" Analysis

In its responses to comments, the Army refers to an "additional analysis" that was performed regarding localized "hot spots" of carcinogenic risk. A more complete explanation of this analysis is needed in order to understand the Army's decision-making process with respect to the elimination of "hot spots". This explanation should include the specifics of those areas which were ranked according to the highest hot spot potential including well identification, soil boring numbers, the spatial distances between these sample locations, the maximum concentrations in comparison to the exposure point concentrations, and a calculation of the upper bound aggregate risk at the subsite.

Because residential exposure can be of long duration over a very localized area, results of an analysis such as the one performed in response to the EPA comment are important to an understanding of potential exposure. The Army has commented to EPA that "[r]isks at localized 'hot spots' within zones 2 and 3 are less than 2 x 10^{-3}". The State requests that the information which has led to this conclusion be included in the document and that the results of this evaluation for all zones be described in the Final version of the EA/FS.

Response

The "additional analysis" referred to is summarized in the response to EPA General Comment No. 1 (March 27, 1992, Volume VIII). The analysis performed at that time is no longer pertinent to the offpost exposure assessment, however, because the data set used for the assessment has been revised to include only groundwater data collected from 1989 to 1991, and the previous analysis was based on older data (1985 to 1990). Further, it has been discovered that some groundwater

REFERENCE PAGE FOR 93012R03
CDH - PAGES 45 THROUGH 57 ARE
NOT INCLUDED IN THE DOCUMENT.

wells used in that analysis and identified as "hot spots" for zone 3 are actually south of 96th Avenue and not offpost. Our previous analysis provides general support for the conclusion that localized hot spots would not result in individual risks exceeding zone-RME estimates by more than a factor of 2.

As described previously in response to CDH General Comment No. 1, a comparison of cumulative Offpost OU hypothetical cancer risks with the acceptable risk range is presented in detail in Volume V, Section 2.2. The cumulative Offpost OU cancer risk is a maximum of 3×10^{-4}. Volume V, Section 2.2 also presents several site-specific factors that suggest remediation of groundwater is preferable to no action in the Offpost OU even considering that the accumulative Offpost OU cancer risk is within the acceptable risk range. Additionally, the above-referenced section of the FS presents information supporting the conclusion that soil, surface water, and sediment media do not require development of remedial action goals because the risk corresponding to these media is low. Because the analysis and calculation of risk performed in the EA fully considered localized high concentration (hot spots) of contaminants in soil, any additional analysis of risk corresponding specifically to hot spots is not necessary.

The dispute resolution process resulted in agreement by the Organizations on the most likely future land use scenarios to be used in the EA. Because the exposure scenarios evaluated in the EA are different from the exposure scenarios commented on by CDH, this comment is no longer relevant.

Comment No. 8 - Environmental Remedial Action Objectives

The Army still has not identified any remedial action objectives nor developed remedial alternatives that are designed to protect the environment as a receptor in and of itself. In its response to the State's comment, the Army states that biota ("all plants and animals potentially exposed to Offpost OU contaminants") was considered in the development of RAOs and that "environmental receptors" were also considered in the evaluation of certain pathways. (Army response to CDH Cover Letter Comment No. 5). This response ignores the substance of the State's comment. To reiterate, the requirement that remedies protect the environment, as well as human health is made very clear in CERCLA §121(d)(1) and the NCP (40 C.F.R. §§ 300.430 §§ (a)(1) and (e)(2)(i)(G)). The plain language of CERCLA §101(8)(B) is equally clear in its definition of the term "environment" (which includes "surface water, groundwater, drinking water supply, land surface or subsurface strata or ambient air"). Thus, the EA/FS must include a consideration of measures which are protective of the environment as defined by CERCLA. These receptors should, at a minimum, include:

a. *The surface water medium. Variations in seasonal surface water flow in the First Creek drainage indicate that surface water runoff is likely to be contaminated from Onpost and Offpost contaminants. A remedial alternative should be developed to address this medium as a receptor of contamination.*

b. *The groundwater medium. There are still no remedial alternatives that address the existing or potential cross contamination among the Alluvial, Denver and Arapahoe aquifers. Although the Army has invited the State to submit a list of wells for closure in the offpost well closure IRA, it has not been receptive to the State's proposals. (See August 2, 1991 Edson (by O'Grady) to Blose letter, re: Criteria for Offpost Abandonment Wells IRA). There are also no alternatives which protect the alluvial aquifer north of the North Boundary Containment System (NBCS) through section 13 to O'Brian Canal. This area will contain groundwater exceeding ARARs migrating north from the NBCS. The State will submit under separate cover a list of wells that should be closed to protect the lower aquifers from further degradation.*

Response

Remedial action objectives developed for the Offpost OU consider both human health and protection of the environment. As described in the response to CDH general comment No. 1, remedial action objectives were not developed explicitly for the soil, surface water, and sediment media. However, as described in Sections 5.1 through 5.4 in Volume II, a rigorous ecological assessment was performed, including the following components:

1. Exposure assessment for biological receptors and sensitive subpopulations included, a risk characterization for both terrestrial food web ecological risk and aquatic food web ecological risk, and an ecological risk assessment uncertainty analysis. The results of this analysis were used in the derivation of ecological criteria presented in Volume II, Appendix C, derivation of Health Based Criteria Ecological Criteria.

   Data collected in the RI Addendum to characterize Offpost OU surface water in the First Creek drainage and surface-water bodies leading to Barr Lake are representative of seasonal changes to be expected in surface-water flow. As stated in the text of the EA/FS, no remedial action objectives were developed for surface water medium because neither the human health risk nor the ecological risk corresponding to this medium warranted remediation.

   Data collected during the Offpost RI Addendum program included groundwater samples from 14 offpost confined Denver Formation wells in the Offpost OU. Additionally, information concerning the confined Denver Formation groundwater is presented in Section 3.3.2 of the Final Offpost RI report. As discussed in Volume I, Introduction to the EA/FS, subheading Nature and Extent of Confined Denver Formation Contamination, data were examined from fall 1989 and spring 1991 sampling rounds. Analysis of the data indicated that the detections were not consistent from one sampling event to the next for the same well. The observed detections are indicative of sporadic, isolated occurrences of contaminants in the Offpost OU confined Denver Formation. A similar analysis of available data was performed for the confined Arapahoe Formation. Approximately 30 Arapahoe Formation wells were sampled by the Army with two isolated detections of DIMP and chloroform observed. A majority of samples collected from the Arapahoe Formation did not contain detectable concentrations of contaminant.

Comment No. 9 - Surface Water in First Creek

Several State comments were presented to the Army concerning the exclusion of surface water from the FS. The Army has not responded to these comments satisfactorily. The selected remedial alternative depends on the validity of the assumption that PRGs will not be exceeded at the boundaries of RMA. However, the Army's data call this conclusion into question. The Army concludes from four sampling events at the north boundary of RMA at site (SW24002) that it is in compliance with PRGs. However, these samples, which apparently are not representative of storm events, are totally inadequate for the characterization of a surface water flow which is highly variable both in quantity and in quality. The State's FS General Comment No. 17 quotes from the RI stating that chemical concentrations in First Creek are significantly higher during storm events. The Army's response to the State's FS General Comment No. 7, similarly states that "[t]he secondary source of surface water in First Creek offpost is watershed runoff." These two statements indicate that contaminated surface water will enter the offpost OU during storm events. This contamination will not be addressed by upgrading or closing the sewage treatment plant. Therefore, additional means of verifying that surface water PRGs will be met at the RMA north boundary must be provided by the Army.

Response

Surface water was not identified as a medium requiring development of remedial action objectives because the risk corresponding to surface water is 5×10^{-7}. Refer to Section 2.2 in Volume V of the FS and response to CDH general comment No. 1 for additional information concerning comparison of Offpost OU cumulative cancer risk to the acceptable risk range and discussion of individual media risk.

The Army disagrees with CDH's assumption that surface-water data collected is inadequate for characterization of Offpost OU surface water. Data were collected in the Offpost RI Addendum program from offpost surface water in 1988, from two periods in 1990, and from the 1988 and 1989 surface-water comprehensive monitoring program annual report. Sufficient data from Offpost OU surface-water sampling plans was available for characterization of Offpost OU surface water.

