

**FINAL DETAILED ANALYSIS
OF ALTERNATIVES REPORT**

Version 4.1

Water DAA
Volume V of VII

October 1995

Contract No. DAAA 05-92-D-0002



FOSTER WHEELER ENVIRONMENTAL CORPORATION

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TECHNICAL SUPPORT FOR
ROCKY MOUNTAIN ARSENAL

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Prepared by:

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Prepared for:

U.S. Army Program Manager's Office for the
Rocky Mountain Arsenal

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DIRECTORY

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Plate 1 Summed Target Organic Analyte Plume Map for Unconfined Flow System

LIST OF ACRONYMS AND ABBREVIATIONS

14DCLB	1,4-Dichlorobenzene
3-D	three-dimensional
ACGIH	American Conference of Governmental Industrial Hygienists
ACM	asbestos-containing material
ALDRN	Aldrin
AMC	Army Materiel Command
AOC	Area of Contamination
AOPs	advanced oxidation processes
AR	Army Regulations
ARARs	applicable or relevant and appropriate requirements
Army	U.S. Army
atm-m ³ /mol	atmospheres per cubic meter per mole
ATP	Anaerobic Thermal Processor
ATSDR	Agency for Toxic Substances and Disease Registry
B	Soil Density
BCRL	Below Certified Reporting Limit
BCS	Boundary Containment System
BCY	bank cubic yard
BDA	Bilateral Destruction Agreement
BDAT	best demonstrated available technology
BEST	Basic Extraction Sludge Treatment
BFI	Browning Ferris Industries
BOD	Biological Oxygen Demand
BRRN	North Bedrock Ridge Plume
BRRS	South Bedrock Ridge Plume
BTEX	benzene, toluene, ethylbenzene, and xylenes
BTU	British thermal unit
CAMU	Corrective Action Management Unit
CAR	Contamination Assessment Report
CCA	chromated-copper-arsenate
CCR	Code of Colorado Regulations
CD	Cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfm	cubic feet per minute
CFR	Code of Federal Regulations
CFS	Confined Flow System
CH ₂ CL ₂	Methylene Chloride
CHCL ₃	Chloroform
CL ₆ BZ	Hexachlorobenzene
CLC ₂ A	Chloroacetic Acid
cm/sec	centimeters per second

cm ²	centimeters squared
CMP	Comprehensive Monitoring Program
COC	contaminant of concern
CPE	chlorinated polyethylene
CPMS	p-Chlorophenylmethyl Sulfide
CPRP	Chemical Personnel Reliability Program
CRL	certified reporting limit
CSI	Conservation Services, Inc.
CSPE	chlorosulfonated polyethylene
Cu	copper
CWA	Clean Water Act
CWC	Chemical Weapons Convention
CY	cubic yards
DA	Department of the Army
DAA	Detailed Analysis of Alternatives
DADS	Denver Arapahoe Disposal Service, Inc.
db(A)	decibels
DBCP	dibromochloropropane
DCE	Dichloroethylene
DCPD	dicyclopentadiene
DDE	2,2-bis(p-Chlorophenyl)-1,1-dichloroethene
DDT	2,2-bis(p-Chlorophenyl)-1,1,1-trichloroethane
DHHS	Department of Health and Human Services
DIMP	diisopropylmethyl phosphonate
DMMP	Dimethylmethylphosphonate
DNAPL	dense nonaqueous phase liquid
DOD	Department of Defense
DOT	Department of Transportation
DRE	destruction/removal efficiency
DRMO	Defense Reutilization and Marketing Office
DSA	Development and Screening of Alternatives
DTG	Design treatment goal
DWELS	Drinking Water Equivalent Levels
EA	Endangerment Assessment
Ecology	U.S. Ecology, Inc.
EDSVEP	Enhanced Deep Soil Vapor Extraction Process
EIF	enter into force
ENSCO	Environmental Systems Company
Envirosafe	Envirosafe Services of Idaho, Inc.
EOD	Explosive Ordnance Disposal
EPA	U.S. Environmental Protection Agency
ERC	Ecological Risk Characterization
ESSVEP	Enhanced Surface Soil Vapor Extraction Process

ETTS	Ecotechniek Thermal Treatment System
FC2A	fluoroacetic acid
FFA	Federal Facility Agreement
FML	flexible membrane liner
foc	Fraction Organic Carbon in Soil
fpm	feet per minute
FRP	fiber - reinforced plastic
FRG	final remediation goal
FS	feasibility study
ft	feet or foot
ft/day	feet per day
ft ³	cubic feet
GAA	granulated activated alumina
GAC	granular activated carbon
GB	isopropylmethylphosphonofluoridate (nerve agent-sarin)
GIS	Geographical Information System
GMP	Groundwater Monitoring Program
gpm	gallons per minute
H:V	horizontal to vertical
H ₂ O ₂	hydrogen peroxide
HA	Health Advisories
HBCs	Health based criteria
HBr	hydrogen bromide
HCCPD	hexachlorocyclopentadiene
HCL	hydrochloric acid
HCPD	Hexachloropentadiene
HD	mustard
HDPE	high-density polyethylene
HE	high explosive(s)
HEP	habitat evaluation protocol
HEPA	high efficiency particulate air
HF	hydrofluoric acid
HHEA	Human Health Exposure Assessment
HHRC	Human Health Risk Characterization
HI	hazard index
ICP	inductively coupled plasma
ICS	Irondale Containment System
IDLH	Immediately Dangerous to Life and Health
IEA	Integrated Endangerment Assessment
IITRI	IIT Research Institute
IMPA	Isopropyl Methylphosponic Acid
INCS	Internal Containment System
IRA	interim response action

IT	International Technology
IWT	International Waste Technologies
Kg	Kilogram
K _{oc}	partition coefficient
K _p	Partitioning Coefficient for Soil
kW	Kilowatt
kWh	Kilowatt hour
L	Lewisite
lbs	pounds
lbs/acre	pounds per acre
LCY/hr	loose cubic yards per hour
LCY	loose cubic yards
LDR	land disposal restriction
LF	linear foot
LNAPL	light nonaqueous phase liquid
LT ³	Low-Temperature Thermal Treatment
LTTA	Low-Temperature Thermal Aeration
MCL	Maximum Containment Level
MEXCLR	Methoxychlor
mg/l	milligrams per liter
mg/m ³	milligrams per cubic meter
mg/kg	milligrams per kilogram
mg/cm ³	milligrams per cubic centimeter
MGL	milligrams per liter
MKE	Morrison-Knudsen Engineering
ml/g	milliliters per gram
mm	millimeters
MMBTU	million British thermal units
MOU	Memorandum of Understanding
MPA	Methylphosphonic Acid
mph	miles per hour
MTR	minimum technology requirement
n	Total Porosity
NaOH	sodium hydroxide
NAPL	Nonaqueous Phase Liquid
NBCS	North Boundary Containment System
NCP	National Contingency Plan
NDMA	Nitrosodimethylamine
NEPA	National Environmental Policy Act
NNDMEA	N-Nitrosodimethylamine
NWBCS	Northwest Boundary Containment System
O&M	operations and maintenance
OAS	Organizations and State

°C	degrees Centigrade
OCP	organochlorine pesticides
°F	degrees Fahrenheit
OPHGB	organophosphorus compounds, GB-agent related
OPHP	organophosphorus compounds; pesticide related
OSCH	organosulfur compounds; herbicide related
OSCM	organosulfur compounds; mustard agent related
OSHA	Occupational Safety and Health Administration
PAHs	polynuclear aromatic hydrocarbons
PBC	probabalistic biota criteria
PCB	polychlorinated biphenyl
pcf	pounds per cubic foot
PCP	pentachlorophenol
PDA	Pilot Demolition Assessment
PEC	plume evaluation criteria
PKPP	potassium pyrophosphate
ppb	parts per billion
PPDDE	dichlorodiphenyldichloroethylene
PPDDT	dichlorodiphenyltrichloroethane
PPE	personal protective equipment
PPLV	preliminary pollutant limit value
ppm	parts per million
ppt	Parts per Trillion
PQL	practical quantitation limit
PRG	preliminary remediation goal
psi	pounds per square inch
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RAO	remedial action objective
RC	Risk Characterization
RCRA	Resource Conservation and Recovery Act
RF	radio frequency
Ri	Retardation Factor
RI	remedial investigation
RISR	Remedial Investigation Summary Report
RMA	Rocky Mountain Arsenal
ROD	Record of Decision
RPO	representative process option
SACWSD	South Adams County Water and Sanitation District
SAR	Study Area Report
SARA	Superfund Amendments and Reauthorization Act
SCC	Secondary Combustion Chamber
SEC	Site evaluation criteria

SF	square feet
SFS	Supplemental Field Study
Shell	Shell Oil Company
SHO	Semivolatile halogenated organics
SITE	Superfund Innovative Technology Evaluation
SPNP	South Plants North Plume
SPNS	South Plants North Source Plume
SPSE	South Plants Southeast Plume
SQI	submerged quench incinerator
STC	Silicate Technology Corporation
STF	South Plants Tank Farm
SVE	soil vapor extraction
SVOCs	semivolatile organic compounds
SY	square yards
TBCs	to be considered criteria
TCLP	toxicity characteristic leaching procedure
TEA	triethylamine
TEC	Target Effluent Concentration
TIS	transportable incineration system
TMV	toxicity, mobility, and volume
TOC	total organic carbon
tpd	tons per day
TSCA	Toxic Substances Control Act
TSD	Treatment Storage and Disposal
TSGM	two-step geometric mean
UFS	Unconfined Flow System
µg/g	micrograms per gram
µg/l	micrograms per liter
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USPCI	U.S. Pollution Control, Inc.
UST	Underground Storage Program
UV	ultraviolet
UXO	unexploded ordnance
VAO	volatile aromatic organic compounds
VHC	volatile hydrocarbon compounds
VHO	volatile halogenated organics
Vi	Velocity of Component i in Aquifer
VOC	volatile organic compound
VX	ethyl s-dimethyl aminoethyl methyl phosphonothiolate
WES	Waterways Experimental Station

Section 1

1.0 INTRODUCTION

1.1 BACKGROUND

The Detailed Analysis of Alternatives for the water medium (Water DAA) at Rocky Mountain Arsenal (RMA) is the final stage of the Water Feasibility Study (Water FS) and is a follow-on to the Development and Screening of Alternatives for the water medium (Water DSA) (EBASCO 1992). This document provides significantly greater detail than the Water DSA, incorporating new analytical data, groundwater modeling, and treatability study results as well as performing additional statistical analysis of chemical data and an integrated analysis of all alternatives proposed for the soil, water, and structures media to ensure that they are compatible and work together to achieve the remedial action objectives (RAOs) established for RMA.

The analysis of alternatives that is described in this document was conducted according to U.S. Environmental Protection Agency (EPA) guidance (OERR-EPA 1988).

1.2 DSA SUMMARY

The Water DSA (EBASCO 1992) identified five different plume groups, which are further described in Section 3.1: Northwest Boundary, Western, North Boundary, Basin A, and South Plants. As a result of the screening process (Figures 1.2-1 through 1.2-5), a range of remedial alternatives including no action, containment, and treatment options was retained for each plume group. The existing boundary containment systems and groundwater-related interim response actions (IRAs) are also incorporated into all except the No Action alternatives (Table 1.2-1).

Both No Action and Continued Existing Action alternatives were retained for each of the plume groups in the Water DSA. The No Action alternative does not involve any remedial activities or restrictions at a site. Therefore, activities that are currently in place, such as the boundary containment systems and IRAs, would be discontinued. The Continued Existing Action alternative involves continued implementation of the RMA access and use restrictions stipulated in the Federal Facility Agreement (FFA) (EPA et al. 1989) and continued operation of the existing boundary containment and treatment systems, the IRAs currently in place, and any

planned additions or upgrades to those systems. The provisions of the Continued Existing Action alternative are included in all other alternatives, which represent additional remedial measures beyond continuation of existing actions.

For ease of identification, each alternative is designated as follows. The first one or two letters in the designation identifies the plume group (i.e., N for North Boundary, NW for Northwest Boundary, W for Western, A for Basin A, SP for South Plants). The next letter, "C" or "T", identifies the alternative as a groundwater control or treatment alternative, respectively. Finally, a number is appended to these letters that reflects the order in which the alternatives are described. The first two control alternatives described for each plume group are always No Action and Continued Existing Action. For example, in the Northwest Boundary Plume Group, the No Action and Continued Existing Action alternatives are designated as NWC-1 and NWC-2, respectively. The alternatives retained from the DSA (EBASCO 1992) for each of the five plume groups are briefly discussed below.

The two alternatives retained for the Northwest Boundary (Figure 1.2-1) and Western Plume Groups (Figure 1.2-2) were No Action and Continued Existing Action. The Water DSA evaluation (EBASCO 1992) determined that for both of these plume groups additional on-post groundwater capture and treatment would be of minimal benefit (as summarized in Sections 4 and 5 of this document).

Besides the No Action and Continued Existing Action alternatives, two additional groundwater control alternatives were retained for the North Boundary Plume Group (Figure 1.2-3). These were Alternatives NC-3, which consists of capture and extraction of the North Plants Plume in the source area followed by piping to the North Boundary Containment System (NBCS) combined with extraction, treatment, and reinjection of the Basins C and F Plume, and Alternative NC-6, which involves the same extraction system in North Plants combined with installation of a slurry wall and cap in the Basins C and F area. The treatment alternatives retained for the Basins C and F Plume were granular activated alumina (GAA) adsorption,

granular activated carbon (GAC) adsorption, air stripping combined with GAC adsorption, and oxidation.

In addition to the No Action and Continued Existing Action alternatives, two different groundwater control configurations were retained for the Basin A Plume Group (Figure 1.2-4). Alternative AC-3 involves extraction of water from all Basin A plumes followed by treatment and reinjection. Treatment alternatives retained for AC-3, in addition to continued operation of the Basin A Neck IRA system, were GAC adsorption combined with air stripping and oxidation followed by air stripping and GAC adsorption. Alternative AC-7, a dewatering alternative, employs a cap combined with extraction and treatment of water at the Basin A Neck IRA system.

Besides the No Action and Continued Existing Action alternatives, four additional groundwater control alternatives were retained for the South Plants Plume Group (Figure 1.2-5). Alternative SPC-3 involves extraction from all four plumes in this plume group for aboveground treatment, while Alternative SPC-5 involves extraction followed by aboveground treatment for all plumes except for the South Tank Farm Plume, which is to be treated by in situ biodegradation. Under Alternative SPC-5, as in one scenario of Alternative SPC-3, the South Tank Farm Plume is treated separately from the other plumes: in Alternative SPC-5, in situ biodegradation is combined with aboveground oxidation, and, in Alternative SPC-3, direct biological treatment is followed by GAC adsorption. Treatment alternatives that were retained for the remaining plumes under Alternatives SPC-3 and SPC-5 are oxidation combined with GAC adsorption and air stripping followed by GAC adsorption. Both Alternative SPC-6 and Alternative SPC-7 are dewatering alternatives involving extensive extraction pumping to rapidly lower the South Plants groundwater mound (compared to slower rate at which the mound will drop without active pumping). Alternative SPC-6 consists of groundwater extraction, treatment, and reinjection only, while Alternative SPC-7 also includes installation of a cap. The treatment processes retained for both alternatives were oxidation combined with GAC adsorption and air stripping followed by GAC adsorption.

1.3 CHANGES FROM THE WATER DSA

The Water DAA incorporates new groundwater analytical and hydraulic data as well as additional information obtained through groundwater modeling and treatability studies since publication of the DSA (EBASCO 1992). A discussion of potential contamination of the deeper aquifer was added in Section 3, and the impact of remedies on the deeper aquifer has been considered. Plume maps used during the DSA were updated using 1989–1994 water-quality data.

1.3.1 Reduced Plume Flow Rates and Concentrations

Groundwater flow modeling, conducted during the DAA for the Basin A and South Plants areas to assist in the evaluation of remedial alternatives, typically showed significantly lower flow rates in all plumes than the Water DSA estimates (see Sections 7 and 8; EBASCO 1992). In addition, further statistical analysis of the most recent chemical data (January 1989–1994) show lower contaminant concentrations than previously estimated. Contaminant concentrations reported in the DAA were lower than in the DSA primarily as a result of differences in the well networks and the statistical method used to calculate concentrations for each plume. During the DSA, various data needs were identified and new wells were installed in many of the plumes described in the DSA. The water quality data gathered from these wells increased our understanding of contaminant concentrations in the areas of proposed groundwater systems. Groundwater quality from the new wells were added to the plume data sets. Estimates of influent concentrations to proposed extraction systems were calculated using the average weighted geometric mean in the DSA and the two-step geometric mean (TSGM) in the DAA (see Section 3.2.2). The TSGM was used in the DAA because it is resistant to outliers and anomalies and provides a more representative estimate of the mean contaminant concentration of a plume. Results between the DAA and DSA also changed because the data set for the DSA included 1989 to 1991 data while the data set for the DAA included 1989 to mid-1994 data. The two-step geometric mean (TSGM) values calculated (see Section 3.2.2) for wells in the immediate upgradient vicinity of the groundwater control systems were used to estimate the influent concentrations for all treatment alternative designs and comparative evaluations. The estimated concentrations are flow weighted between plumes. New estimates for extraction rates and contaminant concentrations in

some cases led to reconfiguration of control and treatment systems. Specific changes for each plume group are described below.

1.3.2 Plume-Group-Specific Changes

No changes were made in the DAA to alternatives or conclusions for the Northwest Boundary Plume Group. For the Western Plume Group, an alternative was added that involves treatment of the water at the Irondale Containment System (ICS) and discontinuation of the Motor Pool and Railyard IRA capture systems because the contamination levels in water being extracted by these systems are dropping so substantially that the systems may possibly be shut down. Both the Continued Operation of All Systems alternative and Operation of Boundary Systems Only alternative were based on a 4-year rather than a 30-year operating period because of expected removal of all contaminants in this area within this time frame. For the North Boundary Plume Group, the intercept system for the North Plants Plume was eliminated because of relatively low contaminant concentrations but high flow rates, which would not make this system cost-effective (see Section 6.0). The treatment plant in the Basins C and F area was eliminated because of low predicted extraction rates from that control system; water extracted from the Basins C and F Plume by the Basin F Groundwater IRA is piped either to the NBCS or the Basin A Neck IRA treatment system for treatment. An alternative involving continued operation of the NBCS and discontinuation of Basin F Groundwater IRA was also added because the extraction rate from the IRA system is just 1–2 gallons per minute (gpm).

In the Basin A and South Plants Plume Groups, extraction rates were estimated (through groundwater modeling) to be significantly lower than the previous Water DSA estimates (EBASCO 1992). Additional statistical analysis of TSGM values conducted with the use of recent chemical data from upgradient wells also indicated lower contaminant concentrations. Accordingly, the control/treatment alternatives in the Basin A and South Plants areas were reconfigured to support soil remedial alternatives through dewatering to lower the water table and promote containment of contamination. In addition, a new alternative (AC-9) was developed to intercept the flow of the Section 36 Bedrock Ridge Plume in conjunction with continued

operation of the Basin A Neck IRA. This alternative was developed to achieve greater containment of groundwater migrating from Basin A compared to the Continued Existing Action alternative.

The analysis of more recent groundwater data also indicated that the South Plants Southwest Plume contained very low levels of contaminants, and this plume was consequently eliminated from the treatment alternatives. The other South Plants plume combinations remain as they were in the Water DSA except that Alternatives SPC-6 and SPC-7 are phased approaches involving initial dewatering of the South Plants North Source, Southeast, and South Tank Farm Plumes for 10 years to lower the groundwater mound and achieve mass reduction as other remedial activities in South Plants are performed. Once this 10-year period is over and other South Plants activities are completed, the whole South Plants area is dewatered, if necessary, based on the results of the initial 10 years of pumping.

The new South Plants Alternative involves maintaining hydraulic controls and monitoring to prevent contaminant plumes from entering the lakes and causing harm to the water species. This alternative is proposed along with extensive control measures, mostly caps, in the South Plants area.

1.3.3 Effluent Goals and Criteria

Terminology developed in the DSA (EBASCO 1992) and used in previous versions of the DAA for effluent criteria for boundary systems, preliminary remediation goals (PRGs), and for proposed on-post systems, target effluent concentrations (TECs), has been simplified in the Final DAA so that all effluent criteria are now termed PRGs. However, the values that these PRGs represent will vary among systems. The specific criteria are discussed further in Section 2.2. Another term introduced in the previous versions of the DAA, design treatment goal (DTG), has also been eliminated.

Criteria for shutting down the boundary and internal systems have been developed and are provided as follows:

- Existing wells within the boundary and off-post containment systems (BCS) can be removed from production when concentrations of constituents detected in the well are less than applicable or relevant and appropriate requirements (ARARs) established in the ROD and/or it can be demonstrated that discontinuing operation of a well would not jeopardize the containment objective of the systems. The containment objective of the systems will be outlined in the ROD. Wells removed from production and monitoring wells upgradient and downgradient of the BCS will be monitored quarterly for a period of 5 years to determine if contaminants reappear; however, those wells turned off for hydraulic purposes will not be subject to the quarterly monitoring requirements. BCS extraction wells removed from production for water quality reasons will be placed back into production if contaminant concentrations exceed ARARs established in the ROD. Wells with concentrations less than ARARs established in the ROD can remain in production if additional hydraulic control is required.
- Existing wells within the internal containment systems can be removed from production when concentrations of constituents detected in the wells are less than ARARs established in the ROD and/or it can be demonstrated that discontinuing operation of a well would not jeopardize the containment objective of the systems. The containment objective of the system will be outlined in the ROD. Wells removed from production and monitoring wells upgradient and downgradient of the internal containment systems will be monitored quarterly for a period of 5 years to determine if contaminants reappear; however, those wells turned off for hydraulic purposes will not be subject to the quarterly monitoring requirements. Internal containment system extraction wells removed from production for water quality reasons will be placed back into production if contaminant concentrations exceed ARARs established in the ROD. Wells with concentrations less than ARARs established in the ROD can remain in production if additional hydraulic control is required.

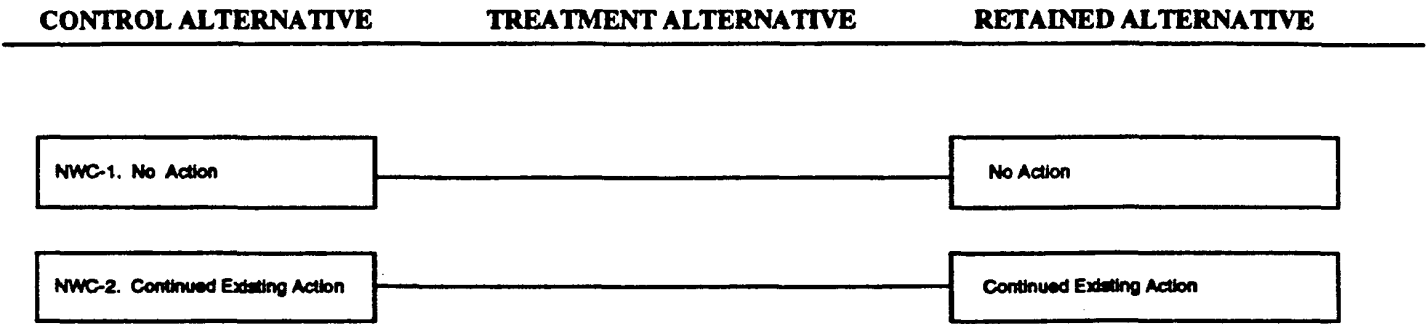
1.4 ORGANIZATION OF THE DOCUMENT

Each section of this document describes both general FS procedures and site-specific information. The contents of the different sections are summarized below.

Section 2 outlines Water DAA objectives, RAOs, PRGs, and the interaction between the water, soil, and structures media and describes the detailed analysis and alternatives selection process. Section 3 provides background information for control and treatment technologies, including a discussion of the plume groups and the groundwater models used.

Sections 4 through 8 address each of the five plume groups alternatives individually by providing descriptions and individual detailed analyses for each alternative, comparative analyses between alternatives, and selection of plume-group-specific preferred alternatives for consideration as part of the sitewide alternatives. Section 9 combines selected plume group alternatives into sitewide alternatives and describes the selection of a preferred sitewide alternative.

IRA	Objective	Completion Date of IRA Construction
• Groundwater Intercept and Treatment System North of RMA	• Eliminate much of the potential for any future alluvial groundwater plumes north of RMA.	December 1992
• Improvement of the North Boundary Containment System and Evaluation of Existing Boundary Containment Systems	• Evaluate and improve, as necessary, all RMA boundary systems and eliminate off-post migration of contaminated alluvial groundwater above compliance levels.	December 1988 - September 1993
• Groundwater Intercept and Treatment System North of Basin F (Basin F Groundwater IRA)	• Intercept and treat contaminated alluvial groundwater originating from the Basin F area.	September 1990
• Closure of Abandoned Wells at RMA	• Identify, locate, examine, and properly close old or unused wells at RMA to prevent migration of contamination between aquifers.	Began February 1990 Ongoing
• Groundwater Intercept and Treatment System in the Basin A Neck Area (Basin A Neck IRA)	• Intercept and treat contaminated groundwater in the alluvial aquifer between Basins A and F.	July 1990
• Remediation of Other Contamination Sources (Hot Spots)	• Mitigate the threat of releases from selected contamination sources.	March 1994
Hot Spots Identified Include:		
• Lime Settling Basins	• Mitigate the threat of migration of contaminants to the underlying groundwater.	June 1993
• M-1 Settling Basins	• Mitigate any potential for infiltration of contaminants to groundwater and preclude potential for volatile emissions.	December 1992
• Motor Pool Area - Trichloroethylene Plume	• Intercept and treat contaminated alluvial groundwater originating at the Motor Pool Area and mitigate soil contamination to prevent continued migration to groundwater.	September 1991
• Rail Classification Yard - Dibromochloropropane Plume	• Intercept and treat contaminated alluvial groundwater originating at the Rail Classification Yard.	September 1991
• Shell Trenches	• Mitigate the migration of contaminants to the underlying groundwater.	November 1991
• South Tank Farm Plume	• Monitor the South Tank Farm Plume to verify plume data and plume location.	March 1994
• Pretreatment of CERCLA Liquid Waste (CERCLA Wastewater Treatment Plant)	• Treat wastewater resulting from CERCLA-related activities at RMA.	July 1992
• Army Complex Disposal Trenches	• Monitor groundwater beneath the Army Complex Disposal Trenches and re-evaluate annually the need for active control or treatment.	1991



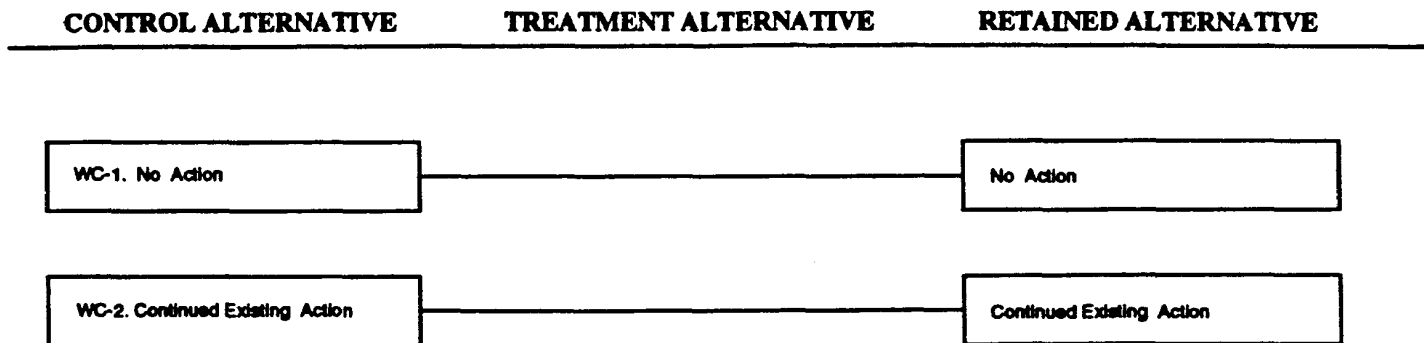
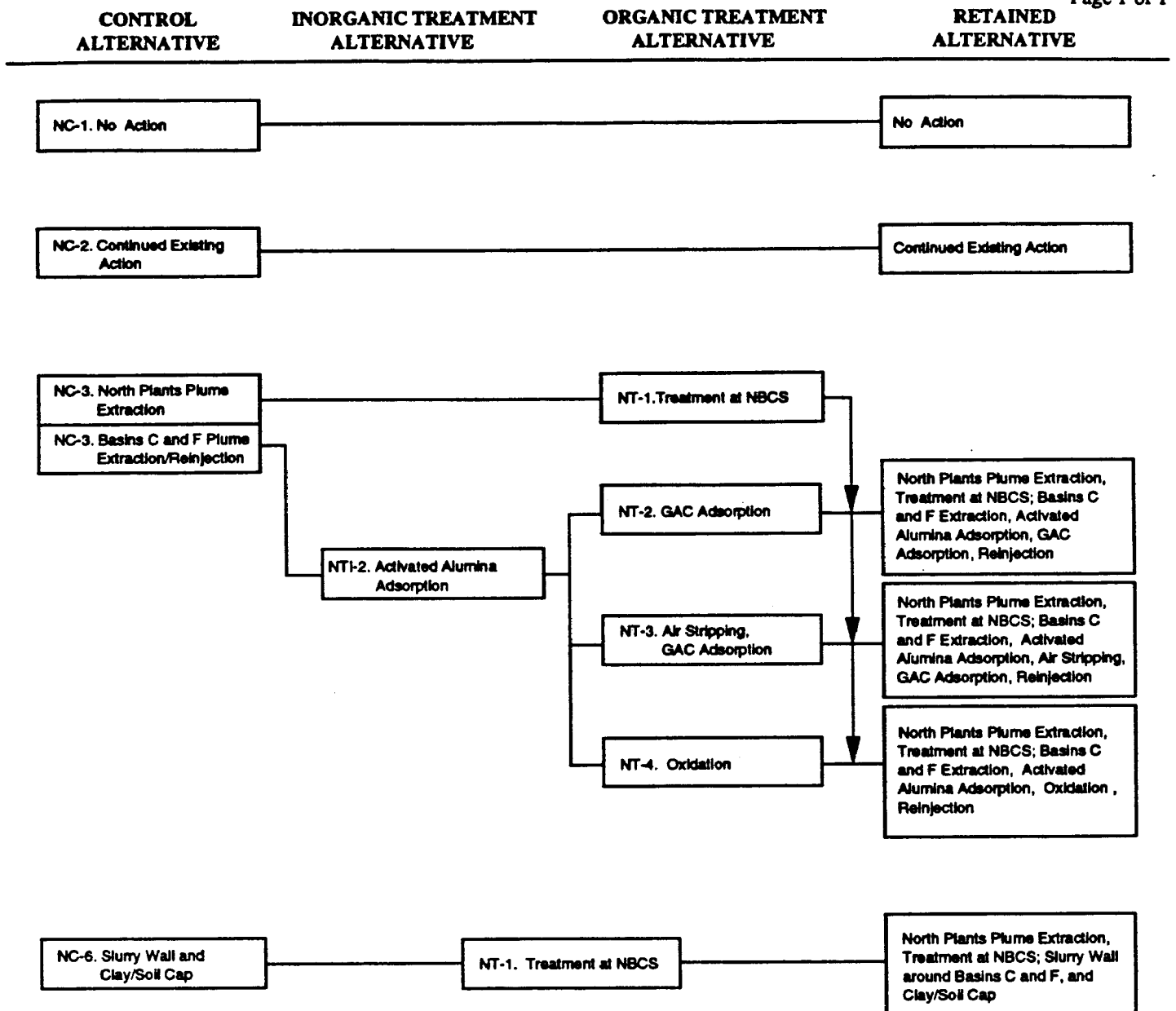
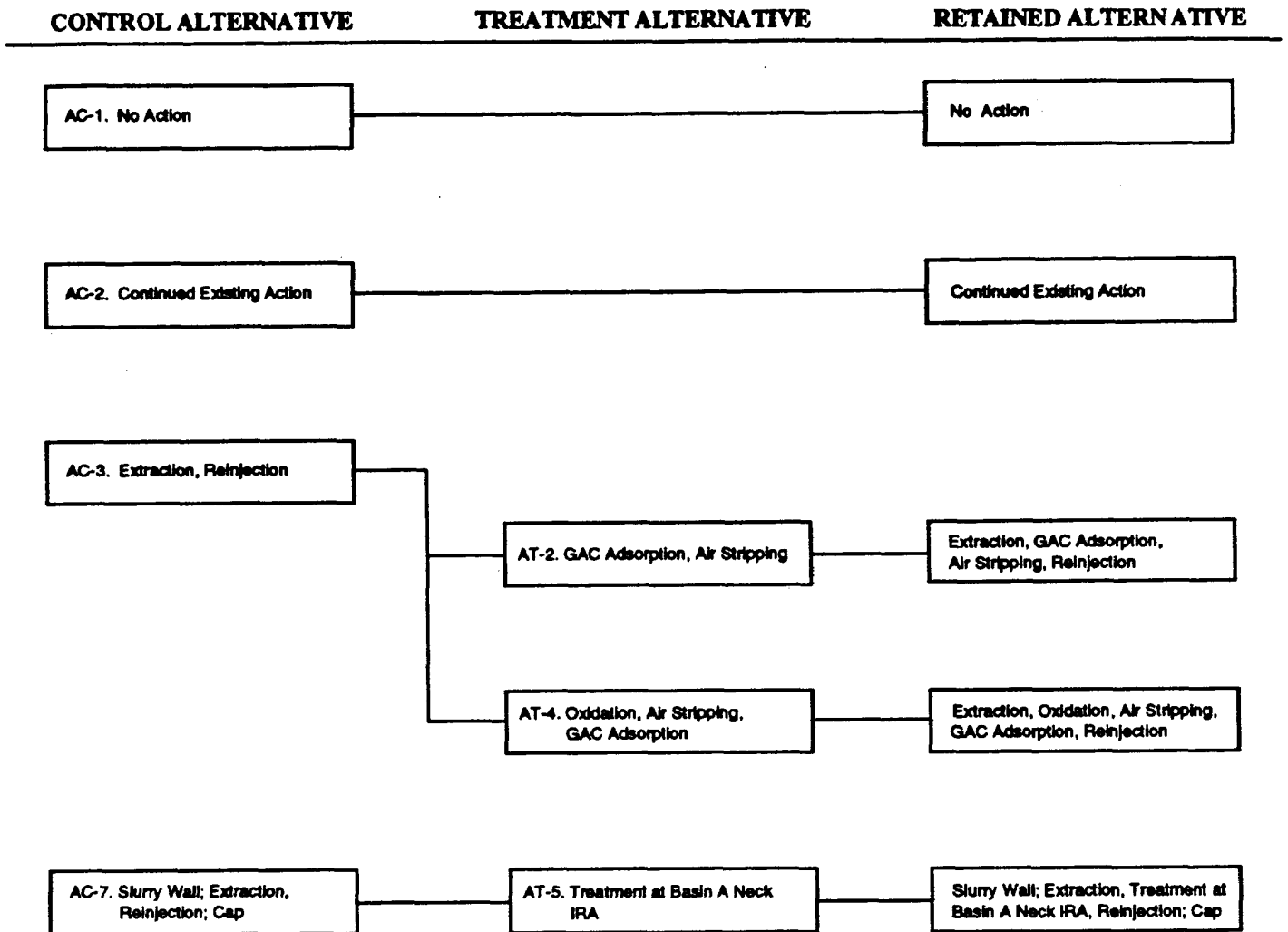


**Figure 1.2-2 Western Plume Group
Alternatives Retained in DSA**



NBCS - North Boundary Containment System
GAC - Granular Activated Carbon

Figure 1.2-3 North Boundary Plume Group Alternatives Retained in DSA



GAC - Granular Activated Carbon
 IRA - Interim Response Action

**Figure 1.2-4 Basin A Plume Group
 Alternatives Retained in DSA**

CONTROL ALTERNATIVE

TREATMENT ALTERNATIVE

RETAINED ALTERNATIVE

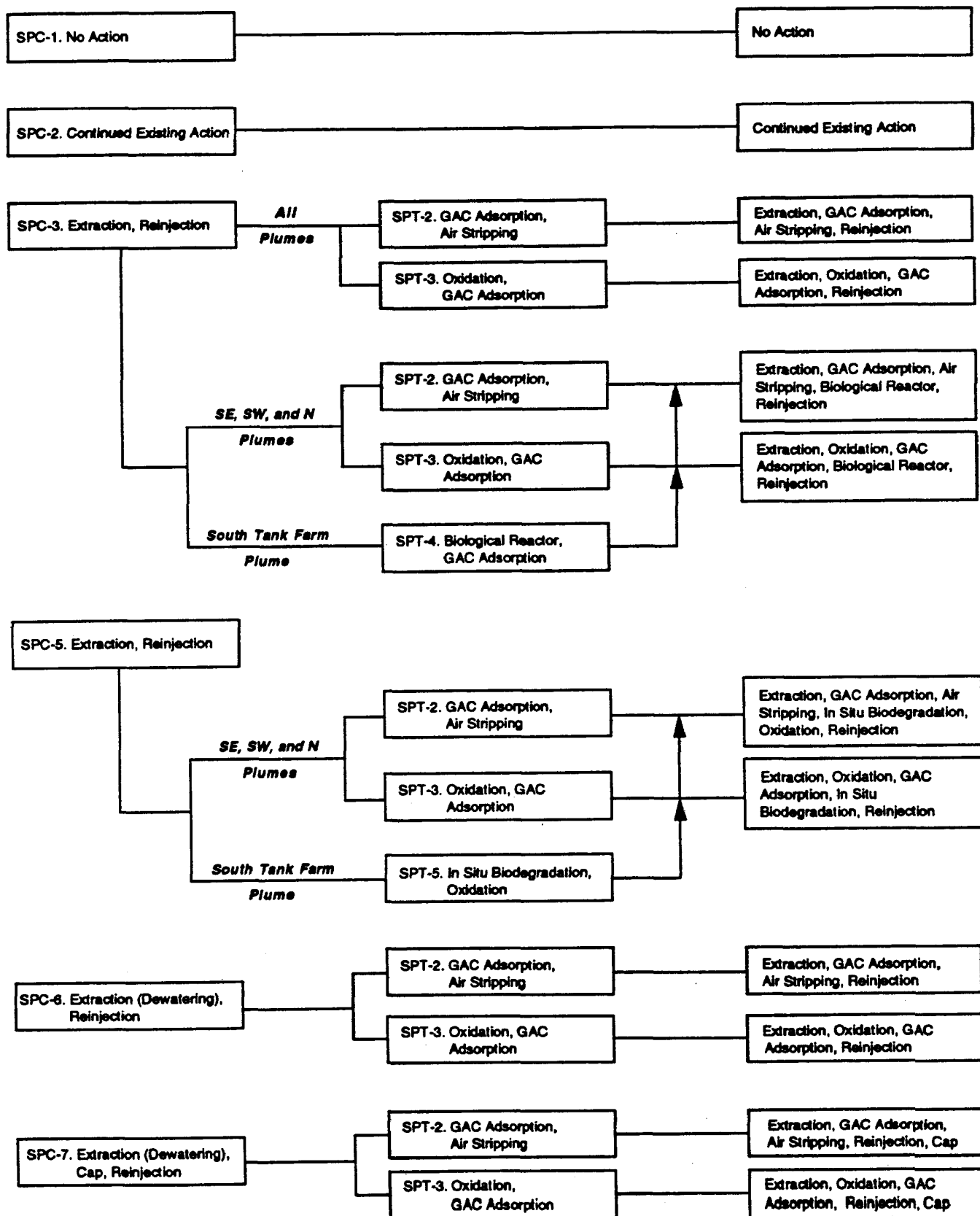


Figure 1.2-5 South Plants Plume Group
Alternatives Retained in DSA

Section 2

2.0 GENERAL DAA METHODOLOGY

2.1 DAA OBJECTIVES

The DAA, the final step in the analytical process that leads to the selection of a preferred alternative for the remediation of RMA, is designed to provide sufficient information to adequately compare alternatives and select the appropriate remedy. The analysis was conducted in accordance with EPA guidance (OERR-EPA 1988) and involved the assessment of each alternative against specific evaluation criteria, followed by a comparative analysis of the alternatives with regard to the criteria. A detailed description of these criteria is provided in the Executive Summary. All of the EPA evaluation criteria, except for state and community acceptance (which are addressed at this time if known but generally are addressed as part of the Responsiveness Summary), were considered part of the analysis.

The specific objectives for the Water DAA were to further define each alternative in terms of the following:

- Revised groundwater flow information obtained through modeling and pumping tests
- Revised contaminant information based on additional groundwater sampling
- Revised evaluation of plume characteristics
- Revised process option information based on treatability study results

Similar to the Water DSA (EBASCO 1992), the analysis of groundwater alternatives in the Water DAA was performed separately for each plume group. There was, however, significantly more emphasis placed on the sitewide scenario in the Water DAA, including analyzing whether water extracted from the different plume groups may be treated at a common facility (e.g., treat water from South Plants and Basin A at a common facility) or whether existing systems may be used (e.g., treat Basins C and F groundwater at the NBCS or at the Basin A Neck IRA). Alternatives were evaluated in terms of their ability to enhance or improve performance of the boundary systems and to enhance or improve performance of soil or structures alternatives.

Additionally, the relationship between soil alternatives and groundwater alternatives, in terms of effects on contaminant sources, the elevation of the water table, timing of remedial actions, and location, was analyzed more closely.

The preferred soil alternative includes some modifications to the size and types of caps that were included in the groundwater models constructed as part of the DAA. The impact of these cap modifications was determined to be small, although dewatering alternatives in the South Plants would need to pump smaller volumes of groundwater to achieve the desired water levels and flow directions. Because the effects of these reconfigured caps are small, the control and treatment alternatives for Basin A and South Plants were not resized, and these changes should have no effect on the selection process.

RAOs for the FS were established in the DSA (EBASCO 1992) and are listed below:

Human Health

- Ensure that groundwater reaching the RMA boundary will be of a quality that is protective of human health as established by preliminary remediation goals at the boundary

Environmental Impacts

- Ensure that biota are not exposed to biota Contaminants of Concern (COCs) in surface water in concentrations capable of causing acute or chronic toxicity

2.2 PRELIMINARY REMEDIATION GOALS

The PRGs for water were identified during the Water DSA to address the RAOs established for on-post surface water or groundwater. The remediation goals will be finalized as part of the Record of Decision (ROD). The following PRGs were established for on-post groundwater:

- Ensure that the boundary containment and treatment systems protect groundwater quality off post by treating groundwater flowing off RMA to the PRGs listed for each of the boundary systems in Tables 2.2-1, 2.2-2, and 2.2-3.

- Develop on-post groundwater extraction/treatment alternatives that establish hydrologic conditions consistent with the preferred soil alternatives and also provide long-term improvement in the performance of the boundary control systems, where feasible.

Based on the DSA dispute resolution, it was decided to establish TECs for reinjection of water treated at each of the proposed on-post treatment systems. The dispute resolution agreement states, "For those areas where groundwater treatment is selected, the Army will establish TECs for reinjection. TECs will be developed for each system based on the control/treatment objectives of that system. The TECs will be included as enforceable remediation levels in the Proposed Plan and the Record of Decision." As a result of dispute resolution, the term TEC has been dropped so that the PRGs for the system can be included as enforceable treatment levels in the ROD.

As described in Section 1.3.3, PRGs were developed for the boundaries and the on-post systems. Five sets of PRGs are therefore presented in this document:

- 1) Three sets of PRGs were developed for the three boundary systems as discussed above.
- 2) The Basin A Neck PRGs were derived from the ARARs for the Basin A Neck IRA by adding compounds and introducing new standards.
- 3) The PRGs for other proposed on-post systems were derived from MCLs for indicator compounds to the extent possible and apply to all other on-post systems considered in the DAA.

The PRGs that apply at the ICS are the existing standards for this system (Table 2.2-2). For the NWBCS (Table 2.2-1) PRGs were derived by adding isodrin and NDMA to the existing list of operating standards and using Colorado Basic Standards for Groundwater (CBSGs) for all compounds except isodrin and NDMA. The PRGs that apply at the North Boundary (Table 2.2-3) represent the State (CBSG) or applicable Federal (MCL) standards (whichever is more stringent) and also risk-based values established for off-post groundwater in the off-post FS (HLA 1992), where state or federal standards do not exist. These PRG values, which were established

using applicable or relevant and appropriate requirements (ARARs) and health-based criteria, must be achieved at the RMA boundary.

Due to their regulatory classification as secondary standards and the institutional controls off-post, the time frame to achieve sulfate and chloride PRGs at the NBCS will be estimated through analysis of background concentrations and natural attenuation processes as described below. However, the time frame established must be ultimately protective of human health and the environment.

In the ROD at the NBCS, the PRG for chloride will be 250 mg/L and the PRG for sulfate will be either the natural background concentrations or 250 mg/L. The natural background for sulfate and the estimated time frame required to achieve both PRGs at the NBCS will be determined as outlined below and presented in the ROD and agreed upon by all parties.

Due to the observed complexity of sulfate concentrations within RMA groundwater, it is recognized that accurate time frames to achieve the sulfate PRGs may be difficult. However, a time frame will be estimated for the final ROD with the understanding that existing data and other constraint may reduce accuracy. Review and potential refinement of the natural attenuation time frames to achieve compliance with PRGs will occur at the CERCLA 5-year review and will be agreed upon by all parties.

Chloride

1. A historical review of well data upgradient of the NBCS and the NBCS process data will be performed.
2. Chloride concentrations and flow rates approaching the NBCS will be evaluated.
3. Existing data will be extrapolated to estimate compliance time frames, also considering source control and on-post natural attenuation.

A report will be prepared to document items 1 through 3 within 4 months of this document (i.e. pre-ROD). The PRG and the estimated time frame for achieving it will be made part of the ROD.

Sulfate

1. A historical review of well data upgradient of the NBCS and the NBCS process data will be performed to analyze current and historical sulfate concentrations.
2. Sulfate concentrations and flow rates approaching the NBCS will be evaluated. The natural background sulfate concentration will be reasonably estimated given the constraints imposed and following an evaluation of the concentrations entering the RMA upgradient, or through an evaluation of the concentrations within non-contaminated groundwater on RMA. Additional groundwater samples will be collected as necessary.
3. If the background concentration for sulfate can be reasonably estimated before issuance of the draft final ROD and agreed upon by all parties, and if it is above the standard of 250 mg/L, it will be the PRG in the ROD for the NBCS. If the background concentration cannot be reasonably estimated before issuance of the draft final ROD, or if it is below 250 mg/L, then 250 mg/L will be the PRG in the ROD for the NBCS. The data described in #1 and #2 above will be used to extrapolate a time frame to achieve the standard (250 mg/L or background, as appropriate), also considering source control on-post and natural attenuation.

A report will be prepared to document items 1 through 3 before the draft final ROD and agreed upon by all parties. The PRG and the estimated time frame for achieving it will be made part of the draft final ROD but may be modified as necessary (in compliance with CERCLA), as new information becomes available.

The PRGs for the Basin A Neck IRA system include a number of organic compounds in addition to those included in the ARARs developed for Basin A Neck IRA and represent CBSGs, MCLs, and risk based values. DIMP is not included in the PRG list. The only requirement for DIMP is that the CBSG of 8 is met at NWBCS. These PRGs are listed in Table 2.2-4.

The need for a PRG for n-nitrosodimethylamine (NDMA) was evaluated and it was decided that a risk-based value of 7.0 parts per trillion (ppt) would be the goal, although the certified level

currently available from a commercial laboratory (now 33 ppt) is the PRG that currently applies at the boundary and the Basin A Neck systems.

The PRGs for other internal systems besides Basin A Neck were developed by using maximum contaminant levels (MCLs) and other selected criteria. The Groundwater Monitoring Program (GMP) list of analytes was used as basis for selection of indicator compounds to be used for design. Indicator compounds were selected from the GMP list to represent each of the contaminant groups present in RMA groundwater instead of evaluating all target analytes. The indicator compounds represent the contaminant groups detected in RMA groundwater and are typically those compounds most frequently detected or those that would have a significant impact on design. The PRGs for these compounds are based on MCLs for compounds where MCLs are available. Otherwise, the internal PRG values were taken from EPA health advisories (HAs), drinking water equivalent levels (DWELs), or estimated health-based criteria (HBCs). The PRGs identified for the internal systems are listed in Table 2.2-5.

It should be noted that the selected internal PRGs do not apply to the in situ treatment alternative for the South Tank Farm Plume. The aquifer would, in this case, be remediated to the levels that can be achieved through recirculation of water and injection of nutrients and oxygen during the time period selected for mass reduction.

2.3 SITE-SPECIFIC CONSIDERATIONS

In addition to the nine evaluation criteria specified in the National Contingency Plan (NCP) (EPA 1990), a number of other qualitative factors influence the evaluation and selection of water alternatives. As described below, these factors are often based on regulations, policies, or guidance other than that developed specifically for the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) process.

2.3.1 Federal Facility Agreement

The FFA provides the overall framework for RMA response actions, defines responsibilities for the remediation effort, and places certain requirements and restrictions on each signatory. Restrictions include the future land-use goal of open space at RMA, long-term ownership of the property by the United States, and the continued prohibition of certain activities such as consumption of on-post water, biota, or agricultural products.

The FFA (EPA et al. 1989) also expresses the intent of the Organizations that response actions at the Arsenal will be sufficient to ensure that groundwater and surface water flowing beyond the Arsenal boundaries will be of a quality that is protective of human health and the environment. In addition, the use of groundwater located under, or surface water located on, RMA as a source of potable water is prohibited. These requirements and restrictions must be taken into account in the development and evaluation of alternatives. Alternatives that do not meet the requirements of the FFA (EPA et al. 1989) will be determined to not be implementable.

2.3.2 Wildlife Management

In conjunction with the expressed goal of open space and in recognition of the unique urban wildlife resources provided by RMA, President George Bush, in October 1992, signed legislation that named RMA as a National Wildlife Refuge following cleanup. Designation of RMA as a National Wildlife Refuge severely limits the potential future use of on-post groundwater.

2.3.3 Technical Feasibility

It is not practical, feasible, or cost effective to completely remediate all of the aquifers at RMA. Because of the heterogeneity of the aquifers and contaminants, low permeabilities in Basin A, highly sorptive compounds, high levels of soil and groundwater contamination over significant areas, the presence of contamination sources, and the potential presence of nonaqueous phase liquids (NAPLs) within the Basin A and South Plants unconfined flow system, it is not technically feasible to restore these flow systems to pre-RMA conditions.

2.3.4 Natural Attenuation of Contaminants

Natural attenuation is the process by which contaminant concentrations in groundwater decrease with time under natural environmental conditions, as a result of biodegradation, irreversible adsorption, dispersion/dilution, leaching, volatilization, or by other processes. A significant number of the contaminants at RMA have been shown to attenuate at other sites. Although the attenuation rates may be slow and may decrease with decreasing linearly with decreasing residual concentrations (this is termed first order kinetics) (Shell/MKE 1994). Results from recent sampling efforts for groundwater have indicated that contaminant levels have decreased since samples were originally collected under the Remedial Investigation (RI) program. This decline in contaminant concentrations may be attributed to natural attenuation processes. Although an in-depth, multiyear study would be required to quantify this decline, the occurrence of natural attenuation in soil and groundwater for some compounds is certain, and at all sites, including those where containment, institutional controls, or no action alternatives are selected, contaminant concentrations are expected to continue to decrease over time.

2.3.5 Limited Exposure to Groundwater

Existing FFA restrictions (EPA et al. 1989) on the use of surface water and groundwater and development at RMA eliminate water exposure pathways and, therefore, minimize risk to humans. The Army has also agreed, as a result of dispute resolution, that prior to any nonpotable use of on-post groundwater, the Army will either perform a screening risk assessment to evaluate potential human health or biota impacts of such use or, if ARARs exist, demonstrate that the groundwater meets ARARs for its intended use. If a potential risk is indicated as a result of the screening risk assessment, a full risk assessment will be performed and identified risks will be mitigated or alternative water sources will be used.

Biota at RMA are not normally exposed to groundwater at RMA except in limited areas where there is discharge to surface water from contaminated groundwater (e.g., in a small area of Basin A). Locations with the potential for exposure of biota to contaminated water will be closely monitored and also covered as part of the soil remedy. Additionally, the water table in the

Basin A and South Plants areas will be lowered as a result of natural dewatering following installation of caps in these areas.

2.4 MEDIA INTERACTIONS

Interactions between the soil, structures, and water media were evaluated in this document to ensure that compatible alternatives were selected for the different media. Because the soil medium was selected as the primary focus in developing alternatives for any medium, the selected groundwater alternatives must be compatible with the selected soil alternatives.

Remedial actions for soil may impact water alternatives in many ways. These interactions, described in more detail in Section 2.1 of the Soil DAA, Volume I, include the following:

- Soil alternatives may not provide sufficient runoff control and may adversely impact the quality of surface water through leachate and particle transport.
- Soil alternatives may not provide sufficient source control and may adversely impact the quality of groundwater through leachate migration.
- Soil containment alternatives, such as capping, will limit infiltration and reduce migration through lowering of the water table.
- Soil source-control alternatives may improve the operation of existing boundary groundwater treatment and containment systems by reducing their contaminant load.
- Soil source-control alternatives may enhance proposed groundwater dewatering, mass removal, or plume control alternatives.
- Contaminated water, generated through dewatering activities for soil alternatives involving excavation, will generate an additional demand on existing or proposed water treatment systems.
- Contaminated liquids, generated by soil treatment processes, will generate an additional demand on existing or proposed water treatment systems.

Implementation of soil alternatives may also affect groundwater in terms of timing, i.e., soil alternatives may have to be completed before initiating groundwater alternatives in the same area. The potential for interference among the remedial actions performed for different media was

addressed throughout the DAA. For example, some of the groundwater alternatives developed for the South Plants and Basin A Plume Groups involve the use of horizontal wells to minimize the interference between water and soil remediation.

2.5 FEASIBILITY STUDY ANALYSIS PROCESS

2.5.1 Detailed Analysis of Alternatives

A detailed analysis was conducted to determine how well each alternative satisfies the DAA evaluation criteria (OERR-EPA 1988). As described in the Executive Summary, the DAA focuses on the seven screening criteria (the two criteria not included in this analysis, state acceptance and community acceptance, will be addressed in the ROD).

The alternatives that are developed and evaluated in the DAA are based on currently available information. If other information about technologies or site conditions becomes available at a later date, the alternatives may change. Such changes can be made up to the design stage. Potential changes in alternatives may be the result of changing hydraulic or chemical conditions caused by interim actions or treatability study results indicating that other technologies should be used. Ongoing treatability studies that may impact the DAA alternatives include the horizontal well study in South Plants and the in situ biotreatability study in the South Tank Farm Plume.

The groundwater control/treatment alternatives presented here are not final designs that will actually be constructed. They are preliminary designs that have been developed for relative comparison and evaluation during the FS process. Each alternative has been carried to a preliminary design level because only at this level can actual size, effectiveness and costs be evaluated appropriately. Sufficient detail is provided for each alternative to allow its merits and drawbacks to be easily compared.

The final control/treatment alternative that is selected for a given plume group will be determined as part of the Record of Decision (ROD), the negotiation and decision-making process by which the final site remediation is selected by the Parties. When the alternatives for the plume group

have been selected the remediation will enter a design phase. During the design phase, site specific information will be collected about current site conditions, and a control/treatment system will be designed to meet the specific goals stated in the ROD. Such a design will be generally based on one or more of the alternatives described here, but will undoubtedly differ from it to some degree. For instance, a technology utilized in an alternative may be replaced by a technology that appears to be more appropriate or desirable at the time of design based on new site conditions, costs, results of pilot and treatability studies and other factors. As long as the new technology can be applied to meet the goals of the selected alternative this change can be made.

2.5.2 Comparative Analysis

The comparative analysis uses the same criteria as the detailed analysis but involves a comparison of all the retained alternatives against each criterion. The comparative analysis of the alternatives developed for the water medium was completed on a plume-group-specific basis, i.e., by comparing all of the alternatives within one plume group against each criterion. One or more alternatives from each plume group were retained for development of sitewide alternatives for groundwater.

2.5.3 Selection of a Sitewide Preferred Alternative

Several sitewide remedial alternatives were developed for the groundwater at RMA. The selection of the preferred sitewide alternative is strongly dependent on the preferred soil alternative and involves comparing the performance of each sitewide groundwater alternative relative to the preferred soil alternative and evaluating its ability to achieve hydraulic control and reduce contaminant mass in addition to achieving RAOs.

Table 2.2-1 Preliminary Remediation Goals (PRGs) for the Northwest Boundary Containment System (NWBCS) Page 1 of 1

Chemical Group/Compound	Preliminary Remediation Goals (µg/l)	
Volatile Halogenated Organics (VHOs)		
Trichloroethylene	3 ¹	
Chloroform	6 ²	
Organophosphorous Compounds; Isopropylmethyl Phosphonofluoridate (GB) Agent Related (OPHBGs)		
Diisopropylmethyl phosphonate (DIMP)	8 ²	
Other Organics		
n-Nitrosodimethylamine (NDMA)	0.007 ⁴	(0.033) ³
Organochlorine Pesticides (OCPs)		
Dieldrin	0.002 ²	(0.05) ³
Endrin	0.2 ²	
Isodrin	0.06 ¹	
Arsenic	2.35 ¹	

1 Risk Based Value from Off-Post Operable Unit Endangerment Assessment/Feasibility Study, Harding Lawson Associates, November 1992.

2 Colorado Basic Standards for Groundwater (CBSGs), Code of Colorado Regulations, The Basic Standards for Groundwater, 5 CCR 1002.8, Section 3.11.

3 Current certified reporting limit (CRL) or practical quantitation limit (PQL).

4 Risk based value from Integrated Risk Information System (IRIS), EPA 1995.

Table 2.2-2 Preliminary Remediation Goals (PRGs) for the Irondale Containment System (ICS)

Page 1 of 1

Chemical Group/Compound	Preliminary Remediation Goals (µg/l)
Volatile Halogenated Organics (VHOs)	
Trichloroethylene	5 ^{1,2}
Other Organics	
Dibromochloropropane (DBCP)	0.2 ^{1,2}

¹ Colorado Basic Standards for Groundwater, Code of Colorado Regulations, The Basic Standards for Groundwater, 5 CCR 1002.8, Section 3.11.

² Federal Maximum Contaminant Levels (MCLs), 40 Code of Federal Regulation (CFR) 141.61.

Chemical Group/Compound	Preliminary Remediation Goals (µg/l)	
Volatile Halogenated Organics (VHOs)		
1,2-Dichloroethane	0.4 ¹	(1.1) ⁴
1,2-Dichloroethylene	70 ^{1,2}	
Carbon tetrachloride	0.3 ¹	(0.99) ⁴
Chloroform	6 ¹	
Methylene chloride	5 ^{1,2,6}	
Tetrachloroethylene	5 ^{1,2}	
Trichloroethylene	3 ³	
Volatile Hydrocarbon Compounds (VHCs)		
Dicyclopentadiene	46 ³	
Volatile Aromatic Organics (VAOs)		
Benzene	3 ³	
Xylenes	1,000 ³	
Toluene	1,000 ^{1,2}	
Organosulfur Compounds; Mustard Agent Related (OSCMs)		
1,4-Oxathiane	160 ³	
Dithiane	18 ³	
Organosulfur Compounds; Herbicide Related (OSCHs)		
Chlorophenylmethyl sulfide	30 ³	
Chlorophenylmethyl sulfone	36 ³	
Chlorophenylmethyl sulfoxide	36 ³	
Organophosphorous Compounds; Isopropylmethyl Phosphonofluoridate (GB) Agent Related (OPHGBs)		
Diisopropylmethyl phosphonate (DIMP)	8 ¹	

- 1 Colorado Basic Standards for Groundwater. Code of Colorado Regulations, The Basic Standards for Groundwater, 5 CCR 1002.8, Section 3.11.
- 2 Federal Maximum Contaminant Levels (MCLs), 40 Code of Federal Regulations, (CFR) 141.61.
- 3 Off-Post Operable Unit Endangerment for Groundwater Assessment/Feasibility Study, Harding Lawson Associates, November 1992.
- 4 Current Certified Reporting Limit (CRL) or Practical Quantitation Limit (PQL).
- 5 Risk Based Level, Integrated Risk Information System (IRIS), EPA 1995.
- 6 Methylene chloride is a common laboratory contaminant and analytical anomalies may be observed during compliance monitoring.
- 7 PRGs for chloride and sulfate are outlined in Section 2.2.

Chemical Group/Compound	Preliminary Remediation Goals (µg/l)	
Organophosphorous Compounds; Pesticide Related (OPHPs)		
Atrazine	3 ^{1,2}	
Malathion	100 ³	
Organochlorine Pesticides (OCPs)		
Aldrin	0.002 ¹	(0.05) ⁴
Dieldrin	0.002 ¹	(0.05) ⁴
Endrin	0.2 ¹	
Isodrin	0.06 ³	
Other Organics		
Dibromochloropropane (DBCP)	0.2 ^{1,2}	
n-Nitrosodimethylamine (NDMA)	0.007 ⁵	(0.033) ⁴
Arsenic	2.35 ³	
Anions		
Fluoride	2,000 ¹	
Chloride	250,000 ^{1,7}	
Sulfate	250,000 ^{1,7}	

1 Colorado Basic Standards for Groundwater. Code of Colorado Regulations, The Basic Standards for Groundwater, 5 CCR 1002.8, Section 3.11.