Comment No. 10 - Treatment of Chloroform in the NBCS and NWBCS

The groundwater treatment system at the NBCS appears to effectively remove chloroform from its influent; however, the treatment system at the NWBCS does not. The State requests that an evaluation be performed of the two systems to determine what changes are needed to effectively remove chloroform from the NWBCS's influent, and to ensure that the proposed offpost IRA treatment facility is operated so as to effectively remove chloroform.

Response

The preferred alternative presented in Section 6.0, Volume V for the North Plume Group and the Northwest Plume Group has continued operation of the boundary containment system with modification as necessary to achieve PRGs at the boundary as a major component of the alternative. Additionally, Alternative No. N-4 contains a provision for modification to be made to the IRA A system in the future in the event that PRGs are not being met.

Comment No. 11 - EA: Human Health Soil Ingestion Data

As previously pointed out in State comments on the onpost soil ingestion parameter values, there is currently a great deal of scientific discussion regarding the interpretation and useability of existing soil ingestion data. In recently published articles, Drs. Edward J. Calabrese and Edward Stanek, through the use of a precision of recovery model developed at the University of Massachusetts, demonstrated that only titanium and zirconium values from their Amherst study could be considered reliable. Results from other studies were invalidated by this model. Lately, the reliability of the zirconium values have been called into question due to probable loss during chemical analyses. As a result, new soil ingestion values for children are considered appropriate. Based on the most reliable data from the use of titanium as a tracer, the median value from the Amherst study would be 55 mg/kg/day; the 95th percent value would be approximately 1500 mg/kg/day. An upper 95th percent value based upon all tracers weighted according to their respective precision of recovery, (not including zirconium), would be approximately 640 mg/kg/day. The State again urges the Army to avail itself of the expertise of Dr. Calabrese who is willing to meet with the parties to discuss appropriate soil ingestion estimates.

Response

The Army has applied RME soil ingestion rates recommended by EPA for CERCLA baseline risk assessments. The Army understands that "there is currently a great deal of scientific discussions

regarding the interpretation and useability of existing soil ingestion data." It is the Army's understanding that the thrust of Calabrese's research is that existing studies, including his own 1989 research, have significant design flaws such that the studies do not have sufficient sensitivity to detect and/or quantify the rate of soil ingestion for most of the study subjects. Based on Calabrese's concerns, the Army rejected the ingestion rates suggested by CDH because they are insufficiently supported. Calabrese's research may be able to support the conclusion that soil ingestion rates are "less than" some value but not to determine the actual ingestion rate. Further, the published results from all these studies do not provide sufficient detail to define the distribution of ingestion rates and thus, the 90th or 95th percentiles. Calabrese's recent papers focus on the central tendency of the distribution, such as means or medians, because these statistics are more reliably estimated from the available studies. Although suffering from the same flaws identified here, the Army's review of Calabrese and others (1989) and Davis and others (1990) indicates a 90th percentile of 225 mg/day for children, similar to EPA's recommended RME. The considerable debate and uncertainty regarding quantification of soil ingestion rates indicate that EPA guidance specific to CERCLA assessments is the most reliable and authoritative source for this exposure parameter.

Comment No. 12 - EA: Soil to Egg Partitioning Coefficient

The State specifically requested clarification from the Army regarding derivation of the soil to egg partitioning coefficient (Human Health Endangerment Assessment general comment number 29, page 27). While the Army did respond to this comment, it never supplied information detailing how K_{se} was derived from the results in the Putnam paper. The Army's RME value of .087 would appear to be about an order of magnitude too low based on the following evaluation.

Putnam added pesticides to soil so that the "Low level soil" of aldrin + dieldrin was 0.068 ppm. After exposure to these soils, the resulting concentration of dieldrin in bird tissue was 0.037 ppm. If assumptions derived from Putnam are used (i.e. that aldrin was completely converted to dieldrin, egg and tissue concentrations are equivalent, and no adjustment for control treatment concentrations is made), a rough estimate of K_{se} may be derived as the ratio of soil to bird concentrations, 0.037/0.068 = 0.54. This is approximately an order of magnitude larger than the Army's RME value for K_{se}.

The State requests that the Army demonstrate how they derived their value and distribution for K_{se}, what qualifying assumptions were made, and explain why the number was changed from the one give in earlier EA technical meeting handouts. Absent such information, the State cannot assess the validity of the Army's methodology or have any confidence in the values derived.

Response

Terms:

K_{se} = $\frac{\text{concentration in eggs}}{\text{concentration in soil}}$

f_{ps} = ration of soil ingestion to feed ingestion

K_{pc} = $\frac{\text{concentration in eggs}}{\text{concentration in feed}}$

I_f = ingestion of feed

I_g = ingestion of grain

I_s = ingestion of soil

C_f = concentration in feed

C_g = concentration in grain

C_s = concentration in soil

C_e = concentration in egg

$$I_f = I_g + I_s \tag{1}$$

$$C_f = \frac{I_g}{I_f} C_g + \frac{I_s}{I_f} C_s \tag{2}$$

Then

$$C_f = \frac{I_g C_g + I_s C_s}{I_g + I_s} \tag{3}$$

From Putnam, it is calculated that $f_{ps} \sim \frac{I_s}{I_g} = 3.1\% \pm 1.2$

Then $I_g >> I_s$ and (3) reduces to

$$C_f = C_g + \frac{I_s}{I_g} C_s \tag{4}$$

Then (4) becomes

$$C_f = \frac{I_s}{I_g} C_s \sim f_{ps} C_s \tag{5}$$

By definition

$$K_{pc} = C_e/C_f \tag{6}$$

Substituting for C_f (from [5]) into (6)

$$K_{pc} = \frac{C_e}{f_{ps} C_s} \tag{7}$$

Thus

$$K_{se} = \frac{C_e}{C_s} = f_{ps} K_{pc} \qquad (8)$$

K_{pc} is calculated from BAF values

1.13	Cummings and others, 1966
1.5	Kan & Jonker-den Rooyen, 1978a
2.5	Driver and others, 1977
1.67	Graves and others, 1969
1.35	Waldon & Nabor, 1974
1.18	Kan & Jonker-den Rooyen, 1978b
1.67	Kan & Turinstra, 1976

Thus

$$K_{pc} = 1.57 \pm 0.17$$

$$K_{se} = (1.57)(0.031 = K_{pc} f_{ps}$$

$$= 0.049$$

To find RME:

$$\left(\frac{\partial K_{se}}{K_{se}}\right)^2 = \left(\frac{\partial K_{pc}}{K_{pc}}\right)^2 = \left(\frac{\partial f_{ps}}{f_{ps}}\right)^2$$

$$\Rightarrow \partial K_{se} = 0.049 \left[\left(\frac{0.17}{1.57}\right)^2 + \left(\frac{0.012}{0.031}\right)^2 \right]^{1/2}$$

$$= 0.020$$

$$RME = 0.049 = Z0.1 * 0.02 = 0.049 \times 1.96(0.02)$$

$$= 0.087$$

Using this simple ratio of 0.54 for K_{se} from Putnam and others (1974) one is limited to soil ingestion only when in reality there are other pathways of concern. The derivations that follow lead to an RMA value of 0.087 for K_{se}, which accounts for the grain ingestion pathway plus the incidental soil ingestion pathway.

Comment No. 13 - Sampling of Deeper Aquifers

In the Army's Response to General Comment No. 7, it refers to various sampling programs to assert that the deeper aquifers have been sufficiently evaluated. The State is aware of the Army/Tri-County Health Department domestic sampling program initiated last year. While we are pleased with the Army's decision to monitor domestic use of contaminated ground water, we were never informed by the Army that the domestic use program would be used to characterize Denver/Arapahoe aquifer contamination. When the State was asked to comment on the Army's domestic well sampling plan we were asked to identify residences which appeared to be within contaminant plumes that had not been sampled previously, not to identify locations where sampling should be performed to characterize Denver/Arapahoe contamination.

In addition, it has always been the contention of the Army that characterization of any ground water plumes cannot be achieved through sampling of domestic wells. The State's domestic well sampling program was implemented to identify whether contamination (i.e.; DIMP) exists in the deeper aquifers. Based upon our results, we had anticipated an Army-initiated monitoring well network to be installed to better characterize Arapahoe contamination. As was agreed to by all parties years ago, because of the large screen intervals associated with domestic wells, their use in defining contamination plumes is inappropriate. The State therefore reiterates its concerns that the deeper aquifers beneath the offpost operable unit have not ben adequately investigated and inappropriately omitted from the EA/FS programs.

Response

The Army disagrees with CDH's contentions that deeper aquifers beneath the Offpost OU have not been adequately investigated. Based on a substantial amount of both confined Denver Formation and confined Arapahoe Formation well data, the isolated detections observed are sporadic and not indicative of deep aquifer contamination. Refer to CDH comment No. 8B for more information on the aquifer characterization.

Comment No. 14 - Surface Water PRG Exceedance

In the response to CDH Cover Letter Comment No. 1, the Army states that there is no risk attributable to sediment and surface water in zones other than 3 and 4. However, the May-June 1990 surface water sampling at Station HA1159SE in Section 12, O'Brian Canal (in zone 2), indicated exceedances of the commercial/industrial PRGs developed for zones 3 and 4 for DDT and DDE. The exceedances for these two compounds are not shown on Figure 2.5.3-1 of Volume V (Exceedances of Surface Water PRGs in the Offpost Operable Unit), and are exceedances of surface water PRGs in the Offpost OU. Please explain this omission and why risks associated with these exceedances were not considered or mentioned in the text.

Response

Refer to CDH comment No. 9. Section 2.2 and Volume V of the FS present risk corresponding to the soil medium and rationale for concluding that the soil medium does not require development of remedial action objectives. Refer to response to CDH general comment No. 1 and Section 2.2 in Volume V for additional information.

Comment No. 15 - Aldrin/Dieldrin Soil HBCs

The Health Based Soil Criteria listed in Table 2.4.5-1 for aldrin and dieldrin under the Rural Residential Scenario are 31 ppb and 0.5 ppb, respectively. Even if the exposures to these analytes

are due to secondary sources, the values should be similar. Given the very similar chemical and toxicological properties of these two compounds, such divergent criteria (by several order of magnitude) indicate a flow in the derivation of these values. The State requests that the Army review its methodology with regard to the soil criteria for these two compounds.

Response

ECOLOGICAL RISK CHARACTERIZATION (ERC) COMMENTS

Comment No. 1 - Volume VIII, page 45, Response to ERC General Comment No. 4

The Army asserts that lower trophic level animals will be protected by selected TRVs and by the revised food web model. We have not yet had an opportunity to complete our review of the new food web model, as it was only delivered to us on March 18, 1992. The TRVs, however, clearly do not adequately address the lower trophic levels. Some 87 TRVs have been derived for species that were selected based on the criteria set forth in Vol. II, sec. 3.5.2 (p. II-3-19). Neither this section nor Table 3.3.1-1 addresses TRVs for other than avian and mammalian species. No reptilian, amphibians, nor invertebrate and other lower order species are included. Nor has the Army considered chemical-specific ecosystem TRVs which would be inclusive of most species in an ecosystem regardless of whether a species-specific TRV has been derived. The latter approach has been recommended by van Straalen and Denneman, 1989 and Okkerman et al. 1991, and has recently been accepted by Germany as the preferred approach to performing ecological risk assessment.

Response

The Army has derived TRVs protective of lower trophic organisms as well as nonavian and nonmammalian species. These values are presented in Table 3.3.1-1 as reference media concentrations for vegetation and aquatic organisms. Species-specific TRVs were not derived for reptiles, amphibian, or invertebrate species because of the general lack of chronic toxicity data for these animals. The Army also feels that its chemical/species-specific TRVs provide a more appropriate measure of potential adverse effects in the ecosystem than chemical-specific ecosystem TRVs suggested by CDH because of the Army's receptor specificity.

Comment No. 2 - Volume VIII, page 45, Response to ERC General Comment No. 5

The Army's assertion that "ecotoxicity values do not permit evaluation of multiple chemical exposures" is not consistent with a large body of information and recommendations presented by prestigious national and international organizations, including the National Academy of Sciences and the World Health Organization, as well as leading texts. Attached to these comments is a limited discussion and listing of highly relevant documents which demonstrate the insupportability of the Army's ERC program. The text is taken from Calabrese: Multiple Chemical Interactions (Lewis; 1991).

Response

Although Calabrese is to be commended for his efforts to publish one of the first comprehensive reviews on multiple chemical interactions, the test xeroxed by CDH may not be as applicable to the offpost ecological assessment as CDH would imply. The method described for aquatic ecosystems assumes simple toxicity additivity for chemicals unless proven otherwise. Other

interactions that are possible include antagonism, synergism, and potentiation. All are very different from additivity, yet no alternative methodology is presented.

Also, by xeroxing the references from Chapter 23 of Calabrese's book and making the above comment, CDH implies that there is a tremendous amount of accepted scientific information on multiple chemical interactions. This is hardly the case, especially for ecological receptors. In fact, the study of multiple chemical interactions is in its infancy compared to other types of toxicological studies. Calabrese alludes to this in the opening chapters of his book and points out in Chapter 2 that "over the past two decades, considerable debate has occurred within the biostatistical/epidemiological, pharmacologic, and toxicological communities over the concept of interaction." Certainly, recommendations have been proposed on multiple chemical interaction methodology; however, because of its early investigative stages and lack of scientific consensus, acceptable guidance for use in ecological assessments is lacking.

Comment No. 3 - Volume VIII, page 45, Response to ERC General Comment No. 6

The Army's argument that the RMA ecosystem is probably in equilibrium, given the length of time that contaminants have been present at the site, misses the point of the State's comment. The critical question is not whether the environment as a whole is in steady-state, but rather whether the individual organisms are in steady-state. This is a function not of how long the contaminant has been in the ecosystem, but rather how long the organism has been exposed to the contaminant, and how long it takes for the contaminant to reach steady-state within the organism. This issue must be addressed.

Response

The Army understands that an organism can attain steady state if exposure and biological factors affecting the uptake and loss of a chemical remain constant for a sufficient length of time. However, the Army does not have sufficient data for an inclusive statement regarding steady-state conditions in the Offpost OU.

Comment No. 4 - Volume VIII, page 46, Response to ERC General Comment No. 7

In response to the State's inquiry regarding the intended relationship between the TRVs and the MATissueCs, the Army has asserted that MATissueCs "are most useful for bioaccumulative chemicals and for food sink species. TRVs are more useful for nonbioaccumulative chemicals and for lower trophic level species." Yet, TRVs are proposed for top level predators for highly bioaccumulative chemicals such as organchlorine pesticides. Therefore, the Army's response has not clarified the question, which is how will these values be used in arriving at cleanup levels.

From a toxicological perspective, the MATissueCs and TRVs should be consistent. One should be derivable from the other given knowledge of appropriate toxicokinetic factors. Prior estimated MATissueCs were significantly greater than those that would be predicted by converted TRVs. We have not had an opportunity to interconvert the new TRVs ad MATissueCs. However, any inconsistency between the two values would undercut confidence in the Army's methodology.

Response

The Army would be interested in reviewing CDH's methodology for interconverting TRVs and MATCs. The Army uses both MATCs and TRVs to derive ecological soil criteria (Volume VII, Appendix C of the FS).

Comment No. 5 - Volume VIII, page 46, Response to ERC General Comment No. 8

The food web model has now been calibrated with onpost biota data. The State has formally objected to the use of the limited RMA data base to deviate from peer-reviewed literature derived values. Specific comments on the new Ecological Risk Characterization ("ERC") model and calibrated values could not be compiled in time to meet the Army's April 6, 1992 deadline; however, preliminary review has indicated that, for a variety of reasons, including internal inconsistency and the lack of accord with available scientific information, the proposed model and output cannot be relied upon to predict ecosystem responses to contaminants, and does not appropriately reflect maximum known exposure within the RMA ecosystem. The State intends to transmit detailed comments on the ERC model by April 21 in accordance with the Army's request. Since the offpost values are derived from the ERC model, the State cannot support those values at this time.

Response

Refer to response to USFWS Comments No. 1 and No. 2.

Comment No. 6 - Volume VIII, page 46, Response to ERC MATissueC Comment No. 1

The Army, in defending its sink species methodology, has attempted to avoid its own obligation of proving the protectiveness of its approach, instead challenging the State to prove to the contrary. Such a shifting of the burden of proof is contrary to the prescriptions of CERCLA and the NCP which require the President to demonstrate protectiveness of the environment as a threshold criterion for any remedy selected.