2 Federal Maximum Contaminant Levels (MCLs), 40 Code of Federal Regulations, (CFR) 141.61.

3 Off-Post Operable Unit Endangerment for Groundwater Assessment/Feasibility Study, Harding Lawson Associates, November 1992.

4 Current Certified Reporting Limit (CRL) or Practical Quantitation Limit (PQL).

5 Risk Based Level, Integrated Risk Information System (IRIS), EPA 1995.

6 Methylene chloride is a common laboratory contaminant and analytical anomalies may be observed during compliance monitoring.

7 PRGs for chloride and sulfate are outlined in Section 2.2.

Table 2.2-4 Preliminary Remediation Goals (PRGs) for Groundwater at Basin A Neck IRA Treatment System Page 1 of 2

Chemical Group/Compound	Preliminary Remediation Goals (µg/l)	
Volatile Halogenated Organics (VHOs)		
1,2-Dichloroethane	0.4 ¹	(1.1) ⁴
1,1,1-Trichloroethane	200 ^{1,2}	
1,1-Dichloroethylene	7 ^{1,2}	
Carbon tetrachloride	0.3 ¹	(1.0) ⁴
Chlorobenzene	100 ^{1,2}	
Chloroform	6 ¹	
Tetrachloroethylene	5 ^{1,2}	
Trichloroethylene	5 ^{1,2}	
Volatile Hydrocarbon Compounds (VHCs)		
Dicyclopentadiene	46 ³	
Volatile Aromatic Organics (VAOs)		
Benzene	5 ^{1,2}	
Organophosphorus Compounds; Pesticide Related (OPHPs)		
Atrazine	3 ^{1,2}	
Semivolatile Halogenated Organics (SHOs)		
Hexachlorocyclopentadiene	50 ¹	
Organochlorine Pesticides (OCPs)		
Dichlorodiphenyltrichloroethane (DDT)	0.1 ¹	
Dieldrin	0.002 ¹	(0.1) ⁴
Endrin	0.2 ¹	

1 Colorado Basic Standards for Groundwater. Code of Colorado Regulations, The Basic Standards for Groundwater, 5 CCR 1002.8, Section 3.11.

2 Federal Maximum Contaminant Levels (MCLs), Code of Federal Regulations, 40 (CFR) 141.61.

3 Off-Post Operable Unit Endangerment Assessment/Feasibility Study for Groundwater, Harding Lawson Associates, November 1992.

4 Current Practical Quantitation Limit (PQL) or Certified Reporting Limit (CRL).

Table 2.2-4 Preliminary Remediation Goals (PRGs) for Groundwater at Basin A Neck IRA Treatment System Page 2 of 2

Chemical Group/Compound	Preliminary Remediation Goals (µg/l)
Organosulfur Compounds; Herbicide Related (OSCHs)	
Chloromethylsulfide	30 ³
Chloromethylsulfone	36 ³
Chloromethylsulfoxide	36 ³
Dicyclopentadiene	46 ³
Organosulfur Compounds; Mustard Agent Related (OSCMs)	
1,4-Oxathiane	160 ³
Dithiane	18 ³
Arsenic	50 ^{1,2}
Mercury	2 ^{1,2}

1 Colorado Basic Standards for Groundwater. Code of Colorado Regulations, The Basic Standards for Groundwater, 5 CCR 1002.8, Section 3.11.

2 Federal Maximum Contaminant Levels (MCLs), Code of Federal Regulations, 40 (CFR) 141.61.

3 Off-Post Operable Unit Endangerment Assessment/Feasibility Study for Groundwater, Harding Lawson Associates, November 1992.

4 Current Practical Quantitation Limit (PQL) or Certified Reporting Limit (CRL).

Chemical Group/Compound	Preliminary Remediation Goals (µg/l)
Volatile Halogenated Organics (VHOs)	
Carbon tetrachloride	5 ¹
Chloroform	100 ^{1,5}
Methylene chloride	5 ¹
Trichloroethylene	5 ¹
Volatile Hydrocarbon Compounds (VHCs)	
Dicyclopentadiene	46 ²
Volatile Aromatic Organics (VAOs)	
Benzene	5 ¹
Organosulfur Compounds: Mustard Agent Related (OSCMs)	
Dithiane	18 ²
Organosulfur Compounds: Herbicide Related (OSCHs)	
Chlorophenylmethyl sulfoxide	36 ²
Organophosphorous Compounds: Isopropylmethyl Phosphonofluoridate (GB) Agent Related (OPHGBs)	
Diisopropylmethyl phosphonate (DIMP)	600 ³
Organophosphorous Compounds: Pesticide Related (OPHPs)	
Atrazine	3 ¹
Dibromochloropropane (DBCP)	0.2 ¹
Organochlorine Pesticides (OCPs)	
Dieldrin	0.5 ³
Chlordane	2 ¹
Arsenic	50 ¹

1 Federal Maximum Levels (MCLs) (40 Code of Federal Regulations (CFR) 141.61).

2 Health-based Criterion, Off-Post Operable Unit Endangerment Assessment/Feasibility Study, Harding Lawson Associates, November 1992.

3 Health Advisory (EPA 1993).

4 Drinking Water Equivalent Level (EPA 1994).

5 PRG represents the trihalomethane (THM) MCL.

Section 3

3.0 GROUNDWATER CONTROL AND TREATMENT METHODOLOGY

Groundwater flow volumes and velocities across RMA vary. The highest groundwater flow volumes and velocities at RMA are associated with thick, permeable sand and gravel deposits of the Platte River Valley, which occur along the Western Tier of RMA, and with similar deposits along First Creek. The saturated portion of these alluvial sediments is generally thicker and coarser grained than alluvial sediments in the central portion of RMA. Groundwater flows in the central portion of RMA are one or more orders of magnitude less than in the Western Tier or First Creek areas. This is true because groundwater in the central portion of RMA flows through predominantly thin, fine-grained alluvium and low permeability bedrock.

The regional groundwater flow direction at RMA is northwest toward the South Platte River. Superimposed on the regional groundwater flow system is a large groundwater mound centered over a bedrock topographic high beneath the South Plants. Groundwater in this area flows radially away from the South Plants before joining the regional flow system, where it eventually flows towards the western tier or the northern boundary.

Because RMA is located in a semi-arid environment, the amount of annual groundwater recharge from precipitation is low. Sources of manmade recharge have historically contributed to the groundwater mound in South Plants. These manmade sources include leaking potable and process water systems (used for fire protection), sanitary and storm sewer systems, infiltration of Steam Plant cooling water discharged to ditches, and infiltration of precipitation that ponds in depressions and ditches adjacent to buildings and roadways. The amount of recharge from these manmade sources is decreasing and eventually will be eliminated when remediation activities are completed. As of mid-1994, the sanitary and chemical sewers systems had been closed and the Steam Plant was no longer in operation. Recent measurements indicate that groundwater elevations in the South Plants have decreased several feet. It is currently thought that the decrease in water levels is the result, in part, of the reduction in manmade recharge. However, the past year has been very dry and some of the decreases in water levels are due to drought

conditions. Rainfall in recent months has been greater than normal and water levels in some areas have risen. In the long term, it is likely that water levels in the mound area will decrease as a result of eliminating manmade recharge.

The upper groundwater flow system at RMA has been designated as the unconfined flow system (UFS). The UFS includes saturated portions of the alluvium and weathered upper portions of the Denver Formation. The UFS is not isolated from atmospheric pressure effects by a low permeability unit. The lower groundwater flow system is designated as the confined flow system (CFS). The CFS occurs entirely within the unweathered portion of the Denver Formation. The CFS is isolated from atmospheric pressure fluctuations by one or more low permeability units.

Vertical and, to a lesser extent, lateral groundwater flow and migration of contaminants from the central portion of RMA are restricted by the underlying unweathered portion of the Denver Formation. The Denver Formation is comprised largely of fine-grained sediments and functions more as a confining layer between the overlying unconfined alluvial flow system and the underlying confined aquifers of the Arapahoe Formation. The confined Denver flow system consists primarily of interbedded discontinuous aquiclude and aquitard sequences, generally composed of claystone and siltstone, with interspersed, isolated, coarser-grained, water-bearing units. These finer-grained sequences appear capable of restricting the vertical movement of contaminated groundwater. The presence of low permeability layers, combined with a close examination of relevant hydrologic and water-quality data, indicates that natural vertical and lateral migration of contaminated groundwater within the confined Denver flow system is not significant.

The largest contaminant sources in proximity to groundwater, which include South Plants, the Army and Shell disposal trenches, and Basins A and F, are located in the central portion of RMA, where groundwater flow volumes and velocities, as well as contaminant migration rates, are low.

The distribution of contaminants resulting from migration away from these sources is described in the following sections.

3.1 CHARACTERISTICS OF GROUNDWATER PLUMES

This section describes the plume group configurations and identifies major contaminants for each group. The groundwater quality data discussed in this report are used for design of potential treatment systems and therefore generally represent the areas proximal to and within the capture zone of proposed remedial alternatives, which are the most contaminated portions of a plume. The summary of chemical data does not include an evaluation of all chemical analyses for the entire plume area. Appendix B of the Water DAA includes a compilation of the water quality data that has been summarized statistically.

During the Water DSA (EBASCO 1992), a total of 15 contaminated groundwater plumes were identified and then combined into the following five plume groups: Northwest Boundary, Western, North Boundary, Basin A, and South Plants (Table 3.1-1 and Plate 1). The primary criteria used for defining plume groups was the proximity of the plumes to one another and the location of the plumes with respect to existing or planned groundwater control and treatment systems developed under IRAs and the boundary systems. During the DAA, a final plume map was completed to include recent data that became available after issuance of the DSA (Plate 1) (EBASCO 1992). The plume map was used to evaluate areas on RMA where remedial alternatives may be considered. The concentrations shown on the plume map were not used to design treatment systems. The final plume map for the DAA was generated by summing the geometric means for each target organic analyte detected in wells that sample the UFS over the time period 1989 to mid-1994. These values were hand-contoured using knowledge of several hydrogeologic factors such as current and historical groundwater flow directions and rates, aquifer characteristics, modeling results, bedrock surface configuration, and historical plume geometries. Target organic analytes that were included in the plume maps are listed in Table 3.1-2.

The following sections include plume group descriptions and a discussion of the anticipated impacts each groundwater alternative will have on the deeper, confined aquifer.

3.1.1 Northwest Boundary Plume Group

The Northwest Boundary Plume Group includes the Basin A Neck Plume and the Sand Creek Lateral Plumes. Contaminated groundwater flow occurs primarily within small alluvial-filled paleochannels near the plume sources and within thick, saturated terrace deposits along the northwest RMA boundary. The existing Northwest Boundary Containment System (NWBCS) was installed to intercept and treat these plumes at the RMA boundary on post (Plate 1). The Basin A Neck Plume extends from Basin A in Section 36 to the northwest boundary of RMA. The Sand Creek Lateral Plumes appear to originate in the vicinity of the Sand Creek Lateral in the western portion of Section 35 and merge with the Basin A Neck Plume. During the Water DSA (EBASCO 1992), these plumes were eliminated from further consideration for on-post treatment because contaminants were present at low concentrations and because the NWBCS already provided treatment for these plumes. A review of the water quality in these plumes also shows that no new contaminants, which would require modification to the treatment system, are expected to reach the boundary in the foreseeable future (see Section 3.4). Therefore, no additional statistical evaluation of the contaminant concentrations within these plumes was conducted for the Water DAA.

3.1.2 Western Plume Group

The Western, Motor Pool, and Rail yard Plumes are collectively defined as the Western Plume Group (Plate 1). The sources of the Motor Pool and Rail Yard Plumes are located on post; the Western Plume, however, originates off post to the south and extends onto RMA. The Motor Pool and Rail Yard Plumes and those portions of the Western Plume that extend off post are extracted and treated by the ICS or the South Adams County Water and Sanitation District (SACWSD) water supply wells and water treatment plant. The plumes occur primarily within thick alluvial-terrace deposits. During the Water DSA (EBASCO 1992), this plume group was

eliminated from further consideration for on-post treatment because contaminant concentrations near the RMA boundary were low and the plumes were adequately controlled by the existing systems.

3.1.3 North Boundary Plume Group

The North Boundary Plume Group includes the Basins C and F Plume and the North Plants Plume (Plate 1). The NBCS extracts and treats these plumes as they approach the northern boundary of RMA. The Basins C and F Plume flows primarily within alluvial-filled paleochannels and to a lesser extent through weathered bedrock. The North Plants Plume flows primarily within sandy alluvial material. Water-quality data were reviewed for the portions of these plumes that would be extracted by proposed groundwater control and treatment systems. Within these areas, chloroform is the only contaminant of concern in the Basins C and F Plume that could merit additional on-post treatment and no contaminants were detected in the North Plants Plume at concentrations for which additional on-post treatment would be cost-effective. Future loading on the boundary systems is discussed further in Section 3.4.

3.1.4 Basin A Plume Group

The Basin A Plume Group includes the Basin A Plume, the South Plants North Plume, and the Section 36 Bedrock Ridge Plumes (Plate 1). Contaminated groundwater flow in the South Plants North and Basin A Plumes occurs principally within saturated alluvium, with lesser flow through the underlying weathered bedrock. However, in the Section 36 Bedrock Ridge area, the water table generally lies below the alluvium and groundwater flows predominantly within weathered bedrock. Water-quality data were reviewed for the portions of these plumes that would be extracted by proposed groundwater control and treatment systems. The major contaminants detected in these portions of the Basin A Plume Group include chloroform, methylene chloride, DBCP, tetrachloroethylene, benzene, aldrin, and chlordane.

3.1.5 South Plants Plume Group

The South Plants Plume Group includes the South Plants Southeast, Southwest, North Source, and the South Tank Farm Plumes. The South Plants North Plume was split into the North Source and the South Plants North Plume as part of the Basin A Plume Group during the Water DAA to further describe the South Plants area. Groundwater in these plumes flows principally within the weathered, upper portion of the Denver Formation. Small portions of the South Plants North Source and South Plants Southeast Plumes also flow within areas of thin, saturated alluvium. It was determined that the South Plants Southwest Plume did not have contaminant levels that justify additional on-post treatment or containment. Continued monitoring of groundwater quality adjacent to Lake Ladora will make it possible to assess whether migration of contaminants toward the lake has any potential for adverse effects on biota. The major contaminants in the combined stream from these portions of the South Plants Plume Group include chloroform, benzene, and DBCP.

3.1.6 Vertical Migration of Contaminants

This section presents an assessment of contamination detected in the deeper, confined Denver aquifer based on information from recent evaluations of water quality data from samples collected from the deeper, confined aquifer at RMA conducted by the Army (HLA 1994) and Shell (MKE 1994). The impact of various groundwater alternatives on potential contamination in the deeper aquifer is evaluated based on these results. The results of the Army and Shell investigations indicate that a small number of confined wells show consistent patterns of contamination in the following areas:

- South Plants
- Basin A
- Section 26 (Basins C and F)
- North Boundary (Sections 23 and 24)

One or more target analytes have been detected in 10 wells completed in the confined aquifer beneath South Plants. Seven of these wells (01037, 01071, 01077, 01081, 01102, 02031, and 02061) show repeated analyte detections that are likely to be representative of actual contamination (rather than cross-contamination during sampling or analysis). The highest concentrations of contaminants are observed in wells located beneath the South Plants Central Processing Area and within the "A" Sand or other stratigraphically equivalent units. The major contaminants include organochlorine pesticides, volatile aromatic organics, DBCP, and volatile halogenated organics.

One or more target analytes have been detected in 13 wells completed in the confined aquifer in the Basin A area. Five of these wells (36122, 36171, 36179, 36182, and 36183) show repeated analyte detections that are likely to be representative of actual contamination. Numerous analytes, including organochlorine pesticides, volatile halogenated organics, organophosphorus compounds, volatile aromatic organics, DBCP, and volatile hydrocarbon compounds, have been detected repeatedly at moderate to high concentrations in well 36182, located in the southwestern corner of Section 36. Smaller suites of contaminants have been detected at lower concentrations along the eastern border of Basin A, within Basin A Neck, and in the Section 36 Bedrock Ridge area. Analyte concentrations observed in well 36182 are greater than concentrations in other confined flow system wells in the South Plants and Basin A areas. This well is completed in the "A" Sand aquifer at a total depth of 75 feet. Under existing natural hydrologic conditions, groundwater flow from this portion of the "A" Sand discharges to the alluvial aquifer along the southern bank of the Basin A Neck Paleochannel.

One or more of the target analytes have been detected in 15 wells completed in the confined aquifer in the Basin C and Former Basin F area. Five of these wells (26072, 26084, 26141, 26142, and 26150) show detections of low to moderate concentrations of aldrin, dieldrin, endrin, chlordane, DBCP, chloroform, and inorganics that are likely to be representative of actual contamination. Similar to most areas at RMA, the detections are sporadic; that is, many of these

analytes were detected once during the multiyear sampling history of the well and may represent cross-contamination.

Several deeper wells have shown evidence of contamination along the North Boundary (Sections 23 and 24). It is hypothesized that these contaminants were drawn downward during the early years of the system operation when deeper Denver aquifer wells were a part of the extraction system. These wells have been removed and no longer provide a vertical migration pathway. Contaminants have not been detected in the confined aquifer in this area since 1979.

Well 25016 in the northwest corner of Section 25 has shown low but consistent levels of benzene at a depth of 66 feet. Groundwater at this depth will likely discharge to the alluvium and become part of the alluvial plumes that are intercepted by the NBCS.

Mechanisms for vertical contaminant migration at RMA include intergranular flow, molecular diffusion, vertical migration through fractures, cross-contamination during well installation, and leakage along poorly sealed wells. Intergranular flow and diffusion appear to be viable only in areas where the confining unit between the confined and unconfined aquifers is thin and downward hydraulic and chemical gradients are large. It has been hypothesized that intergranular flow through vertically interconnected sandstone units could explain the presence of some contaminants in the deeper aquifer (EBASCO 1989). However, additional geologic interpretations of the Denver Formation materials in areas underlying the major plume groups show that coarse-grained sandstone units do not form vertically interconnected systems but rather that they are separated by fine-grained claystone aquitards (MKE 1994). Vertical migration through fractures may occur locally; however, fractures observed in drill cores are predominantly horizontal and become increasingly uncommon with depth. Even when inclined fractures are observed, they commonly are truncated by unfractured horizontal beds. Large observed differences in hydraulic head between the confined and unconfined aquifers in areas such as South Plants suggest that there is little vertical communication, so that fractures would not

provide a significant contaminant migration pathway to deeper aquifers over large areas of RMA. However, leakage along poorly sealed wells is a recognized migration pathway at RMA, and many wells have been plugged and abandoned to minimize the potential for future contaminant movement into the deeper aquifer. The Army is currently evaluating the GMP groundwater well network to identify wells that should be abandoned. Wells for which well construction information is incomplete or where there is evidence of poor well construction will be recommended for closure. This evaluation is ongoing and it is anticipated that approximately 30 to 40 wells will eventually be closed. These wells should not require replacement because the remaining wells provide adequate monitoring coverage in the main source areas of RMA; however, if the parties jointly determine that some of the wells to be closed are necessary for future monitoring of the CFS, they will be replaced.

There is no evidence of widespread contamination in the confined aquifer. With few exceptions, the contaminant concentrations are low and decrease with depth. The interbedded clay and sand geometry of the Denver Formation, possible vertical migration mechanisms, and groundwater-quality data all support a hypothesis that leakage of contaminants from the unconfined flow system (UFS) to the deeper, confined aquifer only occurs locally where conditions favor vertical migration. Lateral migration of contaminants that have been detected in the confined aquifer is limited and will occur at very slow rates. The planned capping of Basin A and South Plants, as described in the Soil DAA, will reduce downward vertical hydraulic gradients through reduction of water levels in the UFS, thereby further reducing the spread of contaminants to and within the confined flow system. Actively extracting groundwater from the confined flow system is not proposed in the DAA because it may draw contaminants down into the deeper aquifer. Continued groundwater monitoring and 5-year reviews are proposed to determine the effectiveness of each alternative and to assess whether they need to be upgraded or modified. A groundwater monitoring network for the confined aquifer will be sampled and analyzed annually to assess contaminant levels beneath the three major source areas of RMA, including South Plants, Basin A, and Former Basin F (Figure 3.1-1). The 20 wells selected for this network are screened in

the confined flow system and have shown historic detections of organic analytes. It has been hypothesized that the organic detections in some of these wells were introduced during well installation. If this hypothesis is correct, contaminant concentrations in these wells should decrease relatively quickly in the future. It is anticipated that vertical migration of contaminants into the confined aquifer will decrease as a result of the preferred capping alternatives and contaminant concentrations throughout the deeper aquifer will decrease with time. All wells in this network will initially be sampled and analyzed for the full RMA analytical suite.

The number and location of CFS monitoring wells will be reevaluated based on review of results and observed trends. If necessary, the CFS wells or sampling frequency could be changed.

3.2 ESTIMATION OF CONTAMINANT CONCENTRATIONS

3.2.1 Extraction System Design Concentrations

A two-step approach was used to estimate the concentration of contaminants in groundwater to be extracted by the control/treatment alternatives. In the first step, an areal hydrological and time-based rationale was developed for selecting monitoring points (wells) to include in the estimation. In the second step, the mean concentration of each chemical constituent was estimated using the TSGM method.

Only those monitoring wells that fell inside a groundwater flow stream-tube (i.e., capture-zone) segment that represented the location of the extraction system were selected for use in the calculations. For interceptor systems, it was generally assumed that the stream tube extends upgradient a distance equivalent to 5 years of travel time for water under current-flow conditions. However, at the Section 36 Bedrock Ridge area where travel times are estimated to be in the tens of feet per year or less, a slightly larger stream tube area was selected. For dewatering system calculations, it was assumed that the capture zone extends a distance equivalent to 5 years of travel time by water under induced-flow conditions. The wells that were identified by this approach as being within the stream tube or capture zone are listed in Table 3.2-1.

Existing water-level contours and flow-net concepts were used to estimate and delineate on a map the width of the stream tube extending upgradient from the proposed groundwater extraction system. The representative average linear velocity of groundwater was calculated using an analytical approach:

$$\bar{v} = \frac{-Ki}{n_e}$$

where:

$\bar{v}$ = mean groundwater velocity

K = hydraulic conductivity

i = hydraulic gradient

n_e = effective porosity

employing the best available estimates of local hydraulic gradient, hydraulic conductivity, and effective porosity (Freeze and Cherry 1979). The distance traveled by groundwater at this velocity during a 5-year time period was calculated and the stream tube was extended that distance upgradient from the proposed extraction system location. For mass reduction calculations and for the contaminants of interest in the vicinity of the well, the apparent retarded velocity of a typical dissolved contaminant was calculated and used to estimate the distance traveled over a 5-year period. Only data from wells falling within the defined capture zone were used in the statistical calculation of the mean contaminant concentration (Table 3.2-1). The capture zone and the method of selection are described in Appendix C.

The retarded velocity of selected contaminants were calculated by the retardation equation (Freeze and Cherry 1979) using soil and chemical parameters taken from the Integrated Endangerment Assessment/Risk Characterization (EBASCO 1994). The methods used and retardation parameters calculated are summarized in Appendix C.

3.2.2 Two-Step Geometric Mean Concentrations

The TSGM of a compound within a given capture zone or stream-tube segment was computed as follows. In the first step, the geometric mean of all samples collected throughout a given time period for each individual well was estimated as:

$$GM_1 = \sqrt[n]{(V_1)(V_2)...(V_n)}$$

where:

GM_1 = geometric mean of analytes in a given well number 1 throughout sampling period t

n = number of samples collected and analyzed

$V_1... V_2$ = individually detected contaminant concentration values. If a value was below the Certified Reporting Limit (CRL), a value was calculated using the Robust Method (Helsel 1990). If the detection ratio for a given well was less than 50 percent (number of detections to number of total samples), one-half of the CRL was used. One-half of the CRL was also used if there were fewer than three total detections in a given well.

In the second step, the geometric mean concentration for the stream tube or capture zone (GM_s) was calculated using all wells (m) located within the capture zone, based on the GM_1 for each of these wells as follows:

$$GM_s = \sqrt[m]{(GM_1)(GM_2)...(GM_m)}$$

where:

GM_s = geometric mean of the GM values for all wells "1" through "m" located within the capture zone

m = number of wells in the capture zone

$GM_1... GM_m$ = individual values of GM, for all wells numbered "1" through "m"

The TSGM method was used to estimate influent concentrations because it is resistant to outliers and anomalies and thus provides a representative estimate of the mean concentration. The wells that were used to estimate influent concentrations for the system considered in the DAA are listed in Table 3.2-1. The data sets used for calculation of TSGM and the results of the calculations are provided in Appendix B of this volume.

3.2.3 Mass Reduction Estimates

For those alternatives that include mass reduction, estimates were made of the rate of removal of dissolved contaminants from the highly contaminated central portion (within the 10,000 micrograms per liter contour on Plate I) of each plume. For design purposes, it was assumed that each mass reduction system will operate for 20 years and will lead to removal of all of the currently dissolved contaminant mass within the targeted portion of each plume.

The amount of dissolved contaminant that would be extracted by each mass reduction system is highly variable depending on local hydrogeologic conditions and on the chemical characteristics of each contaminant. For mass reduction, it was assumed that a volume of contaminated groundwater is removed from the targeted, highly contaminated portion of an aquifer and that desorption of contaminants from aquifer material is not considered.

The period a mass reduction system actually operates would be estimated during the design of the final well configuration in the design phase of the selected remedy and may be adjusted based on performance data. The mass reduction systems were assumed to operate for a 20-year period both to simplify the comparison and costing of alternatives and to allow water produced from the systems to be treated at a common treatment facility over a consistent time period. The methods used to calculate the amount of mass removed that is expected to take place during operation of mass reduction systems as well as the results of the analysis are described in Appendix C.

3.3 USE OF GROUNDWATER MODELING IN THE EVALUATION OF REMEDIAL ALTERNATIVES

The South Plants/Basin A numerical groundwater flow model, which was developed as part of the DAA (Foster Wheeler Environmental 1995), was an important tool during the evaluation of groundwater remedial alternatives, serving to simulate the hydrogeologic flow conditions that may result from the implementation of each groundwater remedial alternative. A numerical groundwater flow model was selected for use because it is particularly helpful where hydrogeologic conditions are complex due to heterogeneity of geologic materials or restrictive boundary conditions. In addition, the numerical model provided a robust means of representing many groundwater extraction/treatment hydraulic components such as wells, trenches, caps, and barriers. The model, therefore, provides a basis for comparison of remedial alternatives within a modeled area.

The following general groundwater modeling objectives were identified for modeling applications during the DAA:

- Aid in evaluation of the effectiveness of various groundwater extraction and injection (control) alternatives and their potential effects on boundary containment systems.
- Aid in evaluation of the range of time that may be required to operate proposed on-post remedial systems.
- Aid in evaluation of the potential impacts of groundwater control alternatives on the hydrogeologic system and on groundwater management practices.
- Develop a better understanding of groundwater flow mechanisms and pathways at RMA.

In addition to these general objectives, the South Plants/Basin A flow model was designed to meet specific modeling objectives. The objectives for the model are discussed in detail, along with details of the hydrogeologic conceptual model, limitations of use, code selection, and other aspects of the modeling process, in the South Plants/Basin A Groundwater Modeling Report (Foster Wheeler Environmental 1995).

The level of modeling sophistication that was applied for a given remedial alternative depended on local hydrogeologic conditions and the complexity of the alternatives considered for use in that area. In general, numerical models are more applicable and robust in areas where the hydrogeology is complex, the alternatives have several components, or the remedial alternatives impact groundwater conditions at another extraction/treatment location. The decision as to which modeling method to employ (numerical or analytical) also considered constraints on the hydrogeologic data available, specific project and modeling goals, and schedule.

The following subsections summarize the modeling approach that was taken for each groundwater plume group.

Northwest Boundary Plume Group

No alternatives retained for this plume group require the application of groundwater flow models.

Western Plume Group

No alternatives retained for this plume group require the application of groundwater flow models.

North Boundary Plume Group

Improved estimates of the groundwater flux through the area north of Basin F were made by using recent estimates of the water table elevation and hydraulic gradient and applying an analytical solution based on Darcy's law.

No additional groundwater treatment alternatives were retained for the North Plants Plume due to low groundwater contaminant levels in that area. Therefore, no modeling was required for the North Plants area.

South Plants and Basin A Plume Groups

The remedial alternatives for the Basin A and South Plants Plume Groups were evaluated using a single three-dimensional (3-D) multilayer groundwater flow model. The primary reason for representing both areas in one model was the expected interaction between groundwater remedial alternatives for the two plume groups. For example, the dewatering alternatives evaluated for the South Plants area have a direct impact on aquifer conditions in Basin A and have significant impacts on alternatives developed for that area. In addition, the model was used to consider interaction between alternatives developed for the soil and water media.

Particle tracking was used to evaluate the capture effectiveness of the control alternatives and to define groundwater flow paths. The model and particle tracker were also used to define the extent of the capture zone of mass reduction wells by tracking the distance traveled by particles to a well over a 5-year period of steady simulated pumping at the well. Analytical solutions were used to evaluate contaminant migration rates in a few specific applications. No contaminant-transport capability was incorporated into the numerical groundwater flow model.

The U.S. Geological Survey (USGS) Modular Finite Difference Groundwater Flow 3-D Model, MODFLOW (McDonald and Harbaugh 1988), was used for simulations. MODFLOW is a widely used model that has been applied to many complex flow problems. A particle-tracking model, PATH3D (Zheng 1992), was coupled with MODFLOW to compute and display flow-path lines used in the development of flow nets. PATH3D uses a semianalytical algorithm to describe the flow path within a grid cell and particle movement along the flow path.

The model was designed and calibrated against observed hydrogeologic information by matching the model-calculated hydraulic heads with observed water levels at well locations through adjustments of hydrogeologic parameters. Water-level elevations for the period of spring 1992 were used as a basis for calibration and were compared to the results of the model simulations. Over most of the study area, the match of simulated to observed water levels was excellent: the

difference among 90 percent of the measuring points was less than 1 foot (ft). This indicates a good match to the observed data and a good calibration. Based on the favorable results from model setup and calibration, the model was considered to be an acceptable representation of the hydrogeologic system in the study area. The full details of model setup, model grid selection, aquifer properties, calibration, and sensitivity analyses, along with selected final simulation results, are presented in the South Plants/Basin A Groundwater Modeling Report (EBASCO 1994a).

After adequate calibration was achieved, simulations were run to assess the performance of various groundwater extraction/treatment system designs for a variety of different dewatering, interception, and other control alternatives. Design runs involved varying the location and pumping rates of the extraction wells and determining the resulting radius of influence for each well and the effect of the overall system on the capture of the contaminated plume. This was accomplished by combining the particle-tracking capability of PATH3D with the hydraulic head results from MODFLOW. Particles were input into the groundwater model along the targeted portion of the contaminant plume. The movement of the particles was then tracked and the effectiveness of capture for alternative design scenarios compared. In this way, the extent of capture was assessed. For mass reduction and dewatering alternatives, the extent of the 5-year capture zone was defined by releasing particles into the flow system around an extraction well and determining the maximum distance traveled in the simulated 5-year period.

In all of the modeled alternatives, it was assumed that the extracted water is treated at an on-post treatment plant and that the treated water is then recharged into the aquifer to maintain the water balance. In the case of the in situ biodegradation alternative for the South Tank Farm Plume (Alternative SPC-5), most of the groundwater treatment actually occurs in the subsurface, so the model simulates the hydraulic control of the injection well and extraction well system.

3.4 BOUNDARY SYSTEMS

Three boundary systems are currently operating at RMA; the Irondale Containment System (ICS), the NWBCS, and the NBCS. These systems extract, treat, and reinject groundwater from the Western, Northwest, and North Boundary Plume Groups, respectively, before it moves off post. All three systems are described in greater detail in the alternative descriptions presented in Sections 4, 5, and 6 of this report.

The systems are currently operating satisfactorily and will be reviewed every 5 years (per CERCLA) to ensure that they continue to meet their operating goals, should aquifer or plume characteristics change over time. Potential changes include a rise or fall in the water table, movement of the plume toward the ends of the containment systems, changes in contaminant concentrations approaching the containment systems, or the detection of new compounds of interest at the boundaries. If any changes occur that require changes or additions to the current boundary systems, the boundary systems will be modified at that time.

In the next 5 years the natural groundwater flow rates are expected to remain constant or drop, and the current boundary system extraction and reinjection networks have sufficient capacity and flexibility to accommodate these changes. Contaminant concentrations reaching the boundary systems are also dropping. For example, in September 1994, no contaminant concentrations in the influent at ICS exceeded the off-post PRGs (HLA 1992), and at the NWBCS only dieldrin exceeded the off-post PRGs. Operation of these systems will be discontinued at some point in the future, if the concentrations drop below the PRGs established for the system. Contaminant concentrations at the NBCS also show a decreasing trend but not enough to allow discontinuation of the system at this time. Of the groundwater being treated at the NBCS, water from the Basins C and F Plume contains the highest concentrations of contaminants. These contaminants, however, are not present in sufficient quantity to require upgrade of the existing system. Moreover, a review of water quality in the plumes approaching the boundary systems shows no new contaminants that would require modifications to the treatment system are expected to reach

the boundary in the next 5 years. However, the NBCS is being evaluated for treatment of NDMA to achieve PRGs, which will be established in the on-post ROD.

Table 3.1-1 Water Medium Plume Groups

Plume Group	Components
Northwest Boundary	Basin A Neck Plume Sand Creek Lateral Plumes ¹
Western	Western Plume Motor Pool Plume Railyard Plume
North Boundary	Basins C and F Plume North Plants Plume
Basin A	Basin A Plume Section 36 Bedrock Ridge Plumes ¹ South Plants North Plume ²
South Plants	South Tank Farm Plume South Plants Southwest Plume South Plants Southeast Plume South Plants North Source Plume ²

¹ The Sand Creek Lateral Plumes and the Section 36 Bedrock Ridge Plumes each consist of two separate plumes.

² The South Plants North Source Plume originates in the South Plants area and then migrates northward into the Basin A area. The portion of the plume that lies within the South Plants area (south of December Seventh Avenue) is called the South Plants North Source Plume and is dealt with as a part of the South Plants Plume Group alternatives. The portion of the plume that lies within the Basin A area is named the South Plants North Plume and is addressed as part of the Basin A Plume Group.

Volatile Halogenated Organic Compounds (VHOs)

1,1,1-Trichloroethane
1,1,2-Trichloroethane
1,1-Dichloroethylene/1,1-Dichloroethene
1,1-Dichloroethane
1,2-Dichloroethenes/1,2-Dichloroethylenes
1,2-Dichloroethane (cis and trans isomers)
Carbon tetrachloride
Chlorobenzene
Chloroform
Methylene chloride
Tetrachloroethylene
Trichloroethylene

Volatile Hydrocarbon Compounds (VHCs)

Bicyclo[2,2,1]hepta-2,5-diene
Dicyclopentadiene (DCPD)
Methylisobutyl ketone

Volatile Aromatic Organics (VAOs)

1,3-Dimethylbenzene/m-Xylene
Benzene
Ethylbenzene
Toluene
Xylenes

Organosulfur Compounds - Mustard Agent Related (OSCMs)

1,4-Oxathianes
Dithiane

Organophosphorous Compounds - Herbicide Related (OSCHs)

Benzothiazole
Dimethyl disulfide
p-Chlorophenylmethyl sulfide (CPMS)
p-Chlorophenylmethyl sulfoxide (CPMSO₂)
p-Chlorophenylmethyl sulfone (CPMSO)

Organosulfur Compounds - GB Related (OPHGBs)

Diisopropyl methylphosphonate (DIMP)
Dimethyl methylphosphonate (DMMP)
Isopropyl methylphosphonic acid/Isopropyl methylphosphonate (IMPA)
Thiodiglycol

Organochloride Pesticides (OCPs)

2,2-Bis (p-chlorophenyl)-1,1-dichloroethene (PPDDE)
2,2-Bis (p-chlorophenyl)-1,1,1-trichloroethane (PPDDT)
Aldrin
Chlordane
Dieldrin
Endrin
Isodrin

Organophosphorus Pesticides

Atrazine
Malathion
N-Nitrosodimethylamine (NNDMEA)
Parathion
Supona
Vapona

Semivolatile Halogenated Organics (SHOs)

Hexachlorocyclopentadiene

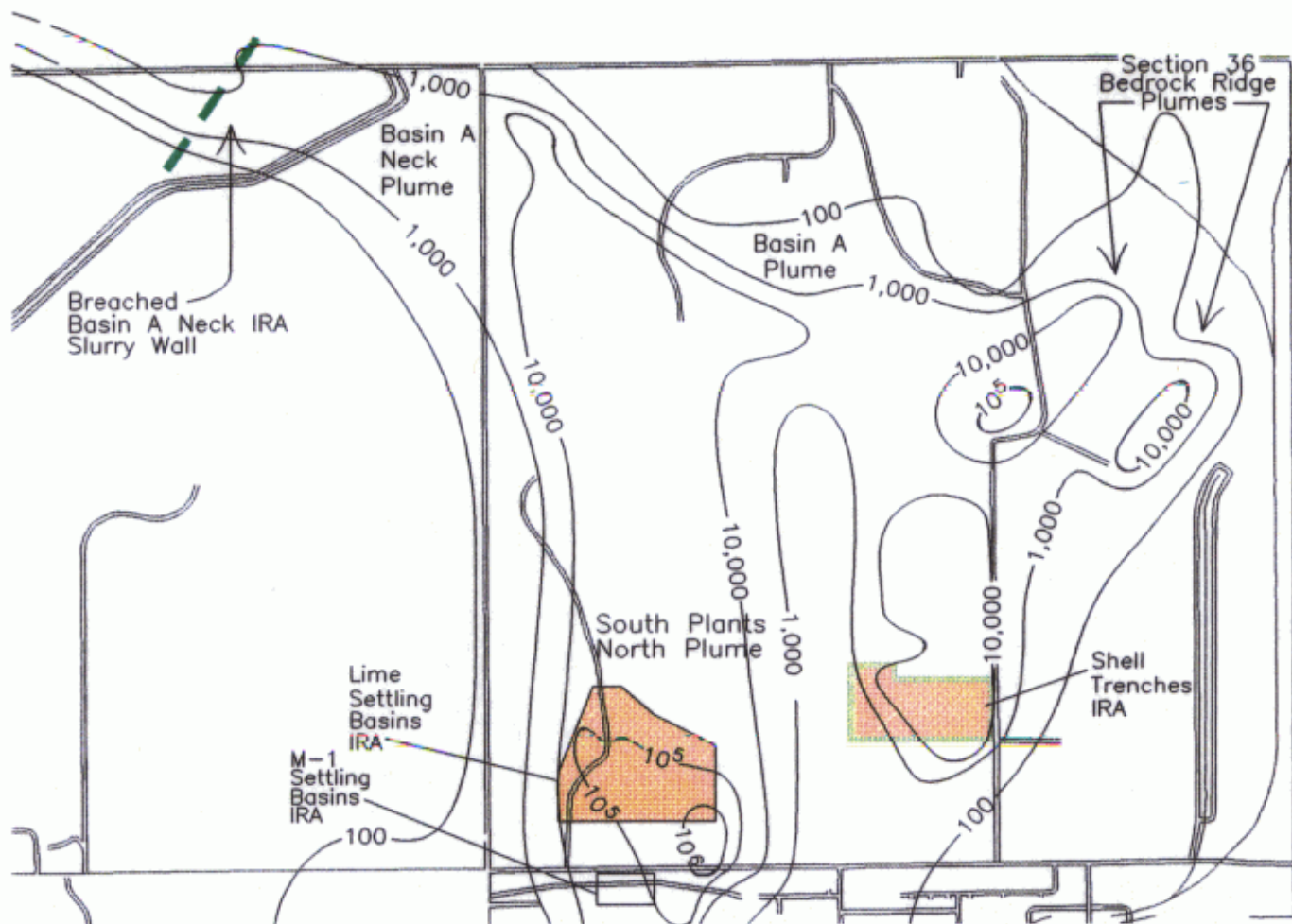
Dibromochloropropane (DBCP)

Table 3.2-1 Wells Used to Calculate TSGM Values

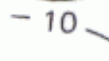
Plume	Well Number
Basins C and F Plume	23049, 23237, 23530, 26041, 26133, 26148, 26149, 26157, 26161, 26162, 26163, 26166, 26171, 26173, 23006
Section 36 Bedrock Ridge North Plume	36184, 36191, 36204
Section 36 Bedrock Ridge South Plume	36185, 36200, 36207
South Plants North Plume	36054, 36055, 36056, 36058, 36076, 36109, 36167, 36168, 36193, 36511, 36512, 36210, 36212, 36181, 36001,
Basin A Plume	36080, 36187, 36188, 36189, 36190, 36202, 36088, 36090, 36203, 36180, 36204, 36205, 36523, 36509, 36510, 36515, 36590
South Plants North Plume Source	01078, 01083, 01507, 01513, 01524, 01525, 01572, 01573, 01516
South Plants Southeast Plume	01061, 01517, 01511
Block 1, Basin A Dewatering	36146, 36108, 36177, 36123, 36094, 36169, 36001, 36181, 36109, 36212, 36210, 36076, 36056, 36187, 36188, 36088, 36085, 36084, 36074, 36521, 36508, 36514, 36522, 36509, 36590, 36510, 36523, 36506, 36164
Block 2, Basin A Dewatering	36202, 36542, 36543, 36090, 36203, 36180, 36158, 36281, 36191, 36184, 36204, 36207
Block 3, Basin A Dewatering	36109, 36056, 36074
Block 4, Basin A Dewatering	36205, 36189, 36198, 36080, 36190, 36063, 36515, 36524, 36525, 36507, 36518
Block 1, South Plants Dewatering	02003, 02005, 02545, 02594
Block 2, South Plants Dewatering	01083, 01524, 01516, 01078, 01517, 01007, 01068, 01084
Block 3, South Plants Dewatering	36193, 36054, 01513, 01525, 36168, 01572, 01507, 01573, 01511, 36512, 36511, 36513, 01020, 01510
Block 4, South Plants Dewatering	01061, 01101, 01017
Block 5 and 6, South Plants Dewatering	01535, 01534, 01565, 01540, 01539, 01533, 01554, 01618, 01552, 01547, 01100, 01089

Table 3.2-1 Wells Used to Calculate TSGM Values

Plume	Well Number
South Tank Farm Plume	01089, 01533, 01534, 01539, 01540, 01541, 01559, 01565, 02561, 02584, 01094, 01560, 02585, 01014, 02522
South Tank Farm - In Situ	01094, 01533, 01534, 01089, 01540, 01047, 01100, 01565, 01539, 01540, 01541, 01559, 02561, 02584, 01560, 02585, 01014, 01552, 01554, 02501, 02562, 02575, 02502, 02576, 01618, 02583, 01587, 01604, 01605, 02522, 01588, 01547



LEGEND

-  Cap
-  Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)
-  Slurry Wall
-  Perforated Slurry Wall



Not To Scale

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

FIGURE 7.1-1
Schematic for Basin A Plume Group
Control Alternative AC-1

Prepared by:
Foster Wheeler Environmental Corporation

Section 4

4.0 NORTHWEST BOUNDARY PLUME GROUP

The Northwest Boundary Plume Group includes the Basin A Neck Plume and the Sand Creek Lateral Plumes. Currently, there is one treatment system, the NWBCS, treating the water in the Northwest Boundary Plume Group. The NWBCS is a pump-and-treat system at the RMA boundary that prevents off-post migration of the contaminants in the Northwest Boundary Plume Group. It consists of a series of extraction wells, three GAC adsorbers (two operated in parallel and one backup), and a reinjection system (a series of reinjection wells). A slurry wall was installed between part of the extraction and reinjection well lines to reduce recirculation of the reinjected water. Section 4.2.1 provides a more detailed description of the NWBCS.

Only two alternatives, NWC-1, No Action, and NWC-2, Continued Existing Action, were retained for further analysis in the Water DAA due to the low contaminant concentrations present in the Northwest Boundary Plume Group. For the DAA, analytical data for the plumes were reviewed to determine if any changes in plume composition or concentrations had occurred that would require developing new, additional alternatives. Operating data from 1989 through 1993 for the NWBCS show that the number of contaminants present in the extraction wells are decreasing (Shell/MKE 1994). The influent water was analyzed for 18 compounds; of these, 10 were detected in 1988 and only 2 were detected in 1993. Of the three compounds that showed detection frequencies of greater than 25 percent (chloroform, diisopropylmethylphosphonate [DIMP], and dieldrin) influent concentrations have dropped to below the PRG for chloroform and decreased slightly for DIMP. Over the same period, dieldrin has maintained a fairly constant concentration of 0.3 to 0.4 µg/l, which exceeds the PRG of 0.05 µg/l. The NWBCS is currently only needed for treatment of these low levels of dieldrin. The PRGs for this system are presented in Table 2.2-1.

Time travel calculations were performed for aldrin, atrazine, chloroform, DIMP, and dieldrin to estimate the time it would take each of these compounds, if dissolved in groundwater, to travel from the Basin A Neck intercept system to the NWBCS. This was done by calculating the groundwater flow rate over this distance and then applying a retardation factor for each

compound and reflect the fact that contaminants usually migrate more slowly than the groundwater moves. Chloroform, atrazine, and DIMP have low retardation factors; that is, their movement in the aquifer is only slightly retarded, and therefore they move close to the rate at which groundwater moves. The calculated shortest travel times for these compounds were less than 2 years. Aldrin and dieldrin, on the other hand, have high retardation factors due to their strong tendency to adsorb to organic material in the aquifer and their reluctance to desorb. The calculated shortest travel times were approximately 33 years for dieldrin and 77 years for aldrin. The travel time calculation method, input parameters, and table of results are presented in Appendix C.

It should be noted that the calculated travel times only pertain to contaminants that have entered the groundwater. If a source of contamination exists, such as contaminants that are adsorbed to soil above or within the aquifer, the travel times will be controlled as much by the rate at which the contaminants enter the groundwater as by the retardation once they are in the groundwater.

A primary source of contamination to the NWBCS was cut off in 1990 when the Basin A Neck IRA began operation. Based on the travel time calculations, it is expected that fast moving contaminants such as chloroform and DIMP will be the first to decrease in concentration as a result of the Basin A Neck IRA. Other sources such as contaminants (e.g., dieldrin) sorbed to aquifer materials and the Sand Creek Lateral Plumes may continue to contribute to contamination at the NWBCS, but to a lesser degree than the higher concentrations that historically flowed through the Basin A Neck pathway.

The relatively constant concentrations of dieldrin indicate that the dieldrin plume has become smeared over a long distance, something that occurs with contaminants that exhibit high retardation factors. Any dieldrin that was present in the aquifer downstream of the Basin A Neck IRA intercept system when it began operation is still free to migrate toward the NWBCS. Based on the calculated behavior of dieldrin, the influent concentrations are likely to be maintained for more than 30 years, although actual monitoring of the plume over time is by far the most reliable

more than 30 years, although actual monitoring of the plume over time is by far the most reliable method for determining the plume composition and the need for treatment. As defined by the shut off criteria in Section 1.3.3 existing wells within the system can be removed from production when contaminant concentrations are below applicable standards and/or it can be demonstrated that discontinuing operation of a well would not jeopardize the containment objective of the system. Wells removed from operation and monitoring wells upgradient and downgradient of the system are monitored quarterly for a period of 5 years to determine if contaminants reappear. Wells are put back into production if contaminants reappear at levels exceeding standards. The need for hydraulic control may justify keeping wells without contaminant exceedances in production.

The following sections provide detailed descriptions and analyses for each of the two alternatives retained from the Water DSA (EBASCO 1992) for the Northwest Boundary Plume Group. Table 4.0-1 presents a summary of the comparative analysis of alternatives.

4.1 ALTERNATIVE NWC-1: NO ACTION

4.1.1 Description of Alternative

Alternative NWC-1 for the Northwest Boundary Plume Group involves discontinuing all current activities. Under this alternative, operation at the NWBCS is discontinued and none of the planned modifications are initiated. The slurry wall is breached by a number of permeable trenches so that the aquifer returns to its natural state rather than building up behind the slurry wall. Dismantling of remedial action support structures, such as the northwest boundary treatment buildings, are included as part of the No Future Use, Other Contamination History Medium Group in the Structures DAA. Groundwater is monitored quarterly for the first 5 years and annually for the remaining years using 10 existing wells in the Northwest Boundary Plume Group area. Figure 4.1-1 presents the No Action alternative.

4.1.2 Analysis of Alternative

4.1.2.1 Overall Protection of Human Health and the Environment

This alternative does not provide protection to human health and the environment. Under this alternative, any existing treatment facilities or IRAs are discontinued. Once the NWBCS is shut down, contaminated groundwater, albeit at low and steadily decreasing concentrations, is free to migrate off post. Human health is protected on post by the FFA, which prohibits the use of RMA groundwater as a potable water source.

4.1.2.2 Compliance with ARARs

Action-specific ARARs do not apply if Alternative NWC-1 is chosen. Because contaminated groundwater is not extracted and treated at the NWBCS, this remedial alternative does not comply with all relevant ARARs or the FFA (EPA et al. 1989) at the northwest boundary, although it does comply with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

4.1.2.3 Long-Term Effectiveness and Permanence

Alternative NWC-1 is not effective in reducing the magnitude of residual risks to off-post receptors. Because no action is taken toward controlling contaminant migration, this alternative is not effective in the long term, and low concentrations of dieldrin are free to migrate off post. Natural attenuation of untreated water will continue, but it is not known if this will be rapid enough to achieve RAOs in 30 years.

4.1.2.4 Reduction of TMV

Alternative NWC-1 does not control or treat contaminants, so the only reduction in contaminant TMV is caused by natural attenuation. Dieldrin, at low concentrations in groundwater, is free to migrate off post.

4.1.2.5 Short-Term Effectiveness

Alternative NWC-1 is not effective in the short term. This alternative causes a minimal negative impact to workers because the only action undertaken is breaching the slurry wall. However, low levels of contamination currently in the aquifer are not treated and are free to migrate off post.

4.1.2.6 Implementability

Alternative NWC-1 is technically implementable. It would require approximately 1 year to shut down the existing systems and breach the slurry wall. The alternative is not feasible, however, because it allows contaminated water that exceeds off-post/boundary PRGs to migrate off post.

4.1.2.7 Costs

The costs for Alternative NWC-1 include breaching the slurry wall, shutting down the NWBCS, and continued monitoring. The capital cost for this alternative is \$43,000. The annual operations and maintenance (O&M) costs are \$96,800 for the first 5 years and \$47,600 for the remaining 25 years, and the 30-year present worth cost is \$1,210,000. A summary of these costs is presented in Appendix A, Table A1-1.

4.2 ALTERNATIVE NWC-2: CONTINUED EXISTING ACTION

Alternative NWC-2 includes capture and treatment of the groundwater by the NWBCS as it approaches the RMA boundary. This alternative also includes continued groundwater compliance monitoring with 5-year evaluations and continued compliance with the FFA.

The current NWC-2 alternative is based on an assumed 30-year operating period. However, complete or partial shutoff of the system at an earlier date is possible pending monitoring results.

4.2.1 Description of Alternative

The NWBCS is designed to capture and treat organic contaminants, primarily dieldrin, in groundwater approaching the northwest boundary. The NWBCS includes extraction wells, a slurry wall, reinjection (recharge) wells, and a GAC adsorption system. The Short-Term

Improvements IRA (MKE 1990) was initiated to modify the system and to address the movement of low levels of dieldrin off post south of the NWBCS. The Long-Term Improvements IRA assessment (Woodward-Clyde Consultants 1991) addresses the long-term operation of the NWBCS, including the Short-Term Improvements IRA. It was assumed that under this alternative the present monitoring programs continue. Figure 4.2-1 presents the Continued Existing Action alternative.

4.2.1.1 Extraction/Reinjection

The original slurry wall was installed along the northwest boundary to minimize migration of the contaminated groundwater flowing across that boundary. The wall, constructed of soil/bentonite, originally measured 1,425 ft long by 3 ft wide by approximately 30 ft deep. The slurry wall extended approximately one-half the length of the extraction/injection system; therefore, a significant volume of treated water that was reinjected recirculated back through the extraction system around the ends of the slurry wall. Originally, a total of 15 extraction wells were used to remove groundwater and 21 reinjection wells were used for recharge. Five extraction wells were located along the slurry wall and the other 10 were installed to the southwest, with no slurry wall between the extraction and reinjection wells.

In October 1990, Phase I of the Short-Term Improvements IRA was completed, which extended the slurry wall an additional 665 ft in the northeast direction to intercept groundwater flowing through the alluvial channel to the northeast. The slurry wall extension was keyed a minimum of 10 ft into the existing slurry wall and the extension ranged from 28 to 35 ft deep. Two additional extraction wells, pumping approximately 1 to 2 gpm each, were also added along the new extension under Phase I of the Short-Term Improvements IRA. In October 1991 under Phase II of the Short-Term Improvements IRA, three extraction wells were also installed just southwest of the NWBCS, as were four reinjection wells to the southeast of the newly installed extraction wells. The reinjection wells were installed to maintain a separation between contaminants migrating to the north versus contaminants migrating to the northwest and to push groundwater toward the NWBCS along a small, localized groundwater divide. The new

southwest extension currently extracts 425 gpm and reinjects approximately 230 gpm with the balance (195 gpm) reinjected at the original NWBCS system (James 1995). The rest of the NWBCS extracts and reinjects approximately 600 gpm and 795 gpm, respectively, for a total system flow of approximately 1,025 gpm (James 1995). The Long-Term Improvements IRA includes the Short-Term Improvements IRA as well as monitoring of the entire NWBCS. Seven monitoring wells were installed in March 1992 as part of the Long-Term Improvements IRA, which was completed in July 1993. Quarterly sampling was conducted from April 1992 to January 1993. Quarterly groundwater sampling will be continued for the first 5 years of the FS, and annual sampling will be performed for the remaining years.

Treated water is currently discharged into an effluent sump from which the water is pumped (using two 500-gpm pumps) through a recharge header pipe to the reinjection (recharge) wells. The system includes two 500-gpm backup pumps. There are 25 recharge wells that range in depth from approximately 40 ft to 60 ft below the ground surface.

4.2.1.2 Treatment

Groundwater is pumped from the extraction wells to the influent sump adjacent to the treatment building. Currently, the treatment system consists of three identical GAC vessels, two of which are operated in parallel; the third is used as a backup unit. Each vessel contains 40,000 pounds (lbs) (1,400 cubic feet [ft³]) of carbon, is operated in an upflow mode, and has a design capacity of 500 gpm and a residence time of 22 minutes. Each of the two on-line carbon vessels treats approximately 500 gpm of water.

The treatment plant also includes a 30,000-lb storage tank for fresh carbon and a 20,000-lb storage tank for spent carbon. Water is pumped from the influent sump through three parallel automatic backwashing filters (100 microns) to remove suspended solids prior to entering the GAC vessels. The effluents from the vessels pass through three more parallel filters where suspended solids, such as carbon fines, are removed. Overflow and backwash streams are recycled through the carbon units.

4.2.1.3 Sidestreams

The NWBCS generates two sidestreams requiring treatment or disposal: spent carbon and filter solids. The spent carbon in the adsorbers is removed and regenerated at an off-post facility. The filter solids and filter bag materials are drummed and disposed in an off-post landfill regulated by the Resource Conservation and Recovery Act (RCRA).

4.2.2 Analysis of Alternative

4.2.2.1 Overall Protection of Human Health and the Environment

Alternative NWC-2 provides protection of human health and the environment. Groundwater is captured and treated to PRGs before it leaves the northwest boundary, which protects the surrounding communities from potential exposure to contaminants via groundwater. Human health is protected on post by the FFA (EPA et al. 1989), which prohibits the use of RMA groundwater as a potable water source.

4.2.2.2 Compliance with ARARs

Alternative NWC-2 is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls, because it uses an existing system that complies with the ARARs identified for this system. The existing system also complies with the FFA (EPA et al. 1989) and with all chemical-specific ARARs at the boundary so long as the Northwest Boundary PRGs are achieved through continued operation of the NWBCS, and ensures compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

4.2.2.3 Long-Term Effectiveness and Permanence

There is low residual risk associated with Alternative NWC-2 because the contaminants in groundwater are treated to PRGs before the water migrates off post. The alternative provides adequate controls, but long-term maintenance is required to ensure the reliability of the NWBCS. The treatment system may require more than 30 years of operation to ensure continued protection of the surrounding community, although declining influent concentrations may lead to shutdown

of the system in specific wells at an earlier date if the shutoff criteria given in Section 1.3.3 are met.

4.2.2.4 Reduction of TMV

Alternative NWC-2 reduces the TMV of contaminants in groundwater through GAC adsorption, which requires regeneration of the spent carbon. The NWBCS is currently treating approximately 1,025 gpm of contaminated groundwater.

4.2.2.5 Short-Term Effectiveness

Alternative NWC-2 provides worker protection under the existing health and safety plan at the NWBCS as well as under any future plans. The community is protected under this alternative because groundwater treatment at the NWBCS minimizes the potential for off-post migration of contaminants.

4.2.2.6 Implementability

Alternative NWC-2 is technically and administratively implementable. The control/treatment systems are currently operating, making this alternative readily implementable.

4.2.2.7 Costs

The costs for this alternative include continued operation of the NWBCS. There are no capital costs associated with this alternative. The annual O&M costs are \$1,130,000 for the first 5 years and \$1,080,000 for the next 25 years, and the 30-year present worth cost is \$21,500,000. A summary of these costs is presented in Appendix A, Table A1-2.

4.3 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section describes the selection of one or more alternatives for the Northwest Boundary Plume Group to be incorporated into sitewide alternatives for RMA groundwater (see Section 9). In this step of the DAA process, a comparative analysis of each of the retained alternatives, each against the EPA screening criteria and each against the others, is performed.

The two alternatives considered for the Northwest Boundary Plume Group are NWC-1, the No Action alternative, which involves removal of existing systems, and NWC-2, the Continued Existing Action alternative, which involves continued operation of NWBCS.

4.3.1 Overall Protection of Human Health and the Environment

Both alternatives are protective of human health and the environment on post as a result of the FFA (EPA et al. 1989). Alternative NWC-2 is also protective of off-post human health and the environment. Alternative NWC-1 is not protective of off-post human health or the environment and may actually lead to increased risk of exposure off post because operation of the boundary containment system is discontinued.

4.3.2 Compliance with ARARs

Alternative NWC-2 is in compliance with all ARARs, while Alternative NWC-1 does not comply with the chemical-specific ARARs identified for the NWBCS or with the FFA (EPA et al. 1989).

4.3.3 Long-Term Effectiveness and Permanence

Alternative NWC-2 reduces concentrations in plumes migrating off post to acceptable levels and provides adequate controls so long as long-term operation is maintained. Alternative NWC-1 increases the potential for off-post exposure relative to Alternative NWC-2 because all existing controls are removed.

4.3.4 Reduction of TMV

Contaminants are irreversibly removed from RMA groundwater by GAC adsorption under Alternative NWC-2, which significantly reduces contaminant toxicity and volume. This extraction and treatment system also reduces contaminant mobility. Alternative NWC-1, on the other hand, is likely to result in increases in toxicity and volume of contaminated groundwater as well as an increase in contaminant migration across the RMA boundary because all controls are removed. Reduction in contaminant levels through natural attenuation is insignificant as compared to the reduction through treatment provided under Alternative NWC-2.

4.3.5 Short-Term Effectiveness

Alternative NWC-2 has minimal negative impact on the environment, workers, and surrounding community. The breaching of the slurry wall under Alternative NWC-1 could have some potential impact on workers but no impact on the surrounding community. The discontinuation of treatment allows contamination to migrate off post, thereby increasing the risk to the community and environment. RAOs are achieved through Alternative NWC-2 but not through Alternative NWC-1.

4.3.6 Implementability

Alternative NWC-2 is technically and administratively feasible and easily implemented because it is already operational. Alternative NWC-1 is technically, but not administratively, feasible because it does not comply with the FFA (EPA et al. 1989).

4.3.7 Costs

There are no capital costs associated with Alternative NWC-2. The capital cost of breaching the slurry wall in Alternative NWC-1 is \$43,000. Annual O&M costs are significantly lower for Alternative NWC-1 (\$96,800 and \$47,600) than for Alternative NWC-2 (\$1,130,000 and \$1,080,000), and the present worth cost is also lower for Alternative NWC-1. However, the costs for Alternative NWC-1 only cover dismantling the existing system and monitoring, while the higher costs for Alternative NWC-2 cover continued capture and treatment to both achieve RAOs as well as continue monitoring.