The principal premise of the Army's ecological risk assessment method is that reliance on sink species via food chain modeling will protect all other species, including those species that may be inherently more sensitive than the sink species at a similar exposure. This premise assumes that the enhanced exposure in the sink species will more than compensate for any differential susceptibility to the agents of concern.

To determine the validity of this assumption, one must identify the degree of interspecies variation in susceptibility that one can expect if the intent is to protect all biota within the ecosystem. Differential susceptibility at the ecosystem level has been inferentially addressed by Slooff et al. (1987) in their comparison of 35 species over 11 taxa. Their work involved a large series of binary comparisons which estimate interspecies differences in susceptibility. The results showed up to 100-fold interspecies variability for 60% of the comparisons, and up to 1000-fold variation for 90% of the comparisons.

A consideration of predicted tissue concentrations from the calibrated biomagnification values (BMF) (Vol. IV, Table H3, Page 2 of 2, First Creek) reveal that the range of tissue concentrations for dieldrin was 6.1-fold (algae to heron), DDT was 6.1-fold for algae to the heron and 427.5-fold for invertebrates to the heron; DDE was 1.8-fold for the algae to bald eagle and 39.7-fold for invertebrate to the bald eagle. In addition, the bald eagle was estimated to bioaccumulate 39.4-fold more DDE, 29.6-fold more DDT, and 5.6-fold more dieldrin than the small fish; 22.6-fold more DDE and DDT, and 6.0-fold more dieldrin than the mallard duck; 19.1-fold more DDE, 13.8-fold more DDT, and 3.3-fold more dieldrin for the large fish.

In the terrestrial food web (Table H2, page 2 of 3) the variation in predicted tissue concentrations of prairie dogs and the great horned owl were 6.2, 4.8, 3.1, and 50.9-fold, for DDE, DDT, dieldrin and endrin, respectively.

Regardless of how one estimates exposure, whether on a mg/kg/dose-rate basis or tissue concentration basis, the Army's existing data indicate that the premise of using sink species to compensate for interspecies variation in response to toxic substances may be seriously flawed.

Response

The Army stands by its original response and fails to see where CDH was challenged to prove otherwise. The data presented above simply illustrate the concept of bioaccumulation and biomagnification, and any other interpretation is conjecture.

Comment No. 7 - Volume VIII, page 47, Response to ERC MATissueC Comment No. 2

To clarify the State's ERC General Comment 2 regarding endpoint selection for biota criteria derivations, "legislative factors" which must be included in cleanup criteria are, for example, the requirements of the Endangered Species Act ("ESA"), the Bald Eagle Protection Act ("BEPA"), and the Migrating Bird Treaty Act ("MBTA"). These Acts, as well as the case law construing them, variously define and prohibit harm and harassment. The Migratory Bird Treaty Act (16 U.S.C. § 703) is intended to "aid in the restoration of such birds...where [they] have become scarce or extinct." The MBTA, similar to the ESA and BEPA, protects individual birds and their parts, nests, or eggs, by prohibiting hunting, taking, possession, killing, etc., of protected species, except as permitted by regulation (see, e.g., 50 C.F.R. pts. 20 & 21).

Further, the purposes of the ESA, as set forth at 16 U.S.C. 1531(b), include providing "a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved..." (emphasis added). Any manifestation of statutory or judicially defined harm must be considered when selecting appropriate endpoints from which to derive action levels, so that these levels are sufficiently protective to prevent such harm to biota.

We are disturbed by the Army's assertion that the Migratory Bird Treaty Act does not require protection of individual animals. The purpose of that act is to "aid in the restoration of such birds...where [they] have became scarce or extinct." Legal interpretation in the courts (see, e.g., U.S. v. Corbin Farm Service, 444 F. Supp. 510 (1978)) supports protection of individuals within a species. Selection of action levels that would kill, harm or take individuals (or parts or eggs) of covered species would clearly contravene the purpose of that Act.

Also, the Army is continuing to ignore the variability in endpoints used to derive MATissueCs. The Army states in volume II, page 3-18, section 3.4, second paragraph, that the MATC values "represent tissue concentrations that correspond to no effect, or minimal effects in a few animals in a population." The specific endpoints used in the derivation of the MATissueCs are not provided with the EA/FS document. We request that a description of the endpoints along with citations given the source literature be included in the final version. The secondary source which is cited by the Army (Onpost HHRA software, version 1.0, EBASCO 1992) does not contain this information.

The most current list of MATissueC endpoints which the Army has supplied the parties is the "MATC supplemental Tables" dated December 2, 1991. In these tables, endpoints range from lethality to no effects. This is an unacceptable range of toxic responses on which the State has commented previously (State letters of September 23, 1992 and December 10, 1991). The Army states in section 3.4 that "[w]hen the endpoint was lethality, an appropriate uncertainly factor was applied." However, the EBASCO 1992 citation does not appear to contain any details of this uncertainly factor.

In human health risk assessment methodology an uncertainty factor of 10 is used if an adverse effect ("LOAEL") is observed; if a frank effect ("FEL") is noted, a modifying factor is available

to adjust for the additional uncertainty introduced. An analogous approach must be developed to protect biota.

Response

Regarding CDH's comment on the ESA, BEPA, and MBTA, Appendix A, Volume VII of the FS has been revised to include in totality the language agreed upon in the dispute resolution process and communicated in a letter from EPA to the parties on September 18, 1992.

The MATCs have been revised and are discussed in Volume II, Section 3.0 and Volume IV, Appendix H of the EA.

Comment No. 8 - Volume VIII, page 48, Response to ERC MATissueC Comment No. 3

The Army has failed to address to State's concern that MATissueCs based on sublethal effects may not even protect populations of exposed biota. The topic of acceptable sublethal effects must be carefully evaluated in both the MATissueC and TRV approaches. The adverse effects are highly variable and present different health consequences to both individuals and populations. For example, if the Army accepts a LOAEL for COC No. 1 at which 30% of the exposed individuals experienced life shortening physical deformity, a LOAEL for COC No. 2 at which 45% experienced behavioral abnormalities that reduce reproductive success, and a LOAEL for COC No. 3 at which 35% experienced increased susceptibility to acute viral disease, population effects are likely to be observed. Analogous problems could be associated with MATissueCs based on sublethal effects. What criteria have the Army used to judge if there would be a population effect and have these criteria been developed and validated for the species of interest? Until a systematic assessment of the role of sublethal effects (both single and multiple concurrent effects) on the survival and vitality of the population is completed, the Army's approach cannot be considered protective of populations.

Response

The MATC values presented in the draft final were obtained from the Onpost ERC. Because the onpost ERC was not finalized at the time of the draft final, several of the MATC values were an item of dispute. On the basis of the dispute resolution process, revised MATC values were derived on a basis of scientific consensus. These revised values are discussed and presented in Volume II, Section 3.0 and Volume IV, Appendix H of the EA.

Comment No. 9 - Volume VIII, page 48, Response to ERC MATissueC Comment No. 5

The Army uses a relationship between human brain and whole body mercury to establish a constant so that whole body values can be estimated when only brain levels are measured in a given species. The State's previously submitted comments documented that there is considerable interspecies variability in organ to organ ratios of mercury depending on the animal species. Since this variability can be extreme, it introduces a high degree of uncertainty in this process. The Army procedure does not recognize this uncertainty; nor does it incorporate a means (e.g. UFs) to compensate for uncertainty.

The Army has responded in part by asserting that the variability noted in the State's comment is addressed within the context of the interspecies UF. However, this assertion is obviously erroneous. First, according to the document, only the TRV methodology includes interspecies UFs, not the MATissueC approach. Yet,it is the MATissueC approach which requires whole body extrapolations, not the TRV. Secondly, even if MATissueC interspecies UFs were to be adopted, they would

normally be triggered when MATissueCs were derived from a literature value based on different species. Since it appears that each MATissueC has been derived from studies on each target species, no UF factor would be deemed necessary. However, the source of the toxicity information is irrelevant to the whole body extrapolation issue because the latter extrapolation is based, not on the toxicity information, but rather, for example, on the mercury brain to whole body ratio that has been determined for humans. Accordingly, the State again maintains that this inaccuracy must be addressed in the MATissueC methodology.

Response

Refer to response to Comment No. 8.

Comment No. 10 - Volume VIII, page 51, Response to Comment No. 1.a

The Army has failed to justify its selection of phylogenetic related interspecies uncertainty factors. In the interest of determining the validity of the Army's theory and proposed values, the State has undertaken an evaluation of existing data pertaining to interspecies susceptibility to chemicals. The results of this analysis are attached and demonstrate that the Army's values cannot be supported. Analyses of thousands of phylogenetic toxicological comparisons summarized by Suter and others indicate that, although the data do generally support the theory of phylogenetic relatedness to a greater extent than previously noted, they refute the Army's proposed values for interspecies uncertainty factor values. For example, for species within genera, at the 99% confidence interval, they observed differential susceptibilities between 6 and 21 fold: for orders within classes, there were differences between 17 and 17,534 fold. These data demonstrate that the Army's proposed values of 2 for each level of phylogenetic difference are not adequate to address interspecies variation in susceptibility to contaminants.

Response

Contrary to CDH's position, the magnitude of the Army's uncertainty factors applied in the derivation of TRVs is supported by the paper published by Suter and Rosen (1988) as well as Barnthouse and others (1990) as discussed in Volume II, Section 3.0 of the EA. CDH's reference to the uncertainty factors associated with the 99 percent confidence interval is not appropriate and would imply the use of extremely conservative uncertainty factors beyond scientific reason.

Comment No. 11 - Volume VIII, page 59, Response to ERC Specific Comment No. 12

In response to the State's previous comment regarding sensitive populations and subpopulations, the Army states that it selected representative receptor species and sensitive subpopulations using EPA criteria and additional information as listed on page III-5-7. However, it is still not clear how such species (i.e., species with lower thresholds to toxic substances) were differently addressed. Please explain how and which species were identified, and the pollutants to which they had lowered threshold tolerances, and the magnitude of differential susceptibility. Also, please explain how the ERC methodology was used to derive TRVs and MATissueCs protective of such species.

In addition, the selection criteria referred to relates only to receptor species: it does not address sensitive subpopulations within a species. Please explain how considerations of such subpopulations have been incorporated in the ERC methodology, and provide examples of the incorporation of such considerations in the derivation of specific TRVs and MATissueCs.

Response

The potential receptors listed in Tables 5.2.1-1 and 5.2.1-2 were qualitatively evaluated against the criteria presented in Section 5.2.1 of Volume III. The selection process was according to the professional judgment of the evaluators. The pollutants to which the receptors were assumed to have lowered threshold tolerances were the organochlorine pesticides primarily because of their bioaccumulative properties. Magnitude of differential susceptibility was based on trophic box level.

The TRV and MATC methodology, including application to sensitive subpopulations, is presented in Section 3.0, Section 5.0, and Appendix H of the EA.

Comment No. 12 - Volume VIII, page 63, Response to ERC Specific Comment No. 28

The Army has failed to justify its requirement that the HI be exceeded by a factor of 10 before remedial action is considered. In response to the rationale presented:

(1) The assertion that the use of UFs, LOAELs and NOAELs in deriving MATissueCs and TRVs is conservative demonstrates a profound lack of understanding of the most fundamental tenets of risk assessment accepted not only by EPA but by major health organizations throughout the world. While many debate about the size of UFs, UFs are not inherently conservative but necessary to make valid extrapolations. In fact, the sparse data base that exists indicates that values traditionally utilized may not be sufficient to account for variability and other considerations obsensibly embodied in each UF. In Comment 8 above the State points out that the use of LOAELs and NOAELs may not be protective, let alone conservative.

(2) The fact that mobile species may have had their exposure overestimated does not eliminate concern with the organisms of limited mobility. Furthermore, if exposure estimates are known to be unrealistic, they should be revised. Unquantified overconservation in this assumption does not support the arbitrary use of, essentially, a 10-fold multiplier of the acceptable does or tissue concentration value.

(3) The Army has not substantiated its belief that modeling assumptions are consistently conservative; regardless, this issue is best dealt with via the construction of the model itself, which should reflect the best estimated exposure.

(4) The assertion that soil intakes are "conservative," especially in light of the high uncertainty in this area, is totally inappropriate and unverified. It therefore cannot be used to justify the Army's HI approach.

The use of a HI of 10 is inherently irrational. The denominator of the hazard index is suppose to be the scientists' best professional estimate of an acceptable dose (or, in the case of RMA, tissue concentration); therefore, any exceedance of such a level should be a cause of concern. If the parties do not believe that the TRV or MATissueC is accurate, it should be changed to accord with the best available scientific information and judgement. To add uncertainty factors on the front end to account for inadequacies, and then basically subtract them in the final analysis, is nonsensical. Essentially, the Army is proposing an UF multiplier of 10 which is without supporting documentation or rationale, and is dramatically deviant from existing risk assessment knowledge and methodology throughout the world.

Response

1. The Army strongly disagrees with CDH. UFs, for the most part, are inherently conservative. This conservatism is eloquently presented in the recent publication by Lewis and others (1990). CDH fails to present evidence from the "sparse database" that traditional UF values (the Army assumes CDH is referring to 10) may not be sufficient to account for variabilities encountered during toxicity extrapolation. The traditional values were initially arbitrarily assigned a value of 10 on the basis of professional judgment. They basically have been accepted by regulatory agencies and organizations as more a matter of convention than a scientific absolute. It is likely that the UFs now applied will be reduced as more useful toxicological data become available. The UF values suggested by EPA for the derivation of human reference doses are not codified. The use of UFs less than 10 at each step of the iterative process in deriving a TRV is supported by the recent literature, including papers cited by CDH. CDH is referred to Volume II, Section 3.0 of the EA for a further discussion of UFs and is encouraged to read the references cited by the Army. The draft final ecological assessment used MATC values derived for the Onpost ERC. On the basis of dispute resolution, some of these values have changed and are discussed and presented in Volume II, Section 3.0 and Volume IV, Appendix H.

2. Because the exposure estimates were known to be unrealistic when presented in the draft final, they have been revised for the final ecological assessment.

3. Again, revisions have been made to estimate more realistic exposures.

4. Refer to 2 and 3 above.

Comment No. 13

The Army previously proposed a reduction factor of 5 to account for the unique concern over protecting Endangered Species. In this draft, the factor has been changed to 2. Neither value has been supported by literature or rational argument. Much literature exists on interindividual variation in response to toxic substances. In the case of the highly heterogeneous human population, interindividual variation exceeding 10-fold is commonly encountered. In the case of the highly inbred rodents, interindividual variation of 3- 5-fold is often seen. These commonly recognized occurrences indicate that a 5-fold factor may not effectively protect individual eagles. Since the federal legislation's intent is to protect all individuals, a factor greater than or equal to 10 is clearly warranted.

Response

The selection of an uncertainty factor of 2 to provide additional protection to the bald eagle population is supported by the literature. The use of a factor of 2 is identical to that selected in the ecological risk assessment Standard Evaluation Procedures (SEPs) developed by the Office of Pesticide Programs in EPA to protect threatened and endangered species.

SPECIFIC COMMENT

Comment No. 1

Volume IV, Appendix F, "Toxicity Profiles of Chemicals of Concern" has MATissueC values which do not match the MATissueC values listed in Appendix H of the same volume. For example, the Toxicity Profile lists aldrin/dieldrin as having a MATissueC of 10 mg/kg. Appendix H lists

aldrin/dieldrin as having MATissueC values ranging from 1.6 to 3.75. Please update the Toxicity Profiles.

Response

Comment noted. The toxicological profile has been updated.