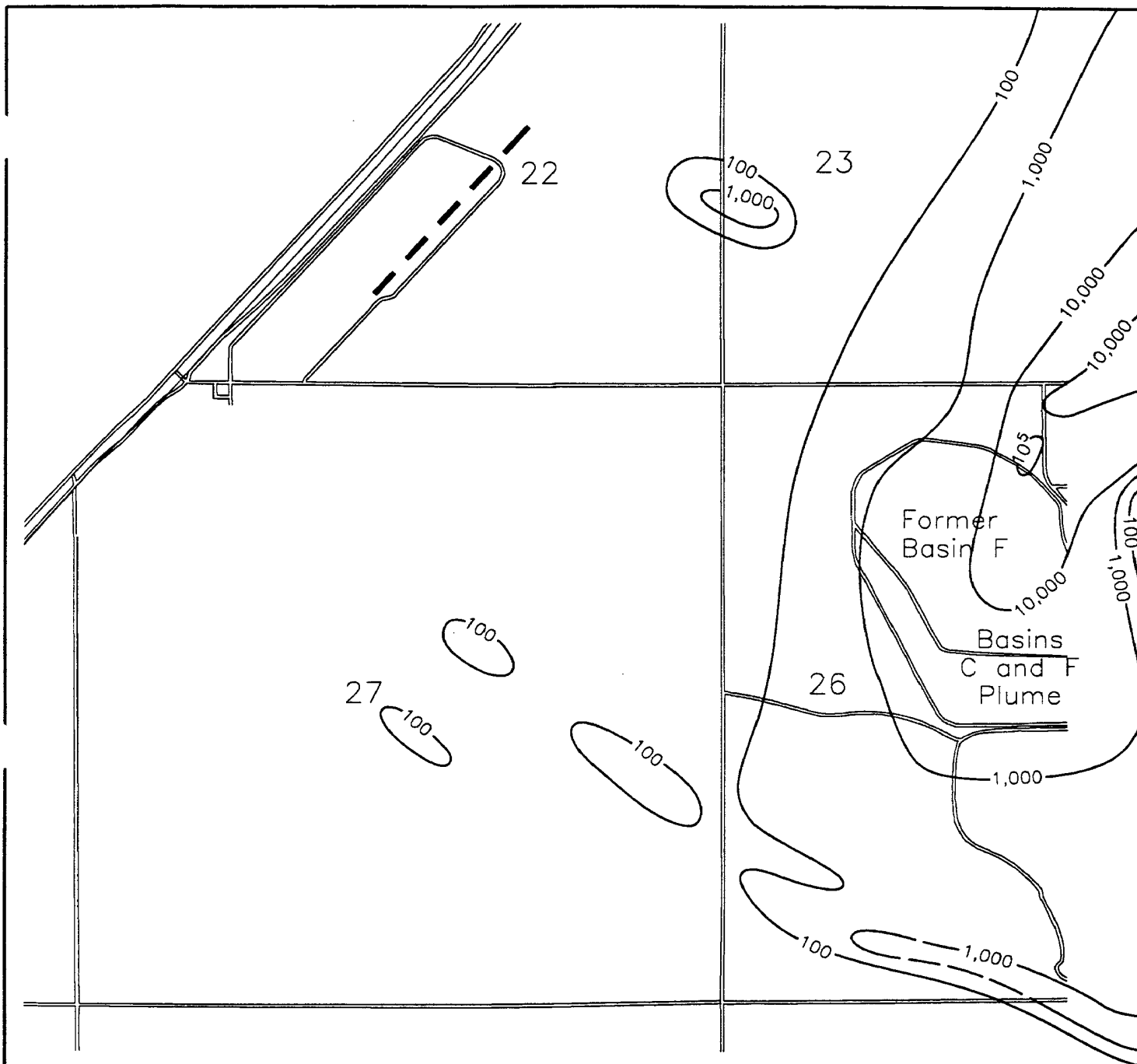
4.3.8 Summary

The comparative analysis of Alternatives NWC-1 and NWC-2 shows that Alternative NWC-2 satisfies all seven EPA evaluation criteria while Alternative NWC-1 does not. Alternative NWC-1 does not provide protection of off-post human health and the environment, is not in compliance with ARARs, may increase potential for off-post exposure in the long term, may potentially lead to an increase in TMV, and is not administratively feasible because it does not comply with the FFA (EPA et al. 1989).

The alternative that is retained for consideration for the Northwest Boundary Plume Group as part of the sitewide alternatives for groundwater (Section 9) is the following:

- Alternative NWC-2: Continued Existing Action

Criteria	ALT NWC-1 No Action	ALT NWC-2 Continued Existing Action
1. Overall protection of human health and the environment	Does not meet RAOs at the boundary; contamination free to migrate off post	Reduces potential exposure to acceptable levels
2. Compliance with ARARs	Complies with location-specific ARARs but not chemical-specific ARARs; action-specific ARARs do not apply	Complies with action-, location-, and chemical-specific ARARs and the FFA
3. Long-term effectiveness and permanence	Potential for off-post exposure due to contaminant migration Existing controls removed	NWBCS minimizes potential for off-post exposure Adequate controls, but long-term maintenance required
4. Reduction of TMV	No treatment undertaken TMV reduced over time by natural attenuation	Contaminants removed by GAC adsorption of 1,025 gpm at NWBCS Contaminants irreversibly transferred to GAC, which requires regeneration
5. Short-term effectiveness	Minimal negative impact on workers and surrounding community Contamination free to migrate off post Natural attenuation of untreated groundwater ongoing but does not meet RAOs	Minimal negative impact on workers or surrounding community No additional impact on environment Achieves RAOs; system may be required to operate at least 30 years
6. Implementability	Technically feasible Not administratively feasible: does not comply with FFA	Technically and administratively feasible Already operational
7. Costs		
–Capital Cost	\$43,000	\$0
–Annual O&M Cost	\$96,800 (yrs 1-5) \$47,600 (yrs 6-30)	\$1,130,000 (yrs 1-5) \$1,080,000 (yrs 6-30)
–Present Worth	\$1,210,000	\$21,500,000



LEGEND

100 Summed Concentration of organic analytes
(Table 3.1-2) in unconfined aquifer (ug/L)

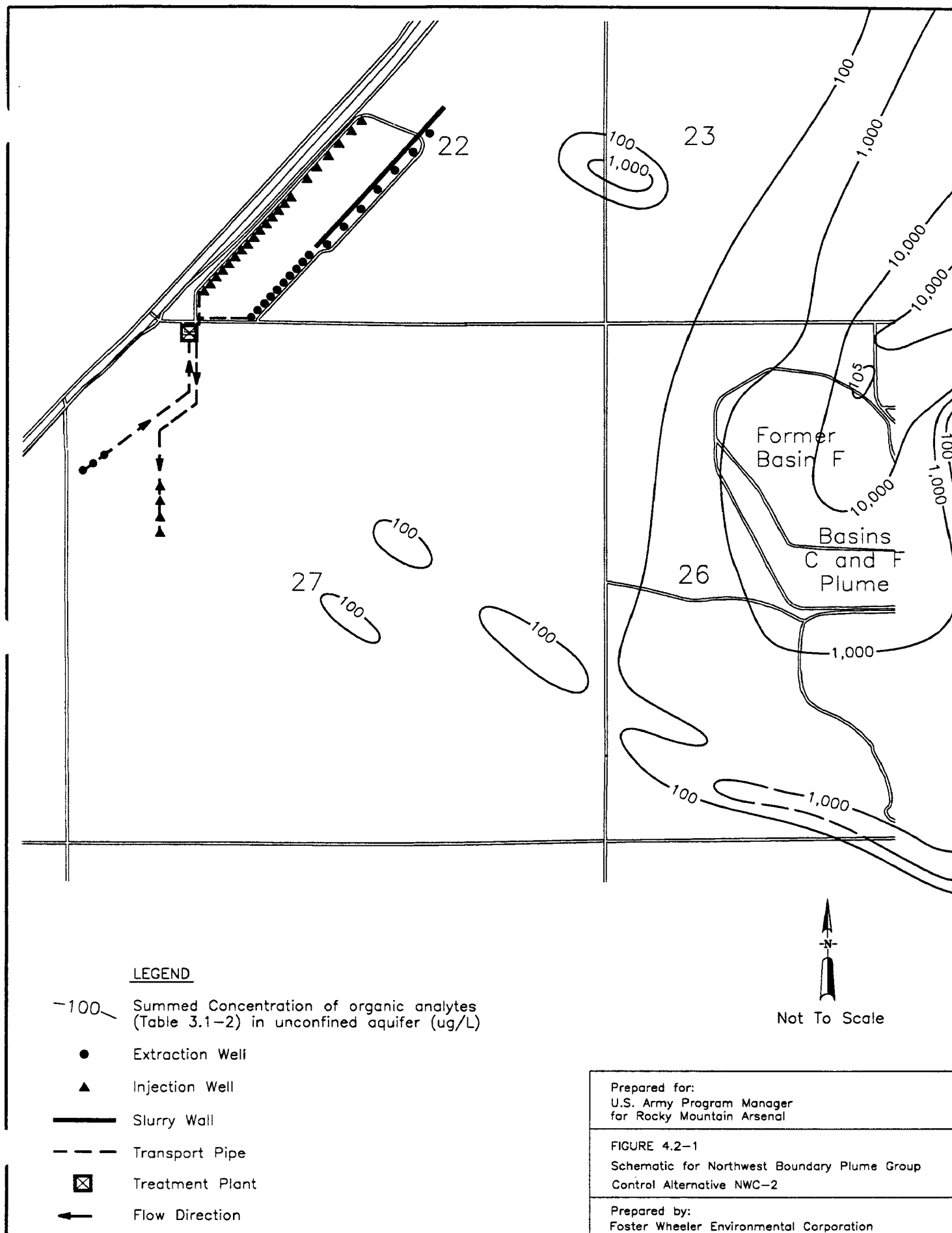
— — Perforated Slurry Wall

Not To Scale

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

FIGURE 4.1-1
Schematic for Northwest Boundary Plume Group
Control Alternative NWC-1

Prepared by:
Foster Wheeler Environmental Corporation



Section 5

5.0 WESTERN PLUME GROUP

The Western Plume Group consists of three plumes—the Western, Rail yard, and Motor Pool Plumes—that coalesce southeast of the ICS, which is located in the northwestern corner of Section 33 along the RMA boundary. The contaminant levels are very low and are controlled through treatment. The concentrations of trichloroethylene (TCE) and dibromochloropropane (DBCP), previously the major contaminants in the three plumes composing the Western Plume Group, have decreased within the Western Plumes over the past 5 years as a result of effective capture systems in the Motor Pool and Rail yard areas. Data presented by Shell/MKE (1994) show a significant decrease in DBCP in the ICS influent from 1987 to 1991, when water from the Rail Classification Yard IRA began to be pumped to the ICS, and a subsequent reduction from 1991 to 1993. The average influent concentration of DBCP in 1995 was less than its detection limit of 0.06 µg/l and well below 0.2 µg/l PRG. The same Shell study also shows that TCE in the ICS influent decreased steadily until the Motor Pool IRA extraction system became operational in 1991. This system added a significant amount of TCE to the ICS influent, but the TCE influent mass was substantially reduced in 1993 compared to the two previous years. It should also be noted that the 1995 average TCE concentration was below the 5 µg/l PRG. The concentrations listed in Table 2.2-2 confirm that the concentrations in the plumes are very low, in most cases less than the PRGs.

Recent concerns about elevated levels of nitrate and dichloroethylene (DCE) outside the western boundary of RMA are being investigated. RMA is not a contributor of these contaminants. There are no significant sources for DCE in any of the potential on-post source areas for the Western Plume. The observed increases in nitrate concentrations are not caused by any on-post activities. The sources of these contaminants are located south of RMA, and studies are being conducted to locate the sources, assess whether there is a problem and, if so, deal with it appropriately. A study of the nitrate problem conducted for the South Adams County Water and Sanitation District (SACWSD) includes maps that indicate that nitrate enters the Arsenal from Section 10 (Black and Veatch 1994).

Three control systems, the ICS and two IRAs, are currently in place and operating to capture and treat contamination in the three Western Plumes. The largest of these systems is the ICS, which was designed to remove DBCP from the groundwater using GAC adsorption. Four additional extraction wells, an upgrade to the ICS, were constructed approximately 2,000 ft upgradient of the existing ICS. Two IRA extraction systems were also constructed to control contaminant sources in the area: the Rail Classification Yard IRA was constructed to capture DBCP, and the Motor Pool Area IRA was constructed to capture trichloroethylene contamination. Extraction wells from the Motor Pool Area and Rail Classification Yard IRAs pump water to the ICS for treatment by GAC adsorption prior to reinjection at the ICS. In addition, the SACWSD wells capture and extract a portion of the Western Plume. Section 5.2 discusses the many modifications to the ICS in more detail.

The following sections provide detailed descriptions and analyses for each of the two alternatives retained from the Water DSA (EBASCO 1992). Table 5.0-1 presents a summary of the analyses. Only two alternatives were retained in the Water DSA due to low contaminant concentrations. In the DAA, plume characteristics were again evaluated and were found not to warrant development and analysis of additional treatment alternatives. However, a variation to one existing alternative, Alternative WC-2A, was added during the DAA. This alternative involves continued operation of the ICS without the IRAs. In addition, Appendix C contains travel time calculations for TCE in groundwater.

5.1 ALTERNATIVE WC-1: NO ACTION

Alternative WC-1 consists of discontinuing operation of the existing ICS and any planned upgrades and discontinuing any existing and planned IRAs.

5.1.1 Description of Alternative

This alternative does not include any current or future remedial activities, and any such activities that are in place are discontinued. The ICS is currently in place to prevent off-post migration of the contaminants within the Western Plume Group. This is a pump-and-treat system that uses

extraction wells, GAC adsorption (to remove organic contaminants), and reinjection wells. Two IRAs that supplement the ICS became operational in September 1991: the Rail Classification Yard IRA and the Motor Pool Area IRA (MKC 1992). The Rail Classification Yard IRA consists of extraction wells upgradient of the ICS that pump water from the Rail yard Plume. Similarly, the Motor Pool Area IRA uses extraction wells upgradient of the ICS to pump water from the Motor Pool Plume. Extracted water from both of these plumes is piped to the ICS for treatment and reinjection.

Under this alternative, operation of the ICS and the two IRAs is discontinued. Dismantling of remedial action support structures, such as ICS treatment buildings, is included as part of the No Future Use, Other Contamination History Medium Group in the Structures DAA. Groundwater monitoring using 15 existing wells is conducted quarterly. Figure 5.1-1 presents the No Action alternative.

No treatment is associated with this alternative. Current treatment with GAC is discontinued.

5.1.2 Analysis of Alternative

5.1.2.1 Overall Protection of Human Health and the Environment

Alternative WC-1 does not ensure protection of human health and the environment off post because it involves elimination of both the ICS capture and treatment system and the Motor Pool Area and Rail Classification Yard IRAs, systems that rely on the ICS for treatment. Elimination of current controls results in increased contaminant migration on post and off post. Human health is protected on post by the FFA, which prohibits the use of RMA groundwater as a potable water source.

5.1.2.2 Compliance with ARARs

Action-specific ARARs do not apply if Alternative WC-1 is chosen because contaminated groundwater is not extracted and treated at the ICS to achieve PRGs. This alternative is not in compliance with the FFA (EPA et al. 1989), nor does it comply with all chemical-specific

ARARs identified for the ICS. This alternative complies with location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

5.1.2.3 Long-Term Effectiveness and Permanence

Under Alternative WC-1, the lack of groundwater controls and treatment leads to a potential for off-post exposure as a result of unrestricted contaminant migration. Therefore, this alternative does not achieve long-term effectiveness and permanence.

5.1.2.4 Reduction of TMV

Alternative WC-1 does not provide any significant reduction in contaminant TMV because no active extraction/treatment is undertaken. The removal of existing controls results in increased contaminant migration and increased contaminant TMV. There may, however, be a slight reduction in TMV over time as a result of natural attenuation.

5.1.2.5 Short-Term Effectiveness

There is minimal exposure to workers, the surrounding community, or the environment associated with shutdown of the ICS and the Motor Pool Area and Rail Classification Yard IRAs. The protection that is currently provided through the ICS and the Rail Classification Yard and Motor Pool Area IRAs is eliminated, resulting in potential increase in contaminant levels. RAOs are not achieved through this alternative.

5.1.2.6 Implementability

Alternative WC-1 is technically feasible. However, because it does not meet RAOs and is not in compliance with the FFA (EPA et al. 1989), it is not administratively feasible.

5.1.2.7 Costs

There is no capital cost associated with this alternative. The O&M costs associated with monitoring amount to \$149,000 per year for the first 5 years and \$68,400 per year for the next

25 years, and the present worth cost is \$1,760,000. A summary of these costs is presented in Appendix A, Table A2-1.

5.2 ALTERNATIVE WC-2: CONTINUED EXISTING ACTION

Alternative WC-2 involves continued operation of the existing extraction and treatment systems including the ICS, the Rail Classification Yard IRA, and the Motor Pool Area IRA for the Western Plume Group. Groundwater monitoring is continued on a quarterly basis using existing wells and provisions of the FFA (EPA et al. 1989) are enforced.

This alternative involves the operation of the Irondale System and the Rail yard and Motor Pool Plume IRAs for another 4 years, at which time it is estimated, based on current data, that the shutoff criteria listed in Section 1.3.3 will be achieved. All assumptions and calculations for this alternative are based on an additional 4-year operating period.

5.2.1 Description of Alternative

5.2.1.1 Extraction/Reinjection

Originally, the ICS consisted of two rows of extraction wells and one row of recharge wells. A number of modifications to the ICS system configuration were completed by 1991 to arrive at the current system. Figure 5.2-1 shows all wells, the original wells that have been converted or are no longer operating and the wells that have been added over time. The extraction systems have changed as some wells have reached cleanup goals and more contaminated wells have been added to the system. Six of the original extraction wells are currently operating as extraction wells and three of the original extraction wells have been converted to injection wells. Nine new recharge wells, which reduce the water table depression caused by heavy SACWSD pumping rates and which enlarge the zone of captured groundwater on the south edge of the ICS, were installed south of the original system. Additionally, four new extraction wells, three of which are currently operating, were installed 2,000 ft upgradient of the original ICS in an area of greater saturated thickness than the original ICS extraction wells. These wells, referred to as the east row of extraction wells, are located such that SACWSD pumping has a minimal effect on the capture

of the Motor Pool and Rail Classification Yard Plumes, which allows the wells to operate at a more consistent extraction rate. Finally, an existing extraction well in the original system was changed to become a recharge well (MKC 1992). The total flow rate of the ICS extraction system is approximately 700 gpm, and when combined with the Rail Classification Yard and Motor Pool Area IRAs, is approximately 1,030 gpm, both as of August 1995 (James 1995).

IRA system modifications include the installation of seven new extraction wells under the Rail Classification Yard IRA to intercept DBCP contamination and two extraction wells installed under the Motor Pool IRA to intercept a trichloroethylene plume. These wells became operational in September 1991. Five of the seven wells in the Rail Classification Yard IRA are pumping at a total rate of approximately 230 gpm (James 1995); the two other wells are backup extraction wells and have not been used. The two wells in the Motor Pool area are pumping approximately 100 gpm (James 1995). The groundwater that is extracted from the Motor Pool Area and Rail Classification Yard extraction wells (320 gpm) is pumped from the wells through a metering station to a manifold and then flows by gravity via an 8-inch-pipeline to the ICS.

5.2.1.2 Treatment

All groundwater extracted from the Western Plume Group is treated at the ICS. The water is collected in an influent sump and is treated with GAC adsorption before being reinjected into the aquifer. The treatment plant has three existing treatment trains, each capable of treating a maximum of 700 gpm, although historically only two of the trains were ever run simultaneously.

To allow for additional flow resulting from the Rail Classification Yard and Motor Pool Area IRAs, the capacity of the treatment system was increased by bringing the third GAC bed on line, although this option has not been required with present flow rates (the ICS is treating approximately 1,030 gpm as of August 1995) (James 1995). With all three trains operating in parallel, the ICS has a maximum design capacity of 2,100 gpm.

5.2.1.3 Sidestreams

The ICS generates two sidestreams requiring treatment or disposal: spent carbon and filter solids. The spent carbon in the adsorbers is removed and regenerated at an off-post facility. The filter solids and cartridge filters are drummed and disposed in a RCRA-approved landfill off post.

5.2.2 Analysis of Alternative

5.2.2.1 Overall Protection of Human Health and the Environment

Alternative WC-2 involves continued operation of the ICS and the Motor Pool Area and Rail Classification Yard IRAs to ensure that PRGs are met at the RMA boundary, thereby protecting human health and the environment off post. Continued extraction from the Rail yard and Motor Pool Plumes reduces the migration of contaminated water on post. Human health is protected on post by the FFA (EPA et al. 1989), which prohibits the use of RMA groundwater as a potable water source.

5.2.2.2 Compliance with ARARs

Alternative WC-2 is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls, because it uses an existing system that complies with these ARARs. The existing system also complies with the chemical-specific ARARs identified for the ICS and with the FFA (EPA et al. 1989). Operation of the ICS is in compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

5.2.2.3 Long-Term Effectiveness and Permanence

Continued operation of ICS reduces the potential for off-post exposure to acceptable levels, and the controls provided by Alternative WC-2 are adequate. The system will operate until criteria for shutoff are met, which is estimated to be 4 years.

5.2.2.4 Reduction of TMV

The contaminated groundwater is extracted and treated by GAC adsorption at a rate of 1,030 gpm, which results in a significant reduction of contaminant TMV. The contaminants are irreversibly removed from RMA groundwater through transfer to GAC, which requires regeneration off post.

5.2.2.5 Short-Term Effectiveness

This alternative has minimal negative impact on workers or surrounding communities because no additional actions are undertaken and no existing actions are removed. There is no additional impact on the environment. This alternative achieves RAOs through continued operation of the ICS.

5.2.2.6 Implementability

The system is already operational, and continued operation is technically and administratively feasible.

5.2.2.7 Costs

There is no capital cost associated with this alternative. The O&M costs are \$895,000 per year for the first 4 years and \$91,000 per year for the next 26 years, and the present worth cost is \$4,910,000. These costs are summarized in Appendix A, Table A2-2.

5.3 ALTERNATIVE WC-2A: CONTINUED OPERATION OF ICS

Alternative WC-2A includes continued operation of the existing boundary treatment system for the Western Plume Group but does not include operation of the two IRAs that feed into the treatment plant. In addition, groundwater monitoring is continued on a quarterly basis using existing wells and provisions of the FFA (EPA et al. 1989) are enforced.

5.3.1 Description of Alternative

5.3.1.1 Extraction/Reinjection

Under Alternative WC-2A, the ICS extraction and reinjection systems continue as currently operated (see Section 5.2.1.1) except that extraction wells installed for the Rail Classification Yard and Motor Pool IRA will be turned off. Figure 5.3-1 shows all wells, both operating and nonoperating that are included in this system. Some of these wells are no longer in use because cleanup goals have been met. This alternative involves the original system of extraction and reinjection wells along the RMA boundary, the nine new recharge wells to the south, and the four new extraction wells to the southeast. These wells capture groundwater from the Western Plume Group as it moves toward the RMA boundary. Contaminants in the Motor Pool and Rail Yard Plumes will continue to migrate into the Western Plume and be captured by the ICS. The extraction rate for the ICS system is approximately 780 gpm. Figure 5.3-1 represents Alternative WC-2A.

5.3.1.2 Treatment

All groundwater extracted from the Western Plume Group is treated at the ICS under Alternative WC-2A. The water is collected in an influent sump located adjacent to the treatment plant building. Two 700-gpm influent pumps feed two parallel 700-gpm treatment trains. Each treatment train consists of three cartridge prefilters, one GAC adsorber, and three cartridge postfilters. Two banks of bag guard filters are used by each treatment train. The GAC adsorbers are 10 ft in diameter, 16 ft high, and contain 42,000 lbs of carbon each; they are operated in the upflow mode with a contact time of 15 minutes. Approximate carbon consumption for the ICS is 30,000 lbs per year, and it continues to decrease.

5.3.1.3 Sidestreams

The ICS generates two sidestreams, spent carbon and filter solids, that require treatment or disposal. The spent carbon in the adsorbers is removed and regenerated at an off-post facility. The filter solids and cartridge filters are drummed and disposed in a RCRA-approved landfill off post.

5.3.2 Analysis of Alternative

5.3.2.1 Overall Protection of Human Health and the Environment

Alternative WC-2A involves continued operation of the ICS to ensure PRGs are met at the RMA boundary, thereby protecting human health and the environment off post. Human health is protected on post by the FFA (EPA et al. 1989), which prohibits the use of RMA groundwater as a potable water source. Contaminants in the Rail Yard and Motor Pool Plumes will continue to migrate to the boundary through the aquifer and be extracted and treated by the ICS, although the operation of the Rail Yard and Motor Pool IRAs for the past several years has significantly reduced the concentrations of contaminants in these plumes.

5.3.2.2 Compliance with ARARs

Alternative WC-2A is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls, because it uses an existing system that complies with these ARARs. The existing system also complies with the chemical-specific ARARs identified for the ICS and with the FFA (EPA et al. 1989). Operation of the ICS is also in compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

5.3.2.3 Long-Term Effectiveness and Permanence

Alternative WC-2A reduces the potential for off-post exposure to acceptable levels. The extraction and reinjection system adequately captures the contaminant plume as it moves to the RMA boundary and the treatment plant removes contaminants effectively. The system will operate until criteria for shutoff are met, which is estimated to be 4 years.

5.3.2.4 Reduction of TMV

Under Alternative WC-2A, the contaminated groundwater is extracted and treated by GAC adsorption at a rate of 700 gpm, which results in a significant reduction of contaminant TMV. The contaminants are irreversibly removed from RMA groundwater through transfer to GAC, which requires regeneration off post.

5.3.2.5 Short-Term Effectiveness

Alternative WC-2A has minimal negative impact on workers or surrounding communities because no additional actions are undertaken and the Motor Pool and Rail Yard IRAs are simply shut down. There is no additional impact on the environment. This alternative achieves RAOs through continued operation of the ICS. The system is expected to operate for 4 years.

5.3.2.6 Implementability

The system is already operational, and continued operation is technically and administratively feasible.

5.3.2.7 Costs

There is no capital cost associated with this alternative. The O&M costs are \$880,000 per year for the first 4 years and \$92,000 per year for the next 26 years, and the present worth cost is \$4,890,000. These costs are summarized in Appendix A, Table A2-2A.

5.4 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section describes the selection of one or more alternatives for the Western Plume Group to be incorporated into sitewide alternatives for groundwater at RMA (see Section 9). In this step of the DAA process, a comparative analysis of each of the retained alternatives, against the EPA screening criteria and each against the others, is performed.

Three alternatives were considered for the Western Plume Group: WC-1, the No Action alternative, which involves removal of the existing system; WC-2, the Continued Existing Action alternative, which involves continued operation of the ICS pump-and-treat system and the Motor Pool Area and Rail Classification Yard IRA capture systems; and WC-2A, Continued Operation of the ICS, which involves continued operation of the ICS pump-and-treat system.

5.4.1 Overall Protection of Human Health and the Environment

All alternatives are protective of human health and the environment on post as a result of the FFA. Alternatives WC-2 and WC-2A are protective of human health and the environment off post because PRGs are met at the boundary. The IRA capture systems, included in Alternative WC-2, accelerate treatment of the plume group. Alternative WC-1 does not provide protection of human health or the environment off post because contamination is allowed to migrate freely off post.

5.4.2 Compliance with ARARs

Alternatives WC-2 and WC-2A are in compliance with all ARARs, while Alternative WC-1 does not comply with chemical-specific ARARs at the boundary or with the FFA (EPA et al. 1989).

5.4.3 Long-Term Effectiveness and Permanence

Continued operation of the ICS under Alternatives WC-2 and WC-2A minimizes the potential for off-post exposure by removing contaminants at the RMA boundary. Alternative WC-2 provides additional treatment through continued operation of the Motor Pool Area and Rail Classification Yard IRAs, which reduces the mass of contamination that will reach the ICS. Alternative WC-1 results in a potential for off-post exposure because contaminants are allowed to migrate off post. The controls provided under Alternatives WC-2 and WC-2A are adequate but may require long-term maintenance. All existing controls are removed under Alternative WC-1.

5.4.4 Reduction of TMV

Alternatives WC-2 and WC-2A provide for irreversible removal of contaminants from water captured at the boundary and, for Alternative WC-2, in the Motor Pool and Rail Classification Yard areas through GAC treatment. This results in a significant reduction in contaminant TMV. Under Alternative WC-1, natural attenuation of contamination is expected to only slightly decrease contaminant TMV.

5.4.5 Short-Term Effectiveness

Alternatives WC-2 and WC-2A have minimal negative impact on the environment, workers, and surrounding community because they already are operational, and Alternative WC-1 has minimal negative impact because discontinuation of the actions is easily and safely implemented. Alternatives WC-2 and WC-2A are not expected to have any additional impact on the environment, while Alternative WC-1 allows contamination to migrate off post. Alternatives WC-2 and WC-2A achieve RAOs while Alternative WC-1 does not.

5.4.6 Implementability

Alternatives WC-2 and WC-2A are technically and administratively feasible. Alternative WC-2 is already operational and Alternative WC-2A can be made operational by turning off the pumps in the extraction wells in the Motor Pool and Rail Classification Yard areas. Alternative WC-1 is technically but not administratively feasible because it does not comply with PRGs or the FFA (EPA et al. 1989).

5.4.7 Costs

There are no capital costs associated with any of these alternatives. The O&M costs of Alternative WC-1 (\$149,000 per year for years 1-5) are significantly lower than for Alternatives WC-2 and WC-2A (\$895,000 and \$880,000, respectively, for years 1-4). The same is true for the present worth costs: \$1,760,000 for Alternative WC-1, \$4,910,000 for Alternative WC-2, and \$4,890,000 for Alternative WC-2A. However, Alternative WC-1 costs only include monitoring; costs for Alternatives WC-2 and WC-2A, which are higher, include treatment.

5.4.8 Summary

The comparative analysis of Alternatives WC-1, WC-2, and WC-2A shows that Alternatives WC-2 and WC-2A satisfy all seven EPA evaluation criteria while WC-1 does not. Alternative WC-1 does not provide protection of human health and the environment off post, is not in compliance with ARARs, may increase the potential for off-post exposure in the long term, may

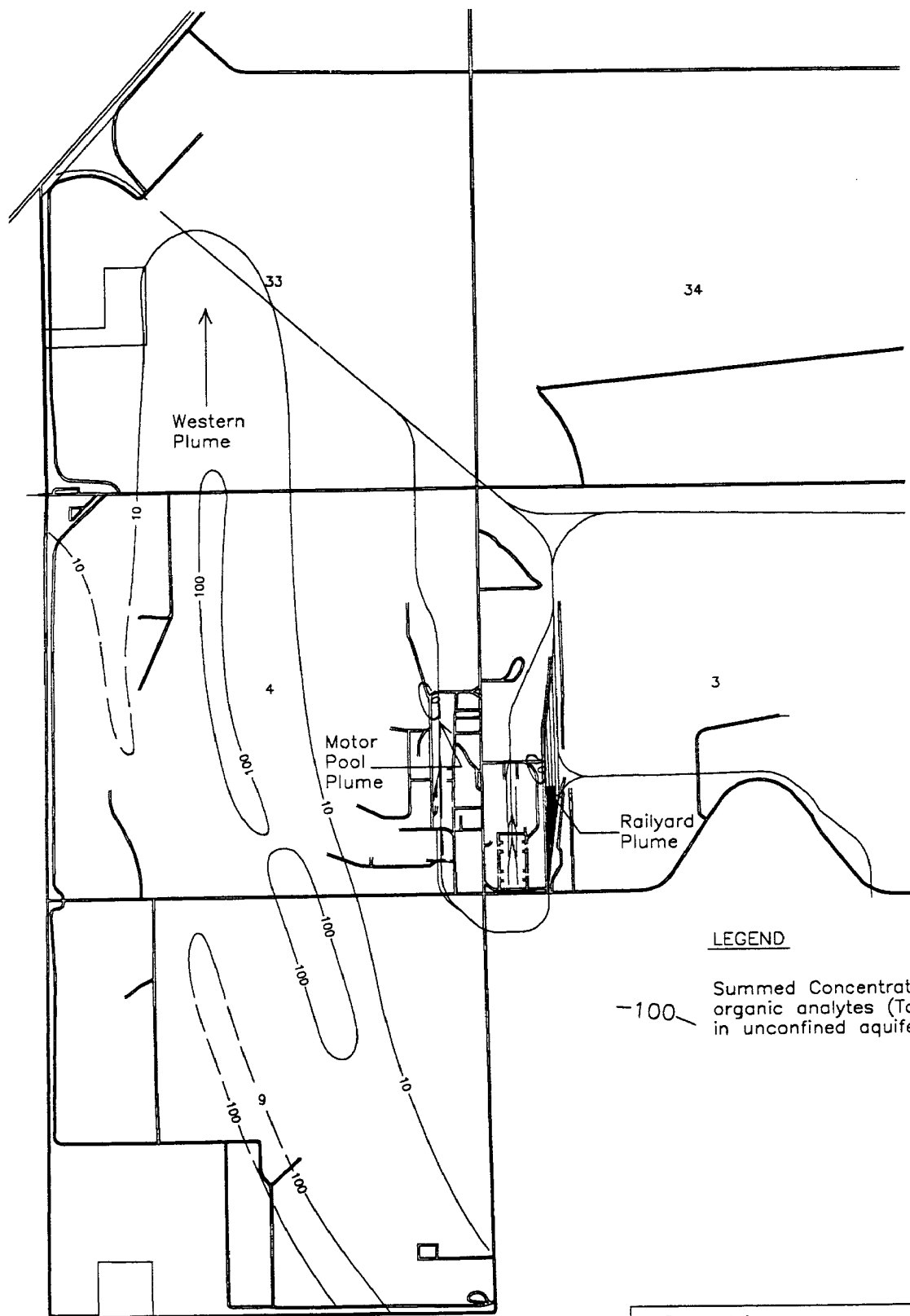
potentially lead to an increase in TMV, and is not administratively feasible because it does not comply with the FFA (EPA et al. 1989).

The alternatives that are retained for consideration for the Western Plume Group as sitewide alternatives for groundwater include the following:

- Alternative WC-2: Continued Existing Action
- Alternative WC-2A: Continued Operation of the ICS

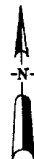
Table 5.0-1 Comparative Analysis of Alternatives: Western Plume Group

Criteria	ALT WC-1 No Action	ALT WC-2 Continued Existing Action	ALT WC-2A Continued Operation of the ICS
1. Overall protection of human health and the environment	Does not meet RAOs at the boundary; contamination free to migrate off post	Reduces potential exposure to acceptable levels	Reduces potential exposure to acceptable levels
2. Compliance with ARARs	Does not comply with chemical-specific ARARs or the FFA; complies with location-specific ARARs Action-specific ARARs do not apply	Complies with action-, location-, and chemical-specific ARARs and the FFA	Complies with action-, location-, and chemical-specific ARARs and the FFA
3. Long-term effectiveness and permanence	Potential for off-post exposure due to contaminant migration Existing controls removed	ICS minimizes potential for off-post exposure Adequate controls, but long-term maintenance required	ICS minimizes potential for off-post exposure Adequate controls, but long-term maintenance required
4. Reduction of TMV	No treatment undertaken TMV reduced over time by natural attenuation	Contaminants in groundwater removed by GAC adsorption at ICS 1,030 gpm removed and treated at ICS Contaminants irreversibly transferred to GAC, which requires regeneration	Contaminants in groundwater removed by GAC adsorption at ICS 700 gpm removed and treated at ICS Contaminants irreversibly transferred to GAC, which requires regeneration
5. Short-term effectiveness	Minimal negative impact on the environment, surrounding community, and worker protection Contamination free to migrate off post Natural attenuation of untreated groundwater ongoing but does not meet RAOs	Minimal negative impact on workers or surrounding community No additional impact on environment Achieves RAOs	Minimal negative impact on workers or surrounding community No additional impact on environment Achieves RAOs
6. Implementability	Technically feasible Not administratively feasible: does not comply with FFA	Technically and administratively feasible Already operational	Technically and administratively feasible Already operational
7. Costs			
- Capital cost	\$0	\$0	\$0
- Annual O&M cost	\$149,000 (yr 1-5) \$68,400 (yr 6-30)	\$895,000 (yr 1-4) \$91,000 (yr 5-30)	\$880,000 (yr 1-4) \$92,000 (yr 5-30)
- Present worth	\$1,760,000	\$4,910,000	\$4,890,000
Summary	Not retained: does not comply with chemical-specific ARARs or FFA; does not provide protection of human health and environment	Retained: operational; minimizes potential for off-post exposure	Retained: modification to operational system; minimizes potential for off-post exposure



LEGEND

-100- Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)

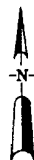
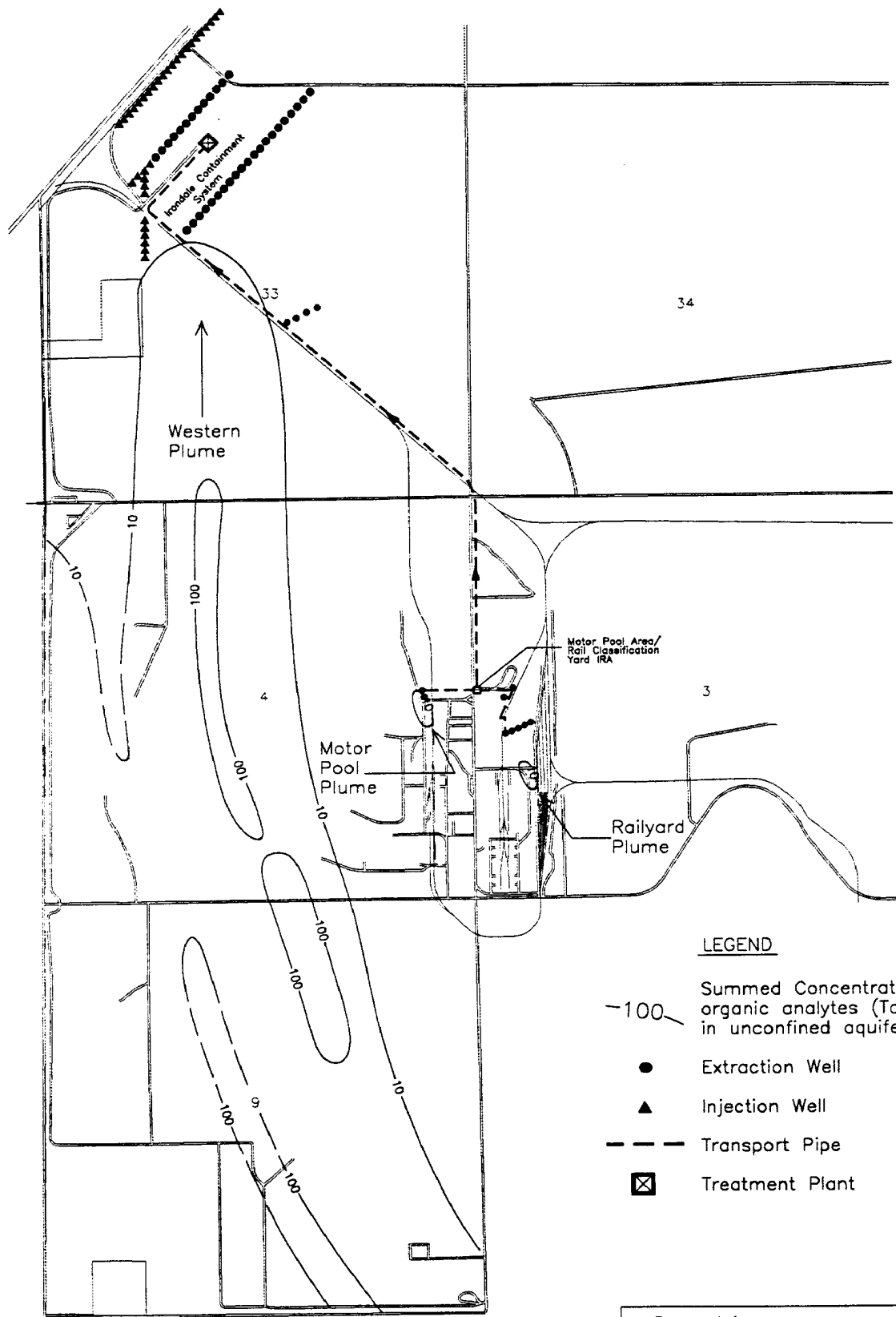


Not To Scale

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

FIGURE 5.1-1
Schematic for Western Plume Group
Control Alternative WC-1

Prepared by:
Foster Wheeler Environmental Corporation

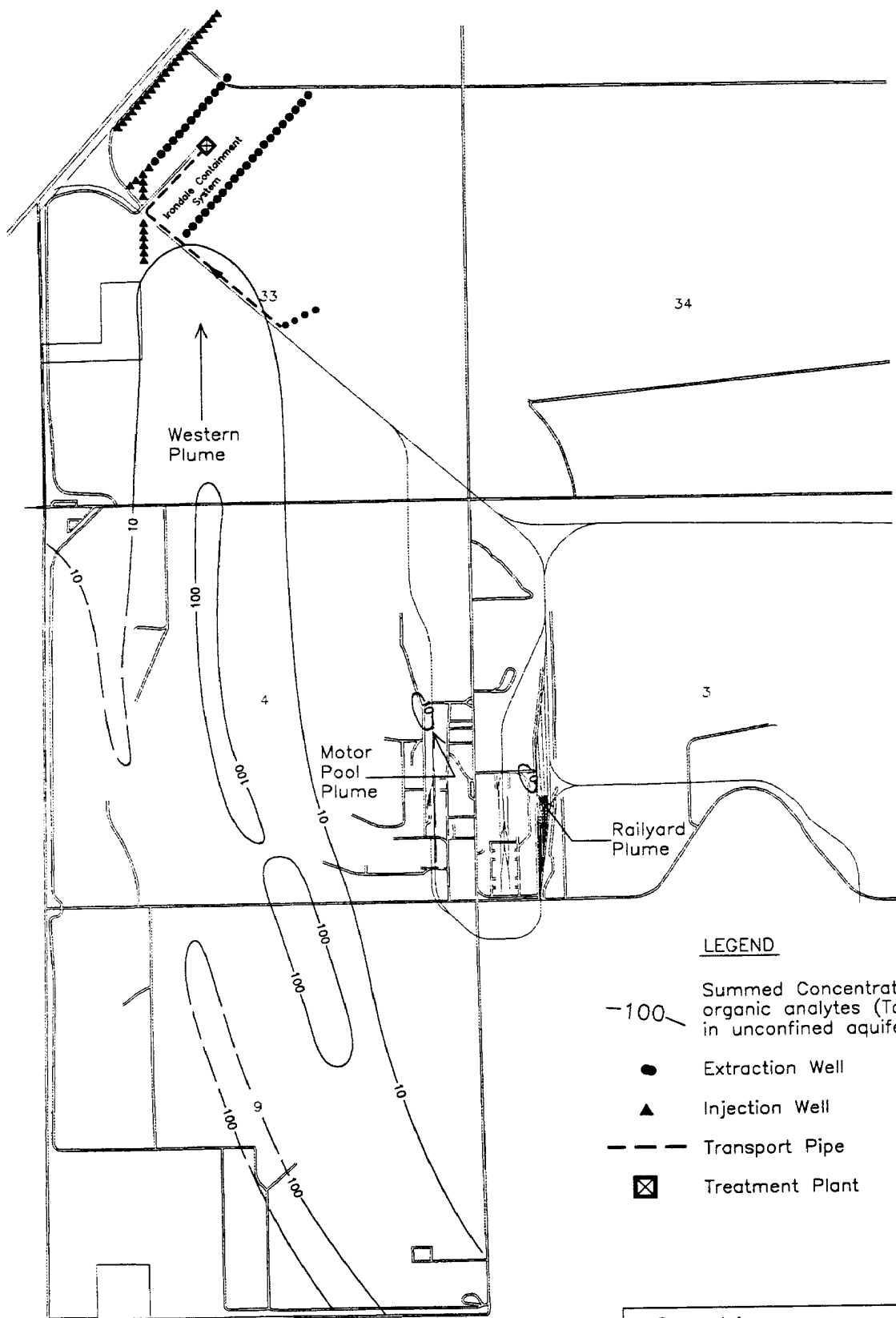


Not To Scale

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

FIGURE 5.2-1
Schematic for Western Plume Group
Control Alternative WC-2

Prepared by:
Foster Wheeler Environmental Corporation



LEGEND

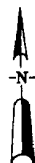
-100- Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)

● Extraction Well

▲ Injection Well

- - - Transport Pipe

⊗ Treatment Plant



Not To Scale

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

FIGURE 5.3-1
Schematic for Western Plume Group
Control Alternative WC-2A

Prepared by:
Foster Wheeler Environmental Corporation

Section 6

6.0 NORTH BOUNDARY PLUME GROUP

Six alternatives were retained from the Water DSA (EBASCO 1992) for the North Boundary Plume Group. Four of the six alternatives were modified as a result of new groundwater flow information and chemical analysis information obtained during the Water DAA. Based on additional analysis of groundwater flow in this area, groundwater extraction rates are now projected to be significantly lower than those estimated in the Water DSA. The construction of an extraction system near the source of the North Plants Plume has been eliminated from consideration, thus requiring revisions to most of the North Plants Plume Group alternatives retained in the DSA (EBASCO 1992). Another modification is that the predicted extraction rate of water from the Basins C and F area is low enough that the extracted water can be treated by existing facilities, i.e., the NBCS or the Basin F Groundwater/Basin A Neck IRA treatment facility.

The North Boundary Plume Group includes two plumes, the high flow North Plants Plume and the more contaminated but lower flow Basins C and F Plume. The primary contaminants in the Basins C and F Plume, based on the TSGM analysis of the data, are benzene, atrazine, TCE, dicyclopentadiene (DCPD), DBCP, chloroform, and dichlorophenyltrichloroethane (DDT). NDMA has been detected in the area and in the influent and effluent to the NBCS. Further investigations will be conducted to assess the extent of the problem by June 1996 using a 20 ppt method detection limit. A feasibility study of potential remedial actions (both on-post and at the boundary, or adjacent to the boundary) to achieve PRGs at the RMA boundary will be prepared. Contaminated groundwater migrates northward, primarily through the saturated alluvium and to a lesser extent through the upper weathered portion of the Denver Formation. In this area, the extent of contamination in the weathered Denver Formation is limited. Because of the low concentrations and high flow rate of the North Plants Plume, combined with the fact that the flow is captured by the NBCS, treatment near the potential source of the North Plants Plume was therefore eliminated from further consideration.

wells to remove contaminated groundwater that is treated by GAC adsorption and reinjected into on-post reinjection trenches. The system includes a 6,740-ft slurry wall between the extraction and reinjection wells to prevent recirculation of the groundwater. Two IRAs associated with the North Boundary Plume Group have been implemented. The first IRA consists of modifications to the NBCS. The second IRA, known as the Basin F Groundwater IRA, consists of an extraction well north of Basin F from which groundwater is piped to the Basin A Neck IRA treatment facility, where it is treated by air stripping and GAC adsorption. Section 6.2 presents a more detailed description of the NBCS and the IRAs.

The following sections provide detailed descriptions and analyses for each of the six alternatives retained from the Water DSA for the North Boundary Plume Group. Table 6.0-1 presents a summary of the comparative analysis of these alternatives. In addition, Appendix C contains travel time calculations for several contaminants in the North Boundary Plume Group.

6.1 ALTERNATIVE NC-1: NO ACTION

Alternative NC-1 consists of discontinuing operation of the existing NBCS and any planned upgrades and discontinuing operation of the Basin F Groundwater IRA.

6.1.1 Description of Alternative

Under the No Action alternative, operation of the NBCS is discontinued. The slurry wall is breached with approximately nine permeable trenches, allowing the aquifer to return to its natural state (Figure 6.1-1) and preventing an increase in hydraulic head in the contaminated alluvial aquifer that could result in contaminated alluvial water entering the Denver Formation. In addition, the groundwater currently being pumped away from the Basin F area by the Basin F Groundwater IRA returns to its natural flow through the alluvial channel. Groundwater monitoring, using 20 existing wells, is conducted on a quarterly basis for the first 5 years and annually thereafter. No treatment is associated with this alternative because current GAC treatment at the NBCS is discontinued. Dismantling remedial support structures, such as the

NBCS, is included as part of the No Future Use, Other Contamination History Medium Group in the Structures DAA.

6.1.2 Analysis of Alternative

6.1.2.1 Overall Protection of Human Health and the Environment

Alternative NC-1 does not ensure protection of human health and the environment off post because it involves elimination of the NBCS, thereby allowing contaminants to migrate off post. Human health is protected on post by the FFA (EPA et al. 1989), which prohibits the use of RMA groundwater as a potable groundwater source.

6.1.2.2 Compliance with ARARs

Action-specific ARARs do not apply if the No Action alternative is chosen. Because contaminated groundwater is not extracted and treated at the NBCS to achieve the PRGs for this system, this remedial alternative does not comply with the chemical-specific ARARs identified for NBCS nor does it comply with the FFA (EPA et al. 1989). However, this alternative is in compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

6.1.2.3 Long-Term Effectiveness and Permanence

The lack of groundwater controls and treatment under this alternative results in a potential for off-post exposure because of unrestricted contaminant migration across RMA boundaries. The protection that is currently provided by the NBCS is eliminated, resulting in a potential increase in contaminant levels. Natural attenuation may occur, but it will not significantly reduce contaminant concentrations to achieve PRGs.

6.1.2.4 Reduction of TMV

Alternative NC-1 does not provide any significant reduction in contaminant TMV because no remedial actions are undertaken. Compared to current conditions, there is an increase in

contaminant mobility and volume because of increased contaminant migration. There may be some reduction of contaminant levels over time as a result of natural attenuation processes.

6.1.2.5 Short-Term Effectiveness

There is some potential risk of exposure to workers during activities associated with breaching of the slurry wall, but risks can be adequately reduced through use of personal protective equipment (PPE). The activities involved in this alternative do not have any significant impact on the surrounding community. RAOs are not achieved through this alternative.

6.1.2.6 Implementability

Alternative NC-1 is technically feasible. However, because it does not meet RAOs and it is not in compliance with the FFA (EPA et al. 1989), it is not administratively feasible.

6.1.2.7 Costs

The capital cost associated with this alternative is \$154,000. Annual O&M costs are \$195,000 for the first 5 years and \$91,200 for the next 25 years, and the present worth cost is \$2,500,000. These costs are summarized in Appendix A, Table A3-1.

6.2 ALTERNATIVE NC-2: CONTINUED EXISTING ACTION

Alternative NC-2 includes continued operation of the existing treatment systems for the North Boundary Plume Group. These consist of the NBCS, including improvements completed as part of the Improvement of the North Boundary Containment System and Evaluation of Existing Boundary Containment Systems IRA and the Basin F Groundwater IRA. Continued groundwater monitoring on a quarterly basis for the first 5 years and an annual basis thereafter and continued compliance with the FFA are also included. This alternative is carried out in conjunction with capping/covering of Basins B, C, D, and F and construction of a hazardous waste landfill between Former Basin F and North Plants as part of the soil alternative. The PRGs for this alternative are listed in Table 2.2-3.

6.2.1 Description of Alternative

6.2.1.1 Extraction/Reinjection

The NBCS is a pump-and-treat system that consists of 35 extraction wells approximately 35 ft deep, 12 of which are currently operating, and a 6,740-ft-long, 3-ft-wide, 30-ft-deep soil/bentonite slurry wall. The extracted water is treated at the treatment plant with GAC and recharged through 15 reinjection trenches. The NBCS was upgraded as a result of an assessment completed as part of the IRA for this system. The upgraded system has an improved treatment system, 5 new recharge trenches installed in 1990, and 10 recharge trenches installed in 1988. The trenches run parallel along the line of extraction wells and are located about 45 ft north of the existing soil/bentonite slurry wall. The existing 38 recharge wells are not in operation but can be used as backups if the trenches fail. The trenches were installed close to the slurry wall to better maintain a reverse gradient. Flow through the treatment plant averages 270 gpm (James 1995). Figure 6.2-1 presents a schematic of this alternative and also includes the caps and landfill developed as part of the preferred soil alternative.

The NBCS will not be updated to incorporate treatment of NDMA at this time, but such an operational modification may be made later. The Army and Shell will continue monitoring and perform an assessment of the NDMA plume within one year using a 20 ppt method detection limit. A feasibility study of potential actions will be conducted, both on-post and at the boundary or adjacent to the boundary in order to achieve PRGs at the RMA boundary. The Army has conducted treatability studies at the U.S. Army Corps of Engineers Waterways Experiment Station (WES) in Vicksburg, Mississippi, to evaluate sorbent materials and the removal efficiencies that might be obtained for this compound. Additional monitoring and data evaluation will be used to assess if a treatment system for NDMA is necessary at NBCS. If any of these sorbent treatability studies prove to be successful, another sorbent column could be added to the NBCS. Upon completion of the treatability studies the Army will select and implement, if necessary, the appropriate technology applying the CERCLA criteria. If sorbent technologies do not prove successful, other treatment technologies such as oxidation could be considered. The DAA does not address any additional systems or associated costs.

The Basin F Groundwater IRA was implemented to capture contamination moving north out of the Basin F area. Water is extracted using one well at a rate of 1 to 4 gpm and is then piped to the Basin A Neck IRA system. Figure 6.2-1 presents a schematic of this alternative.

This alternative also includes groundwater quality and water level monitoring of the confined aquifer beneath the Former Basin F area as described in Section 3.1.6. Wells in this network have shown historic detections of organic analytes. Five wells will be sampled and analyzed annually for the full RMA analytical suite. Due to poor construction or documentation of well installation techniques, screened intervals, and bentonite seal locations, approximately 30 to 40 confined flow system wells will be closed and abandoned. For cost estimating purposes, it is assumed that 12 wells with average depths of 100 feet will be closed in the former Basin F and North Boundary areas.

6.2.1.2 Treatment

The treatment for this alternative is accomplished at the NBCS. The NBCS originally included prefiltration units, three 30,000-lb GAC adsorbers operated in parallel, and a combination of cartridge and bag postfilters. Treated effluent is discharged to a sump for groundwater recharge. The treatment plant has undergone minor operational changes (associated mostly with carbon handling) and now has two 20,000-lb GAC adsorbers operated in series, with the third unit available as a backup. The GAC units operate in downflow mode, and the estimated carbon usage is approximately 100,000 lbs per year. The total capacity of the modified extraction/treatment system is estimated to be 450 gpm.

6.2.2 Analysis of Alternative

6.2.2.1 Overall Protection of Human Health and the Environment

Alternative NC-2 provides protection of human health and the environment off post. Groundwater is captured and treated to PRGs at the NBCS before it leaves the north boundary of RMA, thereby ensuring adequate protection of human health and the environment off post. The Basin F Groundwater IRA reduces migration of a low volume of highly contaminated on-

post groundwater toward the boundary. Caps installed as part of the preferred soil alternative may lower the water table and further reduce contaminant migration. Human health is protected on post by the FFA (EPA et al. 1989), which prohibits the use of RMA groundwater as a potable water source.

6.2.2.2 Compliance with ARARs

This remedial alternative is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls, because it uses an existing system that complies with these ARARs. The existing system also complies with chemical-specific ARARs and the FFA so long as PRGs are achieved through continuing operation of the NBCS. Currently, effluent from the NBCS exceeds PRGs for NDMA. However, treatment of NDMA is currently being evaluated and treatability studies are being conducted as described in Section 6.2.1. An assessment of the NDMA plume (by June 1996) will aid in determining whether modifications to the NBCS are necessary. PRGs for chloride and sulfate are outlined in Section 2.2. The NBCS complies with all potential location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

6.2.2.3 Long-Term Effectiveness and Permanence

Controls implemented through the NBCS and Basin F Groundwater IRA minimize the potential for off-post exposure. RAOs are achieved with this alternative, but the NBCS extraction and treatment system will need to continue operation for a long time, as determined by contaminant migration and concentrations. Because the NBCS relies on natural groundwater gradients and flow to capture contaminants, it is anticipated that the system will operate for more than 30 years. The current NC-2 alternative is based on an assumed 30-year operating period. However, complete or partial shutoff of the system at an earlier date is possible pending monitoring results. The system or existing wells within the system can be shut off when the criteria defined in Section 1.3.3 are met. Wells removed from operation and monitoring wells upgradient and downgradient of the system will be monitored quarterly for a period of 5 years to determine if contaminants reappear. Wells will be put back into production if contaminants reappear at levels

exceeding standards. The need for hydraulic control may justify keeping wells without contaminant exceedances in production.

6.2.2.4 Reduction of TMV

Contaminants are irreversibly removed from RMA groundwater through GAC adsorption at the NBCS and through air stripping and GAC adsorption at the Basin F Groundwater/Basin A Neck IRA treatment system, thereby ensuring a reduction in contaminant TMV. Water is extracted and treated at a flow rate of approximately 270 gpm at the NBCS and 1 to 4 gpm at the Basin F Groundwater IRA. Mobility is further reduced by installation of caps under the preferred soil alternative. Contaminants are transferred to GAC, which requires regeneration.

6.2.2.5 Short-Term Effectiveness

There are no changes to the system that is currently operating at RMA. Consequently, implementation of this alternative has minimal impact on workers, the community, or the environment.

RAOs are achieved through operation of the NBCS. However, the system will have to operate until criteria for shutoff are met, which may take at least 30 years.

6.2.2.6 Implementability

The NBCS and Basin F Groundwater IRA are already operational and will continue to operate in the current manner. This alternative is, consequently, both technically and administratively feasible.

6.2.2.7 Costs

The capital costs associated with Alternative NC-2 are \$80,000. The O&M costs are \$1,820,000 per year for the first 5 years and \$1,690,000 per year for the next 25 years, and the corresponding present worth cost is \$34,200,000. The costs for this alternative are summarized in Appendix A, Table A3-2.

6.3 ALTERNATIVE NC-2A: CONTINUED OPERATION OF THE NBCS

Alternative NC-2A includes continued operation of the NBCS as it currently exists. The operation of the extraction well that is currently part of the Basin F Groundwater IRA is discontinued. Water from the Basins C and F Plume is currently being extracted by this well and pumped to the Basin A Neck IRA for treatment and reinjection. Continued groundwater monitoring on a quarterly basis for the first 5 years and on an annual basis for the remaining years and continued compliance with the FFA (EPA et al. 1989) are also included in this alternative. The PRGs for this alternative are listed in Table 2.2-3.

6.3.1 Description of Alternative

6.3.1.1 Extraction/Reinjection

The NBCS is a pump-and-treat system consisting of extraction wells, a slurry wall, and reinjection trenches. The number and location of wells and trenches are described in greater detail in Section 6.2.1.1. The NBCS is currently pumping and treating a flow of approximately 270 gpm (James 1995). Figure 6.3-1 represents a schematic of this alternative.

6.3.1.2 Treatment

The treatment for Alternative NC-2A is accomplished at the NBCS treatment facility. The treatment plant at the NBCS is described in Section 6.2.1.2 and uses GAC adsorption for treatment.

6.3.2 Analysis of Alternative

6.3.2.1 Overall Protection of Human Health and the Environment

Contaminants captured at the NBCS are treated to PRGs, thereby ensuring adequate protection of human health and the environment off post by reducing the potential for exposure. Human health is protected on post by the FFA (EPA et al. 1989), which prohibits the use of RMA groundwater as a potable water source.

6.3.2.2 Compliance with ARARs

Alternative NC-2A is in compliance with all action-specific ARARs, including those related to the extraction systems, because it uses an existing system that complies with these ARARs. The existing system also complies with chemical-specific ARARs (except for NDMA, chloride and sulfate) and the FFA so long as PRGs are achieved through continuing operation of the NBCS. Treatment of NDMA is currently being evaluated and treatability studies are being conducted as described in Section 6.2.1. An assessment of the NDMA plume (by June 1996) will aid in determining whether modifications to the NBCS are necessary. The approach to evaluating compliance with ARARs for chloride and sulfate is outlined in Section 2.2. The NBCS complies with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume.

6.3.2.3 Long-Term Effectiveness and Permanence

Controls implemented through the NBCS minimize the potential for off-post exposure. RAOs are achieved with Alternative NC-2A. Because the NBCS relies on natural groundwater gradients and flow to capture contaminants, it is anticipated that the system will operate.

The current NC-2A alternative is based on an assumed 30-year operating period. However, complete or partial shutoff of the system at an earlier date is possible pending monitoring results. The system or existing wells within the system can be shut off when the criteria defined in Section 1.3.3 are met. Wells removed from operation and monitoring wells upgradient and downgradient of the system are monitored quarterly for a period of 5 years to determine if contaminants reappear. Wells are put back into production if contaminants reappear at levels exceeding standards. The need for hydraulic control may justify keeping wells without contaminant exceedances in production.

6.3.2.4 Reduction of TMV

Contaminants are irreversibly removed from RMA groundwater through GAC adsorption at the NBCS treatment system, thereby ensuring a reduction in contaminant TMV. Water is extracted

and treated at a flow rate of approximately 270 gpm at the NBCS, and contaminants are transferred to GAC, which requires regeneration.

6.3.2.5 Short-Term Effectiveness

The only change from current operations required by Alternative NC-2A involves shutting off the Basin F Groundwater IRA extraction well. Consequently, implementation of this alternative has minimal negative impact on workers, the surrounding community, or the environment.

RAOs are achieved through operation of the NBCS; however, the system may have to operate for more than 30 years.

6.3.2.6 Implementability

The NBCS is already operational and will continue to operate in the current manner. This alternative is, consequently, both technically and administratively feasible.

6.3.2.7 Costs

There is no capital cost associated with Alternative NC-2A. The O&M costs are \$1,790,000 per year for the first 5 years and \$1,690,000 per year for the next 25 years, and the corresponding present worth cost is \$33,900,000. The costs for this alternative are summarized in Appendix A, Table A3-2A.

6.4 ALTERNATIVE NC-3/NT-2: INTERCEPTION, TREATMENT AT NBCS

This alternative consists of groundwater extraction from the Basins C and F Plume and treatment at the NBCS. Table 6.4-1 presents the estimated influent concentrations for the combined flow of groundwater extracted from the Basins C and F Plume and for groundwater extracted at the NBCS. Groundwater monitoring on a quarterly basis for the first 5 years and on an annual basis for the remaining years is also included.