GLOSSARY

ABS	absorption factor
ARAR	applicable or relevant and appropriate requirement
BAF	bioaccumulation factor
BCF	bioconcentration factor
BEPA	Bald Eagle Protection Act
BGEPA	Bald and Golden Eagle Protection Act
BMF	biomagnification factor
CBSG	Colorado Basic Standards for Groundwater
CCR	Colorado Code of Regulations
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	chemical of potential concern
CRL	certified reporting limit
DDE	2,2-bis (para-chlorophenyl)-1,1-dichloroethene
DDT	2,2-bis (para-chlorophenyl)-1,1,1-trichloroethane
DIMP	diisopropyl methylphosphonate
EA	endangerment assessment
Ebasco	Ebasco Services, Inc.
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
ERC	Ecological Risk Characterization
ESA	Endangered Species Act
FFA	Federal Facility Agreement
FS	feasibility study
GC/MS	gas chromatography/mass spectroscopy

HA	health advisory
HBC	health-based criteria
IRA	Interim Response Action
IRA A	Additional Interim Response Action
LDR	Land Disposal Restrictions
LOAEL	lowest-observed-adverse-effect level
MATC	Maximum Allowable Tissue Concentration
MBTA	Migratory Bird Treaty Act
MCL	Maximum Contaminant Level
mg/day	milligrams per day
NCP	National Contingency Plan
NOAEL	no-observed-adverse-effect level
NWBCS	Northwest Boundary Containment System
OAS	Organizations and State
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PC	permeability coefficient
PCB	polychlorinated biphenyl
PMRMA	Program Manager for Rocky Mountain Arsenal
ppm	parts per million
PRG	preliminary remediation goal
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RMA	Rocky Mountain Arsenal
RME	Reasonable Maximum Exposure
SACWSD	South Adams County Water and Sanitation District
SEP	Standard Evaluation Procedure

TBC	to be considered
TRV	toxicity reference value
UF	uncertainty factor
USFWS	U.S. Fish and Wildlife Service
UST	underground storage tank
USC	United States Code

ATTACHMENT A

DEPARTMENT OF THE ARMY
PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO 80022-2180

REPLY TO
ATTENTION OF:

May 5, 1992

Office of the Program Manager

Mr. Lewis D. Walker
Deputy Assistant Secretary of the Army
for Installation, Logistics, and Environment
Pentagon, Room 2E577
Washington, DC 20310-0103

Mr. Roy Gerard
Shell Oil Company
P.O. Box 2463
Houston, TX 77252

Mr. Galen Buterbaugh
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 25486
Denver Federal Center
Denver, CO 80225

Mr. Jack McGraw
Deputy Regional Administrator
U.S. Environmental Protection Agency
Suite 500, South Tower
999-18th Street
Denver, CO 80202-2405

Dear Sir:

Following several weeks of dispute resolution discussions at the RMA Committee and Council levels regarding the Offpost Operable Unit (OU) Endangerment Assessment/Feasibility Study (EA/FS), the Organizations have reached agreement on all but one issue.

The resolutions to the dispute issues for the Offpost EA/FS are enclosed. The most complex of the resolved issues was the issue regarding the Ecological Risk Assessment. The Army agreed to incorporate the values described in the enclosure with the understanding that they represent conservative values based on interpretations of the literature and may not be representative of site-specific conditions present in the Offpost OU. These values have been accepted by the Army in the spirit of cooperation to facilitate the completion of the Ecological Risk Assessment.

The unresolved issue concerns whether the Endangered Species Act (ESA), Migratory Bird Treaty Act (MBTA), and Bald and Golden Eagle Protection Act (BGEPA) are applicable or relevant and appropriate requirements (ARARs) for the Offpost OU, and, if so, what type of ARAR (e.g., location-, action-, or chemical-specific) they are. EPA argues that all three acts should be chemical-specific ARARs. The Army and USFWS

contend that the acts are not ARARs but are independently enforceable. Shell's position is that the ESA, MBTA, and BGEPA are not chemical-specific ARARs.

The discussion of the ARAR issue is now taking place at the national level between the Department of Interior and EPA. However, because the parties have agreed to the ecological parameters for the Offpost OU, the offpost process should go forward while the issue is being resolved at the national level.

The resolution to the dispute, as described, will require an additional six months to complete. The delay in completing the EA/FS will also cause a delay in the issuance of the Offpost Record of Decision of up to six months.

Sincerely,

Eugene H. Bishop
Colonel, U.S. Army
Chairman, RMA Council

Enclosure

Copies Furnished:

Major John M. Fomous, U.S. Army Environmental Law Division, 901 N. Stuart Street, Suite 400, Arlington, Virginia 22203-1837
Mr. Bradley Bridgewater, U.S. Department of Justice, 999-18th Street, Suite 501, North Tower, Denver, Colorado 80202
Mr. Thomas Cope, Holme Roberts and Owen, Suite 4100, 1700 Lincoln Street, Denver, Colorado 80203
Ms. Victoria Peters, Attorney General's Office, CERCLA Law Division, One Civic Center Plaza, 1560 Broadway, Suite 250, Denver, Colorado 80202
Mr. David C. Shelton, Director, Hazardous Material and Waste Management Division, Colorado Department of Health, 4210 East 11th Avenue, Denver, Colorado 80220
Mr. Thomas Looby, Colorado Department of Health, 4210 East 11th Avenue, Denver, Colorado 80220
Mr. William Clemmens, U.S. Environmental Protection Agency, Region VIII, One Denver Place, Suite 801, 999-18th Street, Denver, Colorado 80202-2405
Document Tracking Center, AMXRM-IDT, Room 132, Building 111, Rocky Mountain Arsenal, Commerce City, Colorado 80022^R

Offpost Operable Unit Dispute Resolution Agreement

The resolution to the dispute, as described, will require an additional six months to complete. The delay in completing the EA/FS will also cause a delay in the issuance of the offpost record of Decision of up to six months.

Approval:

Eugene H. Bishop
Army

Robert Duprey
EPA

William McKinney
Shell

John L. Spinks
USFWS

OFFPOST ENDANGERMENT ASSESSMENT/FEASIBILITY STUDY DISPUTE RESOLUTION

It is the intent of the Organizations to achieve resolution on language prior to finalization of the document on November 13, 1992.

1. Development of Preliminary Remediation Goals (PRGs)

ISSUE: EPA questioned the methodology (but did not dispute given the magnitude of the impact under the current factual situation) whether the effects of multiple chemicals within a medium and whether the effects of chemicals of concern (COCs) in multiple media were considered when PRGs were developed.

RESOLUTION: The Army will modify the text in Volume V, Section 2.4.5, and in Volume VII, Appendix C. The Army modifications will include additional discussion about how soil PRGs were developed and will incorporate comments provided by EPA on April 23, 1992.

2. Use of 10^{-4} vs. 10^{-6} Risk as Point of Departure

ISSUE: EPA invoked dispute concerning whether 10^{-4} or 10^{-6} cancer risk was used as the point of departure for determination of HBC. The Army had added sections in the Proposed Final EA/FS that were intended to address an EPA comment, but EPA found the changes to be insufficient.

RESOLUTION: The Army asked EPA to provide specific comments concerning sections of the EA/FS that still need to be clarified. The Army will incorporate those comments (received on April 23, 1992) into the Final EA/FS, specifically Volume II, Sections 2.4 and 2.5, and Volume V, Section 2.4.3.2.

3. Uncertainty Analysis

ISSUE: EPA invoked dispute concerning the presentation of the uncertainty analysis in the EA/FS, particularly (1) the possibility that risks may be underestimated in some areas but not discussed and (2) the discussion of the uncertainty analysis and its representation of exposure relative to the reasonable maximum exposure (RME).

RESOLUTION: The Army will incorporate EPA comments (received on April 23, 1992) to clarify the uncertainty discussions in the EA/FS.

4. Division of Soil Concentrations by 5

ISSUE: EPA questioned the methodology (but did not dispute given the magnitude of the impact under the current factual situation) of the Army's modification of soil exposure concentrations for the plant uptake model by a factor of 5.

RESOLUTION: The Army will add discussion of uncertainty to Volume II, Section 2.6, to explain why the factor of 5 was used to account for the lower concentrations of COCs available to plant roots (i.e., because COCs accumulate in the surface 1 to 2 inches of soil).

5. FS Alternative Selected

ISSUE: EPA invoked dispute concerning the groundwater alternative selected in the FS, contending that all alternatives were variations of the same technology/configuration and that the alternatives were essentially equivalent. EPA also stated that the FS did not evaluate configurations that potentially could achieve a more rapid remediation.

RESOLUTION: The Army will clarify the methodology used and the basis for the development of remedial alternatives. Specifically, the Army will describe: (1) the controlling contaminant and hydrogeologic considerations, (2) resultant estimated remediation time frames, (3) relative positions of remedial components for each alternative, (4) limitations on additional components, and (5) level of aggressiveness of the remedial alternatives.