6.4.1 Description of Alternative

6.4.1.1 Extraction/Reinjection

Alternative NC-3/NT-2 includes installation and operation of a groundwater extraction system that incorporates the existing Basin F Groundwater IRA extraction well. Under Alternative NC-3/NT-2, all extracted groundwater is transferred to the NBCS for treatment. The NC-3 extraction system removes contaminants in proximity to sources in Basins C and F, thereby reducing the migration of contaminants through Section 23 and lowering the water table near the extraction system. As a result of the groundwater-flow and contaminant-loading analysis performed as part of the Water DAA, this alternative no longer includes an extraction system at North Plants or a recharge trench in the Basin F area as it did in the Water DSA (EBASCO 1992). Groundwater is treated at the existing NBCS under treatment Alternative NT-2; inorganics are not treated because ARARs are achieved at the boundary.

The extraction system consists of six newly installed wells and the existing Basin F Groundwater IRA extraction well. The wells are located along an approximate east-west line that crosses Ninth Avenue (Figure 6.4-1). All extraction wells under this alternative are constructed using 12-inch-diameter borings with gravel pack surrounding the 6-inch-diameter casing and screen (thereby increasing the effective intake radius of the screen). All pipelines are double walled, all submersible pumps in wells are one-third horsepower, and all booster pumps are 1.5 horsepower. The wells are approximately 60 ft deep and are screened over the bottom 15 ft in the weathered bedrock; the screens are extended into the overlying saturated alluvium (where present). Groundwater is extracted at a total rate of approximately 6 gpm over the entire well field. Water is pumped from each well to a collection tank and is then transferred to the NBCS for treatment and injection into the existing NBCS recharge trenches.

Groundwater-quality and water-level data from a monitoring network of existing plume evaluation monitoring wells and newly installed performance monitoring wells are used to evaluate the effectiveness and operation of the extraction system. The final location of the new wells is based upon review of existing well locations and screened intervals.

Alternative NC-3 is an addition to the existing Basin F Groundwater IRA and provides greater capture of groundwater flow in proximity to the Basins C and F source areas. Saturated alluvium in this area is generally 0 to 2 ft thick. Operation of the extraction system lowers the water table, reducing the saturated thickness of the alluvium locally. When this occurs, groundwater flows primarily in the weathered bedrock and flow rates to the extraction system are reduced. This low-flow system provides additional source control in the Basins C and F area.

The groundwater extracted from the Basins C and F Plume is recharged to the aquifer through the 15 recharge trenches that currently exist at the NBCS.

6.4.1.2 Treatment

The 6-gpm flow is added to the NBCS 270-gpm influent. Table 6.4-1 shows the contaminant concentrations of the NBCS influent after the Basins C and F water is added. The overall impact on the current performance of the NBCS is negligible.

6.4.1.3 Sidestreams

Alternative NC-3/NT-2 does not generate any additional sidestreams beyond those that currently exist at the NBCS. The additional carbon consumption required to treat the Basins C and F water is insignificant.

6.4.2 Analysis of Alternative

6.4.2.1 Overall Protection of Human Health and the Environment

Human health and the environment are protected off post by operation of the NBCS, which captures and treats groundwater to PRGs at the north boundary before it migrates off-post, minimizing the risk for potential exposure to contaminated groundwater off post. Human health is protected on post by the FFA, which prohibits the use of RMA groundwater as a potable water source. Extracting contaminated groundwater from the Basins C and F Plume upgradient of the NBCS reduces the potential for this contamination to spread on post before it migrates to the boundary system. Although the Basin F Groundwater IRA extraction well already intercepts and

extracts contaminated groundwater for treatment, this alternative intercepts groundwater over a larger area and treats a somewhat larger volume of groundwater (6 gpm 1-4 gpm), thus slightly increasing the mass of contamination that is removed from that plume.

6.4.2.2 Compliance with ARARs

Alternative NC-3/NT-2 is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls, because it only expands an existing extraction well system and treats groundwater with an existing treatment system, both of which comply with these ARARs. The existing system also complies with chemical-specific ARARs (except for NDMA, chloride, and sulfate) and the FFA so long as PRGs are achieved through continuing operation of the NBCS. Treatment of NDMA is currently being evaluated and treatability studies are being conducted as described in Section 6.2.1. An assessment of the NDMA plume (by June 1996) will aid in determining whether modifications to the NBCS are necessary. The approach to evaluate compliance with ARARs (PRGs) for chloride and sulfate is outlined in Section 2.2. The NBCS and the expanded Basin F Groundwater IRA system provide compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

6.4.2.3 Long-Term Effectiveness and Permanence

Alternative NC-3/NT-2 removes contaminants permanently from the aquifer through GAC adsorption. The alternative includes continued operation of the NBCS and an expansion of the already existing and operating Basin F Groundwater IRA. The extraction systems and the NBCS treatment system continue to operate until shutoff criteria defined in Section 1.3.3 are met. Because extraction wells rely on natural groundwater gradients and flow to capture contaminants, it is anticipated that this will not occur for 30 or more years for both the expanded Basin F Groundwater IRA and the NBCS due to the low rate of migration of the contaminants. Long-term monitoring would continue under this alternative. Wells removed from operation and monitoring wells upgradient and downgradient of the system will be monitored quarterly for a period of 5 years to determine if contaminants reappear. Wells will be put back into production

if contaminants reappear at levels exceeding standards. The need for hydraulic control may justify keeping wells without contaminant exceedances in production.

It should be noted that although contaminants are removed more rapidly by this alternative than by Alternatives NC-2 and NC-2A, additional contamination may leach into the groundwater from the soil in the unsaturated zone or may desorb into the groundwater from soil in the saturated zone. Thus, contaminant toxicity and mobility may only decrease very slowly because the contaminants are removed by the treatment system at the same time as they are partially replenished from the environment.

The current NC-3 alternative is based on an assumed 30-year operating period. However, complete or partial shutoff of the system at an earlier date is possible pending monitoring results. Existing wells within the system can be removed from production when contaminant concentrations are below applicable standards and/or it can be demonstrated that discontinuing operation of a well would not jeopardize the containment objective of the system. Wells removed from operation and monitoring wells upgradient and downgradient of the system will be monitored quarterly for a period of 5 years to determine if contaminants reappear. Wells will be put back into production if contaminants reappear at levels exceeding standards. The need for hydraulic control may justify keeping wells without contaminant exceedances in production.

6.4.2.4 Reduction of TMV

Alternative NC-3/NT-2 reduces contaminant TMV to a somewhat greater extent than the existing Basin F Groundwater IRA. Toxicity of the groundwater is reduced when contaminants are adsorbed to the GAC during treatment. Saturated carbon is thermally regenerated off post.

Mobility of contaminated groundwater is decreased on post when groundwater from the Basins C and F Plume is intercepted and extracted closer to the source of contamination than when extraction is performed at the NBCS. Extracting groundwater closer to the source prevents contaminants from dispersing and diluting as they move through the aquifer and prevents them

from adsorbing to the soils, and possibly desorbing later, as groundwater migrates to the NBCS. Off-post migration of contaminated groundwater is minimized through operation of the NBCS. As treatment continues, the volume of contaminated water is reduced.

6.4.2.5 Short-Term Effectiveness

Operation of Alternative NC-3/NT-2 has minimal negative impact on the environment, the surrounding community, or workers. The only construction required is the installation of extraction wells at the Basins C and F Plume and piping to the NBCS. These types of activities have been undertaken in the past with minimal impact on the environment and community. Because this alternative uses the existing NBCS for treatment and recharge, there are no additional impacts once the new extraction system is operational.

A potential exists for workers to be exposed to hazardous conditions during construction of the wells and piping; however, this is addressed by the health and safety plan for the remedial construction.

6.4.2.6 Implementability

Alternative NC-3/NT-2 is both technically and administratively feasible. Extraction systems, transport systems, reinjection systems, and GAC adsorption are proven, reliable, and available technologies already in use at RMA. The NBCS is already in place and operating, so very little, if any, additional training is needed for the plant personnel. All activities take place on post and comply with the provisions of the FFA (EPA et al. 1989).

6.4.2.7 Costs

The capital cost for this system is \$345,000, and annual O&M costs are \$1,890,000 for the first 5 years and \$1,750,000 for the next 25 years. The present worth cost is \$35,600,000. The costs for this alternative are summarized in Appendix A, Table A3-3.

6.5 ALTERNATIVE NC-3/NT-3: INTERCEPTION, TREATMENT AT BASIN A NECK IRA

This alternative is similar to Alternative NC-3/NT-2 except that the groundwater extracted from the Basins C and F Plume (using the expanded Basin F Groundwater IRA) is treated at the Basin A Neck IRA treatment system rather than the NBCS. Table 6.5-1 presents the estimated chemical influent concentrations contributed by the Basins C and F Plume intercept system. Groundwater monitoring on a quarterly basis for the first 5 years and on an annual basis for the remaining years is also included.

6.5.1 Description of Alternative

6.5.1.1 Extraction/Reinjection

Alternative NC-3/NT-3 includes the same groundwater control system that is used for Alternative NC-3/NT-2 with the exception of the location to which the extracted water is pumped and then treated. Under Alternative NC-3/NT-3, the extracted groundwater is transferred to the existing Basin A Neck IRA for treatment and reinjection. The extracted groundwater is transferred through the piping already in place for the Basin F Groundwater IRA. Figure 6.5-1 presents a schematic of this alternative.

Treated water is recharged to the aquifer through the three existing recharge trenches of the Basin A Neck IRA. Water extracted and treated at the NBCS is recharged through the 15 trenches already located at that system.

6.5.1.2 Treatment

The Basins C and F Plume groundwater is treated at the Basin A Neck IRA treatment facility using the existing equipment. The only difference is the increased flow rate used in this alternative. The water is first pumped through the air stripper where the volatile organics are transferred to the air stream and treated with vapor-phase carbon. The water effluent from the air stripper is mixed with the Basin A Neck IRA water and is treated in the liquid-phase GAC adsorbers.

6.5.1.3 Sidestreams

This treatment system produces two major sidestreams, vapor emissions from the air stripper and spent carbon from the adsorbers. Vapor-phase emissions from the air stripper are treated with vapor-phase GAC, which requires periodic replacement. Estimated GAC consumption for this unit is 2,500 lbs per year (or approximately seven 400-lb units). Spent carbon from the liquid-phase GAC units is collected by the vendor supplying the GAC and is regenerated off post. The additional carbon consumption for treating the Basins C and F Plume at the Basin A Neck IRA is 30 lbs per year. This will have a negligible impact on operating costs at the Basin A Neck IRA treatment facility.

6.5.2 Analysis of Alternative

6.5.2.1 Overall Protection of Human Health and the Environment

Human health and the environment are protected off post by operation of the NBCS, which captures and treats groundwater in the Basins C and F and North Plants Plumes to PRGs before it migrates across the RMA boundary. Operation of the NBCS reduces contaminant concentrations in the water to acceptable levels (off-post PRGs) before it moves off post. Human health is protected on post by the FFA (EPA et al. 1989), which prohibits the use of RMA groundwater as a potable water source. Extracting contaminated groundwater from the Basins C and F Plume upgradient of the NBCS reduces the potential for this contamination to spread on post. The proposed system intercepts groundwater over a larger area and treats a somewhat larger volume of groundwater (6 gpm vs 1-4 gpm) than the existing Basin F Groundwater IRA. Capturing the groundwater where it is most contaminated increases the mass of contaminant that is removed from that plume. The Basin F Groundwater IRA extraction well is already operating at this location and groundwater is treated at the Basin A Neck IRA.

6.5.2.2 Compliance with ARARs

Alternative NC-3/NT-3 is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls, because it only expands an existing extraction well system and treats groundwater with an existing treatment system, both of which comply with

these ARARs. The treatment system also complies with chemical-specific ARARs at the boundary (except for NDMA, chloride, and sulfate) and for Basin A Neck IRA Treatment System and the FFA so long as PRGs are achieved through continued operation of the NBCS and the Basin A Neck Treatment System. Treatment of NDMA is currently being evaluated and treatability studies are being conducted as described in Section 6.2.1. An assessment of the NDMA plume (by June 1996) will aid in determining whether modifications to the NBCS are necessary. The approach to evaluate compliance with ARARs (PRGs) for chloride and sulfate is outlined in Section 2.2. The NBCS and the expanded Basins C and F extraction well system comply with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume.

6.5.2.3 Long-Term Effectiveness and Permanence

Alternative NC-3/NT-3 permanently removes contaminants from the aquifer through extraction and treatment of groundwater at two different locations. Groundwater from the Basins C and F Plume is captured near the source through an expansion of the currently existing and operating Basin F Groundwater IRA. Groundwater contaminants are permanently removed from the Basins C and F plumes through air stripping and GAC adsorption. Contaminants in the air stripper emissions are treated with vapor-phase GAC adsorption. The NBCS also removes contaminants permanently from the aquifer through treatment with GAC.

The NBCS extraction and treatment system continues to operate until shutoff criteria defined in Section 1.3.3 are met. In a similar manner, the expanded Basin F IRA extraction system will continue to operate until the criteria for internal systems are met. Because the extraction well systems rely on natural groundwater gradients and flow to capture contaminants, it is anticipated that the systems will operate for 30 or more years. Long-term monitoring continues under this alternative. Wells removed from operation and monitoring wells upgradient and downgradient of the system will be monitored quarterly for a period of 5 years to determine if contaminants reappear. Wells will be put back into production if contaminants reappear at levels exceeding

standards. The need for hydraulic control may justify keeping wells without contaminant exceedances in production.

It should be noted that although contaminants are removed more rapidly by this alternative than by Alternatives NC-2 and NC-2A, additional contamination may leach into the groundwater from the soil in the unsaturated zone or may desorb into the groundwater from soil in the saturated zone. Therefore, contaminant toxicity and mobility may only decrease very slowly because the contaminants are removed by the treatment system at the same time as they are partially replenished from the environment.

The current NC-3/NT-3 alternative is based on an assumed 30-year operating period. However, complete or partial shutoff of the system at an earlier date is possible pending monitoring results. Existing wells within the system can be removed from production when contaminant concentrations are below applicable standards and/or it can be demonstrated that discontinuing operation of a well would not jeopardize the containment objective of the system. Wells removed from operation and monitoring wells upgradient and downgradient of the system will be monitored quarterly for a period of 5 years to determine if contaminants reappear. Wells will be put back into production if contaminants reappear at levels exceeding standards. The need for hydraulic control may justify keeping wells without contaminant exceedances in production.

6.5.2.4 Reduction of TMV

Alternative NC-3/NT-3 reduces contaminant TMV to a somewhat greater extent than does the currently operating Basin F Groundwater/Basin A Neck IRAs. Toxicity of the groundwater is reduced when contaminants are irreversibly removed from RMA groundwater through GAC adsorption or air stripping. Contaminants in the air emissions from the air stripper are removed with vapor-phase GAC. Both the vapor-phase and liquid-phase carbon are thermally regenerated off post.

Mobility of contaminated groundwater is decreased on post when groundwater from the Basins C and F Plume is intercepted and extracted closer to the source of contamination than at the NBCS. Extracting groundwater closer to the source prevents contaminants from dispersing and diluting through the aquifer and adsorbing to the soils, possibly desorbing later as groundwater migrates to the NBCS. Mobility of contaminated groundwater off post is minimized through operation of the NBCS. As treatment continues, the volume of contaminated water is reduced.

6.5.2.5 Short-Term Effectiveness

Operation of Alternative NC-3/NT-3 has minimal negative impact on the environment, the surrounding community, or workers. The only construction required is the installation of extraction wells at the Basins C and F Plume and piping to the Basin A Neck IRA treatment plant. These types of activities have been undertaken in the past with minimal impact on the environment and community. Because this alternative uses the existing Basin A Neck IRA and NBCS for treatment and recharge, there are no additional impacts once the new extraction system is operational.

A potential exists for workers to be exposed to hazardous conditions during construction of the wells and piping; however, this is addressed by the health and safety plan for the remedial construction.

6.5.2.6 Implementability

Alternative NC-3/NT-3 is both technically and administratively feasible. Extraction systems, transport systems, reinjection systems, GAC adsorption, and air stripping are demonstrated, reliable, and available technologies already in use at RMA. The treatment plants at the NBCS and Basin A Neck IRA are already in place and operating, so very little, if any, additional training is needed for the plant personnel. All activities take place on post and comply with the provisions for the FFA (EPA et al. 1989).

6.5.2.7 Costs

The capital cost for this system is \$356,000, and annual O&M costs are \$1,890,000 for the first 5 years and \$1,750,000 for the next 25 years. The present worth cost is \$35,600,000. A summary of the costs for this alternative is presented in Appendix A, Table A3-4.

6.6 ALTERNATIVE NC-3/NT-4: INTERCEPTION, OXIDATION

This alternative is similar to Alternative NC-3/NT-3 except that the groundwater, extracted from the Basins C and F Plume using the expanded extraction system (which incorporates the Basin F Groundwater IRA), is treated in an oxidation reactor at the location of the Basin A Neck IRA treatment system. Table 6.5-1 presents the estimated chemical influent concentrations contributed by the Basins C and F Plume intercept system. Groundwater monitoring on a quarterly basis for the first 5 years and on an annual basis for the remaining years is also included.

6.6.1 Description of Alternative

6.6.1.1 Extraction/Reinjection

The extraction and reinjection systems for Alternative NC-3/NT-4 are exactly the same as those used for Alternative NC-3/NT-3 (Section 6.5.1.1). Figure 6.5-1 presents a schematic of this alternative, and Section 6.4.1.1 a description of the extraction and injection systems and water quality.

6.6.1.2 Treatment

Groundwater from the Basins C and F Plume is not treated by the air stripper or the GAC adsorber at the Basin A Neck IRA treatment facility. Instead, an ultraviolet light (UV)/hydrogen peroxide oxidation reactor is installed in the Basin A Neck IRA treatment facility to remove the organics from the Basins C and F Plume groundwater. The existing support systems, including the collection tanks, filters, pumps, wiring, and other equipment, are incorporated as needed. Figure 6.6-1 is a process flow diagram for this system.

Treatability studies currently being performed by WES are evaluating the effectiveness of this technology, in addition to the peroxone process (which uses ozone and hydrogen peroxide but not UV), for the contaminant mixtures at RMA.

The existing collection tank is used to collect the extracted water. Hydrogen peroxide is injected into the water stream that is taken from the collection tank and the water passes through a cartridge filter to remove any iron and manganese precipitates caused by the addition of the hydrogen peroxide. The water then enters the oxidation reactor, where organic compounds are largely destroyed. The oxidation reactor uses UV light and hydrogen peroxide to break down the target organic compounds, primarily chloroform, methylene chloride, DIMP, and atrazine. The reactor destroys all contaminants to below PRGs. After treatment, the water is pumped through another cartridge filter to the existing effluent collection tank.

6.6.1.3 Sidestreams

Sidestreams generated by Alternative NC-3/NT-4 consist of used cartridges from the two filters located on either side of the oxidation reactor, spent carbon from the NBCS, and water and sediments in the settling tank. The cartridges and sediments from the settling tank are drummed and landfilled while any remaining water in the settling tank is recirculated to the collection tank. Spent carbon is regenerated off post.

6.6.2 Analysis of Alternative

6.6.2.1 Overall Protection of Human Health and the Environment

Human health and the environment are protected off post by operation of the NBCS, which captures and treats groundwater in the Basins C and F and North Plants Plumes to PRGs before it migrates across the RMA boundary, thereby minimizing the risk for potential exposure to contaminated groundwater off post.

Human health is protected on post by the FFA, which prohibits the use of RMA groundwater as a potable water source. Extracting contaminated groundwater from the Basins C and F Plume

upgradient of the NBCS reduces the potential for this contamination to spread on post before it migrates to the boundary. Although the Basin F Groundwater IRA already intercepts, extracts, and treats contaminated groundwater, the proposed system intercepts groundwater over a larger area and treats a somewhat larger volume of groundwater (6 gpm vs 1-4 gpm).

6.6.2.2 Compliance with ARARs

Alternative NC-3/NT-4 is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls, because it expands an existing extraction well system and treats groundwater with a redesigned existing treatment system, both of which comply with these ARARs. The existing systems also comply with chemical-specific ARARs identified for the NBCS (except for NDMA, chloride, and sulfate) and for Basin A Neck and the FFA so long as PRGs are achieved through continuing operation of the NBCS and the Basin A Neck Treatment System (this alternative involves using a modified Basin A-Neck system to treat water from north of Basin F). Treatment of NDMA is currently being evaluated and treatability studies are being conducted as described in Section 6.2.1. An assessment of the NDMA plume (by June 1996) will aid in determining whether modifications to the NBCS are necessary. The approach to evaluating compliance with ARARs (PRGs) for chloride and sulfate is outlined in Section 2.2. The NBCS and the expanded Basins C and F extraction well system comply with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume.

6.6.2.3 Long-Term Effectiveness and Permanence

Alternative NC-3/NT-4 permanently removes contaminants from the aquifer through extraction and treatment of groundwater at two different locations. Groundwater from the Basins C and F Plume is captured near the source through an expansion of the currently existing and operating Basin F Groundwater IRA. This increases the mass of contamination that can be removed and may also reduce future loading on the NBCS. Groundwater contaminants are permanently removed from the Basins C and F groundwater and destroyed with UV/hydrogen peroxide oxidation. The NBCS also removes contaminants permanently from the aquifer through treatment with GAC.

The current NC-3/NT-4 alternative is based on an assumed 30-year operating period. However, complete or partial shutoff of the system at an earlier date is possible pending monitoring results. The systems or existing wells within the systems can be shut off when criteria defined in Section 1.3.3 are met. Wells removed from operation and monitoring wells upgradient and downgradient of the system will be monitored quarterly for a period of 5 years to determine if contaminants reappear. Wells will be put back into production if contaminants reappear at levels exceeding standards. The need for hydraulic control may justify keeping wells without contaminant exceedances in production.

It should be noted that although contaminants are removed more rapidly by this alternative than by Alternatives NC-2 and NC-2A, additional contamination may leach into the groundwater from the soil in the unsaturated zone or may desorb into the groundwater from soil in the saturated zone. Therefore, contaminant toxicity and mobility may only decrease very slowly because contaminants are removed by the treatment system at the same time as they are partially replenished from the environment.

6.6.2.4 Reduction of TMV

Alternative NC-3/NT-4 reduces contaminant TMV to a somewhat greater extent than does the currently operating Basin F Groundwater/Basin A Neck IRAs. Toxicity of the groundwater is reduced when contaminants are irreversibly destroyed by oxidation. TMV of water pumped from the Basin F Groundwater IRA is reduced through an on-post treatment system, in contrast to GAC (which must be regenerated off post).

Mobility of contaminated groundwater is decreased on post because groundwater from the Basins C and F Plume is intercepted and extracted closer to the source of contamination than at the NBCS. Extracting groundwater closer to the source prevents contaminants from dispersing and diluting as they move through the aquifer and prevents them from adsorbing to the soils, and possibly desorbing later, as groundwater migrates to the NBCS. Mobility of contaminated

groundwater off post is minimized through operation of the NBCS. As treatment continues, the volume of contaminated water is reduced.

6.6.2.5 Short-Term Effectiveness

Operation of Alternative NC-3/NT-4 has minimal negative impact on the environment, the surrounding community, or workers. The only construction required is the installation of extraction wells at the existing Basin F Groundwater IRA, piping to the Basin A Neck IRA treatment plant, and installation of a small oxidation unit. These types of activities have been undertaken in the past with minimal impact on the environment and community. Because this alternative uses the NBCS and the existing Basin A Neck IRA building and reinjection system for treatment and recharge, there are no additional impacts once the new extraction system is operational.

A potential exists for workers to be exposed to hazardous conditions during construction of the wells and piping; however, this is addressed by the health and safety plan for the remedial construction.

6.6.2.6 Implementability

Alternative NC-3/NT-4 is both technically and administratively feasible. Extraction systems, transport systems, and reinjection systems are demonstrated, reliable, and available technologies already in use at RMA. Advanced oxidation processes, such as UV/hydrogen peroxide oxidation, are innovative technologies, and treatability studies must be conducted before a design can be finalized (Technology Descriptions Volume, Section 14.1); however, this process is expected to treat contaminants to the required levels. As noted, WES is currently conducting an oxidation treatability study. The treatment plant at the NBCS is already operational, so no additional training is needed for the plant personnel. Some training may be required for personnel operating the oxidation system.

6.6.2.7 Costs

The capital cost for this system is \$1,180,000, and annual O&M costs are \$2,000,000 for the first 5 years and \$1,870,000 for the next 25 years. The present worth cost is \$38,800,000. A summary of the costs is presented in Appendix A, Table A3-5.

6.7 ALTERNATIVE NC-6: CLAY/SOIL CAP

This alternative consists of installation of a clay/soil cap over the Basins C and F Plume and continued operation of the existing Basin F Groundwater IRA and NBCS. No additional treatment is needed beyond continued operation of the NBCS and the Basin F Groundwater IRA. Groundwater monitoring on a quarterly basis for the first 5 years and on an annual basis for the remaining years is also included.

6.7.1 Description of Alternative

6.7.1.1 Extraction/Reinjection

Alternative NC-6 provides for the installation of a clay/soil cap over the Basins C and F Plume to reduce leaching of contaminants and groundwater recharge in the source area (Figure 6.7-1). A more extensive cap/soil cover is also being considered as one remedial alternative for soil for this area. This alternative also includes continued operation of the NBCS and the Basin F Groundwater IRA. However, Alternative NC-6 is only cost effective for groundwater if capping is retained as the preferred soil alternative for the Former Basin F and Basin C sites. The installation of a slurry wall was included in the Water DSA (EBASCO 1992) but is not included in the present alternative because caps are highly effective in containing contamination in this area. Little added benefit would be gained by installing a slurry wall due to low groundwater flow rates. This alternative minimizes downward migration of contaminants from contaminated soil to the groundwater and reduces loading at the NBCS in the long term. Because the water levels would decline beneath the sources and groundwater would primarily flow in bedrock rather than in alluvium, the volume and velocity of groundwater flow toward the NBCS is reduced somewhat. The cap requires periodic maintenance.

Alternative NC-6 involves the installation of a low-permeability clay/soil cap, with proper grading and drainage to minimize infiltration, across the top of the area. The clay cap consists of a 2-ft layer of compacted low-permeability soil, a 1-ft biota barrier of cobbles, and a 4-ft soil/vegetation layer that includes 6 inches of topsoil. The construction timing and methods are coordinated with the soil remediation because the preferred soil alternatives for Former Basin F and Basin C are capping/covering. The installation and maintenance of a soil cap is further described in Section 6.2 of the Technology Descriptions Volume.

Groundwater-quality and water-level data from a monitoring network of existing plume monitoring wells located both around and within the capped area are monitored to evaluate the effectiveness of this alternative. Lowering of water levels may cause a shift in the groundwater divide that underlies this area and may affect groundwater flow directions in the Basins C and F area. Currently, groundwater flows north from one side of the divide and west or northwest from the other side. Monitoring water levels within and outside of the capped area allows for the evaluation of possible changes in the direction of groundwater migration.

Alternative NC-6 requires no additional recharge capacity for trenches on the NBCS or the Basin A Neck IRA and is only cost effective if a similar capping scenario is selected as the preferred soil remedial alternative. Because water levels in the area decline due to lack of recharge, contaminant migration occurs primarily in weathered bedrock, resulting in reduced flow and loading at the NBCS.

6.7.1.2 Treatment

The existing treatment systems at the NBCS and the Basin F Groundwater/Basin A Neck IRAs continue to operate. No additional groundwater is extracted, so new treatment systems are not required.

6.7.1.3 Sidestreams

Alternative NC-6 does not generate any new sidestreams.

6.7.2 Analysis of Alternative

6.7.2.1 Overall Protection of Human Health and the Environment

Alternative NC-6 provides protection of human health and the environment off post. Groundwater is captured and treated and contaminant concentrations in the water are reduced to PRGs at the NBCS prior to leaving the boundary, thereby protecting human health off post. Extracting contaminated groundwater at the Basin F Groundwater IRA upgradient of the NBCS reduces the migration of contamination from Basin F toward the boundary and provides protection of the on-post environment. Human health is protected on post by the FFA (EPA et al. 1989), which prohibits the use of RMA groundwater as a potable water source.

In addition, installation of a cap over Basin C and Former Basin F reduces recharge under the cap and thereby reduces leaching of additional contaminants into the groundwater from the unsaturated zone.

6.7.2.2 Compliance with ARARs

Alternative NC-6 is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls, because it uses an existing system that complies with these ARARs. Installation of the clay/soil cap complies with potential air emission ARARs regarding particulate and opacity concerns. The existing system also complies with chemical-specific ARARs (except for NDMA, chloride, and sulfate) and the FFA (EPA et al. 1989) so long as PRGs are achieved through continuing operation of the NBCS. However, treatment of NDMA is currently being evaluated and treatability studies are being conducted as described in Section 6.2.1. An assessment of the NDMA plume (by June 1996) will aid in determining whether modifications to the NBCS are necessary. The approach to evaluating compliance with ARARs (PRGs) for chloride and sulfate is outlined in Section 2.2. The NBCS provides compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

6.7.2.3 Long-Term Effectiveness and Permanence

Alternative NC-6 removes contaminants permanently from the aquifer through treatment with GAC and reduces the mass of contamination that may leach into the groundwater under the cap. The NBCS extraction and treatment system continues to operate until shut off criteria defined in Section 1.3.3 are met. Because the extraction well systems rely on natural groundwater gradients and flow to capture contaminants, it is anticipated that this will not occur for 30 or more years for the Basin F Groundwater IRA or the NBCS. The current NC-6 alternative is based on an assumed 30-year operating period. Wells removed from operation and monitoring wells upgradient and downgradient of the system will be monitored quarterly for a period of 5 years to determine if contaminants reappear. Wells will be put back into production if contaminants reappear at levels exceeding standards. The need for hydraulic control may justify keeping wells without contaminant exceedances in production.

It should be noted that although contaminants are removed by this alternative and the potential for future leaching into the aquifer is reduced, thus reducing the total mass of contamination in the aquifer, additional contamination may leach into the groundwater from the soil in the unsaturated zone that is not covered by the cap or may desorb into the groundwater from soil in the saturated zone. Therefore, contaminant toxicity and mobility may only decrease slowly because contaminants are removed by the treatment system at the same time as they are partially replenished from the environment.

6.7.2.4 Reduction of TMV

Contaminant TMV is reduced by Alternative NC-6. Toxicity of the groundwater is reduced when contaminants are adsorbed to the GAC during treatment. The carbon is thermally regenerated off post.

Mobility of contaminants is decreased on post by reducing recharge under the cap. Mobility of contaminated groundwater off post is minimized through operation of the NBCS. The cap

reduces the volume of contaminated water by reducing the amount of water infiltrating into the ground.

6.6.2.5 Short-Term Effectiveness

Some short-term impacts to the environment or community may exist during construction of the cap; however, these can be minimized through dust and vapor emission controls. Once the cap is in place, operation of this alternative has minimal negative impact on the environment, surrounding communities, or workers. Because this alternative uses the existing NBCS and Basin F Groundwater/Basin A Neck IRAs for treatment and recharge, there are no additional impacts once the new cap is in place.

6.7.2.6 Implementability

Alternative NC-6 is both technically and administratively feasible. Clay/soil caps and GAC adsorption are both demonstrated, reliable, and available technologies already in use at RMA. The treatment plants are already in place and operating, so very little additional training, if any, is needed for the plant personnel. All activities take place on post and comply with the provisions of the FFA (EPA et al. 1989).

6.7.2.7 Costs

The capital cost for this system is \$16,100,000 (for installation of the cap over Basin C; capping Basin F is included in the soil remediation costs), and annual O&M costs are \$1,850,000 for the first 5 years and \$1,750,000 for the next 25 years. The present worth cost is \$51,100,000. A summary of costs is presented in Appendix A, Table A3-6.

6.8 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section describes the selection of one or more alternatives for the North Boundary Plume Group to be incorporated into sitewide alternatives for groundwater at RMA (see Section 9). In this step of the DAA process, a comparative analysis of each of the retained alternatives against the EPA screening criteria, and each against the other, is performed.

Six alternatives were considered for the North Boundary Plume Group and are summarized as follows. Alternative NC-1 involves the discontinuation of the NBCS and the Basin F Groundwater IRA. Alternative NC-2 includes continuation of the existing boundary system and IRA, while Alternative NC-2A includes continuation of the boundary system only. Alternatives NC-3/NT-2 and NC-3/NT-3 are similar, involving expansion of the Basin F Groundwater IRA, except that the latter treats water at the Basin A Neck IRA rather than the NBCS. Alternative NC-3/NT-4 is similar to Alternative NC-3/NT-3 except that extracted water is treated in an oxidation reactor at the Basin A Neck IRA. Alternative NC-6 involves capping of the Basin C and Former Basin F area, along with continued operation of the Basin F Groundwater IRA and the NBCS.

6.8.1 Overall Protection of Human Health and the Environment

Except for Alternative NC-1, the No Action alternative, all alternatives provide protection of human health and the environment. Human health is protected on post by FFA restrictions that limit the use of on-post groundwater. Protection of human health and the environment off post through operation of the NBCS, which treats groundwater to off-post PRGs before it leaves the RMA boundary, is ensured by all alternatives except Alternative NC-1.

Alternative NC-2 is protective of human health off post through operation of the NBCS and on post through the provisions of the FFA (EPA et al. 1989). Continued operation of the Basin F Groundwater IRA provides additional reduction in contaminant migration. The activities included in this alternative are also included in all of the other alternatives except Alternatives NC-1 and NC-2A.

Alternative NC-2A is protective of human health off post through operation of the NBCS and on post through the provisions of the FFA (EPA et al. 1989).

The added benefit provided by additional groundwater capture and treatment, as in Alternatives NC-3/NT-2 (extraction, GAC adsorption, reinjection), NC-3/NT-3 (extraction, air stripping, GAC adsorption, reinjection), and NC-3/NT-4 (extraction, oxidation, reinjection), is small. These alternatives use extraction wells to capture a relatively small volume of contaminated groundwater (6 gpm) from the Basins C and F Plume and then treat it to meet established standards.

Alternative NC-6, which involves installation of a cap over Basin C and Former Basin F, is also protective. Installation of the cap reduces the mass of contaminants that may leach into the aquifer from the unsaturated zone by reducing recharge, but this alternative removes slightly less contamination from the groundwater than do the NC-3 alternatives.

6.8.2 Compliance with ARARs

All of the alternatives except Alternative NC-1 comply with action-, chemical-, and location-specific ARARs except for NDMA (see Section 6.2.2.2) and for chloride and sulfate (Section 2.2). Alternative NC-1 allows contamination to migrate off post, which does not comply with chemical-specific ARARs at the boundary or the provisions of the FFA (EPA et al. 1989).

6.8.3 Long-Term Effectiveness and Permanence

All alternatives except Alternative NC-1 provide long-term effectiveness off post because they operate until shut off criteria for boundary and internal systems, identified in Section 1.3.3, are met. Alternatives NC-2, NC-3/NT-2, NC-3/NT-3, and NC-3/NT-4 involve additional on-post extraction and treatment systems that remove contaminant mass from the Basins C and F Plume before the plume reaches the boundary. By intercepting contaminants where the plume is most concentrated, a greater contaminant mass is removed. The differences in mass removed by the alternatives is relatively small. The NC-3 alternatives remove only slightly more contaminant mass than do the NC-2 alternatives, and Alternative NC-2 is only slightly more effective than Alternative NC-2A. If the plume is allowed to migrate naturally to the north boundary, it becomes more diluted and dispersed through Sections 23 and 24 and may require a longer period

of treatment of a large volume of water. These alternatives do not provide additional extraction and treatment of the North Plants Plume, which is treated at the NBCS.

Alternative NC-2 is effective for interception of the relatively small volume of groundwater flow (1-4 gpm) through a limited extent of saturated alluvium. The operation of the Basin F IRA provides control of contaminated groundwater movement near the source.

Alternative NC-6 is slightly less effective than the NC-3 alternatives in the long term because it does not remove and treat as much contaminated groundwater, although installation of a cap reduces recharge and leaching of contaminants.

Alternative NC-1 is not effective in the long term because contaminants currently in the aquifer, or those that may leach into the aquifer, are not removed. These contaminants remain in the aquifer and move off post where there is a potential for human exposure through drinking water wells.

6.8.4 Reduction of TMV

Treatment with GAC at the NBCS is the primary treatment method for all alternatives except Alternative NC-1. The NBCS extracts and treats up to 270 gpm for each of these alternatives and effectively reduces the contaminant TMV by transferring contaminants from the extracted groundwater to the GAC. Alternative NC-3/NT-4 pumps Basin F Groundwater IRA water to the Basin A Neck IRA for treatment using a different treatment technology.

Alternatives NC-2 and NC-2A rely on the NBCS to reduce contaminant TMV through treatment of the North Plants and Basins C and F Plumes. Alternative NC-2 is also effective for the partial control of contaminant migration through the alluvium near the Former Basin F.

The three alternatives that use the NC-3 control system provide some additional reduction of contaminant TMV through extraction and treatment of up to 6 gpm, some of which comes from

the Basins C and F Plume, compared to Alternative NC-2A. Alternative NC-3/NT-2 uses GAC, Alternative NC-3/NT-3 uses air stripping followed by GAC, and Alternative NC-3/NT-4 uses oxidation followed by GAC to treat this stream. Alternative NC-3/NT-4 uses the least amount of carbon because a large fraction of the contaminants are destroyed in the oxidation reactor. Alternative NC-3/NT-3 has the next highest carbon consumption, and Alternative NC-3/NT-2 uses the most carbon.

Alternative NC-6 reduces contaminant mobility and volume by reducing infiltration and subsequent leaching of contaminants from soil in the Basin C and F areas. Contaminant toxicity is reduced through treatment at the NBCS and the Basin F Groundwater IRA.

Alternative NC-1 provides reduction of TMV only through natural attenuation. Contamination in the aquifer and vadose zone decreases very slowly in the environment and continues to migrate off post.

6.8.5 Short-Term Effectiveness

The short-term effectiveness of Alternatives NC-2, NC-2A, NC-3/NT-2, NC-3/NT-3, and NC-3/NT-4 is roughly equivalent. None of the alternatives have a significant impact on the environment and surrounding community during construction, and none pose special threats to workers. One tradeoff between the NT-2, NT-3, and NT-4 treatment alternatives is that NT-2 and NT-3 include off-post shipment and treatment of contaminated GAC from the Basin A Neck IRA treatment plant, while NT-4 does not ship contaminated media off post from the treatment system but does transport potentially hazardous reagent (hydrogen peroxide) on post (all of these alternatives still involve off-post shipment of GAC from the NBCS). These alternatives also achieve RAOs at the boundary through operation of the NBCS, and all are estimated to operate for at least 30 years.

Alternative NC-6 is slightly less effective in the short term than the other alternatives because constructing a clay/soil cap may cause more of an impact on the workers and community. Dust

suppression may be required during construction to minimize impacts on the surrounding community. This alternative also meets RAOs at the boundary and is expected to operate for more than 30 years.

Alternative NC-1 is the least effective in the short term because the environment is not adequately protected. Although natural attenuation is ongoing, RAOs are not achieved at the boundary and contamination is free to migrate off post.

6.8.6 Implementability

All of the alternatives are technically feasible in that all involve demonstrated, available technologies (well installation, cap installation, GAC adsorption, and air stripping) already in use at RMA. Alternative NC-3/NT-4 includes an innovative technology (oxidation) that requires more oversight and additional operator training compared to the other alternatives.

All of the alternatives are administratively feasible, with the exception of Alternative NC-1. This alternative is not in compliance with the FFA (EPA et al. 1989) because it allows contaminants to migrate off post.

6.8.7 Costs

Alternative NC-1 has a present worth cost of \$2,500,000, which is significantly lower than any of the other alternatives. This is followed by Alternatives NC-2 and NC-2A at approximately \$34,000,000. Capital costs, annual O&M costs, and present worth costs are approximately equal for Alternatives NC-3/NT-2 and NC-3/NT-3 and increase slightly for NC-3/NT-4. The capital cost for Alternative NC-6, at \$16,100,000, is one order of magnitude higher than for the other alternatives, although the annual O&M costs are comparable to the other alternatives. Alternative NC-6 also has the highest present worth cost at \$51,100,000.

6.8.8 Summary

The comparative analysis of the North Boundary Plume Group alternatives is summarized in Table 6.0-1. Alternative NC-1, No Action, is unable to meet even the threshold requirements of overall protection of human health and the environment and compliance with ARARs. This alternative was not considered further.

All of the remaining alternatives meet all of the screening criteria by removing contamination at the NBCS before it can potentially come into contact with humans. This is done irreversibly and with minimal impact on the environment, surrounding community, and workers. Alternatives NC-2 and NC-2A rely on existing systems to remove contamination and therefore have no capital costs associated with them. They also have the lowest operating costs of the acceptable alternatives. The NC-3 alternatives (NC-3/NT-2, NC-3/NT-3, and NC-3/NT-4) all include additional extraction of contaminated water near the Basin F IRA extraction well and treatment by a variety of methods. These alternatives remove a slightly greater mass of contamination than Alternatives NC-2 and NC-2A but at a higher operating cost and at a significantly higher capital cost. Alternative NC-6, a clay/soil cap over the Basin C and F area, provides protection that is comparable to the other alternatives but at a capital cost that is an order of magnitude higher than the NC-3 alternatives.

The alternatives that are retained for consideration for the North Boundary Plume Group are listed below. Because all of the alternatives except NC-1 meet the compliance and other criteria cost became the major consideration in determining which alternatives to retain, NC-3 was not retained due to high costs and minimal added benefit compared to continued operation of the existing system. NC-6 was determined not to be as cost effective as a water only alternative and was therefore not retained as presented here. It should, however, be noted that more extensive capping in this area is considered and costed as a soil alternative, and this was taken into account in the evaluation of the NC-2 alternative. The following alternatives will be included in the sitewide alternatives for groundwater, which are developed in Section 9:

- Alternative NC-2: Continued Existing Action
- Alternative NC-2A: Continued Operation of NBCS

Table 6.0-1 Comparative Analysis of Alternatives: North Boundary Plume Group

Criteria	ALT NC-1 No Action	ALT NC-2 Continued Existing Action	ALT NC-2A Continued Operation of the NBCS
1. Overall protection of human health and the environment	Does not meet RAOs at the boundary; contamination free to migrate off post	Reduces potential exposure to acceptable levels	Reduces potential exposure to acceptable levels
2. Compliance with ARARs	Does not comply with chemical-specific ARARs and FFA; complies with location-specific ARARs; action-specific ARARs do not apply	Complies with action-, location-, and chemical-specific ARARs and the FFA, except for NDMA, which will be evaluated for possible system modifications.	Complies with action-, location-, and chemical-specific ARARs and the FFA, except for NDMA, which will be evaluated for possible system modifications.
3. Long-term effectiveness and permanence	Potential for off-post exposure due to contaminant migration Existing controls removed	NBCS minimizes potential for off-post exposure Adequate existing controls, but long-term maintenance required	NBCS minimizes potential for off-post exposure Adequate existing controls, but long-term maintenance required
4. Reduction of TMV	No treatment undertaken TMV reduced over time by natural attenuation	Contaminants removed by GAC adsorption at NBCS and air stripping and GAC adsorption at the Basin A Neck IRA treatment facility 270 gpm removed and treated at NBCS; 1-4 gpm by Basin F Groundwater IRA Contaminants irreversibly transferred to GAC, which requires regeneration	Contaminants removed by GAC adsorption at NBCS treatment facility 270 gpm removed and treated at NBCS Contaminants irreversibly transferred to GAC, which requires regeneration
5. Short-term effectiveness	Minimal negative impact on the environment, surrounding community, or workers Contamination free to migrate off post Natural attenuation ongoing, but does not meet RAOs	Minimal negative impact on the environment, surrounding community, or workers RAOs achieved; may require operation for more than 30 years	Minimal negative impact on the environment, surrounding community, or workers RAOs achieved; may require operation for more than 30 years
6. Implementability	Technically feasible Not administratively feasible: does not comply with FFA	Technically and administratively feasible Already operational	Technically and administratively feasible Already operational
7. Costs -Capital Cost -Annual O&M Cost -Present Worth	\$154,000 \$196,000 (yr 1-5) \$91,200 (yr 6-30) \$2,500,000	\$80,000 \$1,820,000 (yr 1-5) \$1,690,000 (yr 6-30) \$34,200,000	\$0 \$1,790,000 (yr 1-5) \$1,690,000 (yr 6-30) \$33,900,000
Summary	Not retained: does not meet RAOs	Retained: meets RAOs and is in compliance with ARARs and the FFA	Retained: meets RAOs and is in compliance with ARARs and the FFA

Table 6.0-1 Comparative Analysis of Alternatives: North Boundary Plume Group

Criteria	ALT NC-3/NT-2 Interception, Treatment at the NBCS	ALT NC-3/NT-3 Interception, Treatment at the Basin A Neck IRA
1. Overall protection of human health and the environment	Reduces potential exposure to acceptable levels	Reduces potential exposure to acceptable levels
2. Compliance with ARARs	Complies with action-, location-, and chemical-specific ARARs and the FFA, except for NDMA which will be evaluated for possible system modifications.	Complies with action-, location-, and chemical-specific ARARs and the FFA, except for NDMA which will be evaluated for possible system modifications.
3. Long-term effectiveness and permanence	Reduces potential for off-post exposure COCs intercepted near source and at NBCS, treated at NBCS Monitoring program continues	Reduces potential for off-post exposure Contaminants intercepted near source and at NBCS and treated at Basin A Neck IRA treatment facility and NBCS Monitoring program continues
4. Reduction of TMV	Contaminants removed by GAC adsorption; capture system close to source reduces migration through the aquifer 6 gpm from Basins C and F Plume and 270 gpm from NBCS removed and treated Contaminants irreversibly transferred to GAC, which requires regeneration	Contaminants removed by GAC adsorption at NBCS; Basins C and F Plume treated with air stripping and GAC adsorption; capture system close to source reduces migration through the aquifer 6 gpm from Basins C and F Plume and 270 gpm from NBCS removed and treated; contaminants irreversibly transferred to vapor- and liquid-phase GAC, which requires regeneration; lower GAC consumption than NT-2
5. Short-term effectiveness	Minimal negative impact on the environment, surrounding community, or workers RAOs achieved; may require operation for more than 30 years	Minimal negative impact on the environment, surrounding community, or workers RAOs achieved; may require operation for more than 30 years
6. Implementability	Technically feasible: demonstrated, available technologies, reliable equipment, and experienced operators Administratively feasible	Technically feasible: demonstrated, available technologies, reliable equipment, and experienced operators Administratively feasible
7. Cost		
-Capital Cost	\$345,000	\$356,000
-Annual O&M Cost	\$1,890,000 (yr 1-5) \$1,750,000 (yr 6-30)	\$1,890,000 (yr 1-5) \$1,750,000 (yr 6-30)
-Present Worth	\$35,600,000	\$35,600,000
Summary	Not retained: minimal added benefit of additional treatment for added cost	Not retained: minimal added benefit of additional treatment for added cost

Table 6.0-1 Comparative Analysis of Alternatives: North Boundary Plume Group

Criteria	ALT NC-3/NT-4 Interception, Oxidation	ALT NC-6 Clay/Soil Cap
1. Overall protection of human health and the environment	Reduces potential exposure to acceptable levels	Reduces potential exposure to acceptable levels
2. Compliance with ARARs	Complies with action-, location-, and chemical-specific ARARs and the FFA, except for NDMA which will be evaluated for possible system modifications.	Complies with action-, location-, and chemical-specific ARARs and the FFA, except for NDMA which will be evaluated for possible system modifications.
3. Long-term effectiveness and permanence	Reduces potential for off-post exposure COCs intercepted by expanded extraction system near source at Basins C and F and treated at Basin A Neck IRA facility; and intercepted and treated at NBCS Monitoring program continues	NBCS minimizes potential for off-post exposure Contaminants intercepted by Basin F groundwater IRA; and treated at Basin A Neck IRA and intercepted and treated at NBCS Monitoring program continues Cap requires habitat restrictions to burrowing animals Cap reduces leaching by reduced recharge from surface
4. Reduction of TMV	Contaminants removed by GAC adsorption at NBCS; Basins C and F water treated with oxidation; capture system close to source reduces migration through the aquifer 6 gpm from Basins C and F Plume and 270 gpm from NBCS removed and treated; contaminants destroyed by oxidation or transferred to GAC, which requires regeneration; lower GAC consumption than NT-2 or NT-3	TMV reduction through reduced leachate generation and continued operation of the NBCS and Basin F Groundwater IRA Damage to cap would allow remobilization of contaminants 1-4 gpm from Basins C and F Plume and 270 gpm from NBCS removed and treated Contaminants at NBCS transferred to GAC, which requires regeneration; lower GAC consumption than NT-2, NT-3, or NT-4
5. Short-term effectiveness	Minimal negative impact on the environment, surrounding community, or worker protection RAOs achieved; may require operation for more than 30 years	Worker exposure controls during cap construction; dust and vapor controls for community protection RAOs achieved; may require operation for more than 30 years
6. Implementability	Technically feasible: GAC adsorption is demonstrated, available technology, with reliable equipment, and experienced operators; advanced oxidation process is innovative, requires more oversight and additional operator training Administratively feasible	Technically feasible: demonstrated, available technologies; reliable equipment; and experienced operators Administratively feasible
7. Cost		
-Capital Cost	\$1,180,000	\$16,100,000
-Annual O&M Cost	\$2,000,000 (yr 1-5) \$1,870,000 (yr 6-30)	\$1,850,000 (yr 1-5) \$1,750,000 (yr 6-30)
-Present Worth	\$38,800,000	\$51,100,000
Summary	Not retained: minimal added benefit of on-post treatment at significant added cost	Not retained: minimal added benefit of on-post treatment at significant added cost

Table 6.4-1 NC-3/NT-2 North Boundary Plume Group Estimated Influent Concentrations

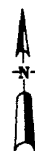
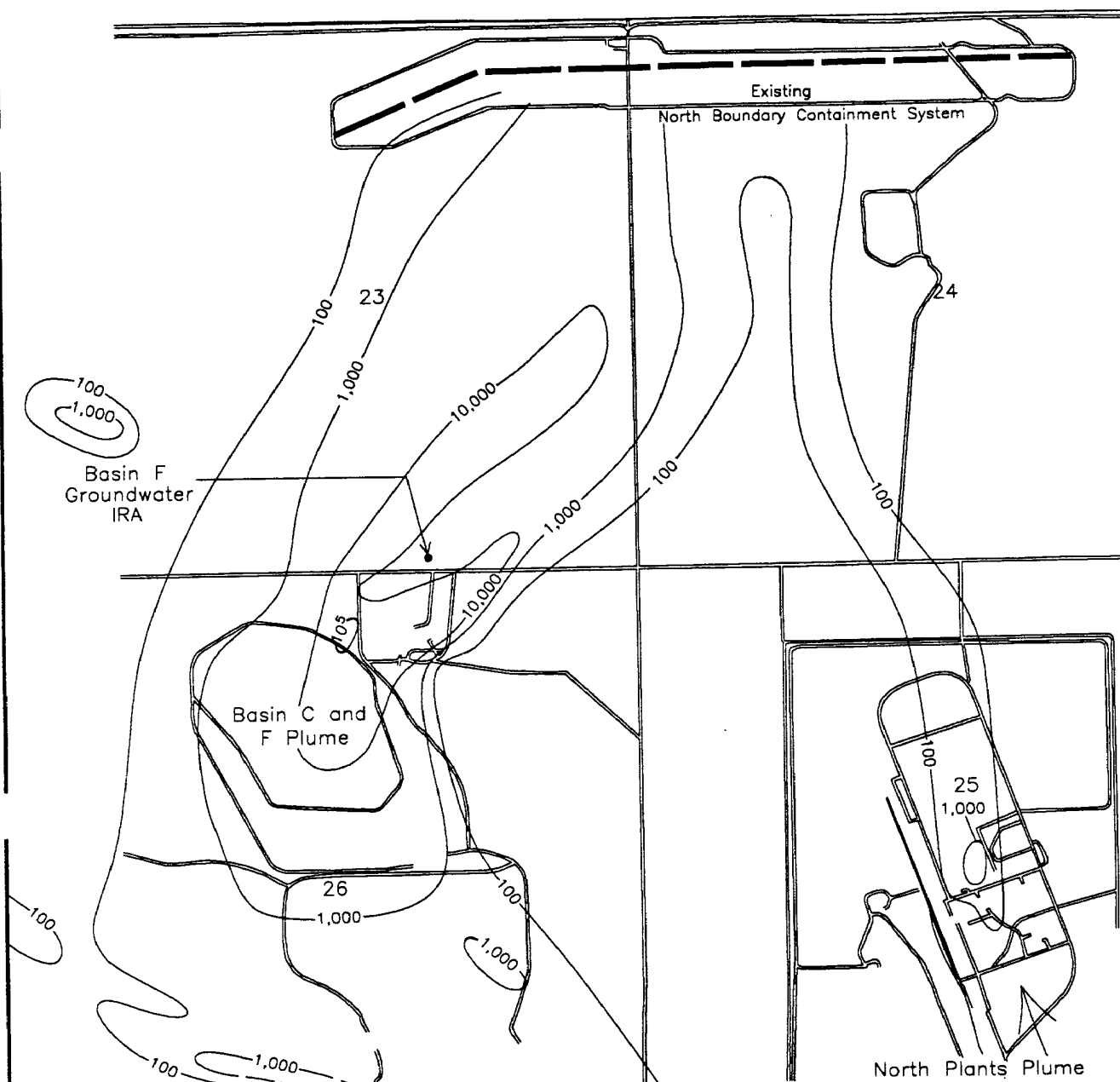
Page 1 of 1

Chemical Group/Compound	Estimated Influent Concentration (µg/l)
Volatile Halogenated Organic Compound (VHOs)	
Carbon tetrachloride	0.84
Chloroform	5.9
Methylene chloride	2.8
Trichloroethylene	0.52
Volatile Hydrocarbon Compounds (VHCs)	
Dicyclopentadiene	5.7
Volatile Aromatic Organic Compounds (VAOs)	
Benzene	0.75
Organosulfur Compounds, Mustard Agent Related (OSCMs)	
Dithiane	1.4
Organosulfur Compounds, Herbicide Related (OSCHs)	
Chlorophenylmethyl sulfoxide	6.3
Organophosphorous Compounds, GB-Agent Related (OPHGBs)	
Diisopropylmethyl phosphonate (DIMP)	13
Organophosphorus Compounds, Pesticide Related (OPHPs)	
Atrazine	3.3
Dibromochloropropane (DBCP)	
Dibromochloropropane	0.11
Organochlorine Pesticides (OCPs)	
Chlordane	0.06
Dieldrin	0.06
Hydrazine-Related Compounds	
N-nitrosodimethylamine	0.04
Arsenic	
Arsenic	1.6

Table 6.5-1 NC-3/NT-3,NT-4 Basin C & F Intercept System Estimated Influent Concentrations

Page 1 of 1

Chemical Group/Compound	Estimated Influent Concentration (µg/l)
Volatile Halogenated Organic Compound (VHOs)	
Carbon tetrachloride	0.82
Chloroform	130
Methylene chloride	9.0
Trichloroethylene	7.7
Volatile Hydrocarbon Compounds (VHCs)	
Dicyclopentadiene	65
Volatile Aromatic Organic Compounds (VAOs)	
Benzene	8.8
Organosulfur Compounds, Mustard Agent Related (OSCMs)	
Dithiane	20
Organosulfur Compounds, Herbicide Related (OSCHs)	
Chlorophenylmethyl sulfoxide	11
Organophosphorous Compounds, GB-Agent Related (OPHGBs)	
Diisopropylmethyl phosphonate (DIMP)	360
Organophosphorus Compounds, Pesticide Related (OPHPs)	
Atrazine	21
Dibromochloropropane (DBCP)	
Dibromochloropropane	0.38
Organochlorine Pesticides (OCPs)	
Chlordane	0.24
Dieldrin	0.32
Hydrazine-Related Compounds	
N-nitrosodimethylamine	1.5
Arsenic	
Arsenic	9.5



Not To Scale

LEGEND

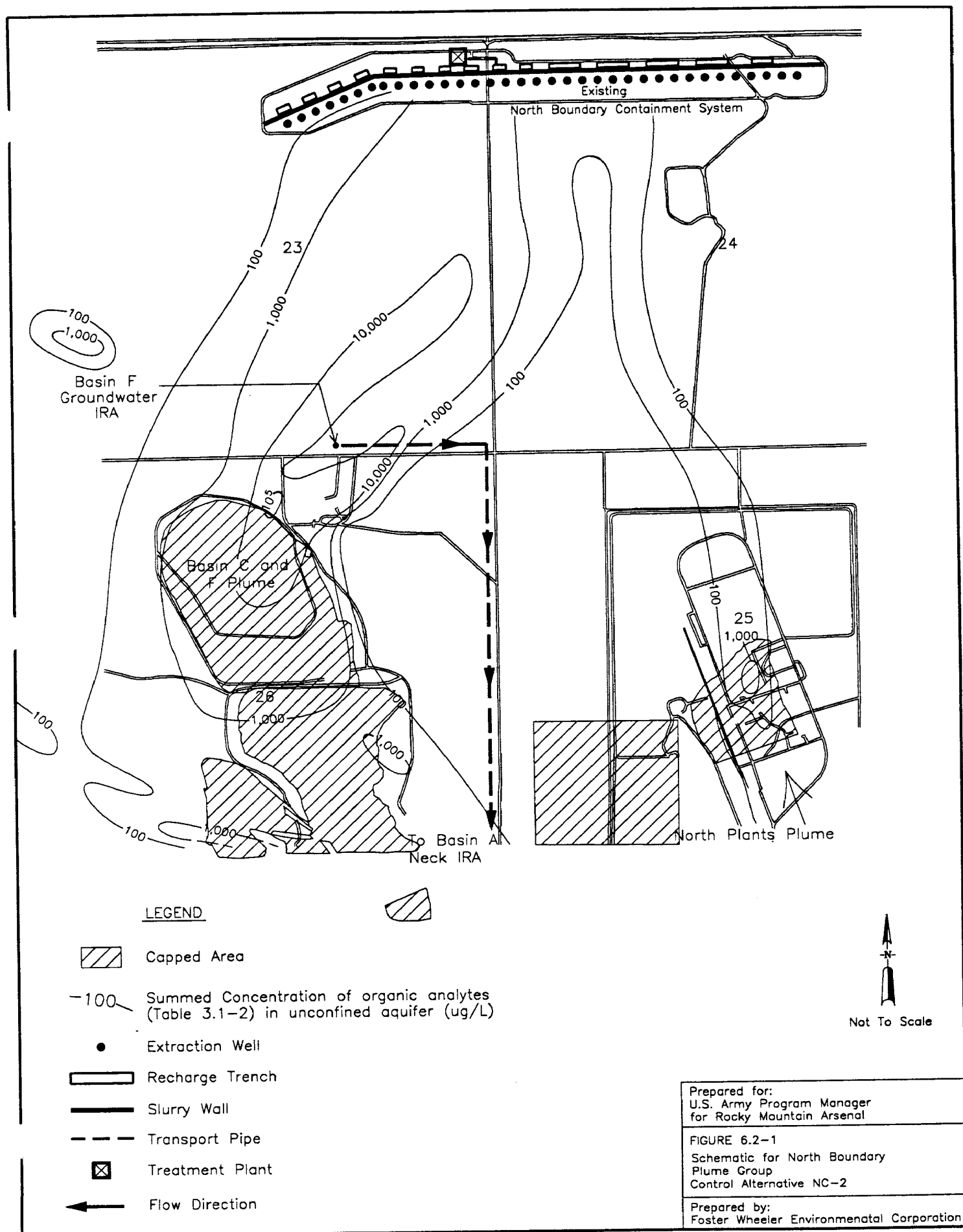
-100- Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)

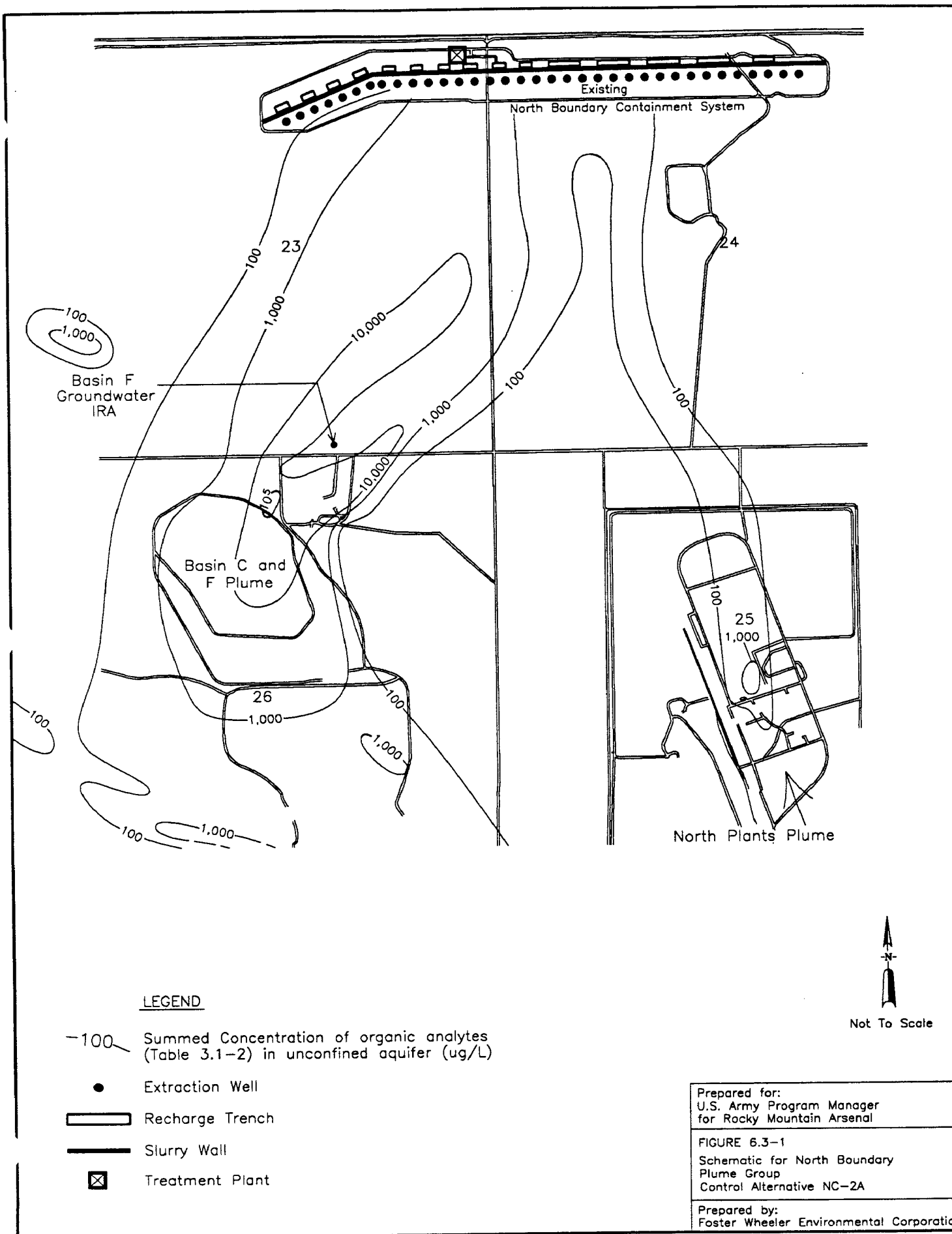
--- Perforated Slurry Wall

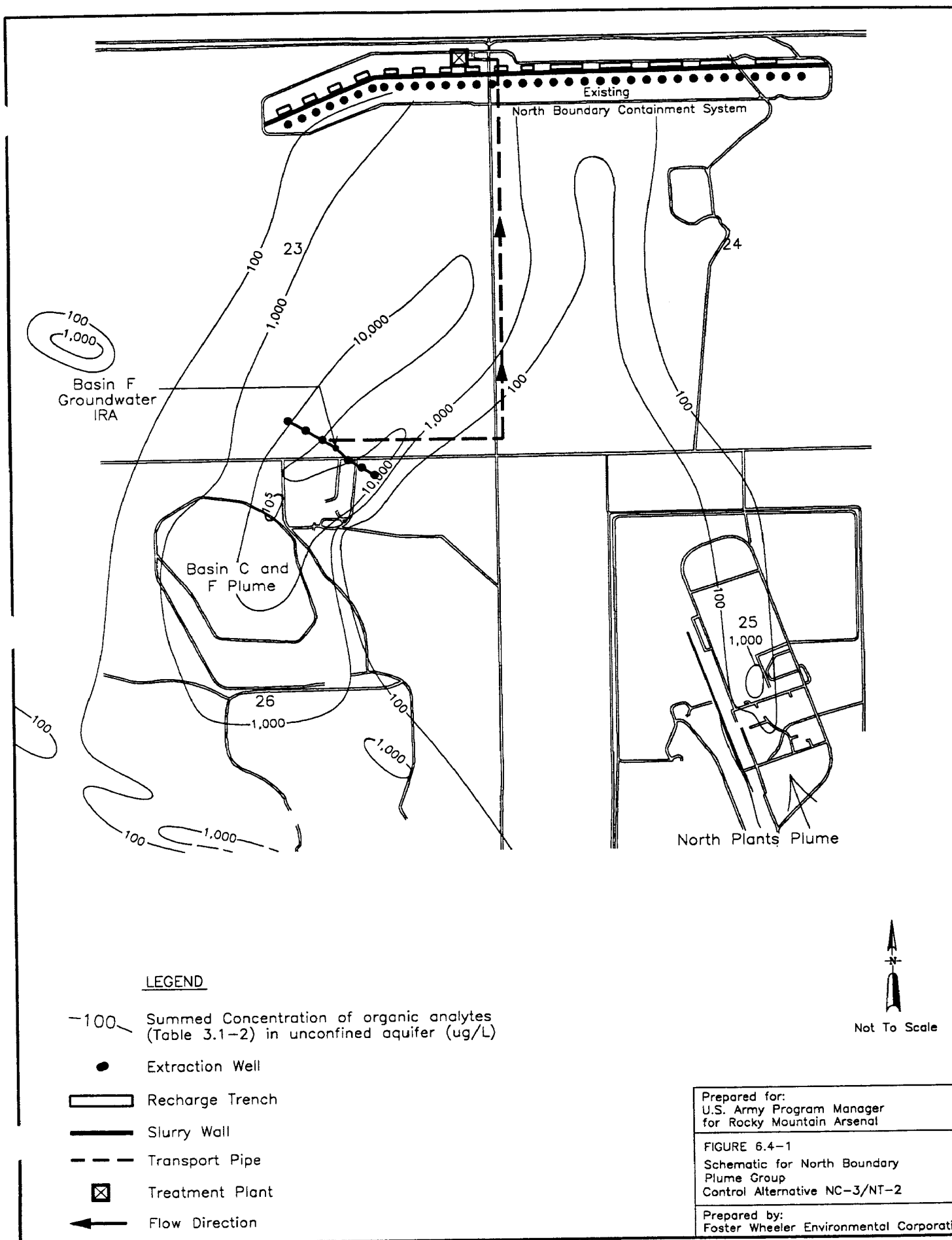
Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

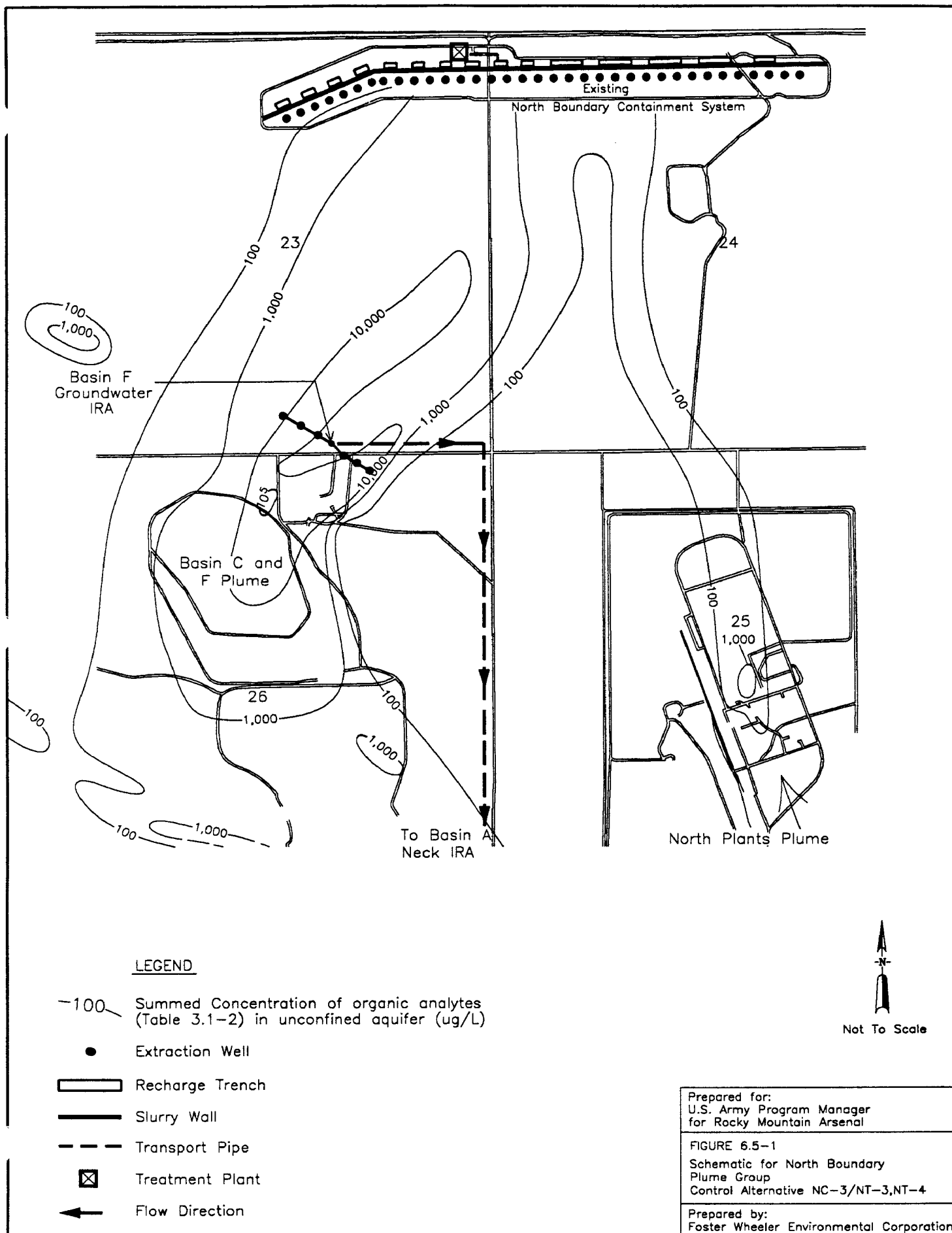
FIGURE 6.1-1
Schematic for North Boundary
Plume Group
Control Alternative NC-1

Prepared by:
Foster Wheeler Environmental Corporation



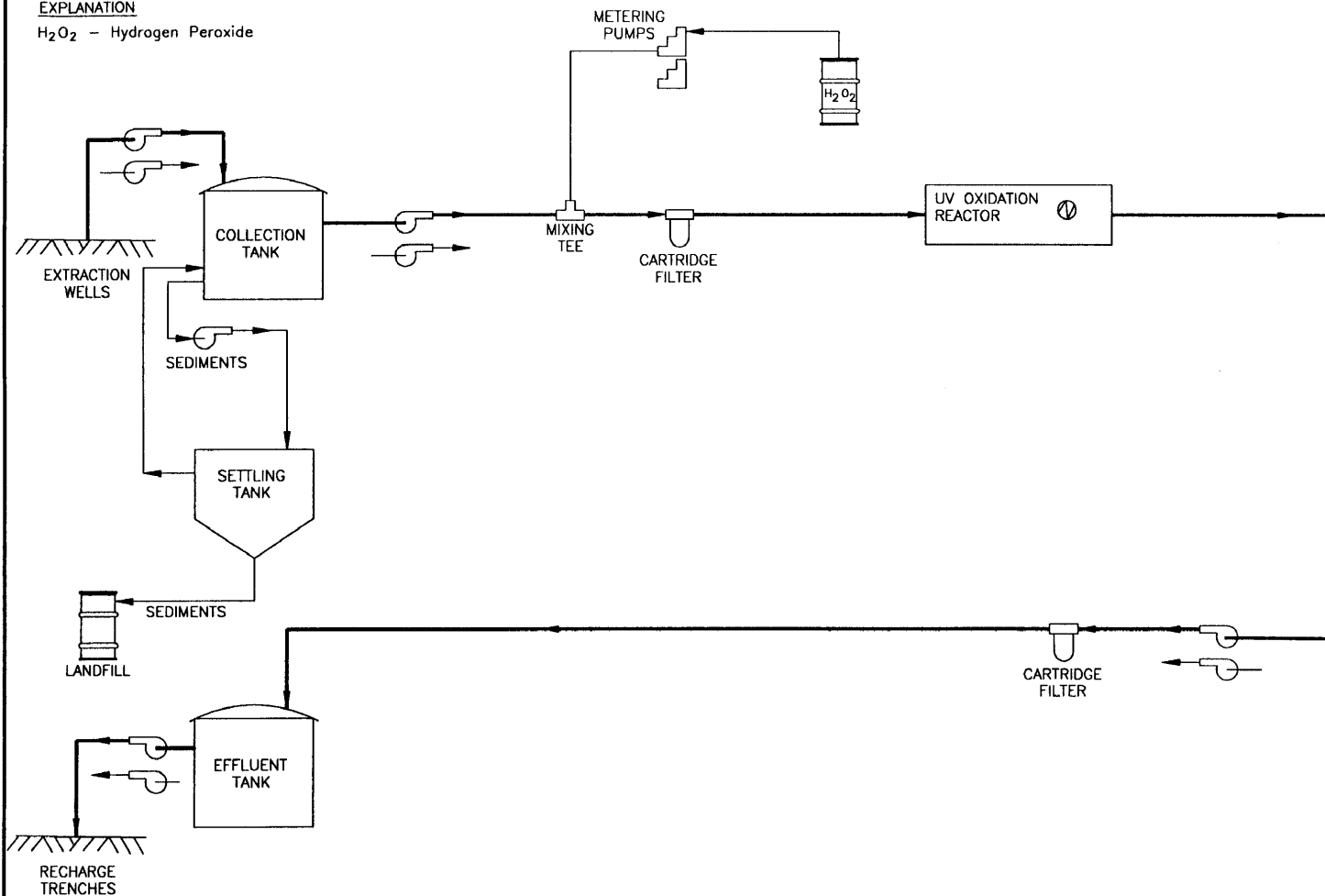






EXPLANATION

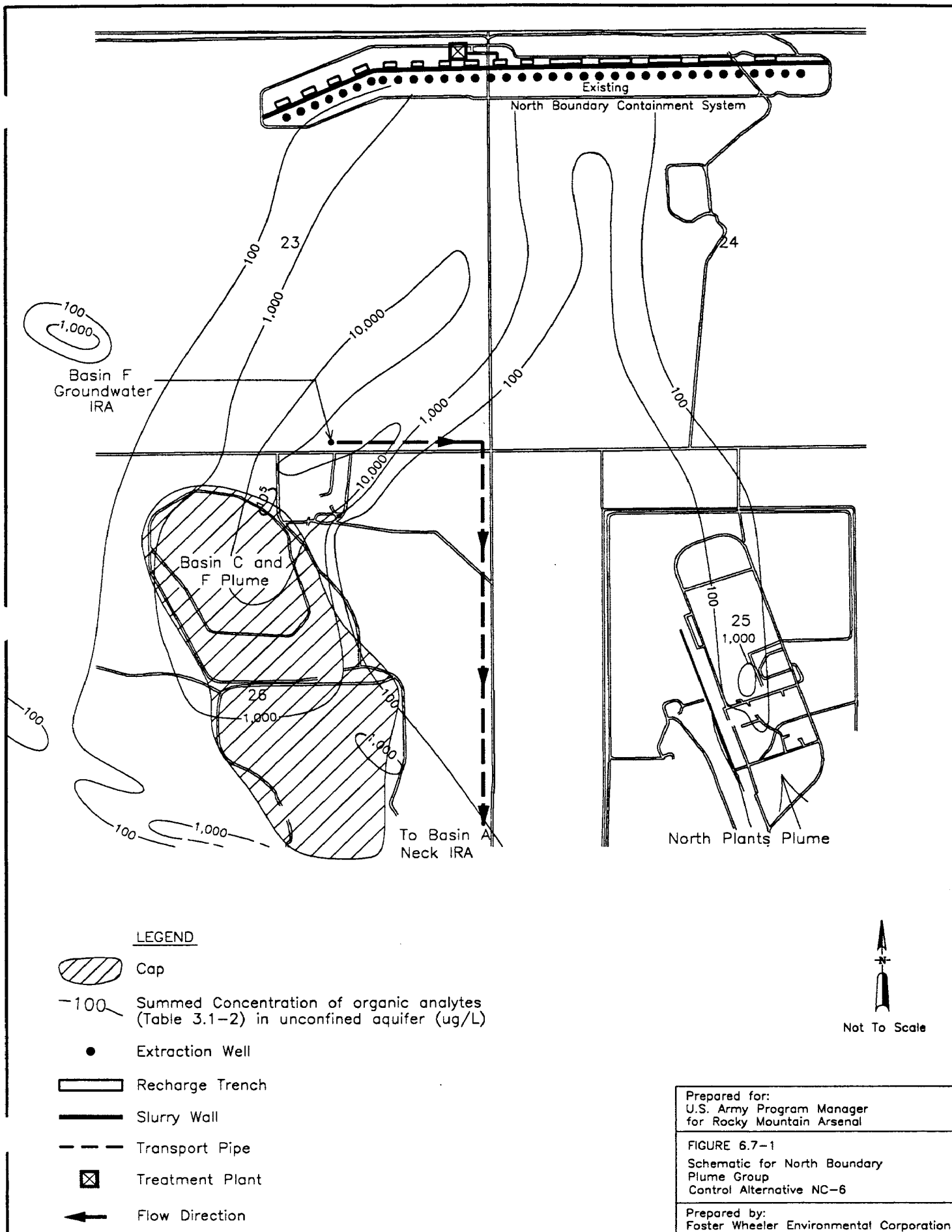
H₂O₂ - Hydrogen Peroxide



Prepared for:
Office for the Program Manager
for Rocky Mountain Arsenal

FIGURE 6.6-1
Process Flow Diagram
Treatment Alternative NT-4,
Oxidation

Prepared by:
Foster Wheeler Environmental Corporation



Section 7

7.0 BASIN A PLUME GROUP

The groundwater control/treatment alternatives presented here are not final designs that will actually be constructed. They are preliminary designs that have been developed for relative comparison and evaluation during the FS process. Each alternative has been carried to a preliminary design level because only at this level can actual size, effectiveness and costs be evaluated appropriately. Sufficient detail is provided for each alternative to allow its merits and drawbacks to be easily compared.

The final control/treatment alternative that is selected for a given plume group will be determined as part of the Record of Decision (ROD), the negotiation and decision-making process by which the final site remediation is selected by the Parties. When the alternatives for the plume group have been selected the remediation will enter a design phase. During the design phase, site specific information will be collected about current site conditions, and a control/treatment system will be designed to meet the specific goals stated in the ROD. Such a design will be generally based on one or more of the alternatives described here, but will undoubtedly differ from it to some degree. For instance, a technology utilized in an alternative may be replaced by a technology that appears to be more appropriate or desirable at the time of design based on new site conditions, costs, results of pilot and treatability studies and other factors. As long as the new technology can be applied to meet the goals of the selected alternative this change can be made.

Five alternatives were retained for consideration in the Water DAA for the Basin A Plume Group. These alternatives include no action, continued existing action, and three groundwater extraction and treatment or capping alternatives. Rather than constructing the treatment systems discussed in this section for this plume group, the CERCLA Wastewater Treatment Plant could, upon redesign and expansion, be used to treat the Basin A groundwater. Such a decision depends on the available capacity of the plant and its planned use, as well as whether modifications to the plant (including expansion and change from batch to continuous operation), can be made at the time the selected groundwater remedy begins.

Three additional control/treatment alternatives were incorporated into the DAA for this plume group. Two of these alternatives involve dewatering the aquifer in Basin A, and one focuses on a specific plume in this plume group. These three alternatives were developed in coordination with and support of various Basin A soil remediation alternatives.

The Basin A Plume Group is made up of the Basin A, South Plants North, and Section 36 Bedrock Ridge Plumes (North and South) (Table 3.1-1). Primary contaminants in these plumes include chloroform, methylene chloride, TCE, benzene, DBCP, and atrazine. These contaminants have only been detected in dissolved form in groundwater; however, if NAPL is determined to be present in this area, the planned or existing extraction/treatment systems are modified to include appropriate NAPL treatment.

One treatment system currently in place, the Basin A Neck IRA, removes contamination from the Basin A Plume. This pump-and-treat system, located north and south of Eighth Avenue, just west of "D" Street, also accepts groundwater from the Basin F Groundwater IRA extraction system. Treatment at the Basin A Neck IRA facility includes air stripping (Basin F groundwater only) and GAC adsorption (combined stream). Two other IRAs, the Shell Trenches and the Lime Settling Basins IRAs, are also in place as source-control activities.

The existing internal containment/treatment systems can only be shut down under specific conditions. Existing wells within the internal containment systems can be removed from production when concentrations of constituents detected in the wells are less than ARARs established in the ROD and/or it can be demonstrated that discontinuing operation of a well would not jeopardize the containment objective of the system. The containment objective of the system will be outlined in the ROD. Wells removed from production and monitoring wells upgradient and downgradient of the internal containment systems will be monitored quarterly for a period of 5 years to determine whether contaminants reappear. Those wells turned off for hydraulic purposes will not be subject to the quarterly monitoring requirements. Internal containment system extraction wells removed from production for reasons of water quality will be placed back into production if concentrations exceed ARARs established in the ROD. Wells

with concentrations less than ARARs established in the ROD can remain in production if additional hydraulic control is required.

Those alternatives evaluated for the Basin A and South Plants Plume Groups that involve construction of a treatment facility assume that separate facilities are built. A combined Basin A/South Plants treatment plant may prove to be more efficient; however, at this stage of planning it is not known which alternative will be chosen for either the Basin A or the South Plants Plume Group. Because this choice will affect the quantity of groundwater being treated from either plume group, the total flow through the treatment plant is still unknown. Therefore costs have been developed based on separate treatment for each plume group. When a decision has been finalized regarding which alternative from Basin A and which alternative from South Plants will be implemented, a treatment plant for the combined flow can be considered.

Recent modifications to the caps considered for the soil medium for sites in Section 36 have not, with the exception of Alternative AC-9, been incorporated into the water alternatives. Based on the new cap configurations, the impact of these modifications was determined through groundwater modeling to be small, and further changes to the cap designs are possible until the remedial design is completed. These small changes should have no impact on the selection process. Because Alternative AC-9 is one of the most recently developed water alternatives and it was developed in conjunction with the revised cap design for the preferred soil alternative, it does include these cap changes.

The following sections provide detailed descriptions and analyses for each of the eight alternatives. Table 7.0-1 presents a summary of these analyses. In addition, Appendix C contains travel-time calculations for several contaminants in the Basin A Plume Group.

7.1 ALTERNATIVE AC-1: NO ACTION

Under this alternative, operation of the Basin A Neck IRA is discontinued and the existing slurry wall between the extraction wells and the reinjection trenches at this system is breached. Neither

the Shell Trenches IRA (because it is already completed and does not include any groundwater extraction activities), nor the Lime Settling Basins IRA is affected by this alternative.

7.1.1 Description of Alternative

7.1.1.1 Extraction/Reinjection

Alternative AC-1 specifies that any groundwater controls be discontinued, which impacts the Basin A Neck IRA. This IRA consists of seven extraction wells, a slurry wall barrier, three reinjection trenches, a GAC adsorption system, and an air stripper with off-gas treatment (for groundwater pumped from the Basin F Groundwater IRA). The GAC system operates at approximately 20 gpm (James 1995) and the air stripper operates at 1 to 4 gpm. Under this alternative, the operation of this system is terminated and the slurry wall is breached. Perforation of the slurry wall prevents an increase in hydraulic head in the contaminated alluvial aquifer on the upgradient side of the barrier. Dismantling the Basin A Neck IRA treatment structure has been addressed by alternatives evaluated for the No Future Use, Other Contamination History Medium Group in the Structures DAA. Figure 7.1-1 presents the schematic diagram for Alternative AC-1.

The Shell Trenches IRA, located in the southeast corner of Basin A in the area of the Shell Trenches, is not impacted by Alternative AC-1. This source-control action consists of a vertical slurry wall barrier and a low-permeability cap to reduce the lateral migration of contaminants emanating from the Shell Trenches (MKC 1991). The slurry wall is not destroyed under this alternative because the wall entombs contaminants and does not significantly disrupt the normal flow of groundwater in this area.

The Lime Settling Basins IRA consists of the placement of a cover with a vegetative barrier over the Lime Basins. Alternative AC-1 does not affect this IRA.

7.1.1.2 Treatment

No treatment is associated with Alternative AC-1. Current GAC treatment at the Basin A Neck IRA is discontinued.

7.1.1.3 Sidestreams

No sidestreams are generated by this alternative.

7.1.2 Analysis of Alternative

7.1.2.1 Overall Protection of Human Health and the Environment

Alternative AC-1 allows contaminants to migrate from their source areas at Basin A toward the RMA boundary. It is, however, assumed that the boundary systems are in operation and capture any contamination reaching the boundary. This alternative is consequently protective of human health and the environment offpost so long as PRGs are met at the boundary. Human health is protected on post by the FFA (EPA et al. 1989), which prohibits the use of RMA groundwater as a potable water source.

7.1.2.2 Compliance with ARARs

Alternative AC-1 is in compliance with all action-specific ARARs and the FFA (EPA et al. 1989). Chemical-specific ARARs do not apply to this alternative since no on-post action is undertaken. Location-specific ARARs do not apply. (All ARARs are listed in Appendix A of the Technology Descriptions Volume.)

7.1.2.3 Long-Term Effectiveness and Permanence

The lack of controls or treatment under Alternative AC-1 increases the potential for contaminant migration and additional loading on the boundary systems. All existing controls associated with the Basin A Neck IRA are removed as part of the No Action alternative for the Basin A Plume Group. Monitoring continues.

7.1.2.4 Reduction of TMV

No treatment is undertaken in the Basin A area as part of Alternative AC-1. By eliminating the currently operating Basin A Neck IRA, toxicity of the Basin A Plume Group is not decreased through treatment. Instead, the mobility and volume of contaminants migrating from the Basin A area are increased. This increase in TMV eventually impacts the boundary systems, which may

then require upgraded treatment systems. Some TMV reduction may be experienced as a result of natural attenuation.

7.1.2.5 Short-Term Effectiveness

There is some potential exposure to workers during breaching of the slurry wall, but the risks to workers can be adequately reduced through use of PPE. The activities required by this alternative do not have any significant impact on the surrounding community or the environment. The protection that is currently provided through the Basin A Neck IRA is eliminated, resulting in a potential increase in contaminant levels in on-post groundwater. RAOs are achieved so long as the boundary systems continue to operate.

7.1.2.6 Implementability

Alternative AC-1 is both technically and administratively feasible.

7.1.2.7 Costs

The capital cost of this alternative is \$28,500, and the annual O&M costs are \$195,000 for the first 5 years and \$91,200 for the next 25 years. The present worth cost is \$2,370,000. A summary of costs for this alternative is presented in Appendix A, Table A4-1.

7.2 ALTERNATIVE AC-2: CONTINUED EXISTING ACTION

Alternative AC-2 includes continued operation of the existing IRA systems for the Basin A Plume Group. These consist of the Basin A Neck, Shell Trenches, and Lime Settling Basins IRAs. PRGs for the Basin A Neck system are listed in Table 2.2-5. Continued groundwater monitoring and continued compliance with the FFA (EPA et al. 1989) are components of this alternative.

7.2.1 Description of Alternative

7.2.1.1 Extraction/Reinjection

The Basin A Neck IRA is a pump-and-treat system that intercepts and treats contamination in groundwater as it moves northwest from Basin A. The extraction system consists of seven alluvial wells that pump a total flow of approximately 20 gpm (James 1995). Water from the

Basin F Groundwater IRA is also piped to the Basin A Neck treatment system at a rate of 1 to 4 gpm and pre-treated with an air stripper, after which it is fed into the Basin A Neck flow and treated by GAC. Three gravel-filled recharge trenches (160 ft, 170 ft, and 180 ft in length) are located across the more permeable, deeper portions of the Basin A Neck. A soil/bentonite slurry wall extends 830 ft across the Basin A Neck between the extraction wells and the recharge trenches to limit recirculation of water between the two systems and inhibit any flow of contaminants not captured by the extraction wells (Figure 7.2-1). Treated water from the CERCLA Wastewater Treatment Plant is conveyed by an underground pipeline, combined with Basin A Neck treatment plant effluent at a rate of 5 gpm, and reinjected in the Basin A Neck reinjection trenches. The CERCLA Wastewater Treatment Plant treats water in a semibatch mode on an as-needed basis.

The Shell Trenches IRA is complete. The objective of this IRA was to reduce the lateral migration of contaminants (dissolved and separate phase) emanating from the Shell Trenches. The IRA consists of a vertical slurry wall barrier and a low-permeability cap.

Construction of the Lime Settling Basins IRA began in 1992, but trenching for the slurry wall was abandoned due to the discovery of UXO. The cap placed over the Lime Settling Basins was completed.

7.2.1.2 Treatment

Groundwater extracted from both the Basin A Neck and the Basin F Groundwater IRAs is treated at the Basin A Neck IRA treatment facility. Approximately 1 to 4 gpm of groundwater from the Basin F Groundwater IRA is filtered and then treated in an air stripper. The vapor emissions from the air stripper are treated by two vapor-phase carbon vessels operated in series and an additional backup unit. The effluent from the air stripper is combined with the Basin A Neck IRA influent and treated by pre-filtration through a multimedia filter followed by adsorption in two 2,000-lb carbon vessels in series (one backup vessel is on standby). When the concentration of the effluent in the first vessel is equal to 50 percent of the influent concentration, the carbon is replaced. The GAC effluent is filtered through multimedia filters and discharged to a

3,000-gallon effluent tank. Water from the tank is then filtered through 5-micron bag filters and pumped to the recharge trenches. Approximately 20 gpm of groundwater is treated by the Basin A Neck IRA (James 1995).

7.2.1.3 Sidestreams

The Basin A Neck IRA treatment system generates two sidestreams requiring treatment or disposal, spent carbon and filter solids. The GAC in the adsorbers is removed and regenerated at an off-post facility. The filter solids and bag filters are drummed and disposed in the on-post RCRA landfill or off post.

7.2.2 Analysis of Alternative

7.2.2.1 Overall Protection of Human Health and the Environment

Alternative AC-2 is protective of human health and the environment off post so long as PRGs are met at the boundary. The Basin A Neck IRA reduces contaminant migration to the boundary systems, thereby reducing future loading on these systems. Human health is protected on post by the FFA (EPA et al. 1989), which prohibits the use of RMA groundwater as a potable water source.

7.2.2.2 Compliance with ARARs

Alternative AC-2 is in compliance with all action-specific ARARs and chemical-specific ARARs identified for the Basin A Neck System. It is also in compliance with all location-specific ARARs since it involves operation of an existing system. All ARARs are listed in Appendix A of the Technology Descriptions Volume.

7.2.2.3 Long-Term Effectiveness and Permanence

Under Alternative AC-2, contaminant migration is minimized through capture and treatment of contaminants close to the source. Moreover, the Basin A Neck IRA system reduces the potential for additional loading on the boundary systems. The system may have to operate for more than 30 years, based on the estimated travel times of contaminants from the plumes to the Basin A

Neck IRA capture system. However, as described by the criteria in Sections 1.3.3 and 7.0, the system or individual extraction wells may be shut off earlier. Monitoring continues.

7.2.2.4 Reduction of TMV

Contaminants captured at the Basin A Neck IRA are treated with GAC adsorption. Groundwater is extracted at a flow rate of approximately 20 gpm (James 1995), which results in a significant reduction of contaminant TMV. Contaminants are irreversibly transferred to GAC, which requires regeneration off post. Long-term maintenance is required.

7.2.2.5 Short-Term Effectiveness

Alternative AC-2 has no additional impact on workers, surrounding communities, or the environment since no additional actions are undertaken and no existing actions are removed. This alternative achieves RAOs through continued operation of the boundary systems. The Basin A Neck IRA may be required to operate for more than 30 years.

7.2.2.6 Implementability

The Basin A Neck IRA is already operational and continued operation is technically and administratively feasible.

7.2.2.7 Costs

There is no capital cost associated with this alternative. The O&M costs for continued operation of the Basin A Neck IRA and plume monitoring are \$1,140,000 per year for the first 5 years and \$1,000,000 per year for the next 25 years; the present worth cost is \$20,500,000. A summary of costs for this alternative is presented in Appendix A, Table A4-2.

7.3 ALTERNATIVE AC-3/AT-2: MASS REDUCTION, STRIPPING/SORPTION

This alternative consists of groundwater extraction in a mass reduction configuration followed by treatment using air stripping and GAC adsorption. The treated water is reinjected in recharge trenches. This alternative is accomplished in conjunction with capping of the area under the

preferred soil remedial alternative. Table 7.3-1 presents the estimated chemical influent concentrations for mass reduction of the Basin A Plume Group under this alternative.

7.3.1 Description of Alternative

7.3.1.1 Extraction/Reinjection

Alternative AC-3 consists of mass reduction systems located in each of the plumes within the Basin A Plume Group (Figure 7.3-1). This alternative is accomplished in conjunction with the preferred sitewide soil alternative for capping Basin A and is to be coordinated with the selected South Plants groundwater alternative. The "intercept" well configuration, illustrated in the Water DSA, was modified into a mass reduction configuration in the Water DAA (Alternative AC-3) because further hydrogeologic evaluation suggests that site conditions favor a mass reduction approach due to the relatively low mobility of many contaminants. The Basin A Neck IRA also continues to operate.

The total estimated pumping from the Basin A Plume Group is approximately 20 gpm: 10 gpm from South Plants North Plume, 8 gpm from the Basin A Plume, and 2 gpm from the Section 36 Bedrock Ridge Plumes. The extraction wells of the groundwater extraction system are generally located along the central axis of each plume where concentrations tend to be higher and pumping results in greater removal of contaminant mass. For costing and comparison purposes it was assumed that the mass reduction systems operate for 20 years to remove all of the currently dissolved contaminant mass in the targeted central area of each plume.

The mass reduction operation for the Basin A Plume Group is accomplished over a 20-year period. Estimates of the total mass of dissolved organic contaminants that are present in the targeted areas of the aquifer are approximately 3,400 kilograms (kg) in the Basin A Plume, 38,000 kg in the South Plants North Plume, 930 kg in the North Bedrock Ridge Plume, and 130 kg in the South Bedrock Ridge Plume. The pumping rates mentioned above correspond to removal of all of the currently dissolved contaminant mass from the Basin A Plume Group. Twenty years of extraction of contaminated groundwater from the targeted plume areas will result in the following estimated quantities of mass removal from each plume assuming complete

removal of one pore volume of water: 3,400 kg (100 percent of initial dissolved mass) for the Basin A Plume, 38,000 kg for the South Plants North Plume, 930 kg for the North Bedrock Ridge Plume, and 130 kg for the South Bedrock Ridge Plume. As groundwater is removed from these portions of the aquifer, water having lower contaminant concentrations is expected to flow in from adjacent areas, contaminant mass sorbed on aquifer solids will be released into this water, thereby increasing contaminant levels in groundwater for some time. Current estimates indicate that the mass of contaminants sorbed onto aquifer materials is a relatively large fraction of total contaminant mass present in the aquifer (see Appendix C).

The Basin A Neck IRA intercept system continues to operate and extracts remaining contaminants indefinitely after installation of the mass reduction systems and capping of Basin A under the soil medium remedial alternative. The cap described in the current version of the Soil DAA has been modified and is somewhat different from the cap considered here. However, the difference has minimal impact on this alternative.

All extraction wells under this alternative are constructed using 12-inch-diameter borings with gravel pack surrounding the 6-inch-diameter casing and screen (thereby increasing the effective intake radius of the wells), and all pipelines are double-walled. All submersible pumps in wells were assumed to be one-third horsepower and all booster pumps to be 1.5 horsepower for costing purposes. Well heads are extended upward as needed when the soil backfill and cap are emplaced as part of the preferred soil alternative.

The mass reduction system located in the South Plants North Plume consists of 18 extraction wells. The wells are located in a north-south orientation along the axis of the South Plants North Plume (Figure 7.3-1). The wells are approximately 35 ft deep with 15-ft-long well screens that extend into both the alluvium and the weathered Denver Formation. The total flow of 10 gpm for the South Plants North Plume is pumped to a collection tank and from there is pumped via a buried pipeline to the treatment plant near South Plants. The treated water is then recharged into two to four recharge trenches located in Section 27. Three areas are being considered as possible sites for the injection trenches. These areas include Section 27 upgradient of the

NWBCS, Sections 23 and 24 upgradient of the NBCS, and Sections 25 and 31 upgradient of North Plants and the NBCS. At this time the Section 27 option is preferred because it is located in a permeable aquifer that can accept the estimated flow volumes without significant impact to the aquifer or contaminant migration. The Section 27 location was used to develop costs for this report. If further evaluation indicates that another recharge location is more favorable, then the recharge trenches can be relocated to that site.

The mass reduction system located in the Basin A Plume consists of seventeen 35-ft-deep wells located in a north-south orientation along the axis of the Basin A Plume. The extraction wells pump a total of 8 gpm. The extracted groundwater is collected in a collection tank, as is described for the South Plants North Plume, and is piped along with the Section 36 Bedrock Ridge Plumes groundwater to the treatment plant.

There are three wells located along the plume axis of each Section 36 Bedrock Ridge Plume. The three wells in the North Section 36 Bedrock Ridge Plume extract approximately 1 gpm, and the three wells located in the South Section 36 Bedrock Ridge Plume extract approximately 1 gpm. The total of 2 gpm of water from both plumes is collected in a collection tank, the 8 gpm from the Basin A Plume is collected in a second tank, and the 10 gpm from the South Plants North Plume is collected in a third tank. The three tanks are connected in series and then the total flow of 20 gpm is piped to the treatment plant for treatment.

Treated water is pumped from the treatment plant to the reinjection trenches through single-walled PVC pipe. The recharge trenches are lined with a geotextile filter fabric, backfilled with clean gravel, and covered with geotextile filter fabric and 3 ft of soil. Injection distribution pipes, which connect to well points made of PVC, extend 3 ft into the gravel backfill. The recharge trenches are located in permeable alluvium and away from localized impermeable layers to ensure that water is recharged back to the aquifer without restriction.

Each of the proposed extraction systems under Alternative AC-3 requires installation of performance monitoring wells. Groundwater-quality and water-level data from the newly

installed performance monitoring wells are used to evaluate the effectiveness and operation of the extraction system. The final location of the wells is based upon review of existing well locations and screened intervals. If existing wells can be utilized for this purpose, the number of new monitoring wells required can be reduced.

7.3.1.2 Treatment

The treatment system in Alternative AT-2 uses air stripping followed by GAC adsorption to remove contamination from the groundwater. Figure 7.3-2 presents a process flow diagram showing the major pieces of treatment equipment as well as tanks, pumps, and filters included in this alternative.

Extracted water is held in a collection tank prior to being treated. From there the water is pumped through a multimedia filter to remove suspended solids and potassium pyrophosphate (PKPP) is added as a sequesterant to keep the iron and manganese from precipitating in the air stripper. The water then enters a shallow tray air stripper that is operated with an air flow rate of 300 cubic feet per minute (cfm). The stripper is designed to remove volatile organics, such as benzene and chloroform, to meet PRGs. A more detailed description of the air stripping technology is presented in the Technology Description Volume, Section 14.3.

The organic contaminants emitted from the air stripper are destroyed in a catalytic oxidation unit, which uses thermal energy (pre-heating) in the presence of a catalyst to destroy the contaminants. Supplemental fuel is required for the preheater to completely oxidize the organics. The catalyst must be replaced every 3 to 5 years, and is usually returned to the vendor where the catalyst (platinum) is recovered.

The water effluent from the air stripper is pumped to the GAC adsorbers. GAC treatment is accomplished using one modular GAC adsorber that holds 2,000 lbs of GAC. The GAC adsorber is designed to remove the DBCP and organochloride pesticides (OCPs) to concentrations less than the PRGs using an estimated carbon consumption of 4,000 lbs year. When the GAC vessel becomes saturated with contaminants, it is disconnected and replaced with a fresh unit. The spent

vessel is drained and returned to the vendor for regeneration and the drained water is returned to the collection tank. It is anticipated that the GAC unit is replaced approximately twice each year. A more detailed description of the GAC treatment technology is included in the Technology Description Volume, Section 14.2.

The GAC effluent is filtered through a cartridge filter to remove carbon fines and suspended solids. Filtered effluent is held in a collection tank prior to reinjection.

Under this alternative, the Basin A Neck IRA continues to operate.

7.3.1.3 Sidestreams

This treatment system produces three sidestreams, vapor emissions from the air stripper, spent GAC adsorption units, and used cartridges from the filters. In addition, spent carbon from the Basin A Neck IRA is also generated.

The vapor emissions from the air stripper are treated by catalytic oxidation. Because this process actually destroys the contaminants instead of transferring them to another medium, no further treatment of waste products or sorbents is required. The spent GAC is regenerated off post.

Used cartridges from the filters also require disposal. Because they have been in contact with hazardous materials, they are drummed and transported to the on-post hazardous landfill or disposed off post. Wastewater in the wastewater tank is recirculated to the collection tank and sediments from wastewater tank are drummed and landfilled along with the filter cartridges.

7.3.2 Analysis of Alternative

7.3.2.1 Overall Protection of Human Health and the Environment

Alternative AC-3/AT-2 is protective of human health and the environment off post so long as PRGs are met at the boundary. Contaminants from the Basin A area are removed, achieving a measurable reduction in the dissolved contaminant mass during the 20 years of operation based on calculations of the quantity of water and contaminant mass removed (Section 7.3.1 and

Appendix C). The FFA restrictions on future uses of groundwater provide protection of human health on-post.

The permanent removal of contaminants decreases the toxicity and the mobility of the contaminants. The preferred soil remedial alternative for Basin A, the placement of a cap, provides a means of source control by reducing leaching of contaminants into the groundwater.

7.3.2.2 Compliance with ARARs

Alternative AC-3/AT-2 is in compliance with all action-specific ARARs. This alternative was conceptually designed based on an earlier set of ARARs. If selected, it is expected to meet most of the revised CBSG-based chemical-specific ARARs that would be developed. However, some design changes might be required. The systems included in this alternative are in compliance with all location-specific ARARs. The Basin A Neck IRA, which continues to operate under this alternative, is in compliance with all ARARs. (All ARARs are listed in Appendix A of the Technology Descriptions Volume).

7.3.2.3 Long-Term Effectiveness and Permanence

Alternative AC-3/AT-2 reduces the potential for contaminant migration by permanently removing contamination from the groundwater. The potential for off-post exposure is reduced by the mass removal of contaminants from the Basin A, South Plants North, and Section 36 Bedrock Ridge Plumes in conjunction with the continuing operation of the boundary systems and Basin A Neck IRA. A fraction of the groundwater contamination is removed and treated close to the source. The proposed mass removal system lowers the groundwater levels in the Basin A Plume Group to some extent during the 20-year period of operation (but not as much or as long as a dewatering approach). The amount of contaminated soil in contact with groundwater is reduced temporarily by lowering the water table. A cap placed over the Basin A area as part of the soil preferred alternative prevents infiltration, thereby reducing both groundwater migration in the Basin A Plume Group and the leaching of the contaminants from the unsaturated soil column permanently. The Basin A Neck IRA continues to intercept contaminants that migrate from the Basin A Plume Group. This IRA may be required to operate for more than 30 years based on the estimated

travel times of contaminants from the plumes to the extraction wells. However, the system or wells within the system may be shut off earlier if shut off criteria defined in Section 1.3.3 are met. The boundary systems ensure that any groundwater that is not captured and treated on post meets PRGs at the RMA boundary.

Monitoring occurs during the operation of the mass reduction treatment system and continues to evaluate long-term effectiveness and plume migration once the system is shut down. The mass of contamination removed by the mass reduction systems is monitored by influent sampling at the treatment plant and by monitoring of groundwater at monitoring wells. The specific mass reduction system performance objectives will be defined during the design phase of the alternative. For costing and comparison purposes it was assumed that the mass reduction systems operate for 20 years to remove all of the dissolved contaminant mass now in the targeted central areas of each plume.

7.3.2.4 Reduction of TMV

Alternative AC-3/AT-2 reduces toxicity and mobility of contaminants in the groundwater by mass removal of contaminants at the plume centers (Section 7.3.1.1) followed by treatment and reinjection. Under this alternative, air stripping removes the majority of the volatile organics and GAC adsorption treats the remaining organic contaminants. At the Basin A Neck IRA, organic contaminants are treated with GAC adsorption. These processes are irreversible, and the contaminants removed in the air stripper are destroyed by catalytic oxidation. Contaminants treated with GAC adsorption are transferred to the carbon, which is regenerated off post. Contaminants that are not removed by the mass reduction extraction system, or residual contaminants that remain sorbed to the soil in the aquifer and desorb at a later time, are treated by Basin A Neck IRA and the NWBCS boundary system. Toxicity is reduced by the removal of contaminants from the groundwater prior to reinjection.

A mass reduction system extracts the groundwater at the source or in high-concentration areas, reducing the potential for migration through the aquifer. In addition, the water table is lowered temporarily due to groundwater extraction and the contaminants are contained in the soil above

the water table (the vadose zone), limiting their mobility. Mobility is further reduced by the placement of a cap over Basin A, which reduces the leaching of contaminants from the soil and vadose zone. In this system, 20 gpm is extracted from the South Plants North, Basin A, and the Section 36 Bedrock Ridge Plumes. The Basin A Neck IRA extracts and treats contaminants in the Basin A Neck area at flow rates up to 20 gpm. The operation of these systems results in the decrease of contaminant mobility in the Basin A Plume Group and a reduction of contaminant loading on the Basin A Neck IRA.

7.3.2.5 Short-Term Effectiveness

In general, the construction, operation, and final demobilization of Alternative AC-3/AT-2 has minimal negative impact on the environment, workers, or the surrounding community. On-post workers are potentially exposed to contaminants by dermal contact and/or dust inhalation pathways and the physical hazards of unexploded ordnance (UXO) when excavation and well and trench installation activities are performed. To reduce the potential for such exposure, geophysical surveys to clear the site of UXO, dust-control measures, and PPE are used.

Operators of the system must also concern themselves with proper materials-handling techniques when changing the GAC adsorption units. To reduce the potential for exposure, personnel are made aware of on-post health and safety procedures and PPE is used.

RAOs are achieved under this alternative. In the 20 years of operation, a measurable fraction of contaminant mass is removed from the plume centers (see Section 7.3.1.1 and Appendix C). The contaminants are extracted and treated, reducing the volume and toxicity of contaminants in the groundwater. The Basin A Neck IRA may be required to operate for more than 30 years.

7.3.2.6 Implementability

Alternative AC-3/AT-2 is technically feasible. Extraction/reinjection, air stripping, and GAC adsorption are proven and commercially available technologies. As discussed in the Technology Description Volume (Sections 5, 14.3, and 14.2), these technologies are currently being used at RMA. The extraction system incorporates existing wells where possible. The operators do not

require any further training for operation of this alternative. The Basin A Neck IRA is currently operating and no further changes to this system are required.

The alternative is expected to be reliable. The treatment system requires minimal down time for equipment maintenance; in many cases, maintenance can be performed without shutting down the entire system. The system has automated controls that ensure continuous operation with little supervision.

GAC units and air strippers are readily available and supplied in sufficient quantities by large, technically proficient vendors. Filter cartridges and sediments are disposed in the on-post hazardous landfill or an off-post landfill. Precious metals are recovered from the spent catalyst in the catalytic oxidation unit by the supply vendor.

Administratively, this alternative is easily implemented. It requires an operation and maintenance program for the treatment system, contracts with GAC suppliers and vendors who manage hazardous wastes, periodic site monitoring, and 5-year site reviews. An air permit for the treatment system is not required, although the emissions from the air stripper must comply with ARARs.

7.3.2.7 Costs

The capital cost of this treatment system is estimated at \$4,010,000. Approximate annual O&M costs for the 20 years of treatment system operation are from \$1,630,000 for years 1 to 5, and \$1,490,000, for years 6 to 20. The annual O&M costs for the remaining 10 years, including monitoring and Basin A Neck IRA operation, are \$1,010,000. The present worth cost for 30 years of operation is estimated to be \$32,000,000. A summary of costs for this alternative is presented in Appendix A, Table A4-3.

7.4 ALTERNATIVE AC-3/AT-4: MASS REDUCTION, STRIPPING/OXIDATION/SORPTION

This alternative consists of groundwater extraction in a mass reduction configuration followed by treatment using air stripping, oxidation, and sorption. The configuration and benefits of the mass

reduction system are described in Section 7.3. Treated water is reinjected in recharge trenches in Section 27 or another suitable location. This alternative is accomplished in conjunction with the preferred soil remedial alternative, which includes caps over the Basin A area and the South Plants Central Processing Area. Table 7.3-1 presents the estimated chemical influent concentrations for mass reduction of the Basin A Plume Group under this alternative. Under this alternative the Basin A Neck IRA continues to operate as described in Section 7.3.1.1.

7.4.1 Description of Alternative

7.4.1.1 Extraction/Reinjection

Alternative AC-3/AT-4 includes the same groundwater control system that is used for Alternative AC-3/AT-2 (Section 7.3.1.1). For costing and comparison purposes it was assumed that the mass reduction systems operate for 20 years to remove all of the currently dissolved contaminant mass in the targeted central areas of each plume. The Basin A Neck IRA continues to operate.

7.4.1.2 Treatment

The treatment system for Alternative AT-4 uses air stripping followed by oxidation and GAC adsorption to remove contamination from the groundwater. Figure 7.4-1 presents a process flow diagram showing the major pieces of treatment equipment as well as the tanks, pumps, and filters included in this alternative. The pre-treatment and air stripping portions of this alternative are the same as those described for alternative AC-3/AT-2 (Section 7.3.1.2).

The air stripper is designed to remove 95 percent of the volatile organics, including chloroform and benzene, from the groundwater. A more detailed description of the air stripping technology is presented in the Technology Description Volume, Section 14.3. Volatile organics emitted from the air stripper are destroyed using catalytic oxidation as described in Section 7.3.1.2.

Hydrogen peroxide (H_2O_2) is added to the effluent from the air stripper and the water is pumped to the oxidation reactor, where it is exposed to UV light. The reactor is operated to achieve destruction of chlorinated compounds, including OCPs, DBCP, chloroform, carbon tetrachloride,

methylene chloride, and NDMA. A more detailed description of this technology is presented in the Technology Description Volume, Section 14.1.

After treatment in the oxidation reactor, the water is pumped to a GAC adsorption system to remove any remaining organics (mostly benzene). GAC treatment is accomplished using one modular GAC adsorber that holds 2,000 lbs of GAC. It is anticipated that the GAC adsorption unit is replaced approximately twice every year. Operation and maintenance of the adsorption system for this alternative is the same as for Alternative AC-3/AT-2 (Section 7.3.1.2). A more detailed description of the GAC treatment technology is included in the Technology Descriptions Volume, Section 14.2.

A cartridge filter removes any GAC present in the effluent stream. The filtered water is held in a collection tank prior to reinjection.

7.4.1.3 Sidestreams

This treatment system produces three sidestreams, vapor emissions from the air stripper, spent GAC and used cartridges from the filter. In addition, spent GAC from the Basin A Neck IRA treatment system is generated.

Vapor emissions from the air stripper are treated with catalytic oxidation. Because this process actually destroys the contaminants instead of transferring them to another medium, no further treatment of the vapor phase is required. Contaminants treated with GAC adsorption are transferred to the GAC, which is regenerated off post. The used filter cartridges are disposed in an on-post or off-post RCRA landfill, as described for Alternative AC-3/AT-2 (Section 7.3.1.3).

7.4.2 Analysis of Alternative

7.4.2.1 Overall Protection of Human Health and the Environment

Human health and the environment are protected off post so long as PRGs are met at the boundary. Human health is protected on post by the FFA (EPA et al. 1989), which prohibits the use of groundwater at RMA as a potable water source.

Alternative AC-3/AT-4 permanently removes contaminant mass from the plume centers during 20 years of mass reduction, thereby reducing contaminant migration. Additional control of contaminant migration is provided by continued operation of the Basin A Neck IRA. The preferred soil alternative for Basin A, the placement of a cap, provides source control by reducing the leaching of contaminants into the groundwater from soil sources.

7.4.2.2 Compliance with ARARs

Alternative AC-3/AT-4 is in compliance with all action- and location-specific ARARs. This alternative was conceptually designed based on an earlier set of standards. Should it be selected as the preferred alternative, it is expected to meet most of the revised CBSG-based, chemical-specific ARARs that would be developed for it. The Basin A Neck system included in this alternative is in compliance with all ARARs developed for this system. (All ARARs are listed in Appendix A of the Technology Descriptions Volume.)

7.4.2.3 Long-Term Effectiveness and Permanence

Alternative AC-3/AT-4 reduces contaminant migration by permanently removing contamination from the groundwater. The potential for off-post exposure is reduced by the additional mass removal of contaminants from plume centers and by the Basin A Neck IRA system and the boundary systems.

A fraction of groundwater contaminants are removed and treated at the source. The proposed mass reduction system lowers the groundwater levels in the Basin A Plume Group to some extent (but not as much as a dewatering approach), further reducing the potential for migration. The amount of contaminated soil in contact with groundwater is reduced somewhat by lowering the water table temporarily during mass reduction well pumping. A cap placed over the Basin A area as part of the preferred alternative for the soil medium prevents infiltration, thereby reducing groundwater recharge and contaminant migration in the Basin A Plume Group. The cap also permanently reduces the leaching of contaminants contained in the soil column above the water table. The Basin A Neck IRA continues to intercept any contaminants that migrate from the Basin A Plume Group, and it may be required to operate for more than 30 years (based on

estimated contaminant travel times). However, the system, or individual wells within the system may be shut off earlier if shutoff criteria defined in Section 1.3.3 are met. The NWBCS ensures that groundwater that is not captured on post meets off-post PRGs at the RMA boundary.

Monitoring is performed during the operation of the mass reduction treatment system and continues once the system is shut down. Information gathered by the monitoring program is used to evaluate long-term effectiveness and plume migration.

The mass of contamination removed by the mass reduction systems is monitored by influent sampling at the treatment plant and by monitoring of groundwater at monitoring wells. The specific mass reduction system performance objectives will be defined during the design phase of the alternative. For costing and comparison purposes it was assumed that the mass reduction systems operate for 20 years to remove all of the currently dissolved contaminant mass in the targeted central areas of each plume.

7.4.2.4 Reduction of TMV

Alternative AC-3/AT-4 reduces toxicity and mobility of contaminants in the groundwater by mass removal of the contaminants at the plume centers (Section 7.3.1.1) followed by treatment and reinjection. The groundwater extracted from the South Plants North, Basin A, and Section 36 Bedrock Ridge Plumes is treated by a combination of air stripping, oxidation, and GAC adsorption. Air stripping removes the majority of volatile organics, and oxidation destroys the remaining chlorinated compounds. GAC adsorption treats low levels of organic contaminants that may still remain in the water. At the Basin A Neck IRA, organic contaminants are treated with GAC adsorption. All of these treatment processes irreversibly remove contaminants from the groundwater: contaminants are destroyed in the oxidation reactor and those contaminants volatilized in the air stripper are destroyed by catalytic oxidation. Contaminants treated with GAC adsorption are transferred to GAC, which is thermally regenerated off post. Contaminants that are not removed by the mass reduction extraction system, any residual contaminants after treatment, or any contaminants that remain sorbed to the soil in the aquifer and desorb at a later

time are treated at the Basin A Neck IRA or the NWBCS. Toxicity is reduced by the removal of the contaminants from the groundwater prior to reinjection.

A mass reduction system extracts the groundwater at the source, reducing the potential for migration through the aquifer. The water table is lowered temporarily due to groundwater extraction and the contaminants are contained in the soil vadose zone. Mobility is therefore reduced by lowering the water table. Mobility is further reduced by the placement of a cap over Basin A, which permanently reduces the leaching of contaminants from the vadose zone. In this system, a total of 20 gpm is extracted from the South Plants North, Basin A, and Section 36 Bedrock Ridge Plumes. The Basin A Neck IRA captures and treats contaminated groundwater at expected flow rates of 20 gpm. These systems result in a decrease of contaminant mobility in the Basin A Plume Group and reduction of contaminant loading on the boundary systems.

7.4.2.5 Short-Term Effectiveness

In general, construction, operation, and final demobilization of Alternative AC-3/AT-4 have minimal negative impact on the environment, workers, or the surrounding community. On-post workers are potentially exposed to contaminants through dermal contact and/or dust inhalation pathways and the physical hazards to UXO when excavation and well and trench installation activities are performed. To reduce the potential for such exposure, geophysical surveys to locate UXO, dust-control measures, and PPE are used.

Operators of the system must also concern themselves with proper chemical-handling techniques when monitoring the oxidation reactor and when handling spent GAC adsorption units. To reduce the potential for exposure, personnel are made aware of on-post health and safety procedures and PPE is used.

RAOs are achieved for this alternative. In the 20 years of operation, a measurable fraction of the contaminant mass is removed from the plume centers and treated, reducing volume and toxicity of contaminants in the groundwater (see Section 7.3.1.1 and Appendix C). The mass reduction treatment system operates for approximately 20 years based on the estimated volume

of the most highly contaminated groundwater to be removed from the plume. The Basin A Neck IRA may be required to operate for more than 30 years based on the estimated travel times of contaminants from the plumes to the Basin A Neck IRA. However, the extraction rate for the IRA can be expected to decrease with time.

7.4.2.6 Implementability

Alternative AC-3/AT-4 is technically feasible. Extraction/reinjection, air stripping, and GAC adsorption are proven and readily available technologies. As discussed in the Technology Description Volume (Sections 5, 14.3, and 14.2), these technologies are currently being used at RMA. The advanced oxidation process, which uses hydrogen peroxide and UV light, is considered an innovative technology. Pilot-scale studies have been performed as followup to WES bench-scale treatability studies (Zappi 1994) but the results are not available for inclusion in this report.

The equipment required is all commercially available from several vendors, with the exception of that required for oxidation. A limited number of vendors supply oxidation equipment. The extraction system incorporates existing wells where possible. The Basin A Neck IRA is currently operating and no further changes to the system are required.

The alternative is expected to be reliable. The treatment system requires minimal down time for equipment maintenance; in many cases, maintenance can be performed without shutting down the entire system. The system has automated controls that ensure continuous operation with little supervision.

GAC units and air strippers are produced and supplied in sufficient quantities by large, technically proficient vendors. Filter cartridges and sediments are disposed in the on-post hazardous landfill or in an off-post landfill. Precious metals are recovered from the spent catalyst in the catalytic oxidation unit by the supply vendor.

Administratively, this alternative is easily implementable. It requires an operation and maintenance program for the treatment system, contracts with GAC suppliers, and vendors who manage hazardous wastes, periodic site monitoring, and 5-year reviews. An air permit for the treatment system is not required, although the emissions from the air stripper must comply with ARARs.

7.4.2.7 Costs

The capital cost of this treatment system is estimated at \$4,450,000. Approximate annual O&M costs for 20 years of treatment system operations are \$1,740,000 for the first 5 years and \$1,600,000 for the next 15 years. The annual O&M costs for the remaining 10 years, including monitoring and Basin A Neck IRA operation, are \$996,000. The present worth cost for 30 years of operation is estimated to be \$34,100,000. A summary of costs for this alternative is presented in Appendix A, Table A4-4.

7.5 ALTERNATIVE AC-7: CLAY/SOIL CAP

This alternative is accomplished in conjunction with the placement of a cap over Basin A, an alternative developed for the soil medium. Under this alternative, a cap is constructed over Basin A and the Basin A Neck IRA continues to operate. The difference between Alternative AC-3, described in Section 7.3, and Alternative AC-7 is that the former accomplishes mass reduction before and after the cap is installed; in the latter, no mass reduction system is installed.

7.5.1 Description of Alternative

7.5.1.1 Extraction/Reinjection

A clay/soil cap is placed over Basin A consistent with the preferred soil remedial alternative. The construction and maintenance of a soil cap is described in Section 6.2 of the Technology Description Volume of the DAA. Other areas within Section 36 that have already been contained as a result of IRAs, such as the Lime Settling Basins and the Shell Trenches, are not changed as a result of this alternative, but may be addressed through other soil remedial alternatives and surrounded or covered by the newly capped areas. Figure 7.5-1 provides the schematic for Alternative AC-7.

Monitoring wells provide groundwater-quality and water-level data. The monitoring program, conducted for at least 30 years, is used to evaluate the effectiveness of the cap.

Alternative AC-7 is only considered applicable if completed in conjunction with the placement of a cap over Basin A as a soil remedial alternative. The cap reduces groundwater recharge and contaminant leaching in Basin A. The Basin A Neck IRA captures most of the potential contamination migrating from the Basin A area. If the soil cap is not installed, Alternative AC-7 would be the same as Alternative AC-2 and would, therefore, be equally effective in reducing TMV as AC-2.

7.5.1.2 Treatment

No treatment is required for this alternative beyond continued operation of the Basin A Neck IRA treatment system. This system is described in greater detail in Section 7.2.1.2.

7.5.1.3 Sidestreams

No additional sidestreams are generated by this alternative beyond those currently generated by the Basin A Neck IRA treatment system. These are discussed in Section 7.2.1.3.

7.5.2 Analysis of Alternative

7.5.2.1 Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment off post so long as PRGs are met at the boundary. The FFA restrictions on future uses of groundwater provide protection of human health (EPA et al. 1989).

Alternative AC-7 makes use of the preferred soil remedial alternative for Basin A, a cap, as well as the Basin A Neck IRA to reduce the migration of contaminants. The cap reduces groundwater flow and the leaching of contaminants through Basin A, minimizing contaminant transport, and the Basin A Neck IRA reduces the contaminant loading at the NWBCS, contributing to the protection of human health and the environment off post. The Basin A cap is discussed in more detail in the Soil DAA.

7.5.2.2 Compliance with ARARs

Alternative AC-7 is in compliance with all action-specific ARARs. It is also in compliance with all chemical-specific ARARs since no new treatment actions are undertaken, and the FFA (EPA et al. 1989) so long as the boundary systems continue to operate and PRGs are achieved. The systems included in this alternative are in compliance with all location-specific ARARs. (All ARARs are listed in Appendix A of the Technology Descriptions Volume.)