6. Surface Water FS

ISSUE: EPA questioned, but did not dispute, whether surface water alternatives should be developed in the FS.

RESOLUTION: Following further discussion on the issue, EPA withdrew its objection.

7. Groundwater Exposure Point Concentrations

ISSUE: Shell invoked dispute concerning the Army's use of the 1985-1990 groundwater database, use of data with high certified reporting limits (CRLs) from gas chromatograph/mass spectrometer (GC/MS) analysis, and inclusion of duplicate analyses. Shell contended that this approach is unrepresentative of current conditions.

RESOLUTION: The groundwater exposure point concentrations will be revised and will be based on 1989-1991 groundwater data excluding nondetections with high CRLs and duplicate data, as well as on the appropriate statistical procedures.

8. Dieldrin Toxicity Profile

ISSUE: Shell invoked dispute concerning the Army's failure to include Shell's toxicological profile for dieldrin in the EA/FS.

RESOLUTION: Shell's dieldrin toxicity profile will be included in Volume IV, Appendix F, in addition to the Army's dieldrin toxicity profile already in Appendix F. Shell's profile will be added and referenced in the same manner as in the 1991 Onpost Human Health Exposure Assessment.

9. Manganese as a COC

ISSUE: Shell invoked dispute concerning the inclusion of manganese as a COC based on limited data linking manganese to RMA.

RESOLUTION: Shell withdrew the dispute when the Army presented additional onpost and offpost groundwater data concerning manganese.

10. Applicable or Relevant and Appropriate Requirements (ARARs)

ISSUE:

A. EPA disputed the overall completeness/format of the ARARs assessment.

B. Shell disputed the inconsistent treatment and use of land disposal restrictions (LDRs) as ARARs.

C. Shell disputed the use of stormwater discharge regulations as ARARs.

D. Shell disputed the use of Colorado groundwater standards that are more stringent than federal standards as ARARs rather than as TBCs (to be considereds).

E. Shell disputed the selection of some proposed MCLs as ARARs instead of TBCs.

RESOLUTION:

A. The Army will clarify the presentation/screening of ARARs through additional discussion.

B. The Army will revise Volume VII, Appendix A of the Offpost EA/FS as agreed to by the parties. (Attachment A).

C. Shell withdrew the dispute.

D. Although there is some question whether the Colorado Basic Standards for Groundwater are legally enforceable as ARARs, the Army is evaluating whether those standards are ARARs for the purposes of this document.

E. The Army will make appropriate changes to the ARARs listings as part of Item A.

11. Hazard Index (HI) > 1 for Egg Pathway

ISSUE: EPA disputed the Army's use of only dieldrin to assess the egg pathway for human exposure.

RESOLUTION: EPA dropped the dispute, agreeing that the risk assessment will evaluate only dieldrin for this pathway.

12. Land Use Scenarios

ISSUE: Shell invoked dispute concerning the use of the subsistence farmer (rural residential) scenario in the EA/FS. EPA invoked dispute concerning the selection of commercial/industrial land use in the FS in zones 3 and 4.

RESOLUTION: All Organizations agreed to use one land use scenario per zone. Zones 1, 2, and 6 will remain rural residential. Zones 3 and 4 will be urban residential with two presentations of risk estimates in the EA. Zone 5 will be commercial/industrial. See Attachment B for details of the pathways to be considered in each zone.

13. Ecological Risk Assessment

ISSUE:

A. Shell invoked dispute concerning the need for a more quantitative assessment of the spatial and temporal (seasonal) factors involved in the higher trophic level organism foraging habits.

B. Shell invoked dispute considering the conservative nature of the toxicity reference value (TRV) process.

C. EPA invoked dispute concerning the maximum allowable tissue concentration (MATC) value for dieldrin; Shell disputed MATC values for aldrin/dieldrin, DDT/DDE, and endrin; USFWS disputed the dieldrin MATC and had general concerns about other MATC values.

D. EPA, USFWS, and Shell invoked dispute concerning the use of onpost calibrated bioaccumulation factors (BAF) values. Shell requested the use of BAF values as used in the Draft Final version of the EA/FS; EPA requested the use of literature BAF values; USFWS supported literature and/or USFWS BAF values.

E. Shell and USFWS disputed bioconcentration factors (BCFs).

RESOLUTION:

A. All Organizations agreed to the incorporation of a spatial weighting factor to adjust the predicted tissue concentrations and hazard indices for the great blue heron, great horned owl, American kestrel, and bald eagle. The spatial weighting factor will be based on the ratio of available acreage of appropriate habitat and the acreage of taxon-specific home range. Shell withdrew the temporal (seasonal) factor portion of the dispute.

B. All Organizations agreed that the TRV process will follow the approach as originally presented by the Army with uncertainty factor modifications to derive a no observed adverse effect level (NOAEL) rather than a no observed effect level (NOEL) from the critical exposure dose. The Organizations have agreed to accept the aldrin/dieldrin critical exposure dose presented by Shell as the basis for the great blue heron TRV; the great blue heron TRV value will be 0.06 mg/kg/day. The Army agreed to provide documentation supporting the uncertainty factor modifications in the Final EA/FS.

C. The following MATC literature values were agreed to by all Organizations:

Aldrin/Dieldrin

Bald eagle	1.1 ppm
Great blue heron	1.1 ppm
Great horned owl	1.1 ppm
American kestrel	1.1 ppm
Water birds	1.1 ppm
Small birds	1.1 ppm

Endrin

Bald eagle	0.01 ppm
Great blue heron	0.1 ppm
Great horned owl	0.01 ppm
American kestrel	0.01 ppm
Water birds	1.0 ppm
Small birds	0.045 ppm

DDT/DDE

Bald eagle	2.0 ppm
Great blue heron	2.0 ppm
Great horned owl	2.6 ppm
American kestrel	5.1 ppm
Water birds	1.7 ppm
Small birds	1.7 ppm

D. The following BAF literature values (unitless) were agreed to by the Organizations:

Aldrin/Dieldrin

Small bird	2
Small mammal	3
Medium mammal	3
Worm	6
Insect	2.4
Plant	0.4
Owl	19
Kestrel	12
Eagle	19

Endrin

Small bird	8
Small mammal	8
Medium mammal	8
Worm	29
Insect	29
Plant	0.06
Owl	8
Kestrel	8
Eagle	8

DDT/DDE

Small bird	2
Small mammal	6
Medium mammal	6
Worm	3
Insect	32
Plant	1.4
Owl	31
Kestrel	31
Eagle	31

E. All Organizations agreed to use USFWS BCFs (unitless) for small (lower) fish (aldrin/dieldrin, 16,716; DDE/DDT, 70,094) and use literature values for remaining small fish, invertebrates and algae. USFWS is to supply documentation supporting their BCFs.

The Organizations also agreed to use geometric mean soil concentrations to determine predicted tissue concentrations and/or soil criteria exceedances.

This resolution is considered applicable only to the Offpost EA. The Army will incorporate the MATC and BAF values as agreed to by the organizations.

ATTACHMENT A

Based upon offpost sampling process knowledge and EPA guidance concerning the Land Disposal Restrictions (LDRs) under RCRA, the Army has no reason to believe there is any listed or characteristic hazardous waste in the Offpost OU, or that construction of any alternative would involve placement of a listed or characteristic hazardous waste. If it is determined that a listed or characteristic hazardous waste is present and that placement of such a waste would occur, LDRs will be ARARs and the Army will act in a manner consistent with EPA guidance for the management of such wastes in the context of a CERCLA response action.

ATTACHMENT B

A. Rural Residential (EA/FS zones 1, 2, and 6)
- *meat (75%)
- *dairy (75%)
- egg (only evaluated dieldrin)
- *vegetable (40%)
- groundwater (ingestion)
- groundwater (inhalation)
- soil (dermal)
- soil (ingestion)
- sediments (dermal)
- surface water (dermal)

B. Urban Residential (EA/FS zones 3 and 4)
- *vegetable (40%)
- soil (dermal
- soil (ingestion)
- sediments (dermal)
- surface water (dermal)
- groundwater (ingestion)
- groundwater (inhalation)

* All % indicate amount of consumption from local sources.

Risk estimates for Zones 3 and 4 will be presented in two manners:

1. As a baseline risk assessment for all media per EPA guidance. The groundwater portion of the risk assessment will be based on the calculated risks from 1989-1991 groundwater data in those zones.