7.5.2.3 Long-Term Effectiveness and Permanence

Alternative AC-7 reduces the potential for future migration of contaminants by immobilizing the contaminants in the soil and treating the contaminants in the groundwater. The Basin A Neck IRA is the primary interceptor of contaminants migrating from the Basin A Plume. The NWBCS and NBCS act as secondary interceptors of groundwater to ensure off-post PRGs are met at the RMA boundary. The Basin A cap reduces leaching of contaminants through the vadose zone and also reduces groundwater recharge. The Basin A cap and the Basin A Neck IRA reduce the potential for off-post exposure by limiting contaminant migration and loading on the boundary systems. The Basin A Neck IRA may be required to operate for more than 30 years. However, the system or wells within the system may be shut down earlier if shut off criteria defined in Section 1.3.3 are met. Monitoring continues.

7.5.2.4 Reduction of TMV

Alternative AC-7 uses containment combined with treatment to reduce contaminant TMV in groundwater. The Basin A cap reduces the mobility and volume of contaminated groundwater by restricting groundwater recharge, while the Basin A Neck IRA reduces the toxicity of groundwater by GAC adsorption. In this treatment process, contaminants are irreversibly transferred to the GAC, which is thermally regenerated off post. The Basin A Neck IRA reduces the volume of contaminants in the groundwater prior to reinjection, thus minimizing migration of contaminants and reducing loading on the boundary systems. A groundwater flow of 20 gpm (which decreases when the cap minimizes infiltration) is treated by the Basin A Neck IRA. Further reduction of these contaminants occurs at the boundary, if necessary, to meet PRGs.

The mobility of contaminants sorbed to the soil is reduced by lowering the groundwater table through pumping by the Basin A Neck extraction wells and the installation of the cap. Contaminants that desorb from the soil and are not captured by the Basin A Neck IRA are treated by the boundary systems.

7.5.2.5 Short-Term Effectiveness

Steps are taken to ensure minimal negative impacts to the environment, on-post workers, and the community. On-post workers are required to wear appropriate PPE to reduce the potential for exposure. Operators of the Basin A Neck IRA and carbon vendors need to take the appropriate measures to prevent exposure to contaminants when handling and regenerating GAC. Dust-control techniques are used to minimize dust dispersion during cap installation to protect the community, and air monitoring is performed during construction of the cap to evaluate contaminant transport through the air and assess the potential risk to the community. RAOs are achieved so long as the boundary systems continue to operate. The Basin A cap is permanent, and the Basin A Neck IRA may be required to operate for more than 30 years, based on the estimated travel times of contaminants.

7.5.2.6 Implementability

Alternative AC-7 is technically and administratively feasible. Caps have been constructed at numerous hazardous waste sites and have been proven to be effective and reliable and the equipment required for construction is commercially available through numerous vendors. The Basin A Neck IRA is currently operating satisfactorily at RMA; however, upgrades to the system can easily be performed if needed.

7.5.2.7 Costs

The capital cost for Alternative AC-7 is estimated under Alternative 6 for the Basin A Medium Group (see Soil DAA). The O&M costs for 30 years, including the operation of the Basin A Neck IRA and monitoring, are approximately \$1,120,000 per year for the first 5 years and \$990,000 per year for the next 25 years. The present worth cost for 30 years of operation is

estimated to be \$20,200,000. A summary of costs for this alternative is presented in Appendix A, Table A4-5.

7.6 ALTERNATIVE AC-8/AT-2: DEWATERING, STRIPPING/SORPTION

An additional groundwater control alternative, AC-8, Dewatering, has been added to the control alternatives that were retained from the DSA (EBASCO 1992). This alternative consists of groundwater extraction in a dewatering configuration followed by treatment using air stripping and GAC adsorption. Treated water is reinjected in recharge trenches. This alternative is accomplished in conjunction with the preferred soil remedial alternative, which includes caps over the Basin A area and South Plants Central Processing Area (See Figure 7.6-1, and 7.5-1). Table 7.6-1 presents the estimated chemical influent concentrations for dewatering of the Basin A Plume Group under this alternative.

7.6.1 Description of Alternative

7.6.1.1 Extraction/Reinjection

Alternative AC-8, the dewatering alternative, is a groundwater extraction system designed to remove the most contaminated portions of the Basin A Plume Group and to lower and maintain future groundwater levels beneath Basin A. This alternative is accomplished in conjunction with the South Plants dewatering alternative and the preferred soil alternative for capping Basin A. The Basin A Neck IRA and the South Tank Farm In Situ Biotreatability systems also continue to operate.

The operational goal of this alternative is to dewater contaminated portions of the soil and the alluvial aquifer at Basin A. During the first decade, the extraction system removes an estimated 60 gpm and the water table is lowered 20 feet or more in the center of Section 36, and to a lesser degree in other areas beneath Basin A.

It is estimated that the long-term pumping rate sufficient to maintain the targeted water level is approximately 20 gpm in Basin A once the soil cap is in place. The Basin A Neck IRA intercept system continues to operate and extracts contaminants that are downgradient and beyond the

influence of the dewatering system. The dewatering systems are expected to be installed prior to installation of the Basin A and South Plants caps, which are to be completed under the soil remedial alternative. The soil caps are described and costs estimated in detail in the Soil DAA.

The extraction system consists of five horizontal wells each approximately 800 ft in length and constructed from well heads outside of the capped area and extending underneath the cap. (Figure 7.6-1). The horizontal wells are installed near the base of the alluvial aquifer (approximately 40 ft deep) or in the weathered portion of the Denver Formation and are screened along most of their length. Submersible pumps in each well pump the water to one of two collection tanks where a booster pump is used to pump the water via a buried pipeline, to the treatment plant.

The treated water is reinjected in two or more reinjection trenches located in permeable alluvium (Figure 7.6-1). Three areas are possible sites for the injection trenches. These areas include Section 27 upgradient of the NWBCS, Sections 23 and 24 upgradient of the NBCS, and Sections 25 and 31 upgradient of North Plants and the NBCS. At this time the Section 27 option is preferred because it is located in a permeable aquifer that can accept the estimated flow volumes without significant impact to the aquifer or contaminant migration. The Section 27 location was used to develop costs for this alternative. Reinjecting water is eventually captured and retreated at the NWBCS after a period of transport through the alluvial aquifer.

Treated water is pumped from the treatment plant to the reinjection trenches through single-walled PVC pipe. The recharge trenches are lined with a geotextile filter fabric, backfilled with clean gravel, and covered with geotextile filter fabric and 3 ft of soil and are constructed to ensure efficient recharge of the aquifer. Injection distribution pipes, which connect to well points made of PVC, extend 3 ft into the gravel backfill.

Each of the proposed extraction systems under Alternative AC-8 requires installation of performance monitoring wells. Groundwater-quality and water-level data from the newly installed performance monitoring wells are used to evaluate the effectiveness and operation of the

extraction/dewatering system. The final location of the wells is based upon review of existing well locations and screened intervals. Where appropriate, existing wells are utilized in place of construction of new monitoring wells.

7.6.1.2 Treatment

The treatment system in Alternative AT-2 uses air stripping followed by GAC adsorption to remove contamination from the groundwater. Figure 7.6-2 is a process flow diagram showing the major pieces of treatment equipment as well as tanks, pumps, and filters included in the alternative.

This treatment process is the same as that described in Section 7.3.1.2 except for the size of the equipment. A shallow-tray air stripper that is large enough to accommodate 60 gpm of process water and 600 cfm of air is used during Phase I of the groundwater extraction program (years 1 to 10). During Phase II (years 11 to 30) the groundwater flow rate drops to 20 gpm and the air stripper is replaced with a new air stripper that uses 150 cfm of air. A catalytic oxidation unit treats the air emissions from the air stripper and is sized to match the air flow through the air stripper. A new unit is purchased for Phase II because of the change of air-flow rates. Two GAC adsorption units are used during Phase I to treat the 60-gpm groundwater stream. The units are connected in parallel and each hold 2,000 lbs of carbon. It is anticipated that six units are replaced every year. During Phase II, only one GAC unit, also holding 2,000 lbs of carbon, is needed. It is replaced approximately three times each year.

7.6.1.3 Sidestreams

The treatment system produces the same sidestreams at those described in Section 7.3.1.3. These are vapor emissions from the air stripper, spent GAC adsorption units, and used cartridges from the filters. In addition, spent GAC from the Basin A Neck treatment system is generated.

Vapor emissions from the air stripper are treated by catalytic oxidation; spent carbon from the adsorbers is thermally regenerated off post. Used cartridges from the filters are disposed in the on-post hazardous landfill or off post.

7.6.2 Analysis of Alternative

7.6.2.1 Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment off post so long as PRGs are met at the boundary. The FFA (EPA et al. 1989) restrictions on future uses of groundwater provide protection of human health on post. Alternative AC-8/AT-2 removes contaminants from extracted groundwater, achieving a permanent reduction in contaminant mass. Together with the preferred soil remedial alternative, contaminant movement from soil to groundwater is reduced and the potential for downward migration between the upper (alluvial) and lower aquifers is reduced. Lowering of the water table separates the groundwater from contaminated overlying soil, thereby reducing further degradation of groundwater quality. Dewatering also maintains a significant groundwater depression within Basin A, creating inward flow from a wide area in Section 36 as well as from parts of the underlying confined flow system to the extraction system. The removal of mass combined with the hydraulic controls provide additional reduction of contaminant migration. The preferred soil remedial alternative for Basin A, the placement of a cap, provides source control by reducing the leaching of contaminants into the groundwater. This alternative minimizes flow out of Basin A; however, reduced flow through the Section 36 Bedrock Ridge Area would continue as shown in the South Plants/Basin A Groundwater Model Report (EBASCO 1994a).

7.6.2.2 Compliance with ARARs

Alternative AC-8/AT-2 is in compliance with all action-specific ARARs and the FFA (EPA et al. 1989). The new treatment system was conceptually designed based on an earlier set of standards. Should it be selected it is expected to meet most of the CBSG-based chemical-specific ARARs, but some design changes might be required. The Basin A Neck IRA treatment system is in compliance with all ARARs identified for this system. All systems included in this alternative are in compliance with all location-specific ARARs. (All ARARs are listed in Appendix A of the Technology Descriptions Volume.)

7.6.2.3 Long-Term Effectiveness and Permanence

Alternative AC-8/AT-2 reduces the potential for future migration of contaminants by permanently removing contamination from the groundwater, preventing continued contact between groundwater and contaminated soil, controlling hydraulic gradients, and limiting infiltration of precipitation.

Contaminants are removed and treated close to the source. The proposed dewatering system lowers the groundwater levels to the approximate bedrock elevation in the center of Basin A, and creates inward hydraulic gradients throughout most of the Basin A area, further reducing the potential for migration. The amount of contaminated soil in contact with groundwater is reduced by permanently lowering the water table. Horizontal wells are expected to perform well under these conditions.

A cap placed over the Basin A area as part of the soil medium preferred alternative prevents infiltration, thereby reducing both groundwater migration in the Basin A Plume Group and the leaching of the contaminants from the unsaturated soil column. Lowering the water table in the alluvial aquifer reduces the potential for downward contaminant migration. The Basin A Neck IRA continues to intercept contaminants that migrate from the Basin A Plume Group. This IRA may be required to operate for more than 30 years based on the estimated travel times of some contaminants from the plumes to the extraction wells. However, groundwater flux to the IRA will be reduced significantly as Basin A is dewatered. The boundary systems ensure that groundwater that is not captured and treated on post meets PRGs at the RMA boundary.

7.6.2.4 Reduction of TMV

Alternative AC-8/AT-2 reduces toxicity and mobility of contaminants in the groundwater by removing contaminants from the plumes, reducing contact between contaminated soil and groundwater, and maintaining favorable hydraulic gradients to reduce contaminant migration in the confined and unconfined aquifers.

The planned dewatering system extracts the groundwater at the source, thereby reducing the potential for migration through the aquifer. In addition, the water table is permanently lowered and the contaminants are largely contained in the soil above the water table (the vadose zone), limiting their mobility. Mobility is further reduced by the placement of a cap over Basin A, which reduces the leaching of contaminants from the vadose zone. In this dewatering system, 60 gpm is extracted during the first 10 years from the Basin A Plume Group in order to lower the water table and dewater the soil. In the following years, approximately 20 gpm from Basin A is extracted to maintain the desired water levels. The Basin A Neck IRA intercepts the contaminants in the Basin A Neck area. Groundwater, extracted at a flow rate of approximately 20 gpm at Basin A Neck (James 1995), is captured and treated in this system. The operation of these systems results in the decrease of contaminant mobility in the Basin A Plume Group and a reduction of contaminant loading on the Basin A Neck IRA.

Under this alternative, air stripping removes the majority of the volatile organics and GAC adsorption treats the remaining organic contaminants. At the Basin A Neck IRA, organic contaminants are treated with GAC adsorption. These processes are irreversible, and the contaminants removed in the air stripper are destroyed by catalytic oxidation. Contaminants treated with GAC adsorption are transferred to the carbon, which is thermally regenerated off post. Contaminants that are not intercepted by the extraction/dewatering system, or residual contaminants that remain sorbed to the soil in the aquifer and desorb at a later time, are treated by the Basin A Neck IRA or the Northwest Boundary Containment System. Toxicity is reduced by the removal of contaminants from the groundwater prior to reinjection.

7.6.2.5 Short-Term Effectiveness

In general, the construction, operation, and final demobilization of Alternative AC-8/AT-2 have minimal negative impact on the environment, workers, or the surrounding community. On-post workers are potentially exposed to contaminants through dermal and/or dust inhalation pathways when excavation and well and trench installation activities are performed. To reduce the potential for such exposure, dust-control measures and PPE are used. The use of horizontal wells, which are drilled from the periphery of the proposed Basin A cap, reduces both the potential for

chemical exposures and UXO risks to workers and the potential for damage to the extraction system and scheduling conflicts during construction of the soil alternative.

Operators of the system must also concern themselves with proper material-handling techniques when changing out the GAC adsorption units. To reduce the potential for exposure, personnel are made aware of on-post health and safety procedures and PPE is used.

RAOs are achieved under this alternative. However, the system may have to operate for more than 30 years. Contaminated groundwater is extracted and treated, reducing the volume and toxicity of contaminants. The dewatering system operates continuously to maintain the targeted water levels. The Basin A Neck IRA may also be required to operate for more than 30 years. However, groundwater flow to the IRA is reduced significantly as Basin A is dewatered. The system or wells within the system may be shut down earlier if shut-off criteria defined in Section 1.3.3 are met.

7.6.2.6 Implementability

Alternative AC-8/AT-2 is technically feasible. Extraction/reinjection, air stripping, and GAC adsorption are proven and commercially available technologies. As discussed in the Technology Description Volume (Sections 5, 14.3, and 14.2), these technologies are currently being used at RMA. The operators do not require any further training for operation of this alternative. The Basin A Neck IRA is currently operating and no further changes to this system are required.

The use of horizontal wells is expected to enhance the performance of the dewatering systems and reduce the potential for well damage and scheduling conflicts that may arise from construction requirements for the soil alternative. Because the wells can be constructed from the perimeter of the proposed soil cap, the area to be capped can be kept free of well heads and pipelines that could interfere with earth-moving equipment. The horizontal well heads could also be located outside of the cap area and away from the earth-moving activity.

Horizontal borings have been used for the installation of utilities, drains, and pipelines in areas of restricted access for many years. It is not unusual for these borings to extend for several hundred or even one or two thousand feet. Horizontal wells have only been in active use in the environmental remediation field for a few years. By summer 1993, more than 100 horizontal wells had been installed for environmental restoration purposes including air sparging, vapor extraction, and groundwater extraction applications (Wilson and Kaback 1993). The application of horizontal wells has become increasingly widespread as specialized equipment has become available for the near-surface completions required in many environmental installations. Newly designed slant-tower drill rigs and hydraulically steerable downhole drilling motors allow for a good deal of directional control in well construction and shallower completion depths than that available using less specialized equipment. Improved monitoring methods allow for better tracking and control of the downhole directional drilling assembly at shallow depths on the order of plus or minus 5 to 10 percent of vertical depth for commonly used systems and as good as plus or minus 2 percent of vertical depth for some combined magnetic/electromagnetic methods (Wilson 1994). Horizontal wells up to 900 feet long and horizontal drains up to 1,475 ft long have been completed for environmental applications (Eastman-Charrington 1993).

The application of horizontal wells for environmental remediation is increasingly widespread. Many sites, such as DOE's Savannah River Site, have proven the success and reliability of horizontal wells (Wilson and Kaback 1993). Horizontal well technology is considered innovative and is becoming more reliable and cost effective with continuing development of equipment and techniques for environmental application.

This alternative is expected to be reliable. The treatment system requires minimal down time for equipment maintenance; in many cases, maintenance can be performed without shutting down the entire system. The system has automated controls that ensure continuous operation with little supervision.

GAC units and air strippers are readily available and supplied in sufficient quantities by large, technically proficient vendors. Filter cartridges and sediments that settle during treatment are

disposed in the on-post hazardous landfill or off post. Precious metals are recovered from the spent catalyst in the catalytic oxidation unit by the supply vendor.

Administratively, this alternative is easily implemented. It requires an operation and maintenance program for the treatment system, contracts with GAC suppliers and vendors who manage hazardous wastes, periodic site monitoring, and 5-year reviews. An air permit for the treatment system is not required, although the emissions from the air stripper must comply with ARARs.

7.6.2.7 Costs

The capital cost of this alternative is estimated to be \$7,050,000. Approximate annual O&M costs for the first 5 years are \$1,460,000 and for years 6 to 10 are \$1,480,000. The annual O&M costs for the remaining 20 years, including continued operation at a lower flow rate, monitoring, and Basin A Neck IRA operation, are \$1,350,000. The present worth cost for 30 years of operation is estimated to be \$34,600,000. A summary of costs for this alternative is presented in Appendix A, Table A4-6.

7.7 ALTERNATIVE AC-8/AT-4: DEWATERING, STRIPPING/OXIDATION/SORPTION

Alternative AC-8/AT-4 consists of groundwater extraction in a dewatering configuration followed by treatment using air stripping, oxidation, and sorption (Figure 7.6-1). Treated water is reinjected in recharge trenches in Section 27. This alternative is accomplished in conjunction with the preferred soil remedial alternative, which includes caps over the Basin A area and the South Plants Central Processing Area. Table 7.6-1 presents the estimated chemical influent concentrations for mass reduction of the Basin A Plume Group under this alternative. Under this alternative the Basin A Neck IRA continues to operate as described in Section 7.3.1.1.

7.7.1 Description of Alternative

7.7.1.1 Extraction/Reinjection

Alternative AC-8/AT-4 includes the same groundwater control system that is used for Alternative AC-8/AT-2 (Section 7.6.1.1).

7.7.1.2 Treatment

The treatment system for Alternative AT-4 uses air stripping followed by oxidation and GAC adsorption to remove contamination from the groundwater. This is the same treatment system described in Section 7.4.1.2, except that in this instance the system is scaled up to accommodate the larger flow generated by Alternative AC-8. Figure 7.7-1 presents a process flow diagram showing the major pieces of treatment equipment as well as the tanks, pumps, and filters included in this alternative. The pre-treatment and air stripping portions of this alternative are the same as those described for Alternative AC-8/AT-2 (Section 7.6.1.2).

The air stripper is designed to remove more than 95 percent of the volatile organics, including chloroform and benzene, from the groundwater, and the oxidation reactor is operated to achieve destruction of chlorinated compounds, including OCPs, DBCP, chloroform, carbon tetrachloride, and methylene chloride. After treatment in the oxidation reactor, the water is pumped to a GAC adsorption system to remove the remaining organics (mostly benzene). During Phase I (years 1 to 10), two GAC units are used, each holding 2,000 lbs of carbon, and during Phase II (years 11 to 30), one GAC unit is used, also holding 2,000 lbs of carbon. It is anticipated that six GAC units are replaced every year during Phase I and three units are replaced every year during Phase II.

A cartridge filter removes any GAC present in the effluent stream. The filtered water is held in a collection tank prior to reinjection.

7.7.1.3 Sidestreams

This treatment system produces three sidestreams, vapor emissions from the air stripper, spent GAC adsorption units, and used cartridges from the filter. In addition, spent carbon from the Basin A Neck treatment system is generated.

Vapor emissions from the air stripper are treated with catalytic oxidation. Because this process actually destroys the contaminants instead of transferring them to another medium, no further treatment of the vapor phase is required. Contaminants treated with GAC adsorption are

transferred to the GAC, which is thermally regenerated by the vendor off post. Used cartridges from the filter are also disposed in the on-post hazardous landfill or off post.

7.7.2 Analysis of Alternative

7.7.2.1 Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment off post so long as PRGs are met at the boundary. Alternative AC-8/AT-4 removes contaminants from extracted groundwater, achieving a reduction in contaminant mass. Together with the preferred soil remedial alternative, contaminant movement from soil to groundwater is reduced and the potential for downward migration between the upper and lower aquifers is reduced. The permanent removal of contaminants decreases the toxicity and the mobility of the contaminants. Lowering of the water table separates the groundwater from contaminated overlying soil, thereby further reducing the potential for contaminant migration. Dewatering also maintains a significant groundwater depression within Basin A that draws flow from over a wide area in Section 36 as well as from parts of the underlying confined flow system to the extraction system. The preferred soil remedial alternative for Basin A, the placement of a cap, provides source control by reducing the leaching of contaminants into the groundwater. The FFA (EPA et al. 1989) restrictions on the future uses of groundwater at RMA provide protection of human health on post.

This alternative minimizes flow out of Basin A; however, reduced flow through the Section 36 Bedrock Ridge Area would continue as shown in the South Plants/Basin A Groundwater Model Report (EBASCO 1994a).

7.7.2.2 Compliance with ARARs

Alternative AC-8/AT-4 is in compliance with all action-specific ARARs. The new AT-4 treatment system was conceptually designed based on an earlier set of standards. Should it be selected as the preferred alternative, it is expected to meet most of the revised, CBSG-based ARARs that would be developed for it. However, some design changes might be required. The Basin A Neck system is in compliance with the chemical-specific ARARs developed for it. All

systems included in this alternative are in compliance with all location-specific ARARs. (All ARARs are listed in Appendix A of the Technology Descriptions Volume.)

7.7.2.3 Long-Term Effectiveness and Permanence

Alternative AC-8/AT-4 reduces the potential for future migration of contaminants by permanently removing contamination from the groundwater, preventing continued contact between groundwater and contaminated soil, controlling hydraulic gradients, and limiting infiltration of precipitation.

Contaminants are removed and treated close to the source. The proposed dewatering system lowers the groundwater levels to the approximate bedrock elevation in the Basin A Plume Group, further reducing the potential for migration. The amount of contaminated soil in contact with groundwater is reduced by permanently lowering the water table.

The use of horizontal wells is expected to enhance the performance of the dewatering system and reduce the potential for well damage and scheduling conflicts during the construction of the soil alternative.

A cap placed over the Basin A area as part of the preferred soil alternative prevents infiltration, thereby reducing both groundwater migration in the Basin A Plume Group and the leaching of the contaminants from the unsaturated soil column. Lowering the water table in the alluvial aquifer reduces the potential for downward contaminant migration. The Basin A Neck IRA continues to intercept contaminants that migrate from the Basin A Plume Group. This IRA may be required to operate for more than 30 years based on the estimated travel times of some contaminants from the plumes to the extraction wells. However, groundwater flux to the IRA is reduced significantly as Basin A is dewatered. The system or wells within the system may be shut off if the criteria defined in Section 1.3.3 are met. The boundary systems ensure that groundwater that is not captured and treated on post meets PRGs at the RMA boundary. Monitoring continues.

7.7.2.4 Reduction of TMV

Alternative AC-8/AT-4 reduces toxicity and mobility of contaminants in the groundwater by removing contaminants from the plumes, reducing contact between contaminated soil and groundwater and by maintaining favorable hydraulic gradients to reduce contaminant migration in the confined and unconfined aquifers.

The planned dewatering system extracts the groundwater at the source, thereby reducing the potential for migration through the aquifer. In addition, the water table is permanently lowered and the contaminants are largely contained in the soil above the water table (the vadose zone), limiting their mobility. Mobility is further reduced by the placement of a cap over Basin A, which reduces the leaching of contaminants from the vadose zone. In this system, 60 gpm is extracted during the first 10 years from the South Plants, Basin A, and Section 36 Bedrock Ridge Plume Groups to lower the water table and dewater soil. Thereafter, approximately 20 gpm is extracted from Basin A to maintain the desired water levels. The Basin A Neck IRA intercepts the contaminants in the Basin A Neck area. Groundwater, extracted at a flow rate of approximately 20 gpm (James 1995), is captured and treated in this system. The operation of these systems results in the decrease of contaminant mobility in the Basin A Plume Group and a reduction of contaminant loading on the Basin A Neck IRA.

Under this alternative, air stripping removes the majority of the volatile organics and GAC adsorption treats the remaining organic contaminants. At the Basin A Neck IRA, organic contaminants are treated with GAC adsorption. These processes are irreversible, and the contaminants removed in the air stripper are destroyed by catalytic oxidation. Contaminants treated with GAC adsorption are transferred to the carbon, which is thermally regenerated off post. Any contaminants that are not intercepted by the extraction/dewatering system, or residual contaminants that remain sorbed to the soil in the aquifer and desorb at a later time, are treated by the Basin A Neck IRA or the NBCS. Toxicity is reduced by the removal of contaminants from the groundwater prior to reinjection.

7.7.2.5 Short-Term Effectiveness

In general, construction, operation, and final demobilization of Alternative AC-8/AT-4 have minimal negative impact on the environment, workers, or the surrounding community. On-post workers are potentially exposed to contaminants through dermal and/or dust inhalation pathways when excavation and well and trench installation activities are performed. To reduce the potential for such exposure, dust-control measures and PPE are used. The use of horizontal wells, which are drilled from the periphery of Basin A, reduces the potential for chemical exposures and UXO risks to workers.

The use of horizontal wells instead of vertical wells is expected to reduce the potential for damage to the extraction system and scheduling conflicts during construction of the soil alternative.

Operators of the system must also concern themselves with proper chemical-handling techniques when monitoring the oxidation reactor and when handling spent carbon. To reduce the potential for exposure, personnel are made aware of on-post health and safety procedures and PPE is used.

RAOs are achieved for this alternative. In the first 10 years, a significant fraction of the contaminant mass is removed from the groundwater and treated, reducing volume and toxicity of contaminants in the groundwater. The dewatering treatment system operates indefinitely. The Basin A Neck IRA may be required to operate for more than 30 years based on the estimated travel times of some contaminants from the plumes to the Basin A Neck IRA. However, groundwater contaminant concentrations may be reduced to levels such that the Basin A Neck IRA can be shut down.

7.7.2.6 Implementability

Alternative AC-8/AT-4 is technically feasible. Extraction/reinjection, air stripping, and GAC adsorption are proven and readily available technologies. As discussed in the Technology Description Volume (Sections 5, 14.3, and 14.2), these technologies are currently being used at RMA. The advanced oxidation process, which uses hydrogen peroxide, is considered an

innovative technology. Pilot-scale studies have been performed as followup to the WES bench-scale treatability studies, but the results are not available for inclusion in this report.

The use of horizontal wells is expected to enhance the performance of the dewatering systems and reduce the potential for well damage and scheduling conflicts that may arise during construction delineated under the preferred soil alternative. Horizontal wells can be constructed from the perimeter of the proposed soil cap, keeping the area to be capped free of well heads and pipelines that could interfere with earth-moving equipment. The horizontal well heads could be located outside of the cap area and away from the earth-moving activity. The use of horizontal wells in environmental remediation is discussed in Section 7.6.2.6.

The Basin A Neck IRA is already operational and continued operation is technically and administratively feasible. The extraction system incorporates existing wells where possible. The Basin A Neck IRA is currently operating and no further changes to the system are required.

This alternative is expected to be reliable. The treatment system requires minimal down time for equipment maintenance; in many cases, maintenance can be performed without shutting down the entire system. The system has automated controls that ensure continuous operation with little supervision.

The equipment required for the new treatment plant is all commercially available from several vendors, with the exception of that required for oxidation. A limited number of vendors supply oxidation equipment. GAC units and air strippers are produced and supplied in sufficient quantities by large, technically proficient vendors. Filter cartridges and sediments that settle out during treatment are disposed in the on-post hazardous landfill or off post. Precious metals are recovered from the spent catalyst in the catalytic oxidation unit by the supply vendor.

Administratively, this alternative is easily implemented. It requires an operation and maintenance program for the treatment system, contracts with GAC suppliers and vendors who manage

hazardous wastes, periodic site monitoring, and 5-year reviews. An air permit for the treatment system is not required, although the emissions from the air stripper must comply with ARARs.

7.7.2.7 Costs

The capital cost of this alternative is estimated to be \$7,510,000. Annual O&M costs for the first 5 years are \$1,750,000 and for years 6 to 10 are \$1,690,000. The annual O&M costs for the remaining 20 years, including continued operation at a lower flow rate, monitoring, and Basin A Neck IRA operation, are \$1,490,000. The present worth cost for 30 years of operation is estimated at \$39,100,000. A summary of costs for this alternative is presented in Appendix A, Table A4-7.

7.8 ALTERNATIVE AC-9: EXTRACTION, SECTION 36 BEDROCK RIDGE

An additional groundwater extraction alternative, AC-9, has been added to the extraction alternatives retained from the Proposed Final DAA. This alternative consists of groundwater extraction from the Section 36 Bedrock Ridge Plume in an interceptor configuration followed by treatment at the existing Basin A Neck IRA (which includes air stripping and GAC adsorption). Treated water is reinjected to the aquifer through the existing recharge trenches. This alternative is accomplished in conjunction with the preferred soil remedial alternative, which includes caps over the Basin A area (Figure 7.8-1) the South Plants area. The Basin A Neck IRA continues to operate and slurry walls associated with the Shell Trenches and the Army Complex Disposal Trenches are installed and maintained under this alternative. Table 7.8-1 presents the estimated chemical influent concentrations for dewatering of the Section 36 Bedrock Ridge Plume under this alternative.

7.8.1 Description of Alternative

7.8.1.1 Extraction/Reinjection

Alternative AC-9, an interceptor alternative, is a groundwater extraction system designed to prevent further migration of the Section 36 Bedrock Ridge Plume towards the First Creek Alluvial Aquifer. This alternative is accomplished in conjunction with the preferred soil alternative for capping both Basin A and South Plants. The Basin A Neck IRA continues to

operate and groundwater extracted from the Bedrock Ridge Plume is transferred to the Basin A Neck IRA for treatment.

The interceptor system consists of a 1,400-ft-long horizontal well installed to the northeast of the Army complex trenches (Figure 7.8-1). It is installed in the unconfined aquifer within the weathered Denver Formation at a depth of approximately 40 ft.

The operational goal of this alternative is to intercept contaminated groundwater in the Section 36 Bedrock Ridge Plume unconfined aquifer as it flows northeast out of the Basin A area into the First Creek drainage. The estimated groundwater flow through the Bedrock Ridge area is less than 1 gpm. Capping of Basin A and South Plants reduces the infiltration of precipitation and lowers groundwater levels, resulting in decreased hydraulic gradients and flow in the Bedrock Ridge area. Further evaluation of the hydraulic control provided by the proposed system will be performed during the remedial design.

Groundwater-quality and water-level data are collected and used to evaluate the effectiveness and operation of the Bedrock Ridge and Basin A Neck systems. It is assumed that there are sufficient existing wells in both areas to be used for performance monitoring, so no new wells need to be installed.

This alternative also includes groundwater monitoring of the confined flow system as described in Section 3. Monitoring wells located around the Basin A area are sampled and analyzed for the full RMA analytical suite. Data from these wells are assessed to determine whether contaminant levels within the confined flow system are decreasing or migrating significantly with time. Due to poor construction or documentation of well installation techniques, screened intervals, and bentonite seal locations, approximately 30 to 40 confined flow system wells are closed and abandoned. For cost estimating purposes, it was assumed that 12 wells with average depths of 100 feet are closed in the Basin A area.

7.8.1.2 Treatment

Water extracted under Alternative AC-9 is treated by air stripping and GAC adsorption at the Basin A Neck IRA. This treatment system is described in detail in Section 7.2.1.2.

7.8.1.3 Sidestreams

The Basin A Neck IRA treatment system generates two sidestreams requiring treatment or disposal, spent carbon, and filter solids. The GAC in the adsorbers is removed and regenerated at an off-post facility. The filter solids and bag filters are drummed and disposed in the on-post hazardous landfill or off post.

7.8.2 Analysis of Alternative

7.8.2.1 Overall Protection of Human Health and the Environment

Alternative AC-9 is protective of human health and the environment off post so long as PRGs are met at the boundary. The Basin A Neck IRA reduces contaminant migration to the boundary systems, thereby reducing future loading on the boundary systems. Furthermore, the Bedrock Ridge system prevents contaminated groundwater from entering the First Creek drainage. Human health is protected on post by the FFA (EPA et al. 1989), which prohibits the use of RMA groundwater as a potable water source.

7.8.2.2 Compliance with ARARs

Alternative AC-9 is in compliance with all action-specific ARARs and the chemical-specific ARARs identified for the A Neck System and the FFA (EPA et al. 1989). The systems included in this alternative are in compliance with all location-specific ARARs. (All ARARs are listed in Appendix A of the Technology Descriptions Volume.)

7.8.2.3 Long-Term Effectiveness and Permanence

Under Alternative AC-9, contaminant migration from the Army Complex Trenches is minimized through capture and treatment of contaminants close to the source. Moreover, the Basin A Neck IRA system reduces the potential for additional loading on the boundary systems by capturing and treating contaminants migrating from Basin A, and the Bedrock Ridge system prevents

contaminants from migrating into the First Creek drainage. The systems may have to operate for more than 30 years, based on the estimated travel times of contaminants from the plumes to the Basin A Neck IRA capture system. However, the system or wells within the system may be shut off if the criteria defined in Section 1.3.3 are met. Groundwater monitoring data from the unconfined and confined flow systems is collected and assessed to determine whether contaminant levels are decreasing or migrating significantly with time.

7.8.2.4 Reduction of TMV

Contaminants captured at the Basin A Neck IRA are treated with GAC adsorption. Groundwater is extracted at a flow rate of approximately 20 gpm (James 1995), which results in a significant reduction of contaminant TMV. Contaminants are irreversibly transferred to GAC, which requires regeneration off post. Contaminants captured in the Section 36 Bedrock Ridge system are treated with air stripping and GAC adsorption. Groundwater is extracted at a flow rate of less than 1 gpm, which results in some additional reduction in TMV.

7.8.2.5 Short-Term Effectiveness

Alternative AC-9 has minimal additional impact on workers, surrounding communities, or the environment since it only involves installation of the small Bedrock Ridge system. This alternative achieves RAOs through continued operation of the boundary systems. The Basin A Neck IRA may be required to operate for more than 30 years.

7.8.2.6 Implementability

The Basin A Neck IRA is already operational and continued operation is technically and administratively feasible. The new Bedrock Ridge system is easily implemented.

7.8.2.7 Costs

The capital cost of this alternative is estimated to be \$3,540,000. Annual O&M costs for continued operation of the Basin A Neck IRA, the Section 36 Bedrock Ridge system, and for plume monitoring are \$1,080,000 for the first 5 years and \$974,000 for the next 25 years. The present worth for this alternative is \$23,300,000.

7.9 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section describes the selection of alternatives for the Basin A Plume Group to be incorporated into sitewide alternatives for groundwater at RMA (see Section 9). In this step of the DAA process, a comparative analysis of each of the retained alternatives, against the EPA screening criteria, and one against another, is performed.

Eight alternatives were evaluated for the Basin A Plume Group including AC-1 (No Action), AC-2 (Continued Existing Action), AC-3/AT-2 (Mass Reduction, Stripping/Sorption), AC-3/AT-4 (Mass Reduction/Stripping/Oxidation/Sorption), AC-7 (Cap/Soil Cap), AC-8/AT-2 (Dewatering/Stripping/Sorption), AC-8/AT-4 (Dewatering/Stripping/Oxidation/Sorption), and AC-9, (Extraction, Section 36 Bedrock Ridge).

7.9.1 Overall Protection of Human Health and the Environment

All of the alternatives provide protection of human health and the environment. The provisions of the FFA (EPA et al. 1989) require that groundwater on post not be used as potable water. The boundary systems ensure that all water that leaves the RMA boundary complies with off-post PRGs.

Alternative AC-1, the No Action alternative, includes the discontinuation of the Basin A Neck IRA, which allows for increased migration of contaminants toward the boundary systems. Alternatives AC-2, AC-7, and AC-9 rely on the operation of the Basin A Neck IRA for intercepting contaminant migration in the Basin A Plume Group, and in the case of AC-9, for treating water extracted from the Section 36 Bedrock Ridge plume. Alternatives AC-3/AT-2, AC-3/AT-4, and AC-9 provide additional reduction of contaminant migration by reducing contaminant mass in the groundwater near the sources. Alternatives AC-8/AT-2 and AC-8/AT-4 provide further reduction in the potential for future contaminant migration by removing and treating a larger quantity of contaminated groundwater than the other alternatives.

7.9.2 Compliance with ARARs

All of the alternatives developed for the Basin A Plume Group are in compliance with action-specific ARARs, chemical-specific ARARs, and the FFA (EPA et al. 1989). The systems included in this alternative are in compliance with all location-specific ARARs. (All ARARs are listed in Appendix A of the Technology Descriptions Volume.)

7.9.3 Long-Term Effectiveness and Permanence

Alternatives AC-8/AT-2 and AC-8/AT-4 afford the highest degrees of long-term effectiveness and permanence because they remove the largest volume of groundwater for treatment and because they also lower the groundwater levels in the Basin A Plume Group the most, thereby further reducing the potential for migration. Alternatives AC-3/AT-2, AC-3/AT-4, and AC-9 are somewhat less effective in the long term because they remove less groundwater for treatment. They still provide for mass removal and treatment near the sources of the contamination, reducing migration of the contaminants. Alternatives AC-3/AT-2 and AC-3/AT-4 temporarily lower the groundwater levels in the Basin A area, although not permanently as in Alternatives AC-8/AT2 and AC-8/AT-4. Because Alternative AC-2 does not involve any additional extraction of contaminated groundwater beyond the Basin A Neck IRA, it is less effective than the other treatment alternatives.

Except for Alternative AC-1, all of the alternatives include operation of the Basin A Neck IRA, which captures and treats contaminants as they migrate through the Basin A Neck area. This intercept and treatment system reduces contaminant migration and loading on the boundary systems.

Migration of contaminants is not controlled or impacted by Alternative AC-1. This alternative allows the migration of contaminants to the RMA boundaries, increasing the loading on the boundary systems.

7.9.4 Reduction of TMV

Alternatives AC-8/AT-2 and AC-8/AT-4 provide for a reduction of TMV by dewatering the plume area and treating the extracted water. Alternative AC-8/AT-2 employs air stripping to volatilize organics, followed by GAC adsorption to remove remaining compounds that do not volatilize. Alternative AC-8/AT-4 involves oxidation to destroy the majority of the contaminants, air stripping to remove the volatiles, and GAC adsorption to remove the residual contaminants. Vapor-phase emissions in both of these treatment systems are treated by catalytic oxidation. Both treatment systems are effective at treating the contaminants, but Alternative AC-8/AT-4 consumes less carbon than Alternative AC-8/AT-2. These systems extract and treat 60 gpm from the combined extraction systems of the Basin A, South Plants North, and Section 36 Bedrock Ridge Plumes.

Alternatives AC-3/AT-2 and AC-3/AT-4 are similar to Alternatives AC-8/AT-2 and AC-8/AT-4 except that the groundwater extraction system is focused on removal of dissolved contaminant mass rather than dewatering. Consequently the reductions in mobility and volume are less for the AC-3 alternatives. The treatment considerations are also similar, and TMV is reduced through groundwater extraction and treatment near the source. These alternatives extract and treat a combined 20 gpm from the Basin A, South Plants North, and Section 36 Bedrock Ridge Plumes.

From a control perspective, Alternative AC-8 removes the greatest volume of water for treatment and permanently lowers the water table. Groundwater removal continues even after the cap is installed over portions of South Plants and Basin A to maintain the water table at the level of bedrock. Once the caps are installed, however, the long-term pumping rate is decreased to approximately 20 gpm from Basin A in response to decreased infiltration.

Conversely, Alternative AC-3, which removes contaminant mass from the plume centers, does not lower the water table permanently as in Alternative AC-8. (The Basin A Neck IRA intercept system was also assumed to be operating throughout the life of these alternatives.) The mass reduction occurs independently of capping. The reduction of contaminant TMV after the mass

reduction system stops is the same as in Alternative AC-7 as the cap is still operative. Alternative AC-9, which is carried out in conjunction with soil capping in Basin A, results in a somewhat greater reduction in toxicity and mobility than AC-2.

Under Alternatives AC-2, AC-7, and AC-9, reduction in contaminant mobility and plume volume is achieved both by restricting groundwater flow and recharge (through construction of a cap) and treatment at the Basin A Neck IRA. Additional treatment is performed under Alternative AC-9 through extraction of groundwater from the Section 36 Bedrock Ridge. Since recharge is significantly reduced through capping, the water table is lowered, trapping the contaminants that are sorbed to the soil in the vadose zone. Because the groundwater is no longer in contact with these contaminants, contaminant mobility is reduced.

Alternative AC-2 includes the continued operation of the Basin A Neck IRA, which captures and treats contaminants moving out of the Basin A Plume Group area.

Alternative AC-1 does not include any treatment. Contaminants are free to migrate at their current concentrations. Contaminant TMV is reduced over time by natural attenuation.

With the exception of Alternative AC-1, all of the alternatives include a reduction of TMV by the Basin A Neck IRA through GAC adsorption. This system treats approximately 20 gpm through an interception system.

7.9.5 Short-Term Effectiveness

Except for Alternative AC-1, all of the alternatives provide short-term effectiveness. There are minimal impacts on the environment, workers, or the community. RAOs are achieved for all of the evaluated alternatives.

Alternative AC-2 requires no additional construction or handling and has the smallest impact on short-term effectiveness. Alternative AC-9 has minimal added impact due to the installation of the Bedrock Ridge system. Workers and GAC vendors are informed of potential contaminant

risks and the need for use of PPE as necessary. During construction of these systems, proper dust-control measures are also enacted.

Alternative AC-7 requires dust-control techniques to minimize dust dispersion during cap construction. As with the other alternatives, on-post workers are required to wear the appropriate PPE.

It is estimated that the Basin A Neck IRA, which is included in all alternatives except AC-1, is to be operated for more than 30 years. This system requires the replacement of contaminated GAC, which requires health and safety measures for operators and the GAC vendors.

Alternative AC-1 can be implemented without affecting workers or the community.

7.9.6 Implementability

Alternative AC-2 is already in operation and is therefore the easiest to implement. No additional considerations are required in the implementation of this alternative. Alternative AC-9 requires the installation of the Bedrock Ridge system, which is easily implemented, both technically and administratively.

Alternatives AC-8/AT-2, AC-3/AT-2, and AC-7 involve construction of systems that are similar to existing systems at RMA and that do not require any additional training for workers or treatability evaluations. The equipment and technologies are known to be reliable and commercially available. Alternative AC-7 is identical to the second phase of Alternative AC-3.

Alternatives AC-8/AT-4 and AC-3/AT-4 use much of the same readily available equipment as do Alternatives AC-8/AT-2 and AC-3/AT-2. However, the advanced oxidation process is innovative and it requires additional treatability testing to ensure its implementability for this application. Horizontal wells have not been used at RMA to date, but are expected to perform well in this application. They have been used successfully at other hazardous waste sites (see Technology Descriptions Volume).

Alternative AC-1 is easily implemented as it would only require the shutdown of an existing treatment system, the Basin A Neck IRA. However, if the IRA is shut down, justification as to why it is not incorporated in the final response action is required.

7.9.7 Costs

The present worth cost of Alternative AC-2 is \$20,500,000. Alternative AC-2 has no capital costs, but higher O&M and present worth costs than Alternative AC-1. If Alternative AC-1 is evaluated for cost effectiveness, the present worth cost is excessive (\$2,370,000), given that no treatment is involved. Of the remaining alternatives, Alternative AC-7 has no capital cost because these costs are associated with the soil remedial alternative. Therefore, the real cost of Alternative AC-7 would be much higher if the capping cost were included. The present worth cost of Alternative AC-7 is \$20,200,000. Alternative AC-9 has a slightly higher present worth cost of \$23,300,000. Alternatives AC-3/AT-2 and AC-3/AT-4 have similar present worth costs of \$32,000,000 and \$34,100,000, respectively, and differ primarily in first-year capital costs. Alternatives AC-8/AT-2 and AC-8/AT-4 are slightly more expensive, with present worth costs of \$34,600,000 and \$39,100,000, respectively.

7.9.8 Summary

The comparative analysis shows that Alternatives AC-8/AT-2 and AC-8/AT-4 equally meet the seven EPA evaluation criteria as do Alternatives AC-3/AT-2 and AC-3/AT-4. The AC-8 alternatives provide greater reduction in contaminant migration, are more effective in the long term, and provide greater reduction of TMV over time than the AC-3 alternatives. Therefore the mass reduction alternatives AC-3/AT-2 and AC-3/AT-4 are not carried forward for further consideration. Alternative AC-8/AT-2, which involves dewatering combined with air stripping and GAC adsorption, has a lower present worth cost than Alternative AC-8/AT-4 and uses the most easily implemented technologies of the two. For this reason AC-8/AT-4 is not considered further. The effectiveness of Alternative AC-9 is greatly enhanced by the addition of the Basin A cap as part of the soil remediation, which reduces groundwater recharge and contaminant leaching. Alternative AC-1 complies with ARARs and is protective of human health and the environment off post because the boundary systems continue to operate. However, it allows

greater migration of contamination on post. Alternative AC-2 is somewhat less effective than Alternatives AC-3 and AC-8, but it is significantly less costly and most easily implementable (as it involves continued existing action). Alternative AC-9 includes an additional groundwater control system compared to Alternative AC-2 at a slightly higher cost, and it integrates the preferred soil remedial alternative for Basin A.

Alternatives AC-1, AC-2, and AC-9 are retained for further analysis because they meet all compliance requirements, including ease of implementation and low cost. AC-8/AT-2 is retained because it provides greater control of contaminant migration and contributes to the overall effectiveness of the preferred soil remedial alternative.

The alternatives that are retained for consideration for the Basin A Plume Group as sitewide alternatives for groundwater (which are developed in Section 9) are as follows:

- Alternative AC-1: No Action
- Alternative AC-2: Continued Existing Action
- Alternative AC-8/AT-2: Dewatering; Stripping/Sorption
- Alternative AC-9: Extraction from Section 36 Bedrock Ridge, Treatment at Basin A Neck

Criteria	ALT AC-1 No Action	ALT AC-2 Continued Existing Action
1. Overall protection of human health and the environment	Contaminants free to migrate to boundary; will be treated by the boundary systems	Reduces contaminant migration and removes contaminant mass
2. Compliance with ARARs	Complies with location- and chemical-specific ARARs if boundary systems continue to operate Action-specific ARARs do not apply Complies with FFA if boundary systems continue to operate	Complies with action-, location-, and chemical-specific ARARs Action-specific ARARs do not apply Complies with FFA if boundary systems continue to operate
3. Long-term effectiveness and permanence	Increases potential for exposure, due to contaminant migration through Basin A Neck and increases potential for additional loading on boundary systems Monitoring continues Existing controls at Basin A Neck IRA removed	Minimizes potential for off-post exposure; contaminants removed and treated at Basin A Neck IRA; reduced potential for additional loading at boundary systems Monitoring continues Adequate existing controls, but long-term maintenance required
4. Reduction of TMV	No treatment or action undertaken TMV reduced over time by natural attenuation	Organic contaminants removed by GAC adsorption at Basin A Neck IRA Approximately 20 gpm removed and treated at Basin A Neck IRA Contaminants irreversibly transferred to GAC which requires regeneration off post.
5. Short-term effectiveness	Minimal negative impact on workers (mitigated by PPE) or surrounding community Contaminants free to migrate RAOs achieved if boundary systems in operation	Minimal negative impact on workers or surrounding community No additional impact on environment System may require operation for more than 30 years RAOs achieved if boundary systems in operation
6. Implementability	Technically and administratively feasible Increases loading on boundary systems	Technically and administratively feasible Already operational
7. Costs		
–Capital Cost	\$28,500	\$0
–Annual O&M Cost	\$195,000 (yr 1-5) \$91,200 (yr 6-30)	\$1,140,000 (yr 1-5) \$1,000,000 (yr 6-30)
–Present Worth	\$2,370,000	\$20,500,000
Summary	Retained: complies with ARARs and protective of human health and environment but contaminants allowed to migrate for longer time and more area	Retained: operational; complies with ARARs and protective of human health and environment; captures contaminants at Basin A Neck IRA

Table 7.0-1 Comparative Analysis of Alternatives: Basin A Plume Group

Criteria	ALT AC-3/AT-2	ALT AC-3/AT-4
	Mass Reduction, Stripping/Sorption	Mass Reduction, Stripping/Oxidation/Sorption
1. Overall protection of human health and the environment	Removes contaminant mass and reduces contaminant migration	Removes contaminant mass and reduces contaminant migration
2. Compliance with ARARs	Complies with action-, location-, and chemical-specific ARARs	Complies with action-, location-, and chemical-specific ARARs
3. Long-term effectiveness and permanence	Complies with FFA if boundary systems continue to operate	Complies with FFA if boundary systems continue to operate
	Minimizes potential for off-post exposure; contaminants removed and treated close to source and intercepted and treated at boundary systems and Basin A Neck IRA; lowers groundwater levels in Basin A	Minimizes potential for off-post exposure; contaminants removed and treated at source and intercepted and treated at boundary systems and Basin A Neck IRA; lowers groundwater levels in Basin A
4. Reduction of TMV	Monitoring program continues	Monitoring program continues
	Organic contaminants removed by GAC adsorption at Basin A Neck IRA; the Basin A Plume, Section 36 Bedrock Ridge Plumes, and South Plants North Plume treated by air stripping and GAC adsorption; mass reduction system at source reduces potential migration through the aquifer	Organic contaminants removed by GAC adsorption at Basin A Neck IRA; the Basin A Plume, Section 36 Bedrock Ridge Plumes, and South Plants North Plume treated by air stripping, oxidation, and GAC adsorption; mass reduction system at source reduces potential migration through the aquifer
5. Short-term effectiveness	20 gpm from South Plants North, Basin A, and Section 36 Bedrock Ridge Plumes and 20 gpm at Basin A Neck IRA removed and treated	20 gpm from South Plants North, Basin A, and Section 36 Bedrock Ridge Plumes and 20 gpm at Basin A Neck IRA removed and treated
	Contaminants transferred to GAC, which requires regeneration or transferred to vapor phase and destroyed by catalytic oxidation	Contaminants transferred to liquid-phase GAC, which requires thermal regeneration, are destroyed by oxidation, or are transferred to the vapor phase in air stripper. Air stripper emissions destroyed by catalytic oxidation; lower GAC consumption than AT-2
	Minimal negative impact on the environment, surrounding community, or workers	Minimal negative impact on the environment, surrounding community, or workers
	RAOs achieved if boundary systems in operation	RAOs achieved if boundary systems in operation
6. Implementability	Mass reduction treatment system operates for 20 years; Basin A Neck IRA may require operation for more than 30 years	Mass reduction treatment system operates for 20 years; Basin A Neck IRA may require operation for more than 30 years
	Technically feasible: demonstrated, available technologies, reliable equipment, and experienced operators	Technically feasible: air stripping and GAC adsorption are demonstrated, available technologies; advanced oxidation process is innovative and requires more oversight and additional training for operators
7. Costs	Administratively feasible	Administratively feasible
–Capital Cost	\$4,010,000	\$4,450,000
–Annual O&M Cost	\$1,630,000 (yr 1-5)	\$1,740,000 (yr 1-5)
	\$1,490,000 (yr 6-20)	\$1,600,000 (yr 6-20)
	\$1,010,000 (yr 21-30)	\$996,000 (yr 21-30)
–Present Worth	\$32,000,000	\$34,100,000
Summary	Not retained: not as effective as dewatering alternatives for only a slightly lower cost	Not retained: not as effective as dewatering alternatives for only a slightly lower cost

Criteria	ALT AC-7 Clay/Soil Cap	ALT AC-8/AT-2 Dewatering, Stripping/Sorption
1. Overall protection of human health and the environment	Reduces potential for contaminant migration; removes contaminant mass	Removes contaminant mass and reduces contaminant migration
2. Complies with ARARs	Complies with action-, location-, and chemical-specific ARARs	Complies with action-, location-, and chemical-specific ARARs
3. Long-term effectiveness and permanence	Complies with FFA if boundary systems continue to operate Minimizes potential for off-post exposure; contaminants removed and treated at boundary systems and Basin A Neck IRA; lowers groundwater levels in Basin A Monitoring program continues	Complies with FFA if boundary systems continue to operate Minimizes potential for off-post exposure; contaminants removed and treated near source and intercepted and treated at boundary systems and Basin A Neck IRA; maximizes screen area in zone of contamination; dewater Basin A; prevents future contaminant migration Monitoring program continues
4. Reduction of TMV	Cap reduces migration of contaminants; organic contaminants are removed by GAC adsorption at Basin A Neck IRA Approximately 20 gpm removed and treated at Basin A Neck IRA Contaminants transferred to GAC, which requires regeneration off-post	Organic contaminants removed by GAC adsorption at Basin A Neck IRA; the Basin A Plume, Section 36 Bedrock Ridge Plumes, and South Plants North Plume treated by air stripping and GAC adsorption; dewatering system minimizes potential migration through the aquifer 60 gpm from South Plants North, Basin A, and Section 36 Bedrock Ridge Plumes initially (and 20 gpm after 10 years of dewatering) and 20 gpm at Basin A Neck IRA removed and treated Contaminants transferred to GAC which requires regeneration, or transferred to vapor phase and destroyed by catalytic oxidation
5. Short-term effectiveness	Minimal negative impact on the environment, surrounding community, or workers May require operation of Basin A Neck IRA for more than 30 years RAOs achieved if boundary systems in operation	Minimal negative impact on the environment, surrounding community, or workers Dewatering and treatment system may operate for an indefinite period of time; Basin A Neck IRA may require operation for more than 30 years RAOs achieved if boundary systems in operation
6. Implementability	Technically feasible: demonstrated, available technologies, reliable equipment, and experienced operators Administratively feasible	Technically feasible: demonstrated, available technologies, reliable equipment, and experienced operators Administratively feasible
7. Costs*		
–Capital Cost	0	\$7,050,000
–Annual O&M Cost	\$1,120,000 (yr 1-5) \$990,000 (yr 6-30)	\$1,460,000 (yr 1-5) \$1,400,000 (yr 6-10) \$1,350,000 (yr 11-30)
–Present Worth	\$20,200,000	\$34,600,000
Summary	Not Retained: Not as effective as AC-9 at only slightly lower cost.	Retained: complies with ARARs and is protective of human health and environment; removes large mass of contamination while dewatering and controlling groundwater flow

* Costs for the cap are included in Alternative 6F for the Basin A Medium Group.

Criteria	ALT AC-8/AT-4 Dewatering, Stripping/Oxidation/Sorption	ALT AC-9 Extraction, Section 36 Bedrock Ridge
1. Overall protection of human health and the environment	Removes contaminant mass and reduces contaminant migration	Reduces potential for contaminant migration; some contaminant mass removed
2. Compliance with ARARs	Complies with action-, location-, and chemical-specific ARARs	Complies with action-, location-, and chemical-specific ARARs
3. Long-term effectiveness and permanence	Complies with FFA if boundary systems continue to operate	Complies with FFA if boundary systems continue to operate
	Minimizes potential for off-post exposure; contaminants removed and treated at source and intercepted and treated at boundary systems and Basin A Neck IRA; maximizes screen area in zone of contamination; dewater Basins A; prevents future contaminant migration	Minimizes potential for off-post exposure; contaminants removed and treated at boundary systems, Section 36 Bedrock Ridge and Basin A Neck IRA; water table lowered by soil cap
4. Reduction of TMV	Monitoring program continues	Deep well monitoring added
	Organic contaminants removed by GAC adsorption at Basin A Neck IRA; the Basin A Plume, Section 36 Bedrock Ridge Plumes, and South Plants North Plume treated by air stripping, oxidation, and GAC adsorption; dewatering system minimizes potential migration through the aquifer	Cap reduces migration of contaminants; organic contaminants are removed by air stripping and GAC adsorption at Basin A Neck IRA
	60 gpm from South Plants North, Basin A, and Section 36 Bedrock Ridge Plumes initially (and 20 gpm after 10 years of dewatering) and 20 gpm at Basin A Neck IRA removed and treated	Approximately 20 gpm at Basin A Neck IRA and 1 gpm at Section 36 Bedrock Ridges removed and treated
	Contaminants transferred to GAC which requires regeneration, are destroyed by oxidation, or are transferred to the vapor phase in air stripper. Air stripper emissions destroyed by catalytic oxidation; lower GAC consumption than AT-2	Contaminants transferred to GAC which requires regeneration, or transferred to vapor phase and destroyed by catalytic oxidation
5. Short-term effectiveness	Minimal negative impact on the environment, surrounding community, and workers	Minimal negative impact on the environment, surrounding community, or workers
	Dewatering and treatment system and Basin A Neck IRA may require operation for more than 30 years	May require operation of Basin A Neck IRA for more than 30 years
	RAOs achieved if boundary systems in operation	RAOs achieved if boundary systems in operation
6. Implementability	Technically feasible: air stripping and GAC adsorption are demonstrated, available technologies; advanced oxidation process is innovative and requires more oversight and additional training for operators	Technically feasible: demonstrated, available technologies, reliable equipment, and experienced operators
	Administratively feasible	Administratively feasible
7. Costs		
–Capital Cost	\$7,510,000	\$3,540,000
–Annual O&M Cost	\$1,750,000 (yr 1-5) \$1,690,000 (yr 6-10) \$1,490,000 (yr 11-30)	\$1,080,000 (yr 1-5) \$974,000 (yr 6-30)
–Present Worth	\$39,100,000	\$23,300,000
Summary	Not retained: As effective as AC-8/AT-2 but has higher costs and uses less easily implemented technologies	Retained: Meets all basic criteria so long as boundary systems and IRA continue to operate and migration is reduced by soil cap

Table 7.3-1 AC-3 Basin A Plume Group Estimated Influent Concentrations

Page 1 of 1

Chemical Group/Compound	Estimated Influent Concentration (µg/l)
Volatiles Halogenated Organic Compound (VHOs)	
Carbon tetrachloride	14
Chloroform	20,000
Methylene chloride	1,100
Trichloroethylene	120
Volatiles Hydrocarbon Compounds (VHCs)	
Dicyclopentadiene	34
Volatiles Aromatic Organic Compounds (VAOs)	
Benzene	2,000
Organosulfur Compounds, Mustard Agent Related (OSCMs)	
Dithiane	71
Organosulfur Compounds, Herbicide Related (OSCHs)	
Chlorophenylmethyl sulfoxide	14
Organophosphorous Compounds, GB-Agent Related (OPHGBs)	
Diisopropylmethyl phosphonate (DIMP)	220
Organophosphorus Compounds, Pesticide Related (OPHPs)	
Atrazine	31
Dibromochloropropane (DBCP)	
Dibromochloropropane	6.0
Organochlorine Pesticides (OCPs)	
Chlordane	0.57
Dieldrin	0.32
Arsenic	
Arsenic	22

Table 7.6-1 AC-8 Basin A Dewatering Estimated Influent Concentrations

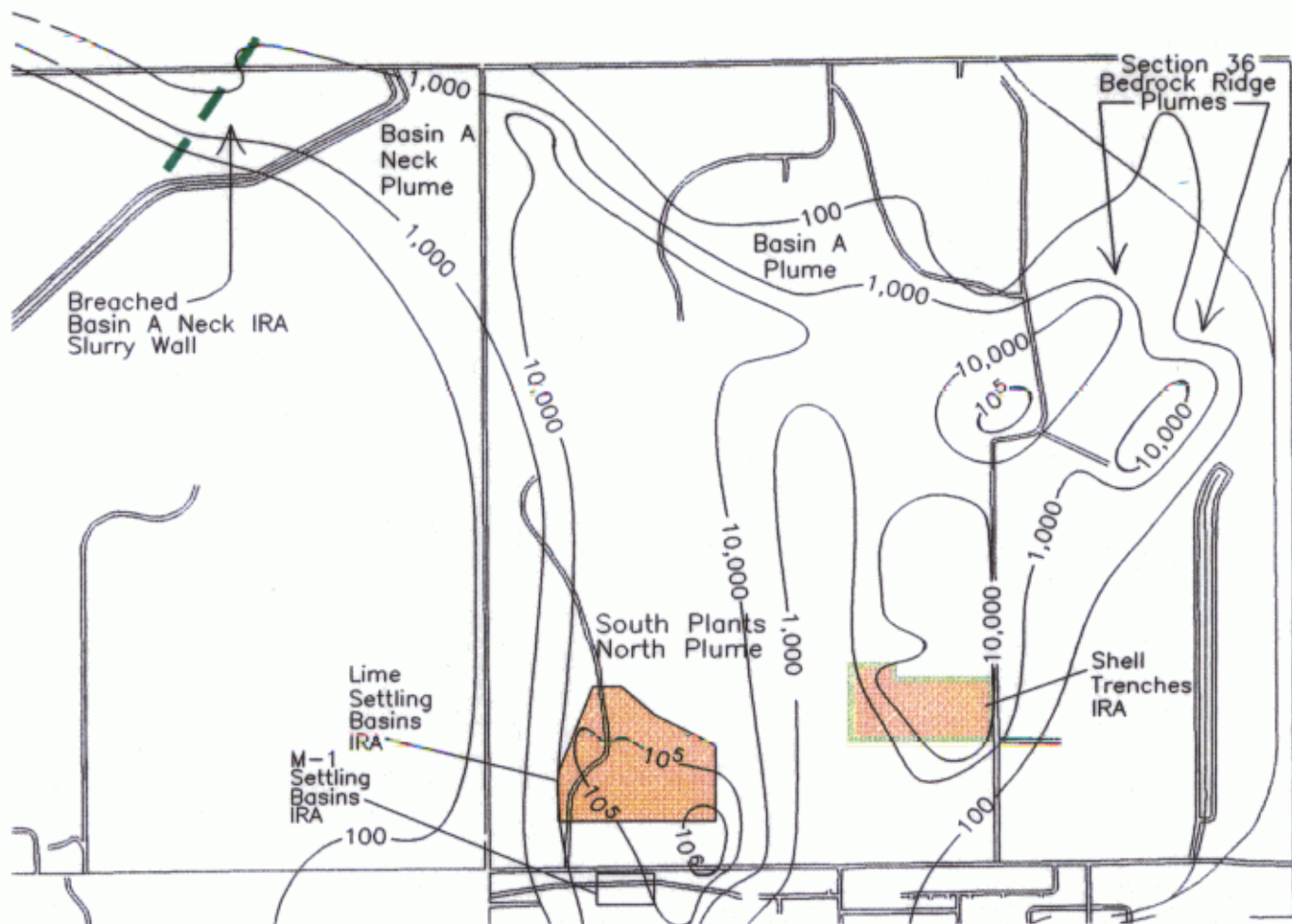
Page 1 of 1

Chemical Group/Compound	Estimated Influent Concentration (µg/l)
Volatile Halogenated Organic Compound (VHOs)	
Carbon tetrachloride	3.4
Chloroform	230
Methylene chloride	98
Trichloroethylene	31
Volatile Hydrocarbon Compounds (VHCs)	
Dicyclopentadiene	18
Volatile Aromatic Organic Compounds (VAOs)	
Benzene	100
Organosulfur Compounds, Mustard Agent Related (OSCMs)	
Dithiane	33
Organosulfur Compounds, Herbicide Related (OSCHs)	
Chlorophenylmethyl sulfoxide	10
Organophosphorous Compounds, GB-Agent Related (OPHGBs)	
Diisopropylmethyl phosphonate (DIMP)	87
Organophosphorus Compounds, Pesticide Related (OPHPs)	
Atrazine	35
Dibromochloropropane (DBCP)	
Dibromochloropropane	11
Organochlorine Pesticides (OCPs)	
Chlordane	0.44
Dieldrin	0.30
Arsenic	
Arsenic	21

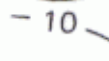
Table 7.8-1 Section 36 Bedrock Ridge Plume Estimated Influent Concentrations

Page 1 of 1

Chemical Group/Compound	Estimated Influent Concentration (µg/l)
Volatile Halogenated Organic Compound (VHOs)	
Carbon tetrachloride	120
Chloroform	2,100
Methylene chloride	1,600
Trichloroethylene	370
Volatile Hydrocarbon Compounds (VHCs)	
Dicyclopentadiene	2.9
Volatile Aromatic Organic Compounds (VAOs)	
Benzene	9.4
Organosulfur Compounds, Mustard Agent Related (OSCMs)	
Dithiane	47
Organosulfur Compounds, Herbicide Related (OSCHs)	
Chlorophenylmethyl sulfoxide	3.5
Organophosphorous Compounds, GB-Agent Related (OPHGBs)	
Diisopropylmethyl phosphonate (DIMP)	280
Organophosphorus Compounds, Pesticide Related (OPHPs)	
Atrazine	28
Dibromochloropropane (DBCP)	
Dibromochloropropane	0.51
Organochlorine Pesticides (OCPs)	
Chlordane	0.10
Dieldrin	0.046
Arsenic	
Arsenic	5.3



LEGEND

-  Cap
-  Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)
-  Slurry Wall
-  Perforated Slurry Wall

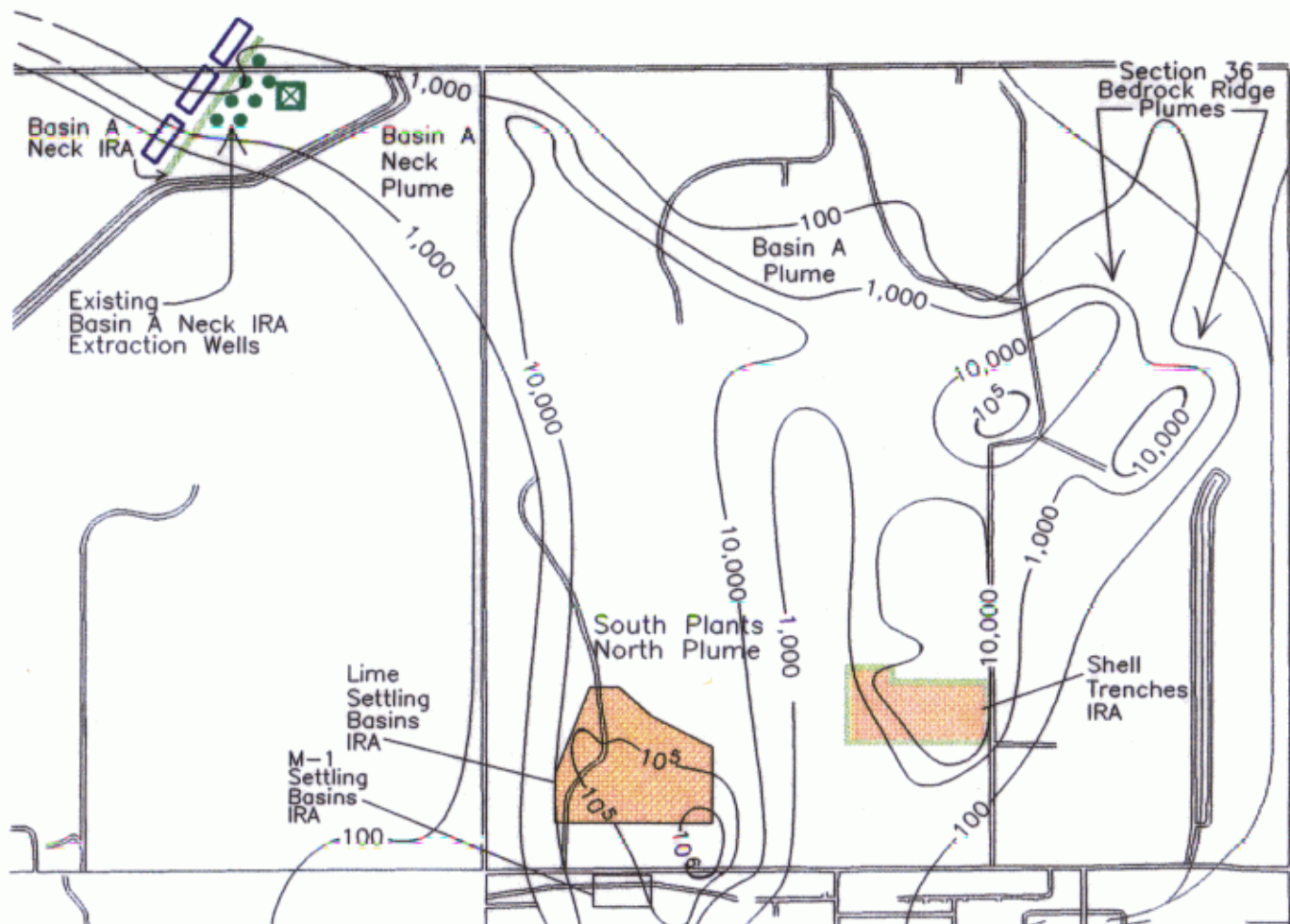


Not To Scale

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

FIGURE 7.1-1
Schematic for Basin A Plume Group
Control Alternative AC-1

Prepared by:
Foster Wheeler Environmental Corporation



LEGEND



Cap

- 10 -

Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)



Extraction Well



Recharge Trench



Slurry Wall



Treatment Plant

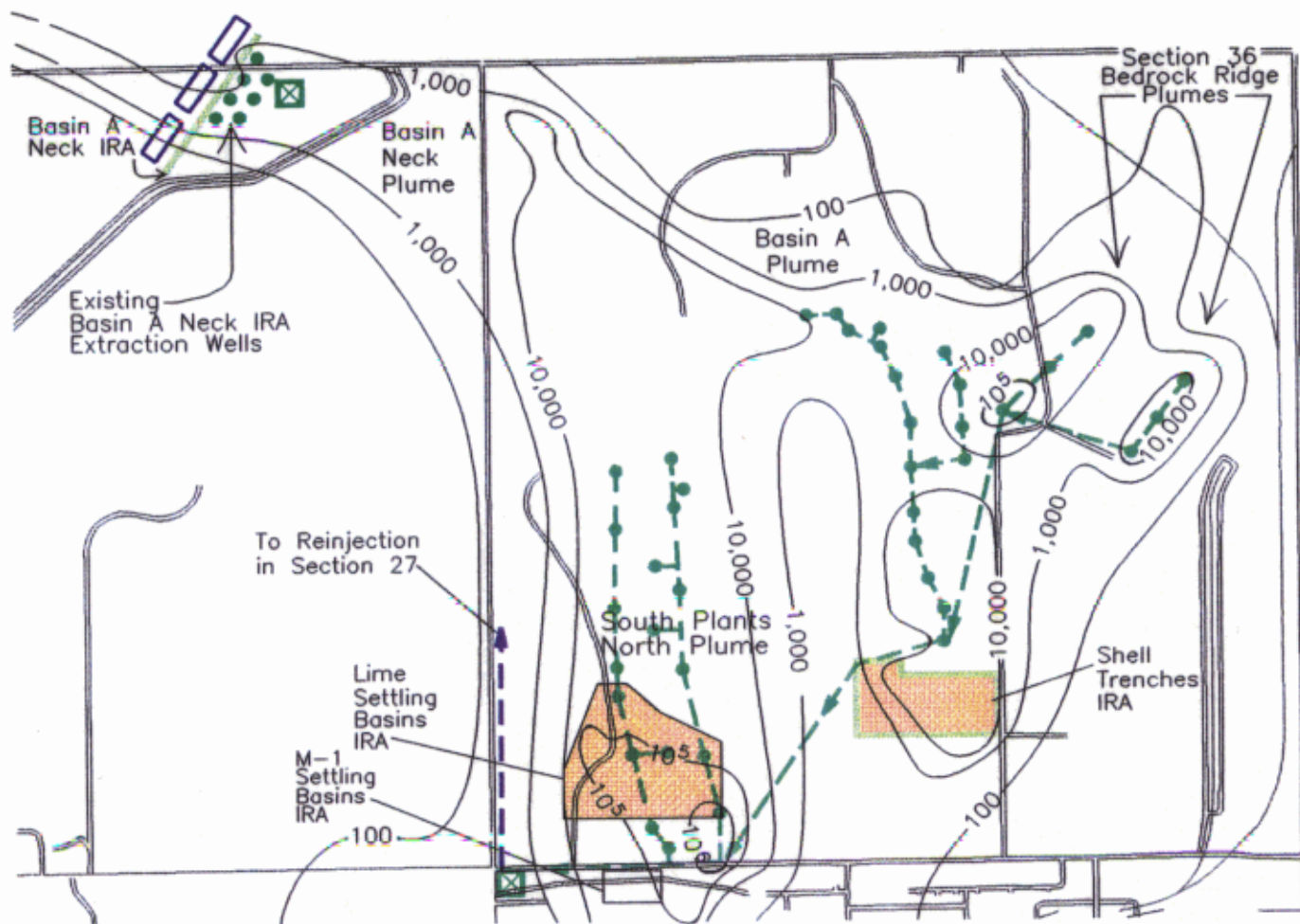


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FIGURE 7.2-1
Schematic for Basin A Plume Group
Control Alternative AC-2

Prepared by:
Foster Wheeler Environmental Corporation



LEGEND



Cap

100 Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)

Extraction Well

Recharge Trench

Slurry Wall

Transport Pipe

Treatment Plant

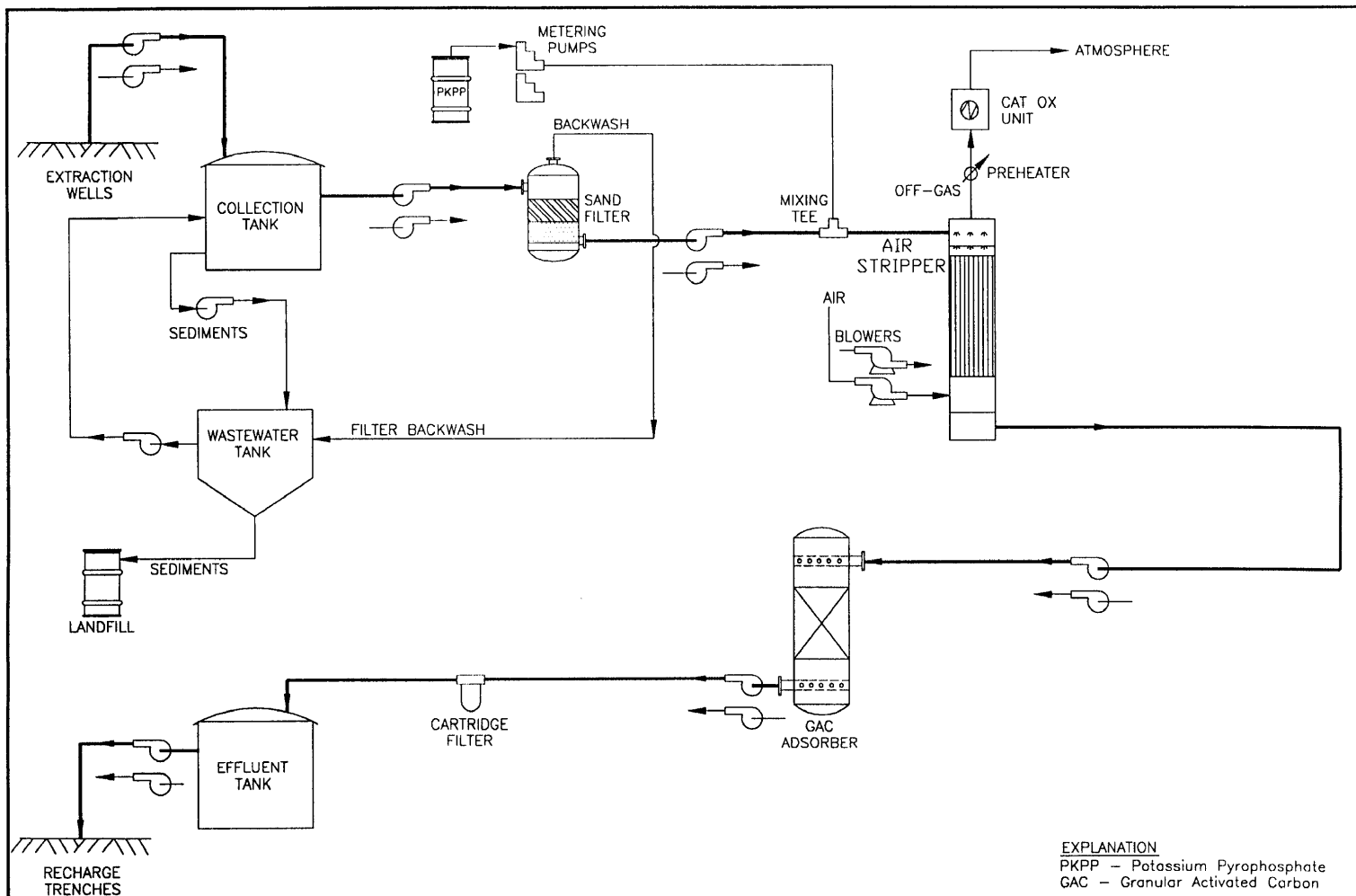


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FIGURE 7.3-1
Schematic for Basin A Plume Group
Control Alternative AC-3

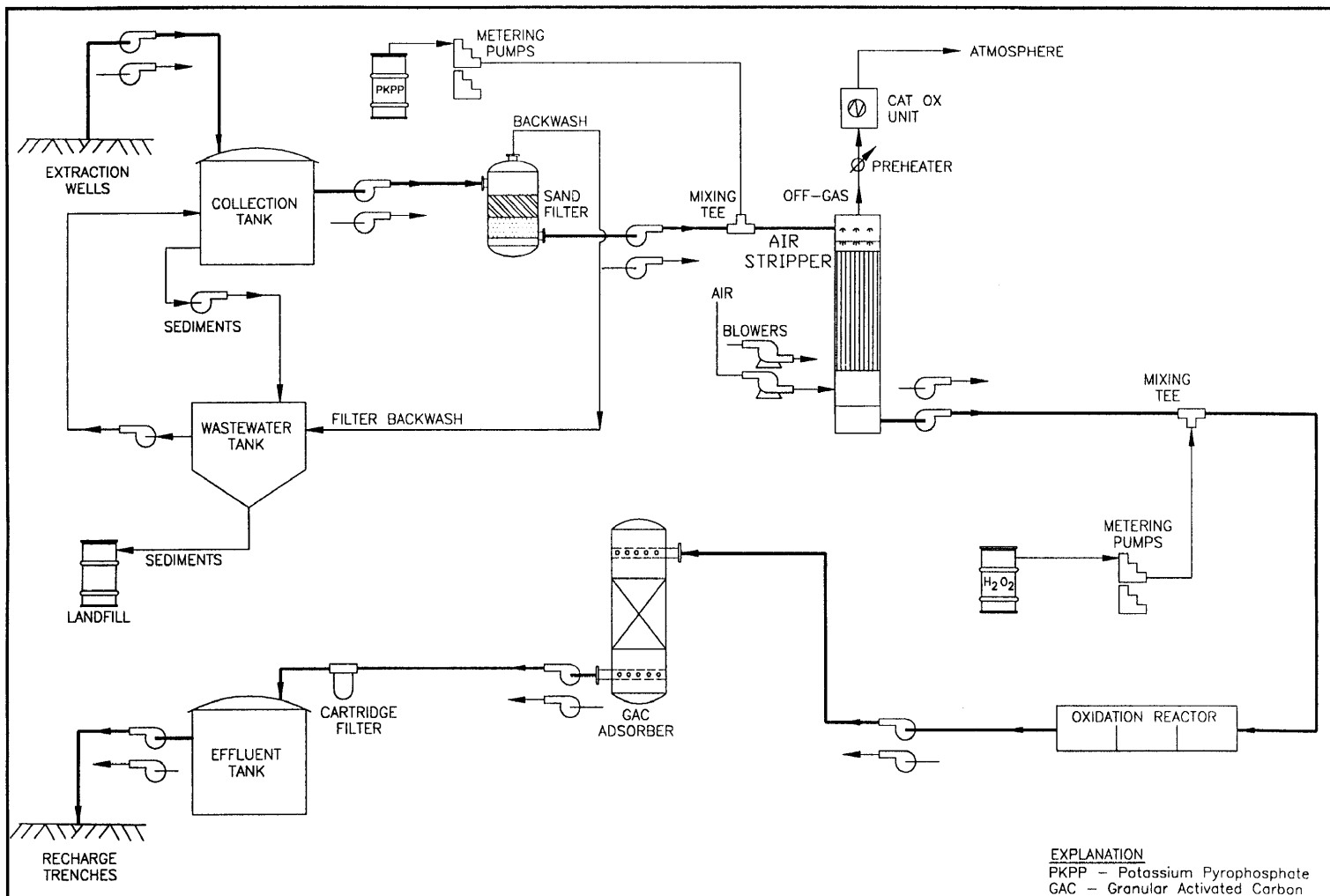
Prepared by:
Foster Wheeler Environmental Corporation



Prepared for:
 Office for the Program Manager
 for Rocky Mountain Arsenal

FIGURE 7.3-2
 Process Flow Diagram
 Treatment Alternative AC-3/AT-2,
 Air Stripping/GAC Adsorption

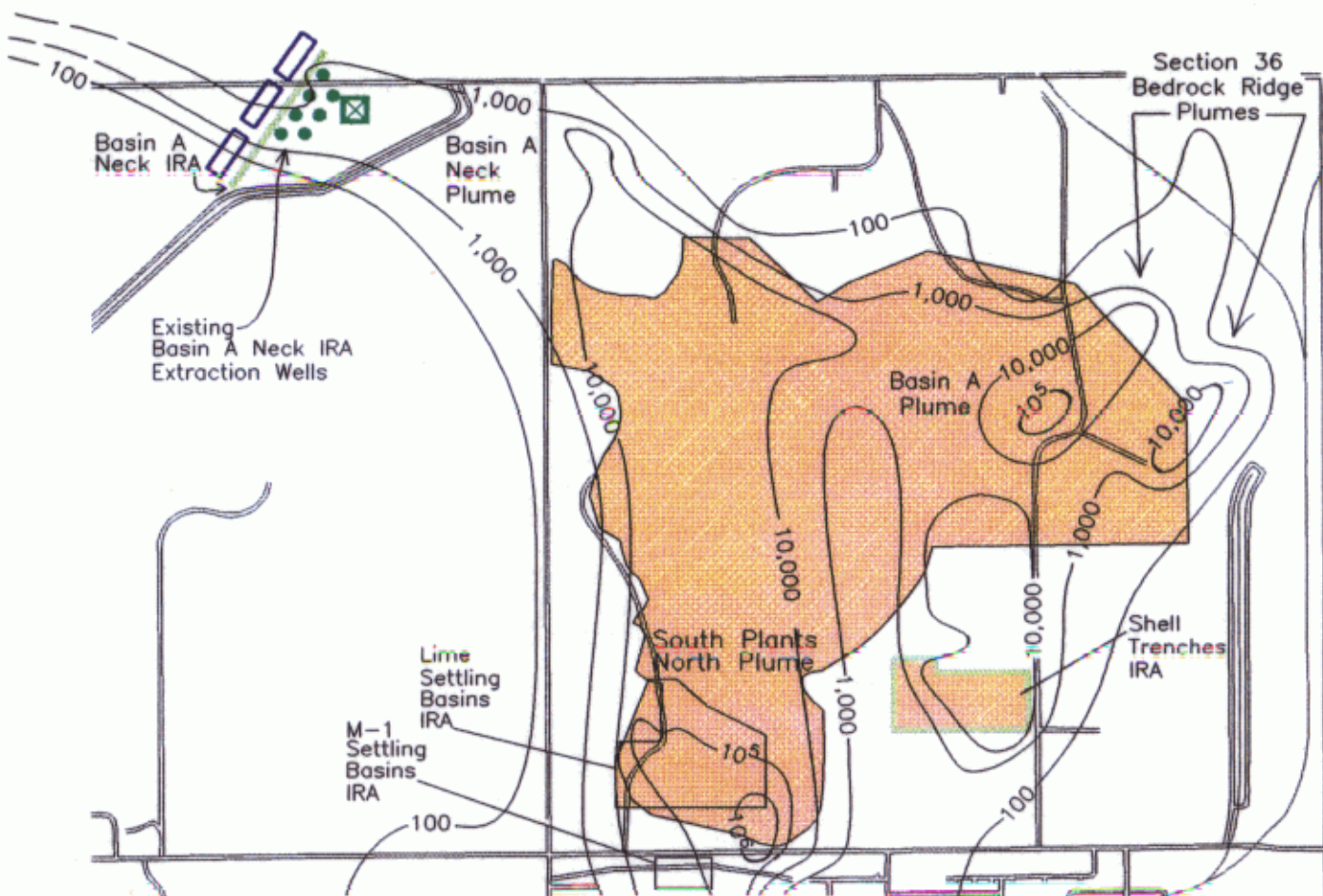
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 Foster Wheeler Environmental Corporation



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FIGURE 7.4-1
 Process Flow Diagram
 Treatment Alternative AC-3/AT-4,
 Air Stripping/Oxidation/GAC Adsorption

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LEGEND

-  Cap
-  Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)
-  Extraction Well
-  Recharge Trench
-  Slurry Wall
-  Treatment Plant

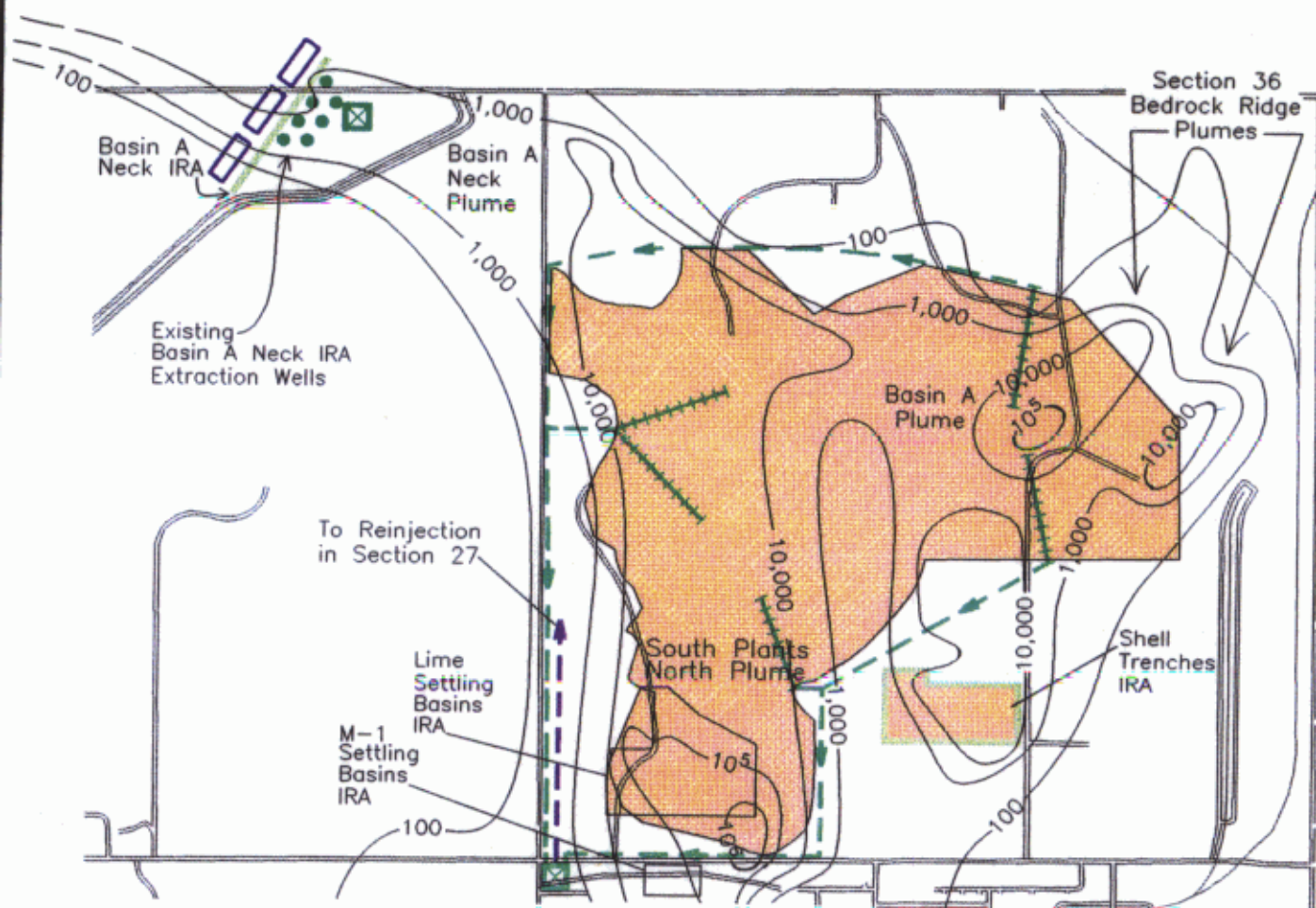


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FIGURE 7.5-1
Schematic for Basin A Plume Group
Control Alternative AC-7

Prepared by:
Foster Wheeler Environmental Corporation



LEGEND

-  Cap
-  Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)
-  Extraction Well
-  Recharge Trench
-  Slurry Wall
-  Treatment Plant
-  Horizontal Extraction Well
-  Reinjection Line to Section 27

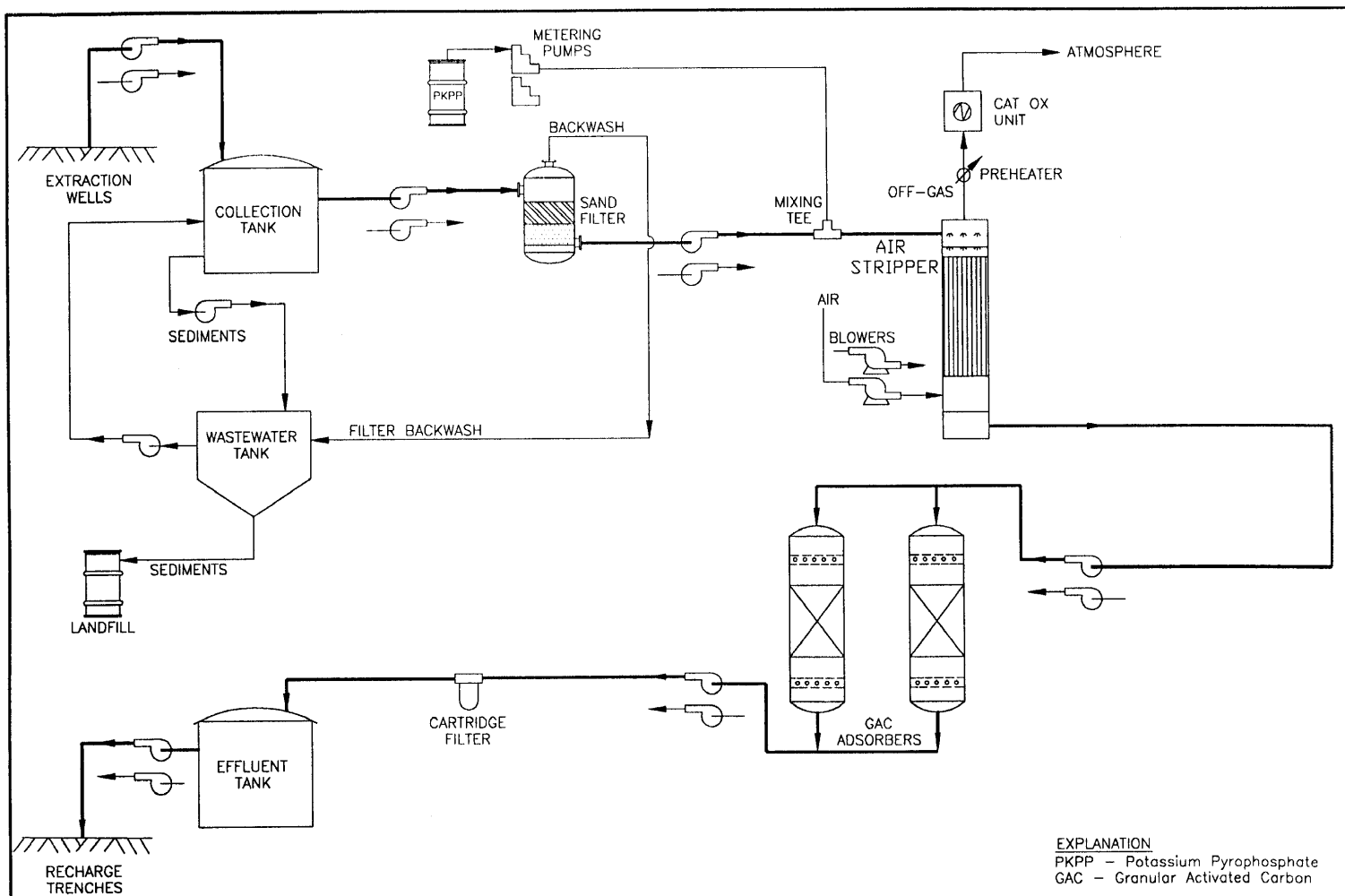


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U.S. Army Program Manager
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FIGURE 7.6-1
Schematic for Basin A Plume Group
Control Alternative AC-8

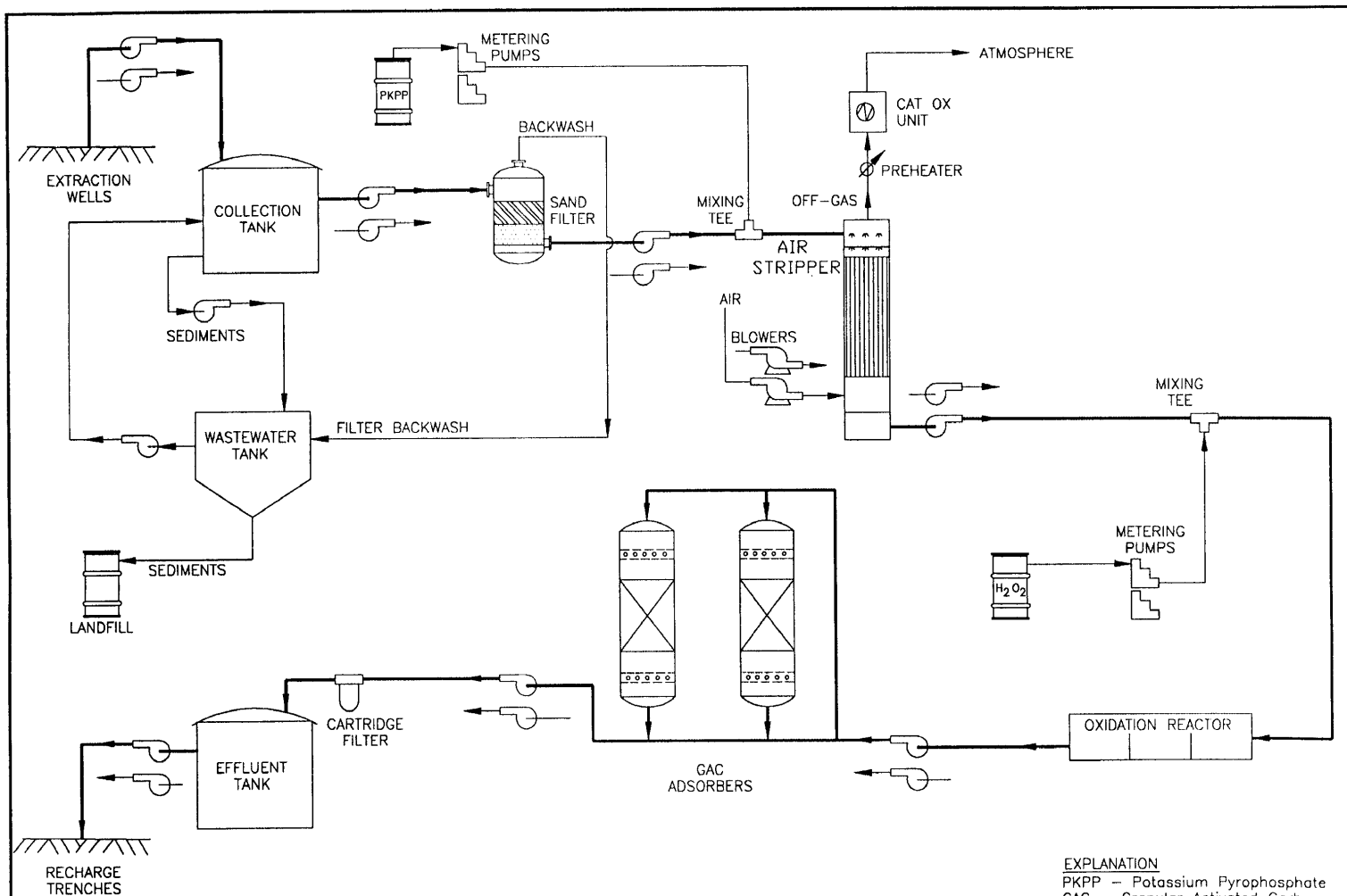
Prepared by:
Foster Wheeler Environmental Corporation



Prepared for:
Office for the Program Manager
for Rocky Mountain Arsenal

FIGURE 7.6-2
Process Flow Diagram
Treatment Alternative AC-8/AT-2,
Air Stripping/GAC Adsorption

Prepared by:
Foster Wheeler Environmental Corporation



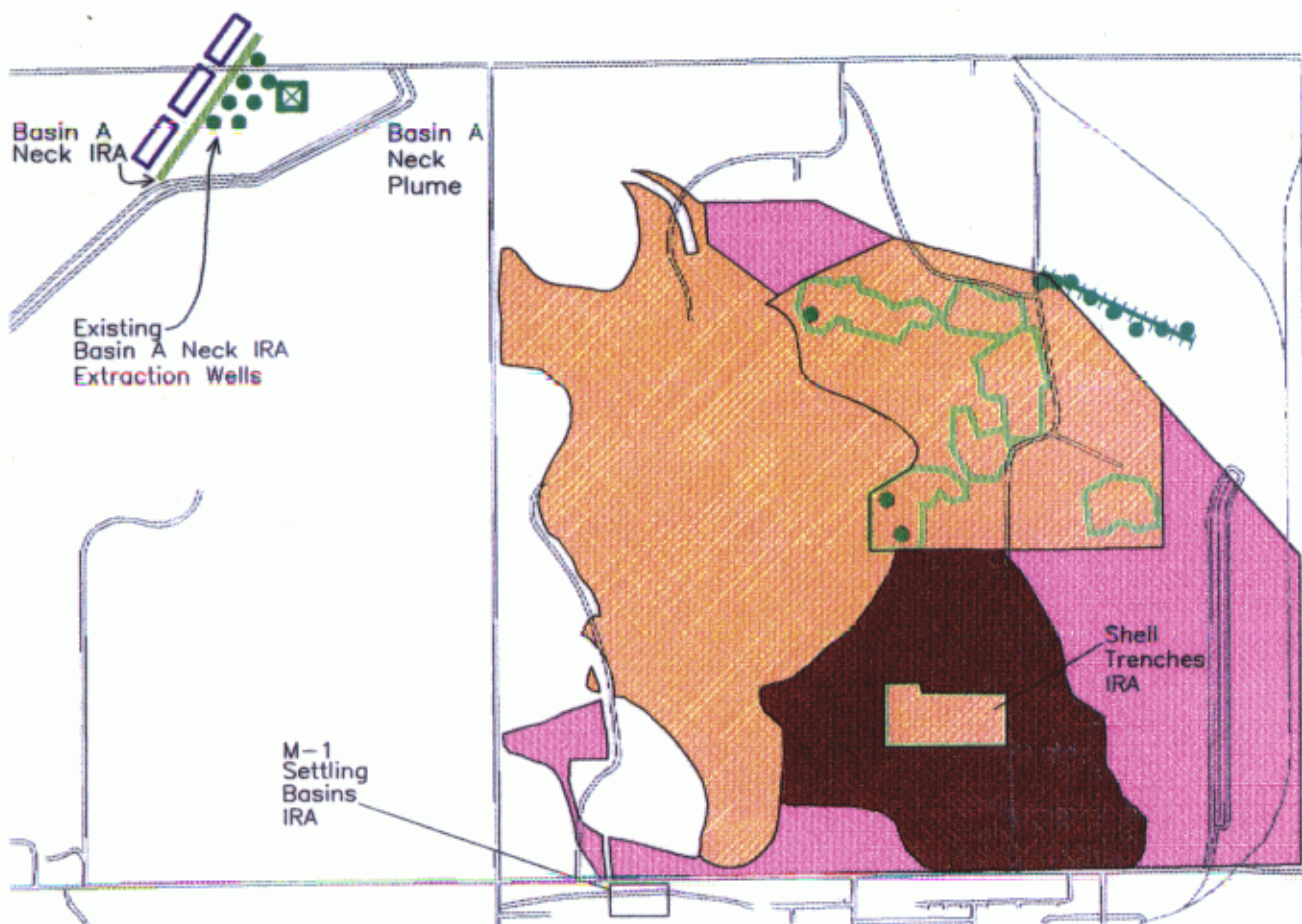
EXPLANATION

PKPP - Potassium Pyrophosphate
GAC - Granular Activated Carbon

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for Rocky Mountain Arsenal

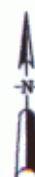
FIGURE 7.7-1
Process Flow Diagram
Treatment Alternative AC-8/AT-4,
Air Stripping/Oxidation/GAC Adsorption

Prepared by:
Foster Wheeler Environmental Corporation



LEGEND

-  4 ft. Thick or Greater Cap or Cover
-  2 ft. Thick Soil Cover
-  1 ft. Thick Soil Cover
-  Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)
-  Extraction Well
-  Recharge Trench
-  Slurry Wall
-  Treatment Plant
-  Horizontal Well



Not To Scale

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

FIGURE 7.8-1
Schematic for Basin A Plume Group
Control Alternative AC-9

Prepared by:
Foster Wheeler Environmental Corporation

Section 8

8.0 SOUTH PLANTS PLUME GROUP

The groundwater control/treatment alternatives presented here are not final designs that will actually be constructed. They are preliminary designs that have been developed for relative comparison and evaluation during the FS process. Each alternative has been carried to a preliminary design level because only at this level can actual size, effectiveness and costs be evaluated appropriately. Sufficient detail is provided for each alternative to allow its merits and drawbacks to be easily compared.

The final control/treatment alternative that is selected for a given plume group will be determined as part of the ROD, the negotiation and decision-making process by which the final site remediation is selected by the parties. When the alternative for the plume group have been selected, the remediation will enter a design phase. During the design phase, site-specific information will be collected about current site conditions, and a control/treatment system will be designed to meet the specific goals stated in the ROD. Such a design will be generally based on one or more of the alternatives described here, but will undoubtedly differ from it to some degree. For instance, a technology utilized in an alternative may be replaced by a technology that appears to be more appropriate or desirable at the time of design based on new site conditions, costs, results of pilot and treatability studies, and other factors. As long as the new technology can be applied to meet the goals of the selected alternative, this change can be made.

Ten alternatives were retained for consideration in the Water DAA for the South Plants Plume Group. Since the completion of the Water DSA (EBASCO 1992), most of these alternatives have been modified based on new information about site conditions or on groundwater modeling results for the South Plants area that show much lower flow rates than those used in the Water DSA (EBASCO 1992). One modification that affects nearly all of the alternatives is the interpretation of water quality in the South Plants Southwest Plume area located in the northeast corner of Section 2. The South Plants Southwest Plume, as defined in the DSA (EBASCO 1992), was based on a few elevated detections of organic analytes in a small number of wells. Results from more recent sampling and analyses from the original wells and newly installed wells

indicate that there is not a well-defined plume of elevated concentration in this area. Extraction and treatment alternatives for the remaining plumes (the South Plants North Source, South Plants Southeast, and South Tank Farm Plumes) are based on a mass reduction and/or dewatering approach. The CERCLA Wastewater Treatment Plant could, upon redesign and expansion, be used to treat the groundwater instead of constructing a new Basin A/South Plants combined treatment plant, given the completion of a potential expansion and the available capacity of the CERCLA Plant previous to when the remedial action is scheduled for implementation. The CERCLA Wastewater Treatment Plant is designed to treat 15 gpm, with a maximum capacity of 30 gpm for operation in a semibatch mode. Its current capacity, therefore, cannot adequately treat the volumes extracted under Alternatives SPC-6 or SPC-7 or Basin A Alternative AC-8. A separate bioremediation system is being considered in seven of the alternatives evaluated for the South Tank Farm Plume.

The primary contaminants of interest present in the South Plants North Source and South Plants Southeast Plumes are carbon tetrachloride, trichloroethylene, methylene chloride, chloroform, benzene, dieldrin and DBCP. The primary contaminant of interest in the South Tank Farm Plume is benzene. Other compounds are present at low concentrations, including the pesticide aldrin the volatile halogenated compound tetrachloroethylene and the volatile hydrocarbon dicyclopentadiene (DCPD). The treatment systems are designed to meet the PRGs established for those systems.

The South Tank Farm Plume is unique in that light nonaqueous phase liquid (LNAPL) is associated with the plume. Starting in 1992, Shell conducted a test to evaluate the effectiveness of a dual pump system for extracting LNAPL in the South Tank Farm Plume. The dual pump recovery system was in continuous operation from mid-June 1992 through early May 1993 (Shell 1994). During that period, approximately 40 gallons of LNAPL and more than 105,000 gallons of water were generated. The results of this test indicate that the volume of freely drainable or recoverable LNAPL is less than the 1,000 to 4,000 gallons previously estimated in the LNAPL/SVE Treatability Study Report (MKE 1991).

Based on the results of Shell's study, it was concluded that continued operation of the LNAPL recovery system would be ineffective. The DAA alternatives, therefore, only include monitoring of LNAPL. If more freely drainable LNAPL were to accumulate in the future, an extraction system would be used to pump LNAPL and groundwater for aboveground separation. Recovered LNAPL would be drummed and sent off post for treatment or disposal, while groundwater would be treated on post. The period of operation is expected to be relatively short and the cost impact on the overall remedial alternatives is insignificant.

Those alternatives evaluated for the Basin A and South Plants Plume Groups that involve construction of a treatment facility include the assumption that separate facilities will be built. A combined Basin A/South Plants treatment plant may prove to be more efficient; however, at this stage of planning it is not known which alternative will be chosen for either the Basin A or the South Plants Plume Group. Because this choice will affect the quantity of groundwater being treated from either plume group, the total flow travelling through the treatment plant is still unknown. Therefore costs have been developed based on separate treatment for each plume group. When a decision has been finalized regarding which alternative from Basin A and which alternative from South Plants will be implemented, a treatment plant for the combined flow can be considered. In Alternative SPC-5, the flow rate of the water extracted from the South Plants North Source and Southeast Plumes is 2 gpm total. In this alternative, the 2-gpm flow is combined with the Basin A Plume Group water to be treated as part of the Basin A Plume Group preferred alternative, whichever alternative that may be.

Recent modifications to caps considered for the soil medium have not been incorporated into these water alternatives, with the exception of SPC-2. The impact of the recent modifications were determined to be small except for the dewatering alternatives, for which smaller volumes of groundwater could be pumped to achieve the desired water levels and flow directions under the new cap alternative. The caps presented in this document were not updated because further changes in the caps are possible through the design stage of remedial activities. This discrepancy should have no impact on the selection process. SPC-2 has been modified for this document to

include additional groundwater monitoring and is therefore presented and considered in conjunction with the soil alternative.

The following sections provide detailed descriptions and analyses for each of the 10 alternatives retained from the Water DSA (EBASCO 1992) for the South Plants Plume Group. Table 8.0-1 presents a summary of the analyses. It should be noted that when the O&M costs differ between different time periods the annual O&M costs presented in this table represent the highest annual costs for that particular alternative.

8.1 ALTERNATIVE SPC-1: NO ACTION

Alternative SPC-1 specifies that any current or future IRAs for the South Plants Plume Group be discontinued (Figure 8.1-1).

8.1.1 Description of Alternative

No groundwater control activities are performed under this alternative. The monitoring that is currently being performed for the South Tank Farm Plume IRA is terminated, although general plume monitoring is continued.

8.1.2 Analysis of Alternative

8.1.2.1 Overall Protection of Human Health and the Environment

Alternative SPC-1 does not prevent contamination from the South Plants area from migrating toward RMA boundaries. However, contaminated groundwater is captured and treated by the boundary systems, and therefore this alternative is protective of human health and the environment off post. Human health is protected on post through the FFA (EPA et al. 1989), which prohibits the use of RMA groundwater as a potable water source. This alternative does not reduce the potential for contaminant migration from the South Plants Plume Group or downward migration into the confined flow system.

8.1.2.2 Compliance with ARARs

Action-specific, chemical-specific, and location-specific ARARs do not apply if Alternative SPC-1 is chosen. This alternative complies with the FFA (EPA et al. 1989). All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

8.1.2.3 Long-Term Effectiveness and Permanence

It appears that there has been little migration of contaminants from the source area in South Plants. However, contaminant migration may eventually increase the loading on the boundary systems, which may require the implementation of boundary system upgrades. As long as the boundary systems achieve off-post PRGs, this alternative is effective. Some migration of contaminants into the confined flow system may occur if the groundwater mound in the unconfined flow system is not reduced sufficiently to eliminate downward vertical hydraulic gradients. No groundwater controls are added as part of this alternative.

8.1.2.4 Reduction of TMV

This alternative involves no active extraction/treatment, nor does it involve the removal of existing controls. If the plumes migrated from the source area, contaminant mobility and volume of on-post plumes could increase; this would also result in an increase in contaminant concentrations (i.e., toxicity) in currently uncontaminated or less-contaminated areas.

8.1.2.5 Short-Term Effectiveness

Implementation of Alternative SPC-1 has no impact on the environment, surrounding community, or workers. Because no controls are implemented, contamination is free to migrate to the boundary. RAOs are achieved so long as the boundary systems continue to operate.

8.1.2.6 Implementability

This alternative is technically and administratively feasible. It is easily implemented because no remedial actions are undertaken or dismantled.

8.1.2.7 Costs

There is no capital cost associated with Alternative SPC-1. The annual O&M costs are \$196,000 for the first 5 years and \$91,000 for the next 25 years, and the present worth cost is \$2,340,000. A summary of costs is presented in Appendix A, Table A5-1.

8.2 ALTERNATIVE SPC-2: CONTINUED EXISTING ACTION

Alternative SPC-2 involves maintaining hydraulic control of the lakes and continued monitoring of the South Tank Farm Plume (Figure 8.2-1). This alternative is implemented in conjunction with the soil alternative involving capping of the South Plants Area.

8.2.1 Description of Alternative

Monitoring of the South Tank Farm Plume as currently performed for the South Tank Farm Plume IRA will continue. Groundwater monitoring is conducted in the lake area as indicated in Figure 8.2-1. Hydraulic controls are maintained to prevent contaminants from entering the lakes at levels that could have an adverse effect on biota. Potential migration will be evaluated prior to the ROD. If monitoring indicates that contaminants from South Plants plumes are migrating into the South Lakes, a focused feasibility study will be performed to evaluate impacts and remedial alternatives. The criteria used to select a remedial approach will be the same as those used in the DAA to evaluate and select alternatives.

Groundwater quality and water-level data are collected from 30 wells located along the western shore of Lake Ladora and the northern shore of Lower Derby Lake to assess groundwater contamination near the lakes. Several different analytes have at different times been detected in groundwater near the lakes; a complete suite of RMA analytes will therefore be analyzed on an annual basis. As water levels in the South Plants mound fall, hydraulic gradients and the flow of contaminated groundwater toward the lakes will decrease.

Additional wells around other areas of the South Plants are also monitored to evaluate the impact of the capping alternative. It is anticipated that there are sufficient existing wells to be used for

this monitoring. Monitoring of the confined flow system continues as described in Section 3.0. The wells to be monitored are located within the South Plants Central Processing Area where contaminant levels in the overlying unconfined aquifer, as well as around the periphery of the South Plants area, are high. Each of these wells has shown historic detections of organic analytes. Continued monitoring of these wells allows for the assessment of potential contaminant migration and degradation within the confined flow system.

Due to poor construction or documentation of well installation techniques, screened intervals, and bentonite seal locations, approximately 30 to 40 confined flow system wells will be closed and abandoned. For cost estimating purposes, it is assumed that 12 wells with average depths of 100 feet will be closed in the South Plants area.

8.2.2 Analysis of Alternative

8.2.2.1 Overall Protection of Human Health and the Environment

Alternative SPC-2, combined with the soil capping alternative, reduces contaminant migration from the South Plants area toward RMA boundaries. Contaminated groundwater is captured and treated by the boundary systems, and therefore this alternative is protective of human health and the environment off post. Human health is protected on post through the FFA, which prohibits the use of RMA groundwater as a potable water source. This alternative reduces the potential for contaminant migration from the South Plants Plume Group or downward migration into the confined flow system as long as the cap in South Plants is installed and maintained.

8.2.2.2 Compliance with ARARs

Action-specific, chemical-specific, and location-specific ARARs do not apply if Alternative SPC-2 is chosen. This alternative complies the FFA (EPA et al. 1989). All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

8.2.2.3 Long-Term Effectiveness and Permanence

So long as the boundary systems achieve off-post PRGs, this alternative is effective. Migration of contaminants into the confined flow system will be reduced as the groundwater mound continues to drop due to lack of recharge beneath the cap. Groundwater controls under this alternative involve lake level maintenance, expanded groundwater monitoring in the lakes area, and deep well monitoring.

8.2.2.4 Reduction of TMV

This alternative does not involve construction of new extraction/treatment systems or the removal of existing systems. Contaminant mobility and volume of on-post plumes may decrease as the water levels decrease in the South Plants source area as a result of capping. Contaminant concentrations (i.e., toxicity) may increase somewhat due to the lack of migration and dilution, but this is not expected to have a significant impact.

8.2.2.5 Short-Term Effectiveness

Implementation of Alternative SPC-2 has no impact on the environment, surrounding community, or workers. Because no controls are implemented, contamination may migrate to the boundary. RAOs are achieved so long as the boundary systems continue to operate.

8.2.2.6 Implementability

This alternative is technically and administratively feasible. It is easily implemented because the only actions undertaken are monitoring and lake level controls.

8.2.2.7 Costs

The capital cost associated with Alternative SPC-2 is \$80,000. The annual O&M costs are \$355,000 for the first 5 years and \$225,000 for the next 25 years, and the present worth cost is \$5,180,000. A summary of costs is presented in Appendix A, Table A5-2.

8.3 ALTERNATIVE SPC-3/SPT-2: MASS REDUCTION, AIR STRIPPING/SORPTION

This alternative consists of groundwater extraction from the South Plants North Source, South Plants Southeast, and South Tank Farm Plumes. The contaminants are removed by extraction wells and, if LNAPL accumulates in the South Tank Farm Plume, it is separated and extracted. Extracted water is treated using air stripping and GAC adsorption and then is reinjected into four recharge trenches conceptually located in Section 27. This alternative is accomplished in conjunction with the preferred Basin A groundwater alternative and also with soils remedial activities, which include caps over Basin A and the South Plants Central Processing Area. Table 8.3-1 presents the estimated chemical influent concentrations for this alternative. For costing and comparison purposes it has been assumed that the mass reduction systems will operate for 20 years and remove all of the currently dissolved contaminant mass in the targeted central areas of each plume.

8.3.1 Description of Alternative

8.3.1.1 Extraction/Reinjection

As shown in Figure 8.3-1, this alternative consists of mass reduction systems located in the South Plants North Source, South Plants Southeast, and South Tank Farm Plumes that use five, three, and ten extraction wells, respectively. These systems operate for approximately 20 years, which is the expected period of time required for removal of all of the dissolved contaminant mass. After 20 years the mass reduction operation would end. If LNAPL in the South Tank Farm Plume accumulates to a sufficient thickness, it is extracted, separated, and sent off post for treatment or disposal.

All extraction wells included in this alternative are constructed using 12-inch-diameter borings with gravel pack surrounding the 6-inch-diameter casing and screen (which increases the effective intake radius of the wells), and all pipelines are double walled unless otherwise noted. All submersible pumps in wells are assumed to be 0.333 horsepower and all booster pumps are 1.5 horsepower for costing purposes.

The mass reduction system located in the South Plants North Source Plume consists of five wells (Figure 8.3-1) that extract a total of 1 gpm of groundwater. The wells are approximately 45 ft deep, with the screened portions penetrating approximately 35 to 40 ft into the weathered Denver Formation. The submersible pumps installed in each well are connected to a collection manifold and then a storage tank, which in turn is connected to a buried transport pipe. The water is pumped to a collection tank at the treatment plant. The total flow of 1 gpm will be combined with the water from the South Plants Southeast and South Tank Farm Plumes.

Groundwater is extracted from the South Plants Southeast Plume using a mass reduction system oriented along the axis of the plume. The three extraction wells have the same design as described for the South Plants North Source Plume. Under this scenario, approximately 1 gpm of extracted groundwater is collected in a collection manifold connected to a tank (the same note as in the paragraph above applies to this flow rate). The water is then piped from the tank to the treatment plant for treatment.

The mass reduction system located in the South Tank Farm Plume uses 10 extraction wells spaced along the axis of the plume (Figure 8.3-1). The extraction wells, which have the same design as those for the other two plumes, pump approximately 5 gpm of groundwater to a collection tank. The water is then pumped by a 1.5-horsepower pump to the treatment plant through double-walled pipe.

The water from the treatment plant is transported through single-walled pipe to reinjection trenches located in permeable alluvium. Three areas are being considered as possible sites for the injection trenches. These areas include Section 27 upgradient of the NWBCS, Sections 23 and 24 upgradient of the NBCS, and Sections 25 and 31 upgradient of North Plants and the NBCS. At this time the Section 27 option is preferred because it is located in a permeable aquifer that can accept the estimated flow volumes without significant impact to the aquifer or contaminant migration. The Section 27 location was used to develop costs for this report. The four recharge trenches are lined with geotextile filter fabric, backfilled with clean gravel, and

covered with geotextile filter fabric and approximately 3 ft of soil. Well points are placed in the gravel during backfilling operations for even distribution of reinjected water. The recharge trenches are located in permeable alluvium to ensure that water is recharged back to the aquifer without restriction in recharge rates caused by localized impermeable layers.

The mass reduction operation for the South Plants Plume Group is accomplished over a 20-year period, which is the expected period required to remove all currently dissolved contaminant mass in the targeted central portions of each plume. Estimates of the total mass of dissolved organic contaminants that are present in the targeted portions of the aquifer are 2,400 kg in the South Plants North Source Plume, 430 kg in the South Plants Southeast Plume, and 30,000 kg in the South Tank Farm Plume. Twenty years of extraction of contaminated groundwater from the targeted plume areas results in the following estimated quantities of mass removal of dissolved organic contaminants from each plume, assuming complete removal of one pore volume of groundwater: 2,400 kg (100 percent of initial dissolved mass) for South Plants North Source, 430 kg for the South Plants Southeast Plume, and 30,000 kg for the South Tank Farm Plume. As groundwater is removed from these portions of the aquifer, water of lower contaminant concentrations is expected to flow in from adjacent areas, contaminant mass that is sorbed onto aquifer solids desorbs into solution, and additional contamination is added to groundwater from soil sources. Current estimates indicate that the mass of contaminants sorbed onto aquifer materials is large for some organic contaminants present, even given the low organic carbon content of the aquifer (see Appendix C).

If LNAPL in the South Tank Farm Plume near Tank 464A accumulates to a sufficient thickness, an extraction system is used to pump LNAPL and groundwater for aboveground separation. Recovered LNAPL is drummed and sent off post for treatment or disposal, while groundwater is treated on post. The period of operation is expected to be relatively short and the cost impact on the overall remedial alternatives is insignificant.

Groundwater-quality and water-level data from a monitoring network of existing plume evaluation and monitoring wells as well as newly installed performance monitoring wells are used to evaluate the effectiveness and operation of the extraction system. The final number and location of the new wells is based upon review of the existing wells.

8.3.1.2 Treatment

The treatment system for Alternative SPT-2 is designed for a flow rate of 7 gpm and uses air stripping followed by GAC to remove contaminants from the groundwater. This treatment continues for 20 years based on the estimated volume of water removal needed to remove all of the dissolved contaminant mass in groundwater in the targeted centers of the plumes. Figure 8.3-2 presents a process flow diagram showing the major pieces of treatment equipment as well as tanks, pumps, and filters used in this alternative.

Extracted water is stored in an equalization tank prior to being treated. The water is then pumped through a multimedia filter to remove suspended soils, and a sequesterant (PKPP) is added to keep dissolved solids, such as calcium and iron, in solution. The water then enters a shallow tray air stripper, which uses an air flow rate of 300 cfm. The air stripper is operated to remove volatile organics to concentrations below their PRGs from the groundwater. A more detailed description of the air stripping technology is presented in the Technology Description Volume, Section 14.3.

The organic contaminants in the air emissions from the air stripper are destroyed using a catalytic oxidation unit, which employs thermal energy in the presence of a catalyst to destroy the contaminants. Electrical energy is required to generate sufficient heat to completely oxidize the organics. In addition, the catalyst must be replaced every 3 to 5 years and is usually returned to the vendor where the catalyst (platinum) is recovered.

The water effluent from the air stripper is pumped to the GAC adsorbers. GAC treatment is accomplished using one modular GAC adsorber that holds 1,000 lbs of carbon. The GAC

adsorber is designed to remove DBCP, OCPs, and remaining volatiles to below their target concentrations. When the carbon becomes saturated, the adsorption unit is replaced. It is estimated that a new unit will be needed every 6 months. The spent unit is drained and transported off post for regeneration; the drained water is returned to the collection tank. A more detailed description of the GAC treatment technology is included in the Technology Description Volume, Section 14.2.

The GAC effluent is run through a cartridge filter to remove carbon fines and suspended solids and is collected in an effluent tank. From there the treated water is pumped to recharge the trenches.

8.3.1.3 Sidestreams

This treatment system produces three sidestreams: vapor emissions from the air stripper, spent GAC adsorption units, and used cartridges from the filter.

The vapor-phase emissions from the air stripper are treated with catalytic oxidation. Because this process actually destroys the contaminants instead of transferring them to another medium, no further treatment of the vapor-phase emissions is required.

Spent GAC units and used cartridges from the filter require disposal. Because the cartridges have been in contact with hazardous materials, they are drummed and transported to an off-post RCRA landfill for disposal. The spent GAC is sent off post to be regenerated. The wastewater in the wastewater tank is recirculated to the collection tank and the sediments from the wastewater tank are drummed and landfilled.

8.3.2 Analysis of Alternative

8.3.2.1 Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment off post as long as PRGs are met at the boundary. Human health is protected on post by FFA restrictions on future uses of

groundwater. Alternative SPC-3/SPT-2 removes chloroform, benzene, DBCP, OCPs, and, if necessary, LNAPL, achieving a reduction in the contaminant mass and potentially reducing loading on the boundary systems over time.