2. The second risk calculations will be based on the continuing beneficial effect of the onpost boundary system operations in a 30-year time frame. The text will state that these are the expected potential exposures for individuals in those zones and the risks associated with those exposures.

C. Commercial/Industrial (EA/FS zone 5)
- soil (dermal)
- soil (ingestion)
- groundwater (ingestion)
- groundwater (inhalation)

If South Adams County Water and Sanitation District (SACWSD) provides appropriate documentation of not planning to install future water wells in Zone 5 over the next 30 years, the groundwater pathway will be removed from Zone 5. In a meeting on April 24, 1992, SACWSD agreed to document that they had no intentions of installing water wells in zone 5 over the next 30 years. The documentation, when received, will remove the groundwater pathway from zone 5.

ATTACHMENT B

SOUTH ADAMS COUNTY WATER AND SANITATION DIST.

6595 EAST 70TH AVENUE
P.O. BOX 597
COMMERCE CITY, COLORADO 80037-0597
TELEPHONE 303 288-2646

May 21, 1992

Mr. Kevin T. Blose
Deputy Program Manager
Remedial Planning Branch
Rocky Mountain Arsenal
Commerce City, CO 80022-2180

Re: **Request for Confirmation of District's Ground Water Development Plans in Zones 3, 4 and 5.**

Dear Mr. Blose:

In response to your letter of April 27, 1992, please be advised that the South Adams County Water and Sanitation District has no current plans to install municipal water wells in the Army's Zones 3, 4 and 5. This planning assumption is, of course, based upon current projections of demand in the immediate vicinity of these zones and existing ground water quality, and therefore could be subject to change if these circumstances also change. The District would certainly make every effort to communicate promptly with the Army if these circumstances do, in fact, change. Also, because ground water supply and quality are so variable throughout the District's existing and potential service areas, please be advised that other requests of this nature will have to be reviewed on a case-by-case basis.

Sincerely,

SOUTH ADAMS COUNTY WATER AND SANITATION DISTRICT

By: _____
Larry L. Ford
District Manager

cc: Col. Eugene H. Bishop
Lt. Col. Jeffrey S. Guilford
Mr. Connally E. Mears
Hon. Hank Brown/Ms. Julie Cella
Lysle R. Dirrim, Esq.
David M. Brown, Esq.
Mr. James I. Michael
Mr. Lewis D. Walker
Mr. Robert L. Duprey

ATTACHMENT C

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
999 18th STREET - SUITE 500
DENVER, COLORADO 80202-2466

SEP 18 1992

VICE PRES.-HSE	
RDG	✓
HVH	JPP
RRK	WJD
OFP	WJM
JLR	WWM cc's by ltr
CGW	MLB
JCW	BAB
	FILE

SEP 22 '92

Ref: 8RC

Mr. Lewis D. Walker
Deputy Assistant Secretary of the Army
for Installation, Logistics and Environment
Pentagon, Room 2E577
Washington, D.C. 20310-0103

Mr. Roy Gerard
Vice President
Shell Oil Company
One Shell Plaza
P.O. Box 2463
Houston, Texas 77252

Mr. Ralph Morgenweck
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 25486
Denver Federal Center
Denver, Colorado 80225

Re: Off-post EA/FS Dispute

Gentlemen:

As you are all aware, the Steering and Policy Committee reached a unanimous resolution of the Off-Post EA/FS dispute concerning the Endangered Species Act, Migratory Bird Treaty Act and Bald and Golden Eagle Protection Act at the September 15, 1992, meeting. Enclosed is statement of that resolution for your review and concurrence.

If you concur that this statement accurately reflects our decision and the basis for the decision, please sign it and return it to me at your earliest convenience.

Sincerely,

Jack W. McGraw
Acting Regional Administrator

Enclosure

Copies with enclosure sent to:

Col. Eugene H. Bishop, U.S. Army
W. J. McKinney, Shell Oil Co.
Ronel Finley, U.S. Fish and Wildlife Service
Bradley Bridgewater, U.S. Department of Justice

RMA DISPUTE RESOLUTION
UNANIMOUS DECISION OF THE
STEERING AND POLICY COMMITTEE

The Endangered Species Act ("ESA"), Migratory Bird Treaty Act ("MBTA") and Bald and Golden Eagle Protection Act ("BGEPA") apply to the Rocky Mountain Arsenal. The Army shall establish remediation goals for site contaminants to maintain and enhance healthy populations of the species subject to the ESA, MBTA and BGEPA and their habitats at the Arsenal.

For the off-post operable unit, remediation goals for off-post contamination that meet the requirements of the ESA, MBTA and BGEPA have been established in coordination with the U.S. Fish and Wildlife Service. These will be included as enforceable remediation levels in the Proposed Plan and the Record of Decision.

For the on-post operable unit, remediation goals for soils and sediments that are consistent with the ESA, MBTA and BGEPA will be established using a methodology agreed to by the Army, Shell and EPA in consultation with the U.S. Fish and Wildlife Service. The Army will also consult with the Fish and Wildlife Service to determine whether any of the CERCLA activities or remedial alternatives might have a short term impact on a subject species or its habitat. If a determination is made that the Army's activities or remedial alternatives could impact a subject species or its habitat, the Army will consult with the Fish and Wildlife Service to determine whether the activity should proceed and what, if any mitigation measures are necessary, in light of any long term benefits to protection of populations of the subject species.

The Organizations expressly reserve their rights to assert their respective positions concerning the ESA, MBTA and BGEPA as ARARs in the future.

Offpost Operable Unit Endangerment Assessment/Feasibility Study, Final Report, Volume VIII of VIII, Task RIFS1 11/24/92, RIC# 93012R03, Harding Lawson Associates, Environmental Science and Engineering, Inc. Diskette #1, ARES8.DOC, ARES8.EXE, CHEMRME2.WK1, MASTRMD2.WK1, READ.ME can be located in the Diskette Archive.

Offpost Operable Unit Endangerment Assessment/Feasibility Study, Final Report, Volume VIII of VIII, Task RIFS1 11/24/92, RIC# 93012R03, Harding Lawson Associates, Environmental Science and Engineering, Inc. Diskette #2, ARES8.DOC, ARES8MLE.EXE, CHEMMLE.WK1, MASTMLE.WK1, READ.ME can be located in the Diskette Archive.

Offpost Operable Unit Endangerment Assessment/Feasibility Study, Final Report, Volume VIII of VIII, Task RIFS1 11/24/92, RIC# 93012R03, Harding Lawson Associates, Environmental Science and Engineering, Inc. Diskette #3, ARES8.EXE, CHEMRME2.WK1, DOCUMENT, MASTRMD2.WK1, READ.ME can be located in the Diskette Archive.

Offpost Operable Unit Endangerment Assessment/Feasibility Study, Final Report, Volume VIII of VIII, Task RIFS1 11/24/92, RIC# 93012R03, Harding Lawson Associates, Environmental Science and Engineering, Inc. Diskette #4, ARES8.DOC, ARES8MLE.EXE, CHEMMLE.WK1, MASTMLE.WK1, READ.ME can be located in the Diskette Archive.

Offpost Operable Unit Endangerment Assessment/Feasibility Study, Final Report, Volume VIII of VIII, Task RIFS1 11/24/92, RIC# 93012R03, Harding Lawson Associates, Environmental Science and Engineering, Inc. Diskette #5, LASUN.WK1, ADBUN.WK1, CADUN.WK1 CHA2UN.WK1, CHE2UN.WK1, DIMPUN.WK1 can be located in the Diskette Archive.

Offpost Operable Unit Endangerment Assessment/Feasibility Study, Final Report, Volume VIII of VIII, Task RIFS1 11/24/92, RIC# 93012R03, Harding Lawson Associates, Environmental Science and Engineering, Inc. Diskette #6, LIMPRECS.DBF, GW1RECS.DBF, GW3RECS.DBF, GW4RECS.DBF, GW5RECS.DBF, GW6RECS.DBF, GW2RECS.DBF, LIMPFORM.DOC, HIMPFORM.DOC, GW1FORM.DOC, GW2FORM.DOC, GW3FORM.DOC, GW4FORM.DOC, GW5FORM.DOC, GW6FORM.DOC, HIMPRECS.DBF can be located in the Diskette Archive.