A measurable fraction of the dissolved contaminant mass is permanently removed from the centers of the plumes in the first 20 years. The permanent removal of contaminants reduces the toxicity and the migration of the contaminants.

Once extraction and treatment is completed and the extraction systems are discontinued, any remaining contaminants are free to migrate. These contaminants occur at lower concentrations and are further reduced by natural attenuation. Any contaminants that reach the boundary systems are intercepted and treated there.

8.3.2.2 Compliance with ARARs

Alternative SPC-3/SPT-2 is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls and with the FFA (EPA et al. 1989). The treatment systems were conceptually designed based on an earlier set of standards. Should this alternative be selected as the preferred alternative, it is expected to meet most of the revised CBSG-based, chemical-specific ARARs that would be developed for it, however, some design parameter changes might be required. Appropriate siting of the treatment plant ensures compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

8.3.2.3 Long-Term Effectiveness and Permanence

Alternative SPC-3/SPT-2 reduces the potential for future migration of contaminants by permanently removing contamination from the groundwater. The potential for off-post exposure is reduced through mass removal from the South Plants North Source, South Plants Southeast, and South Tank Farm Plumes in conjunction with continuing operation of the boundary systems.

A fraction of the groundwater contamination is removed and treated close to the source. The boundary systems ensure that any groundwater that is not captured and treated on post meets off-post PRGs at the RMA boundaries. By lowering water levels and extracting high concentrations of contaminants in the upper (alluvial/weathered bedrock) aquifer, the potential for future migration to the confined flow system is reduced. Because mass reduction systems operate for a relatively short time period (20 years) over relatively small areas and at low pumping rates, the overall beneficial impact of this alternative on contaminants adsorbed to aquifer materials and on the confined aquifer is expected to be small.

Monitoring occurs during the operation of the treatment system and continues once the system is shut down to evaluate long-term effectiveness and plume migration. The mass of contamination removed by the mass reduction systems is monitored by influent sampling at the treatment plant and by monitoring of groundwater at monitoring wells. The specific reduction system performance objective is defined during the design phase of the alternatives. For costing and comparison purposes, it has been assumed that the systems will operate for 20 years and remove all of the currently dissolved mass of contaminants in the targeted area of each plume.

8.3.2.4 Reduction of TMV

Alternative SPC-3/SPT-2 reduces toxicity and mobility of contaminants in the groundwater by removing and treating contaminants from the centers of the plumes (Section 8.3.1.1). Under this alternative, air stripping removes the majority of the volatile organics and GAC adsorption treats the remaining organic contaminants to the PRGs. If freely drained LNAPL accumulates to a sufficient thickness, it is separated from the South Tank Farm Plume using a dual-pump system, drummed, and disposed off post. Toxicity is reduced by removing contaminants from the groundwater prior to reinjection.

A mass reduction system extracts the contaminated groundwater near the source, reducing the potential for migration through the aquifer. The lowering of the water table temporarily due to groundwater extraction reduces the amount of contaminants in the soil that are in contact with

the groundwater. In this system, 7 gpm are extracted from the South Plants North Source, South Plants Southeast, and South Tank Farm Plumes combined. These systems result in a decrease of contaminant mobility in the South Plants Plume Group.

The contaminants are irreversibly transferred from the groundwater to the vapor phase by air stripping and are subsequently destroyed by catalytic oxidation. Contaminants treated with GAC adsorption are transferred to the carbon, which is regenerated off post. Contaminants that are not removed by the mass reduction extraction system or any contaminants that remain sorbed to the soil in the aquifer and desorb at a later time are treated by the boundary systems if they migrate to the boundary.

Some contaminants remain in the South Plants plumes because parts of the plumes containing contaminants may not be removed by the extraction system and because some contaminants may remain sorbed to the soil in the aquifer and desorb at a later time.

8.3.2.5 Short-Term Effectiveness

In general, the construction, operation, and final demobilization of this alternative have a minimal negative impact on the environment, workers, or the surrounding community. On-post workers are potentially exposed to contaminants through dermal contact and dust inhalation during excavation and well and trench installation. To reduce the potential for such exposure, dust-control measures and PPE are used.

Operators of the system must also concern themselves with proper material-handling techniques when replacing the GAC adsorbers. To reduce the potential for exposure, personnel are made aware of health and safety procedures and PPE is used.

RAOs are achieved for this alternative. During the 20 years of mass reduction system operation, a measurable fraction of dissolved contaminant mass is removed from the plume centers

(Section 8.3.1.1 and Appendix C). The contaminants are extracted and treated, reducing the volume and toxicity of contaminants in the groundwater.

8.3.2.6 Implementability

This alternative is technically feasible. Extraction/reinjection systems, air stripping, and GAC adsorption are proven and readily available technologies. As discussed in the Technology Description Volume (Sections 5, 14.3, and 14.2), these technologies are all currently being used at RMA. All required equipment is commercially available. The extraction system will incorporate existing wells where possible. The operators do not require any more training for the implementation of this alternative than for existing systems at RMA.

The alternative is expected to be reliable. The system requires minimal down time for equipment maintenance; in many cases, maintenance can be performed without shutting down the entire system. The system has automated controls that ensure continuous operation with little supervision.

GAC units and air strippers are readily available and supplied in sufficient quantities by qualified vendors. The sludge containing inorganics is stabilized and disposed, along with spent bag filters, in an off-post RCRA landfill. Precious metals are recycled from the spent catalyst by the supply vendor, and GAC is sent off post for regeneration.

Administratively, this alternative is easily implemented. However, it must be coordinated with the soil and structure media remedial actions in South Plants and may not be implemented until these actions are completed. It requires an operation and maintenance program for the treatment system, contracts with GAC suppliers, vendors who manage hazardous waste, and the performance of periodic site monitoring and 5-year reviews.

8.3.2.7 Costs

The capital cost of this treatment system is estimated to be \$2,420,000. Approximate annual O&M costs, including monitoring, are \$696,000 (years 1 to 5), \$563,000 (years 6 to 20), and \$122,000 (years 21 to 30). The present worth cost for construction and 30 years of operation is estimated to be \$12,300,000. A cost summary is presented in Appendix A, Table A5-3.

8.4 ALTERNATIVE SPC-3/SPT-3: MASS REDUCTION, OXIDATION/SORPTION

This alternative consists of groundwater extraction from the South Plants North Source, South Plants Southeast, and South Tank Farm Plumes. Extraction is completed in a mass reduction configuration and, if freely drainable LNAPL accumulates to a sufficient thickness in the South Tank Farm Plume, it is separated and treated as described in Section 8.0. This alternative differs from Alternative SPC-3/SPT-2 (stripping/sorption) in the treatment of the extracted water (oxidation/sorption).

The configuration and benefit of the mass reduction system are described in Section 8.3. Extracted water is treated with oxidation and GAC adsorption and is then reinjected into two or more recharge trenches. Three areas are being considered as possible sites for the injection trenches. These areas include Section 27 upgradient of the NWBCS, Sections 23 and 24 upgradient of the NBCS, and Sections 25 and 31 upgradient of North Plants and the NBCS. At this time the Section 27 option is preferred because it is located in a permeable aquifer that can accept the estimated flow volumes without significant impact to the aquifer or contaminant migration. The Section 27 location was used to develop costs for this report. Table 8.3-1 presents the estimated chemical influent concentrations for this alternative. For costing and comparison purposes, it has been assumed that the mass reduction systems will operate for 20 years and remove all of the currently dissolved contaminant mass in the targeted central areas of each plume.

8.4.1 Description of Alternative

8.4.1.1 Extraction/Reinjection

Alternative SPC-3/SPT-3 includes the same groundwater control systems that are used for Alternative SPC-3/SPT-2 (Section 8.3.1.1).

8.4.1.2 Treatment

The treatment system for Alternative SPT-3 uses oxidation followed by GAC to remove contaminants from the groundwater. The design capacity of the system is 7 gpm. This treatment continues for 20 years based on estimates of the volume of water removal needed to reduce the contaminant mass in groundwater in the centers of the plumes. Figure 8.4-1 presents a process flow diagram showing the major pieces of treatment equipment as well as tanks, pumps, and filters used in this alternative.

Extracted water is collected in a tank prior to being treated. Hydrogen peroxide (H_2O_2) is added through a mixing tee and the water is filtered to remove the iron and manganese that may precipitate as a result of the addition of hydrogen peroxide. The filtered water is then pumped to the oxidation reactor where it is exposed to UV light. The reactor is operated to reduce chlorinated compounds, including chlorinated volatile organics, OCPs, and DBCP, to below their target concentrations. A more detailed description of this technology is included in the Technology Description Volume, Section 14.1.

Treated water exiting the oxidation reactor is pumped to the GAC adsorbers, where the remaining DBCP, OCPs, and volatile organics are removed to below their target concentrations. The GAC adsorption system consists of one GAC unit holding 2,000 lbs of carbon. The estimated carbon consumption for this alternative is 24,000 lbs per year, or approximately one unit per month. A more detailed description of the GAC treatment technology is included in the Technology Description Volume, Section 14.2.

The GAC effluent is filtered through a cartridge filter to remove carbon fines and suspended solids and is collected in an effluent tank. From there the treated water is pumped to the recharge trenches.

8.4.1.3 Sidestreams

This treatment system produces two sidestreams: spent GAC units and used cartridges from the filter. Spent GAC units and used cartridges from the filter require disposal. Because the filters have been in contact with hazardous materials, they are drummed and sent to an off-post RCRA landfill. The spent GAC is sent off post to be regenerated. The wastewater in the wastewater tank is recirculated to the collection tank and the sediments from the wastewater tank are drummed and landfilled.

8.4.2 Analysis of Alternative

8.4.2.1 Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment off post as long as PRGs are achieved at the boundary. Human health is protected on post by FFA (EPA et al. 1989) restrictions on future uses of groundwater. Alternative SPC-3/SPT-3 removes chloroform, benzene, DBCP, and, if necessary, freely drainable LNAPL from the aquifer. This reduces contaminant migration by removing contaminants from the groundwater and protects human health off post by potentially reducing loading on the boundary systems and thereby promoting efficient operation of the treatment system.

A measurable fraction of the dissolved contaminant mass is permanently removed from the centers of the plumes during the first 20 years based on calculations of the quantity of contaminant mass removed (Section 8.4.1.1 and Appendix C). Continued monitoring after 20 years of treatment assesses whether the contaminant concentrations in the groundwater have been permanently reduced. Additional contaminant mass is effectively removed to acceptable levels (off-post PRGs) by the boundary systems, reducing the risks of exposure to human health and the environment off post.

Once extraction and treatment are completed and extraction systems are discontinued, any remaining contaminants are free to migrate. The remaining contaminants occur at low concentrations and are further reduced through natural attenuation.

8.4.2.2 Compliance with ARARs

Alternative SPC-3/SPT-3 is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls, and with the FAA (EPA et al. 1989). The treatment systems were conceptually designed based on an earlier set of standards. Should this alternative be selected as the preferred alternative, it is expected to meet most of the revised CBSG-based, chemical-specific ARARs, that would be developed for it; however, some design parameter changes might be required. Appropriate siting of the treatment plant ensures compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

8.4.2.3 Long-Term Effectiveness and Permanence

This alternative reduces the potential for future migration of contaminants by permanently removing contamination from the groundwater. The potential for off-post exposure is reduced by the additional mass removal and treatment system used in conjunction with the boundary systems.

A fraction of the dissolved groundwater contamination is removed and treated close to the source. The boundary systems ensure that any groundwater that is not captured on post meets PRGs at the RMA boundary. By lowering water levels and extracting high concentrations of contaminants in the upper aquifer, the potential for future migration to the confined flow system is reduced. Because mass reduction systems operate for relatively short time periods (20 years) over relatively small areas and at low pumping rates, the overall beneficial impact of this alternative on contaminants adsorbed to aquifer materials and on the confined aquifer is expected to be small.

Monitoring occurs during the operation of the alternative and continues once the mass reduction system is terminated to evaluate long-term effectiveness and plume migration. The mass of contamination removed by the mass reduction systems is monitored by influent sampling at the treatment plant and by monitoring of groundwater at monitoring wells. The specific mass reduction system performance objective will be defined during the design phase of the alternatives. For costing and comparison purposes, it has been assumed that the mass reduction systems will operate for 20 years and remove all of the currently dissolved contaminant mass in the targeted central areas of each plume.

8.4.2.4 Reduction of TMV

This alternative reduces toxicity and mobility of contaminants in the groundwater by removing and treating contaminants from the centers of the plumes (Section 8.3.1.1 and Appendix C). The groundwater extracted from the South Plants North Source, South Plants Southeast, and South Tank Farm Plumes is treated by a combination of oxidation and GAC adsorption. Oxidation destroys a large fraction of the contaminants and GAC adsorption treats the remaining organic contaminants to the PRGs. If freely drained LNAPL accumulates to a sufficient thickness, it is separated from the South Tank Farm Plume, drummed, and sent off post for disposal. Toxicity is reduced by the removal of the contaminants from the groundwater prior to reinjection.

A mass reduction system extracts the contaminated groundwater near the source, reducing the potential for migration through the aquifer. The lowering of the water table temporarily due to groundwater extraction reduces the amount of contaminants in the soil that are in contact with groundwater, reducing the potential for contaminants to desorb into the groundwater. In this system, 7 gpm is extracted from the South Plants North Source, South Plants Southeast, and South Tank Farm Plumes. These systems result in the decrease of contaminant volume and mobility in the South Plants Plume Group.

The contaminants are irreversibly destroyed by oxidation or transferred from the groundwater to GAC by adsorption. The spent carbon is regenerated off post. Contaminants that are not

removed by the mass reduction extraction system or any contaminants that remain sorbed to the soil in the aquifer and desorb at a later time are treated by the boundary systems if they migrate to the boundaries of RMA.

Some contaminants remain in the South Plants plumes because parts of the plumes containing contaminants may not be removed by the extraction system and because some contaminants may remain sorbed to the soil in the aquifer and desorb at a later time.

8.4.2.5 Short-Term Effectiveness

In general, the construction, operation, and final demobilization of Alternative SPC-3/SPT-3 have minimal negative impact on the environment, workers, or the surrounding community. On-post workers are potentially exposed to contaminants through dermal contact and dust inhalation during excavation and well and trench installation. To reduce the potential for such exposure, dust-control measures and PPE are used.

The oxidation reactor requires hydrogen peroxide, and the handling of contaminated GAC associated with changeout may present a concern for workers. To reduce the potential for exposure, personnel are made aware of health and safety procedures and PPE is used.

RAOs are achieved under this alternative. During the 20 years of mass reduction system operation, a measurable fraction of dissolved contaminant mass is removed from the plume centers (Section 8.4.1.1 and Appendix C). The contaminants are extracted and treated, reducing the volume and toxicity of contaminants in the groundwater.

8.4.2.6 Implementability

This alternative is technically feasible. Extraction/reinjection systems and GAC adsorption are proven and readily available technologies. As discussed in the Technology Description Volume (Sections 5 and 14.2), these technologies are currently being used at RMA. The advanced oxidation process, using hydrogen peroxide and UV light, is an innovative technology

(Technology Description Volume, Section 14.1). Pilot-scale studies have been performed as followup to the WES bench-scale treatability studies, but the results are not available for inclusion in this document.

All equipment required for this alternative is commercially available from several vendors, with the exception of the oxidation reactor, for which a limited number of vendors supply the equipment. The extraction system incorporates existing wells where possible. The operators may require further training for the operation of oxidation reactors.

The alternative is expected to be reliable. The system requires minimal down time for equipment maintenance; in many cases, maintenance can be performed without shutting down the entire system. The system has automated controls that ensure continuous operation with little supervision.

GAC units for this alternative are produced and supplied in sufficient quantities by qualified vendors. The sludge is stabilized and disposed, along with filter cartridges, in an off-post hazardous waste landfill. Precious metals are recovered from spent catalyst by the supply vendor and GAC is sent off post for regeneration.

Administratively, this alternative is easily implemented. However, it must be coordinated with the soil and structures media remedial actions in South Plants and may not be implemented until these actions are completed. It requires an operation and maintenance program for the treatment system, contracts with GAC suppliers, vendors who manage hazardous waste, periodic site monitoring, and 5-year reviews.

8.4.2.7 Costs

The capital cost of this treatment system is estimated to be \$2,550,000. Approximate annual O&M costs, including monitoring, are \$801,000 (years 1 to 5), \$667,000 (years 6 to 20), and

\$122,000 (years 21 to 30). The present worth cost for construction and 30 years of operation is estimated to be \$14,000,000. A cost summary is presented in Appendix A, Table A5-4.

8.5 ALTERNATIVE SPC-3/SPT-2/SPT-4: MASS REDUCTION, AIR STRIPPING/SORPTION, BIOLOGICAL REACTOR/SORPTION

This alternative consists of groundwater extraction from the South Plants North Source, South Plants Southeast, and South Tank Farm Plumes. Extraction is completed in a mass reduction configuration. If freely drainable LNAPL accumulates to a sufficient thickness in the South Tank Farm Plume, it is separated and treated as described in Section 8.0. The configuration and benefit of the mass reduction system are described in Section 8.3. For costing and comparison purposes, it has been assumed that the mass reduction systems will operate for 20 years and remove all of the currently dissolved contaminant mass in the targeted central areas of each plume.

Extracted water from the South Plants North Source and South Plants Southeast Plumes is treated using air stripping and GAC adsorption and is then reinjected into two or more recharge trenches located in Section 27. Three areas are being considered as possible sites for the injection trenches: Section 27 upgradient of the NWBCS, Sections 23 and 24 upgradient of the NBCS, and Sections 25 and 31 upgradient of North Plants and the NBCS. At this time the Section 27 option is preferred because it is located in a permeable aquifer that can accept the estimated flow volumes without significant impact to the aquifer or contaminant migration. The Section 27 location was used to develop costs for this report.

This alternative differs from Alternative SPC-3/SPT-2 in that water from the South Tank Farm Plume is treated first in a biological reactor before being combined with water from the South Plants North Source and South Plants Southeast Plumes for treatment in the GAC units. Extracted water from the South Tank Farm Plume is treated in a biological reactor due to its high concentration of benzene and then by GAC adsorption. Extracted water from the South Plants North Source and South Plants Southeast Plumes is treated with air stripping and is then

combined with water from the South Tank Farm Plume for treatment with GAC adsorption. This alternative is accomplished in conjunction with soil and structures remedial activities. Table 8.5-1 presents the estimated chemical influent concentrations for the South Plants North Source and South Plants Southeast Plumes. Table 8.5-2 presents the estimated chemical influent concentrations for the South Tank Farm Plume.

8.5.1 Description of Alternative

8.5.1.1 Extraction/Reinjection

Alternative SPC-3/SPT-2/SPT-4 includes the same groundwater control systems that are used for Alternative SPC-3/SPT-2 (Section 8.5.1.1), except that the water extracted from the South Tank Farm Plume is treated separately in a biological reactor.

The mass reduction operation for the SPC-3/SPT-2/SPT-4 is accomplished over a 20-year period, which is the expected period required to remove all currently dissolved contaminant mass in the targeted central portion of each plume. Twenty years of extraction of contaminated groundwater from the targeted plume areas results in the following estimated quantities of mass removal of dissolved organic contaminants from each plume, assuming complete removal of one pore volume of groundwater (100 percent of initial dissolved mass): 2,400 kg for South Plants North Source, 430 kg for the South Plants Southeast Plume, and 30,000 kg for the South Tank Farm Plume. As groundwater is removed from these portions of the aquifer, water of lower contaminant concentrations is expected to flow in from adjacent areas, contaminant mass that is sorbed into aquifer solids will desorb into solution, and additional contamination will be added to groundwater from soil sources. Current estimates indicate that the mass of contaminants sorbed onto aquifer materials is large for some organic contaminants present, even given the low organic carbon content of the aquifer (see Appendix C).

8.5.1.2 Treatment

The treatment system for Alternative SPC-3/SPT-2/SPT-4 uses air stripping followed by GAC to remove contamination from the South Plants North Source and South Plants Southeast Plumes. This system is identical to the one for Alternative SPC-3/SPT-2, which is described in Section 8.3.1.2, and is designed to treat a combined total of 2 gpm in the air stripper and 7 gpm in the GAC unit. Figure 8.3-2 presents a process flow diagram showing the major pieces of treatment equipment as well as tanks, pumps, and filters used in this part of the alternative. Water extracted from the South Tank Farm Plume is treated in a biological reactor to remove most of the benzene and is then combined with the flow from the South Plants North Source and South Plants Southeast Plumes as it enters the GAC adsorber, where the remaining benzene is treated (Figure 8.5-1). The GAC adsorber will be replaced approximately five times per year. The GAC adsorber shown in Figure 8.5-1 is identical to the ones shown in Figure 8.3-2.

Water from the South Tank Farm Plume is extracted at a rate of 5 gpm and is treated in a biological reactor, with GAC as the support medium, to remove more than 80 percent of the benzene. Extracted water is pumped to an influent holding tank before being transferred to a reactor tank filled with 670 lbs of GAC (to which the biofilm adheres). A recycle pump is included to support a 23-gpm recycled flow through the reactor tank. An oxygenator and a chemical tank and pump are also included to provide oxygenated nutrients for microorganism growth. Effluent from the reactor is pumped to the GAC units used to treat the South Plants North Source and South Plants Southeast Plume groundwater.

8.5.1.3 Sidestreams

This treatment system produces three major sidestreams, vapor emissions from the air stripper, biomass from the biological reactor, and spent GAC units, as well as used cartridges from the filter. These are disposed as described in Section 8.3.1.3. The biomass is landfilled.

8.5.2 Analysis of Alternative

8.5.2.1 Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment off post as long as PRGs are met at the boundary. FFA restrictions ensures protection of human health on post. Removal of the volatile halogenated organics (VHOs), benzene, DBCP, OCPs, and, if necessary, freely drainable LNAPL from the groundwater in the South Plants North Source and South Plants Southeast Plumes and biodegradation of the benzene in the South Tank Farm Plume results in a reduction in the contaminant mass and reduces the migration of the contaminants.

Once extraction and treatment is completed and the extraction systems are discontinued, any remaining contaminants will migrate in response to the hydraulic gradient of the groundwater system. These residual contaminants, if present, exist at low levels and are further reduced by natural attenuation. Any contaminants that reach the boundary systems are intercepted and treated there.

8.5.2.2 Compliance with ARARs

Alternative SPC-3/SPT-2/SPT-4 is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls, and with the FFA (EPA et al. 1989). The treatment systems were conceptually designed based on an earlier set of standards. Should this alternative be selected as the preferred alternative, it is expected to meet most of the revised CBSG-based, chemical-specific ARARs, that would be developed for it; however, some design parameter changes might be required. Appropriate siting of the groundwater treatment facility ensures compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

8.5.2.3 Long-Term Effectiveness and Permanence

Alternative SPC-3/SPT-2/SPT-4 reduces the potential for off-post exposure by removing and treating dissolved contaminants near the source. Direct biotreatment of the South Tank Farm Plume ensures that benzene levels are significantly and permanently reduced. Any remaining

contaminants either degrade through natural processes or are removed by the boundary systems. By temporarily lowering water levels and extracting high concentrations of contaminants in the unconfined aquifer, the potential for future migration to the confined flow system is reduced. Because mass reduction systems operate for relatively short time periods (20 years) over relatively small areas and at low pumping rates, the overall beneficial impact of this alternative on contaminants adsorbed to aquifer materials and on the confined aquifer is expected to be small. The biotreatment system does not directly treat contaminants in the confined flow system. However, by removing contamination in the overlying unconfined flow system, the potential for future migration of contaminants to the confined flow system is reduced. The long-term effectiveness and plume migration are evaluated through continuing groundwater monitoring.

Monitoring, to evaluate the long-term effectiveness of the alternative, takes place during the operation of the alternative and continues after the mass reduction activities are completed. The mass of contamination removed by the mass reduction system is monitored by influent sampling at the treatment plant and by monitoring of groundwater quality at monitoring wells. The specific mass reduction system performance objectives are defined during the design phase of the alternative. For costing and comparison purposes, it has been assumed that the mass reduction systems will operate for 20 years and remove all of the currently dissolved contaminant mass in the targeted central area of each plume.

8.5.2.4 Reduction of TMV

Alternative SPC-3/SPT-2/SPT-4 reduces the TMV of contaminated groundwater through mass removal of the contaminants with extraction wells at the centers of the plumes (Section 8.3.1.1). The groundwater extracted from the South Plants North Source and South Plants Southeast Plumes is treated by a combination of air stripping and GAC adsorption. Air stripping transfers volatile organics from the water phase to the vapor phase, where they are subsequently destroyed by catalytic oxidation. Residual contaminants (OCPs, DBCP, and volatile organics) in the water are adsorbed onto GAC. Saturated GAC is regenerated off post.

Direct biotreatment of the South Tank Farm Plume groundwater significantly reduces the toxicity and volume of extracted contaminants, thereby further reducing contaminant migration from the South Tank Farm area. If freely drainable LNAPL accumulates to a sufficient thickness, it is separated, drummed, and sent off post for disposal.

Because the contaminants in the South Plants plumes are removed from the groundwater prior to reinjection, the treatment is irreversible. Some contaminants remain in the South Plants plumes because parts of the contaminant plumes may not be removed by the extraction system and because some contaminants that remain sorbed to the soil in the aquifer may desorb at a later time.

8.5.2.5 Short-Term Effectiveness

In general, the construction, operation, and final demobilization of Alternative SPC-3/SPT-2/SPT-4 have minimal negative impact on the environment, workers, or the surrounding community. On-post workers are potentially exposed to contaminants through dermal and/or dust inhalation pathways when excavation and construction activities are performed. To minimize or prevent such exposure, health and safety procedures such as dust-control measures and PPE are implemented. The GAC system and the bioreactor require periodic changeout of the spent carbon.

RAOs are achieved under this alternative. During the 20 years of mass reduction system operation, a measurable fraction of dissolved contaminant mass is removed from the plume centers (Section 8.3.1.1 and Appendix C). The contaminants are extracted and treated, reducing the volume and toxicity of contaminants in the groundwater.

8.5.2.6 Implementability

With the exception of the fluidized-bed reactor proposed for direct biological treatment, which is an innovative technology, Alternative SPC-3/SPT-2/SPT-4 is composed of well-developed technologies: extraction/reinjection wells and trenches, air stripping, GAC adsorption, and

catalytic oxidation. As discussed in the Technology Description Volume (Sections 5, 14.1, 14.3, 14.2, and 15), these technologies are all currently being successfully used at RMA. The equipment required is commercially available from several vendors. The extraction systems use existing wells supplemented with additional new wells. The water treatment system can be assembled on skids prior to shipment to the site. Startup and training can be performed in an acceptable period of time, and operators at RMA already have experience with most of the components of this system.

The alternative is expected to be reliable. The system allows temporary maintenance to be performed with minimal impacts to the schedule of operation. In many cases, maintenance can be performed without shutting down the system. The biotreatment system requires close oversight and additional training for the operators. Startup activities for biotreatment require more time, but the system can be brought on line separately from the remainder of the treatment train. The system has automated controls that ensure continued operation with little supervision.

GAC units and air strippers are produced and supplied in sufficient quantities for this alternative by qualified vendors. The sludge in the wastewater tank is stabilized and disposed, along with filter cartridges, in an off-post RCRA landfill. Precious metals are recovered from spent catalyst by the supply vendor. GAC is regenerated off post. The groundwater and the treatment system are monitored during and after extraction/treatment.

Administratively, this alternative is easily implemented. However, it must be coordinated with the soil and structures media remedial actions in South Plants and may not be implemented until these actions are completed. It requires an operation and maintenance program for the treatment system, contracts with GAC suppliers, vendors who manage hazardous waste, periodic site monitoring, and 5-year reviews.

8.5.2.7 Costs

The capital cost of this treatment system is estimated to be \$2,980,000. Approximate annual O&M costs, including monitoring, are \$823,000 (years 1 to 5), \$690,000 (years 6 to 20), and \$122,000 (years 21 to 30). The present worth cost of the entire remedial alternative is estimated to be \$14,800,000. A summary of costs is presented in Appendix A, Table A5-5.

8.6 ALTERNATIVE SPC-3/SPT-3/SPT-4: MASS REDUCTION, OXIDATION/SORPTION, BIOLOGICAL REACTOR/SORPTION

This alternative consists of groundwater extraction from the South Plants North Source, South Plants Southeast, and South Tank Farm Plumes. Extraction is completed in a mass reduction configuration (see Section 8.3). If freely drainable LNAPL accumulates to a sufficient thickness in the South Tank Farm Plume, it is separated and treated as described in Section 8.0. For costing and comparison purposes, it has been assumed that the mass reduction systems will operate for 20 years and remove all of the currently dissolved contaminant mass in the targeted central area of each plume.

Extracted water from the South Plants North Source and South Plants Southeast Plumes is treated with oxidation and GAC adsorption and is then reinjected into recharge trenches in Section 27 (or other suitable location). Extracted water from the South Tank Farm Plume is treated first in a biological reactor and then by GAC adsorption. This alternative differs from Alternative SPC-3/SPT-2/SPT-4 only in that the extracted water from the South Plants North Source and South Plants Southeast Plumes is treated by oxidation/sorption instead of stripping/sorption. Table 8.5-1 presents the estimated chemical influent concentrations for the South Plants North Source and South Plants Southeast Plumes, and Table 8.5-2 presents the estimated chemical influent concentrations for the South Tank Farm Plume.

8.6.1 Description of Alternative

8.6.1.1 Extraction/Reinjection

Alternative SPC-3/SPT-3/SPT-4 includes the same groundwater control systems that are used for Alternative SPC-3/SPT-2 (Section 8.3.1.1). Extracted water is initially treated in two different

treatment processes, one for the South Plants North Source and South Plants Southeast Plumes and one for the South Tank Farm Plume. Therefore, the water from the South Tank Farm Plume is piped to a separate collection tank. The groundwater extraction and reinjection systems are described in Section 8.3.1.1.

8.6.1.2 Treatment

The treatment system included in Alternative SPC-3/SPT-3/SPT-4 uses oxidation followed by GAC to treat contamination from the South Plants North Source and South Plants Southeast Plumes at the rate of 2 gpm in the oxidation reactor and 7 gpm in the GAC units. In addition, freely drainable LNAPL is recovered from the South Tank Farm Plume and treated by off-post incineration if necessary. Water extracted from the South Tank Farm Plume at the rate of 5 gpm is treated in a biological reactor to remove most of the benzene; the stream is then combined with the oxidation reactor effluent, and the remaining benzene in the combined stream is treated by GAC adsorption. Figure 8.5-1 presents a process flow diagram showing the major pieces of treatment equipment as well as tanks, pumps, and filters used in the biological reactor portion of this alternative.

Extracted water from the South Plants North Source and South Plants Southeast Plumes is stored in a collection tank prior to being pumped to the UV/hydrogen peroxide oxidation reactor. Prior to reaching the reactor, hydrogen peroxide is added to the water as an oxidant and a precipitating agent for inorganics and the water is passed through a multimedia filter to remove the iron and manganese precipitated by the hydrogen peroxide (Figure 8.4-1). The oxidation reactor uses UV light as well as the hydrogen peroxide to break down chlorinated organics—primarily DBCP, chloroform, and benzene. The reactor is operated to reduce chlorinated organics to within their target concentrations. A more detailed description of this treatment technology is included in the Technology Description Volume, Section 14.1.

Effluent from the oxidation reactor is combined with effluent from the biological reactor and pumped to the GAC adsorber. The GAC adsorber is designed to remove the OCPs and remaining

volatile organics. One GAC unit holding 2,000 lbs of carbon is used and requires replacement 5 times per year. A more detailed description of the GAC treatment technology is also included in the Technology Description Volume, Section 14.2.

The GAC effluent is run through a cartridge filter to remove carbon fines and suspended solids and is collected in an effluent tank. From there the treated water is pumped to the recharge trenches.

Water extracted from the South Tank Farm Plume is treated in the bioreactor described in Alternative SPC-3/SPT-2/SPT-4 (Section 8.5.1.2). Effluent from the reactor is pumped to the GAC unit described for this alternative and then flows through a cartridge filter for removal of carbon particles prior to discharge to the effluent tank.

8.6.1.3 Sidestreams

This treatment system produces biomass from the biological reactor, spent GAC, and used cartridges from filter. The spent GAC units are regenerated and used cartridges are disposed as described in Section 8.4.1.3. The biomass is landfilled.

8.6.2 Analysis of Alternative

8.6.2.1 Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment off post as long as PRGs are met at the boundary. FFA restrictions on future use of groundwater ensure protection of human health on post. Removal of the VHOs, benzene, DBCP, OCPs, and, if necessary, freely drainable LNAPL from the groundwater in the South Plants North and South Plants Southeast Plumes and biodegradation of the benzene in the South Tank Farm Plume result in a reduction in the contaminant mass and reduce the migration of the contaminants. A measurable fraction of the dissolved contaminant mass is permanently removed from the centers of the plumes in the first 20 years.

Continued monitoring after the demobilization of the treatment system assesses whether 20 years of treatment has permanently reduced the contaminant concentrations of the groundwater.

Once the mass reduction phase is completed and the extraction systems are discontinued, any remaining contaminants will migrate in response to the hydraulic gradient present in the groundwater flow system. These residual contaminants occur at low concentrations and are further reduced by natural attenuation. Any contaminants that reach the boundary systems are intercepted and treated there.

8.6.2.2 Compliance with ARARs

Alternative SPC-3/SPT-3/SPT-4 is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls and with the FFA (EPA et al. 1989). The treatment systems were conceptually designed based on an earlier set of standards. Should this alternative be selected as the preferred alternative, it is expected to meet most of the revised CBSG-based, chemical-specific ARARs that would be developed for it; however, some design parameter changes might be required. Appropriate siting of the groundwater treatment facility ensures compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

8.6.2.3 Long-Term Effectiveness and Permanence

Alternative SPC-3/SPT-3/SPT-4 reduces the potential for off-post exposure by removing and treating dissolved contaminants near the source. Direct biotreatment of the South Tank Farm Plume ensures that benzene levels are significantly and permanently reduced. Any remaining contaminants either biodegrade naturally or are removed at the boundary systems. By temporarily lowering water levels and extracting high concentrations of contaminants in the upper aquifer, the potential for future migration to the confined flow system will be reduced. Because mass reduction systems operate for relatively short time periods (20 years) over relatively small areas and at low pumping rates, the overall beneficial impact of this alternative on contaminants adsorbed to aquifer materials and on the confined aquifer is expected to be small. The

biotreatment system does not directly treat contaminants in the confined flow system. However, by removing contamination in the overlying unconfined flow system, the potential for contaminant migration into the confined flow system will be reduced. Long-term effectiveness and plume migration are evaluated through continued groundwater monitoring.

Monitoring, to evaluate the long-term effectiveness of the alternative, occurs during the operation of the alternative and continues once the mass reduction system is ended. The mass of contamination removed by the mass reduction system is monitored by influent sampling at the treatment plant and by monitoring of groundwater quality at monitoring wells. The specific mass reduction system performance objective is defined during the design phase of the alternative. For costing and comparison purposes, it has been assumed that the mass reduction systems will operate for 20 years and remove all of the currently dissolved contaminant mass in the targeted central areas of each plume.

8.6.2.4 Reduction of TMV

Alternative SPC-3/SPT-3/SPT-4 reduces the TMV of contaminated groundwater through mass removal of the contaminants with extraction wells at the centers of the plumes (Section 8.5.1.1). The groundwater extracted from the South Plants North Source and South Plants Southeast Plumes is treated by a combination of oxidation and GAC adsorption. Oxidation decomposes chlorinated compounds, including DBCP, OCPs, and chlorinated VHOs. The residual contaminants (mainly benzene) in the water are adsorbed onto GAC. Saturated GAC is regenerated off post.

Direct biotreatment of the South Tank Farm Plume groundwater significantly reduces the toxicity and volume of extracted contaminants, thereby further reducing contaminant migration from the South Tank Farm area. If freely drainable LNAPL accumulates to a sufficient thickness, it is separated and sent off post for disposal.

Because the contaminants in the South Plants plumes are removed from the groundwater prior to reinjection, the treatment is irreversible. Some contaminants remain in the South Plants plumes because parts of the plume containing contaminants may not be removed by the extraction system and because some contaminants may remain sorbed to the soil in the aquifer and desorb at a later time.

8.6.2.5 Short-Term Effectiveness

In general, the construction, operation, and final demobilization of this alternative have minimal negative impact on the environment, workers, or the surrounding community. On-post workers are potentially exposed to contaminants through dermal and/or inhalation pathways when excavation and construction activities are performed. To minimize or prevent such exposure, dust-control measures and PPE are used.

The GAC system requires periodic changeout. To reduce potential exposure, personnel are made aware of health and safety procedures and PPE is used.

RAOs are achieved under this alternative. During the 20 years of mass reduction system operation, a measurable fraction of dissolved contaminant mass is removed from the plume centers (Section 8.5.1.1 and Appendix C). The contaminants are extracted and treated, reducing the volume and toxicity of contaminants in the groundwater.

8.6.2.6 Implementability

Alternative SPC-3/SPT-3/SPT-4 is composed of both well-developed technologies (extraction wells, GAC adsorption, and reinjection trenches) and some innovative technologies (advanced oxidation and direct biological treatment). As discussed in the Technology Description Volume (Sections 5, 11.2, 14.1 and 14.2), most of these technologies are currently being successfully used at RMA. The equipment required is commercially available from several vendors. The extraction systems use existing wells supplemented with additional new wells. The water treatment system can be assembled on skids prior to shipment to the site. Startup and training

can be performed in an acceptable period of time, and operators at RMA already have experience with most of the components of this system.

The alternative is expected to be reliable. The system allows temporary maintenance to be performed with minimal impacts to the operating schedule. In many cases, maintenance can be performed without shutting down the system. The biotreatment system requires close oversight and additional training for the operators. Startup activities for biotreatment require more time, but the system can be brought on line separately from the remainder of the treatment train. The system has automated controls that ensure continued operation with little supervision. The groundwater and the treatment system are adequately monitored during and after extraction/treatment. GAC and hydrogen peroxide are produced and supplied in sufficient quantities by qualified vendors to be used in this alternative. Sludge in the wastewater tank is stabilized and disposed along with the filter cartridges in an off-post RCRA landfill. GAC is regenerated off post.

Administratively, this alternative is easily implemented. However, it must be coordinated with the soil and structures media remedial actions in South Plants and may not be implemented until these actions are completed. It requires an operation and maintenance program for the treatment system, contracts with GAC suppliers, vendors who manage hazardous waste, periodic site monitoring, and 5-year reviews.

8.6.2.7 Costs

The capital cost of this treatment system is estimated to be \$3,160,000. Approximate annual O&M costs, including monitoring, are \$817,000 (years 1 to 5), \$685,000 (years 6 to 20), and \$122,000 (years 21 to 30). The present worth cost of the entire remedial alternative is \$14,900,000. A summary of costs is presented in Appendix A, Table A5-6.

8.7 ALTERNATIVE SPC-5/SPT-2/SPT-5: MASS REDUCTION, STRIPPING/SORPTION, IN SITU BIODEGRADATION

This alternative consists of extraction and aboveground treatment of groundwater from the South Plants North Source and South Plants Southeast Plumes combined with in situ treatment of the South Tank Farm Plume. Extraction is performed using a mass reduction configuration. If freely drainable LNAPL accumulates to a sufficient thickness in the South Tank Farm Plume, it is separated and treated as described in Section 8.0. For costing and comparison purposes, it has been assumed that the mass reduction systems will operate for 20 years and remove all of the currently dissolved contaminant mass in the targeted central area of each plume.

A small amount of extracted water (2 gpm) from the South Plants North Source and South Plants Southeast Plumes requires treatment. Rather than design a treatment system for such a small flow, it has been assumed that this flow can be included in any treatment plant planned for the Basin A Plume Group. Therefore, this alternative can only be implemented if extraction and treatment is selected for the Basin A Plume Group. Treated water from the Basin A treatment plant is reinjected into two or more recharge trenches located in Section 27 (or other suitable location). Three areas are currently being considered as possible sites for the injection trenches: Section 27 upgradient of the NWBCS, Section 23 and 24 upgradient of the NBCS, and Sections 25 and 31 upgradient of North Plants and the NBCS. At this time the Section 27 option is preferred because it is located in a permeable aquifer that can accept the estimated flow volumes without significant impact to the aquifer or contaminant migration. The Section 27 location was used to develop costs for this report. Water from the South Tank Farm Plume is treated by in situ biodegradation.

The in situ biological treatment of the South Tank Farm Plume is what distinguishes this alternative from Alternative SPC-3. This alternative is accomplished in conjunction with the preferred soil remedial alternative, which includes caps over the South Plants area. Table 8.5-1 presents the estimated chemical influent concentrations for the South Plants North Source and

South Plants Southeast Plumes, and Table 8.7-1 presents the estimated chemical influent concentrations for the South Tank Farm Plume in situ biological treatment.

8.7.1 Description of Alternative

8.7.1.1 Extraction/Reinjection

In this alternative, the mass removal, treatment, and reinjection for the South Plants North Source and South Plants Southeast Plumes are the same as described in Alternative SPC-3, as are the well diameters, pumps, and piping. This alternative differs in its use of in situ biodegradation for the South Tank Farm Plume.

The in situ biodegradation system consists of three recirculation cells. Each cell includes a line of injection wells and a line of extraction wells (Figure 8.7-1). Cell I, the northernmost, employs nine injection wells, Cell II, eight, and Cell III, the southernmost, seven. Each cell uses five wells to extract the water injected upgradient. The injection wells are 35 ft deep, and the extraction wells are approximately 45 ft deep with 15-ft-long well screens located in the weathered Denver Formation. The 10 gpm of extracted water is collected in a collection tank and then pumped to an effluent tank. Nutrients and oxygen are added in-line between the two tanks. The water is then piped from the effluent tank to the injection wells through single-walled piping. The treated water from the South Plants North Source Plume and South Plants Southeast Plume is reinjected in the reinjection trenches in Section 27 as described in Alternative SPC-3.

The mass reduction operation for the SPC-5 alternative is accomplished over a 20-year period, which is the expected period required to remove all of the dissolved contaminant mass from the targeted central portion of each plume. Twenty years of extraction of contaminated groundwater from the targeted plume areas results in the following estimated quantities of mass removal of dissolved organic contaminants from each plume, assuming complete displacement (100 percent of initial dissolved mass): 2,400 kg for South Plants North Source and 430 kg for the South Plants Southeast Plume. As groundwater is removed from these portions of the aquifer, water of lower contaminant concentrations is expected to flow in from adjacent areas, contaminant mass

that is sorbed onto aquifer solids will desorb into solution, and additional contamination will be added to groundwater from soil sources. Current estimates indicate that the mass of contaminants sorbed onto aquifer materials is large for some organic contaminants present, even given to the low organic carbon content of the aquifer (see Appendix C). Continued monitoring after 20 years of treatment assesses whether the contaminant concentrations in groundwater have been permanently reduced.

8.7.1.2 Treatment

Under this alternative 2 gpm is extracted from the combined South Plants North Source and South Plants Southeast Plumes. Due to the low flow rate, it was assumed that this 2-gpm flow can be added to the groundwater extracted from the Basin A Plume Group. This combined flow is treated by the preferred Basin A Plume Group alternative. The water from the South Plants North Source and South Plants Southeast Plumes is comparable in quality to the water extracted from the combined plumes in the Basin A Plume Group. Therefore, the Basin A treatment plant is appropriate for treating the additional flow, and the cost of the increased loading on the plant is minimal.

This alternative also includes in situ biodegradation of benzene for the South Tank Farm Plume. Water is extracted from the South Tank Farm Plume at a rate of 10 gpm and an oxygen source and nutrients are mixed into the water prior to reinjection. Figure 8.7-2 displays the flow diagram for this treatment system.

The in situ biodegradation system captures groundwater from the South Tank Farm Plume source area. Extracted groundwater is transferred to a collection tank. The extracted water is reinjected after the appropriate amounts of hydrogen peroxide and nutrients have been added; reinjecting the water flushes the plume as it enhances biological growth and degradation of contaminants in the subsurface.

In situ pilot-scale tracer studies and biodegradation studies are currently being performed to determine whether in situ bioremediation can be implemented. A final decision with regard to whether this technology should be implemented for the South Tank Farm Plume will not be made until results of these studies become available.

8.7.1.3 Sidestreams

The sidestreams produced in this alternative are limited to the slightly increased loading (and therefore increased quantity of sidestreams) at the Basin A water treatment system from the addition of the 2 gpm from the South Plants Plumes.

8.7.2 Analysis of Alternative

8.7.2.1 Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment off post as long as PRGs are met at the boundary. FFA restrictions on future use of groundwater ensure protection of human health on post. Removal of the VHOs, benzene, DBCP, OCPs, and, if necessary, freely drainable LNAPL from the groundwater in the South Plants North Source and South Plants Southeast Plumes and in situ biodegradation of the benzene in the South Tank Farm Plume result in a reduction in the contaminant mass and reduce the migration of the contaminants. A measurable mass of dissolved contaminants is permanently removed from the centers of the plumes in the first 20 years based on calculations of the quantity of contaminant mass removed.

Once extraction and treatment are completed and the extraction systems are discontinued, any remaining contaminants will migrate in response to the hydraulic gradient present in the groundwater flow system. These residual contaminants occur at low concentrations and are further reduced by natural attenuation. Any contaminants that reach the boundary systems are intercepted and treated there.

8.7.2.2 Compliance with ARARs

Alternative SPC-5/SPT-2/SPT-5 is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls, and with the FFA (EPA et al. 1989). The treatment systems were conceptually designed based on an earlier set of standards. Should this alternative be selected as the preferred alternative, it is expected to meet most of the revised CBSG-based, with all chemical-specific ARARs that would be developed for it; however, some design parameter changes might be required. Appropriate siting of all new facilities ensures compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

8.7.2.3 Long-Term Effectiveness and Permanence

Alternative SPC-5/SPT-2/SPT-5 reduces the potential for off-post exposure by removing and treating dissolved contaminants near the source. In situ biotreatment of the South Tank Farm Plume ensures that benzene levels are permanently reduced. Remaining contaminants that are not removed through natural attenuation are treated if they reach the boundary systems. By temporarily lowering water levels and extracting high concentrations of contaminants in the upper aquifer, the potential for future migration to the confined flow system will be reduced. Because mass reduction systems operate for relatively short time periods (20 years) over relatively small areas and at low pumping rates, the overall beneficial impact of this alternative on contaminants adsorbed to aquifer materials and on the confined aquifer is expected to be small. The biotreatment system does not directly treat contaminants in the confined flow system. However, by removing contamination in the overlying unconfined flow system, the potential for future migration of contaminants into the confined flow system is reduced. Long-term effectiveness and plume migration are evaluated through continued groundwater monitoring.

Monitoring, to evaluate the long-term effectiveness of the alternative, occurs during the operation of the alternative and continues once the mass reduction system is ended. The mass of contamination removed by the mass reduction system is monitored by influent sampling at the treatment plant and by monitoring of groundwater quality at monitoring wells. The specific mass

reduction system performance objective is defined during the design phase of the alternative. For costing and comparison purposes, it has been assumed that the mass reduction systems will operate for 20 years and remove all of the currently dissolved contaminant mass in the targeted central area of each plume.

8.7.2.4 Reduction of TMV

Alternative SPC-5/SPT-2/SPT-5 reduces the TMV of contaminated groundwater by mass removal of the contaminants using extraction wells at the centers of the plumes (Section 8.7.1.1). The groundwater extracted from the South Plants North Source and South Plants Southeast Plumes is combined with water extracted from the Basin A Plume Group and treated by a combination of air stripping and GAC adsorption at the rate of 2 gpm. Air stripping transfers volatile organics from the liquid phase to the vapor phase, where they are subsequently destroyed by catalytic oxidation. Residual contaminants (OCPs, DBCP, and volatile organics) in the water are adsorbed onto GAC. Saturated GAC will be regenerated off post.

In situ biotreatment, involving recirculation of 10 gpm of water from the South Tank Farm Plume, significantly reduces the toxicity and volume of contaminants, thereby further reducing contaminant migration from the South Tank Farm area. If LNAPL accumulates to a sufficient thickness, it is separated and collected for analysis and eventual off-post treatment or disposal.

Because the contaminants in the South Plants North Source and South Plants Southeast Plumes are removed from the groundwater prior to reinjection, the treatment is irreversible. A large fraction of the contaminants in the South Tank Farm Plume are destroyed by in situ biodegradation. Some contaminants remain in the South Plants plumes because parts of the plume containing contaminants may not be removed by the extraction system, because some of the contaminants may not biodegrade, and because some contaminants may remain sorbed to the soil in the aquifer and desorb at a later time.

8.7.2.5 Short-Term Effectiveness

In general, the construction, operation, and final demobilization of this alternative have minimal negative impact on the environment, workers, or the surrounding community. On-post workers are potentially exposed to contaminants through dermal and/or inhalation pathways when excavation, extraction, and construction activities are performed. To minimize or prevent such exposure, dust control measures and PPE are used.

In situ biotreatment has minimal negative impact on the environment, workers, or the surrounding community because treatment is carried out in the subsurface environment. Operation of the system involves some chemical-handling activities that require the use of PPE.

RAOs are achieved under this alternative. During the 20 years of mass reduction system operation, a measurable fraction of dissolved contaminant mass is removed from the plume centers (Section 8.7.1.1 and Appendix C). The contaminants are extracted and treated, reducing the volume and toxicity of contaminants in the groundwater.

8.7.2.6 Implementability

With the exception of in situ biological treatment, Alternative SPC-5/SPT-2/SPT-5 is composed of well-developed technologies: extraction wells, air stripping, GAC adsorption, catalytic oxidation, and reinjection trenches. As discussed in the Technology Description Volume (Sections 5, 14.1, 14.2, 14.3, and 15), these technologies are all currently being successfully used at RMA. The equipment required is commercially available from several vendors. The extraction systems use existing wells supplemented with additional new wells. The water treatment system from the selected Basin A remedial alternative is capable of handling the 2-gpm flow from the South Plants North Source and South Plants Southeast Plumes. The groundwater from these plumes is similar in quality to the groundwater from the Basin A plumes, so the flows can be mixed without upsetting the Basin A treatment system.

The alternative is expected to be reliable. In situ pilot-scale tracer and biodegradation studies are required to determine whether in situ biodegradation can be implemented. The in situ treatment system requires simple equipment that is easily installed. Operation is primarily associated with monitoring and feed adjustments. The system can operate continuously throughout the year. The groundwater and the treatment system are adequately monitored during and after extraction/treatment.

Administratively, this alternative is easily implemented. However, it must be coordinated with the soil and structures media remedial actions in South Plants and may not be implemented until these actions are completed. It requires an operation and maintenance program for the treatment system, contracts with GAC suppliers, vendors who manage hazardous waste, periodic site monitoring, and 5-year reviews.

8.7.2.7 Costs

The capital cost of this treatment system is estimated to be \$1,470,000. Approximate annual O&M costs, including monitoring, are \$550,000 (years 1 to 5), \$412,000 (years 6 to 20), and \$120,000 (years 21 to 30). The present worth cost of the entire remedial alternative is \$7,430,000. A summary of costs is presented in Appendix A, Table A5-7.

8.8 ALTERNATIVE SPC-6/SPT-2/SPT-5: DEWATERING, STRIPPING/SORPTION, IN SITU BIODEGRADATION

This alternative consists of dewatering the South Plants groundwater mound and controlling hydraulic gradients in the South Plants North Source and the South Plants Southeast Plumes. Concurrently, groundwater in the South Tank Farm Plume is treated by in situ biodegradation. The South Tank Farm Plume is monitored for the presence of LNAPL and, if freely drainable LNAPL accumulates to a sufficient thickness, it is separated and treated as described in Section 8.0. Dewatering is accomplished using a system of horizontal wells that are installed prior to the initiation of proposed soil and structures media remedial construction activities. Extracted water that is not part of the in situ biodegradation system is treated using air stripping and GAC

adsorption and is then reinjected into recharge trenches located in Section 27 (or other suitable location). Three areas are being considered as possible sites for the injection trenches: Section 27 upgradient of the NWBCS, Sections 23 and 24 upgradient of the NBCS, and Sections 25 and 31 upgradient of North Plants and the NBCS. At this time the Section 27 option is preferred because it is located in a permeable aquifer that can accept the estimated flow volumes without significant impact to the aquifer or contaminant migration. The Section 27 location was used to develop costs for this report. This alternative is accomplished in conjunction with soil remedial activities. Groundwater is extracted at a rate of 20 gpm for the first 10 years (Phase I) to draw down the water table and then is extracted at a rate of 15 gpm (Phase II) for the remaining years once the soil cap is in place. Tables 8.8-1 and 8.8-2 present the estimated chemical influent concentrations for Phase I and Phase II of this alternative.

8.8.1 Description of Alternative

8.8.1.1 Extraction/Reinjection

Alternative SPC-6/SPT-2/SPT-5 consists of dewatering the South Plants groundwater mound, which includes the South Plants North Source and South Plants Southeast Plumes, and treating groundwater in the South Tank Farm Plume by in situ biodegradation. This alternative achieves dewatering and mass reduction over larger areas than the previously proposed mass reduction alternatives and permanently controls the horizontal hydraulic gradients in the South Plants Plume group. If recoverable free product is observed in the South Tank Farm Plume, it is separated and treated as described in Section 8.0. Combined with the Basin A dewatering system, this alternative ensures relatively rapid contaminant concentration reductions and significantly reduces the potential for future contaminant migration.

Under this alternative, dewatering and in situ biotreatment occur concurrently. Because horizontal wells are used, dewatering under the South Plants Central Processing Area can be initiated before or during demolition or capping activities. The use of horizontal wells provides flexibility in the overall cleanup of the South Plants because the wells can be installed from outside the other construction and demolition areas. After several years, the northernmost cell (Cell I) of the in

situ biotreatment system (Figure 8.8-1) becomes inefficient due to dewatering of the South Plants area. At that time, three of the injection wells in Cell I are converted to extraction wells and become part of the overall dewatering system. The remainder of the in situ system continues to operate for an estimated 10 years.

The successful operation of the alternative relies on the active extraction/dewatering of the aquifer to reverse horizontal gradients and induce inward flow to the dewatering well system. Capping and control of groundwater recharge alone cannot provide for this form of gradient control because the regional hydraulic gradient would still be present.

The dewatering system consists of nine horizontal wells installed at depths of approximately 40 feet and averaging 800 feet in length (Figure 8.8-1). Each well is 6 inches in diameter and is screened over most of its length. Each well has a submersible pump within the screened interval to transfer groundwater to one of two surface holding tanks. Two booster pumps are used to transfer water from temporary holding tanks to the South Plants treatment plant. The treated groundwater is then piped to injection trenches using single-walled Schedule 40 PVC piping. The trenches are the same design and in the same location as described in Alternative SPC-3.

Groundwater-quality and water-level data from a monitoring network of existing plume evaluation monitoring wells and newly installed performance monitoring wells are used to evaluate the effectiveness and operation of the extraction system. The final location of the new wells is based upon review of existing well locations and screened intervals.

8.8.1.2 Treatment

The extracted groundwater is treated using different approaches. The South Tank Farm Plume is treated by in situ biodegradation. If freely drainable LNAPL accumulates to a sufficient thickness in the South Tank Farm Plume, it is separated, drummed, and sent off post for disposal.

Groundwater, extracted at a rate of approximately 20 gpm (Phase I) and 15 gpm (Phase II) by the dewatering system, is treated using air stripping followed by GAC adsorption. The stripping/sorption system used in this alternative is described in detail in Section 8.3.1.2. Due to the 20-gpm flow rate of this alternative, the shallow tray air stripper uses an air flow rate of 300 cfm and one GAC adsorption unit containing 2,000 lbs of carbon are needed. The GAC unit is replaced twice per year. All tanks and pumps are also designed for a 20-gpm flow rate. Figure 8.8-2 presents a process flow diagram showing the major pieces of treatment equipment as well as tanks, pumps, and filters used in this alternative. It is anticipated that this plant can be adjusted to the lower flow rate of Phase II without resizing any of the permanent equipment. The in situ biotreatment system for the South Tank Farm Plume is described in Section 8.7.1.2.

8.8.1.3 Sidestreams

This treatment system produces three sidestreams: vapor emissions from the air stripper, spent GAC units, and used cartridges from the filter.

The vapor-phase emissions from the air stripper are treated with catalytic oxidation. Because this process actually breaks down the contaminants instead of transferring them to another medium, no further treatment of the vapor-phase emissions is required.

Spent GAC units are regenerated off post and used cartridges from the filter are transported to an off-post RCRA landfill because they have been in contact with hazardous materials. The wastewater from the wastewater tank is recirculated to the collection tank and the sediments from the wastewater tank are drummed and landfilled.

8.8.2 Analysis of Alternative

8.8.2.1 Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment off post as long as PRGs are met at the boundary. FFA restrictions on future use of groundwater provide protection of human health on post. Removal of VHOs, VAOs, DBCP, OCPs, and, if necessary, freely drainable

LNAPL from the groundwater in the South Plants North and South Plants Southeast Plumes and biodegradation of the benzene in the South Tank Farm Plume result in a reduction in the contaminant mass. Together with the preferred soil alternative, contaminant migration between soil and groundwater is reduced and downward migration between the upper and lower aquifers is eliminated. Most of the contaminant mass will eventually be removed from the aquifer. Permanent lowering of the water table separates the groundwater from contaminated overlying soil, thereby reducing the potential for future contaminant migration.

8.8.2.2 Compliance with ARARs

Alternative SPC-6/SPT-2/SPT-5 is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls and with the FFA (EPA et al. 1989). The treatment systems were conceptually designed based on an earlier set of standards. Should this alternative be selected as the preferred alternative, it is expected to meet most of the revised CBSG-based, chemical-specific ARARs that would be developed for it; however, some design parameter changes might be required. Appropriate siting of the treatment plant ensures compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

8.8.2.3 Long-Term Effectiveness and Permanence

Alternative SPC-6/SPT-2/SPT-5 reduces the potential for future migration of contaminants by permanently removing contamination from the groundwater, preventing continued contact between groundwater and contaminated soils, and controlling hydraulic gradients. The potential for off-post exposure is reduced by removal of contaminants from the South Plants Plume Group in conjunction with the continued operation of the boundary systems. In situ biotreatment of the South Tank Farm Plume ensures that benzene concentrations are significantly and permanently reduced.

Contaminants are removed and treated close to the source. The proposed dewatering system permanently lowers the groundwater levels approximately to the base of the unconfined flow

system in the South Plants Plume Group, further reducing the potential for migration. The amount of contaminated soil in contact with groundwater is reduced by lowering the water table.

The use of horizontal wells is expected to enhance the performance of the dewatering system and reduce the potential for well damage and scheduling conflicts with the construction of the soil alternative. Horizontal wells have been used effectively on a number of sites (Wilson and Kaback 1993) and are expected to perform well for this alternative. Horizontal wells also increase the probability of cross-cutting vertical fractures and joints, thus increasing the amount of water and contamination extracted. Lowering the water table aquifer controls the gradient between the confined and unconfined flow systems thereby further reducing the potential for downward contaminant migration.

8.8.2.4 Reduction of TMV

Alternative SPC-6/SPT-2/SPT-5 reduces TMV of contaminated groundwater by dewatering the South Plants area and treating the water to remove contaminants. The groundwater intercepted at the South Plants North Source and South Plants Southeast Plumes is treated by a combination of air stripping and GAC adsorption at a rate of approximately 20 gpm. Air stripping transfers volatile organics from the liquid phase to the vapor phase, where they are subsequently destroyed by catalytic oxidation. Residual contaminants in the water are adsorbed onto GAC, which is regenerated off post; because the contaminants are removed from the groundwater prior to reinjection, the treatment is irreversible.

In situ biodegradation, involving recirculation of 10 gpm of water from the South Tank Farm Plume, significantly reduces the toxicity and volume of contaminants, thereby further reducing contaminant migration from the South Tank Farm area. LNAPL, if present, is separated and sent off post for disposal. Both of these processes are irreversible.

Contamination is also largely immobilized by dewatering, which includes removal of the South Plants groundwater mound. The water table is lowered, thus reducing the amount of

contaminated soil in contact with the groundwater. Migration of contaminants is reduced by the control of hydraulic gradients.

8.8.2.5 Short-Term Effectiveness

In general, the construction, operation, and final demobilization of Alternative SPC-6/SPT-2/SPT-5 have minimal negative impact on the environment, workers, or the surrounding community. On-post workers are potentially exposed to contaminants through dermal and/or dust inhalation pathway when excavation and construction of the recharge trenches are performed. To minimize or prevent such exposure, dust-control measures and PPE are used. The use of horizontal wells, which are drilled from the periphery of South Plants, reduces the potential chemical exposures and risks to workers. Another advantage horizontal wells provide is that very few wellheads exist and they are located on the periphery of the South Plants complex area, therefore reducing the probability of damage or interference during soil or structures remediation. The GAC system requires periodic changeout of spent carbon. To reduce potential exposure, personnel are made aware of health and safety procedures and PPE is used.

In situ biotreatment has minimal negative impact on the environment, workers, or the surrounding community because treatment is carried out in the subsurface environment. Operation of the system involves some chemical-handling activities that require PPE.

RAOs are achieved under this alternative. The system may have to operate for more than 30 years to maintain the lower water table elevations and associated hydraulic gradients.

8.8.2.6 Implementability

With the exception of in situ biological treatment and horizontal extraction wells, Alternative SPC-6/SPT-2/SPT-5 is composed of well-developed technologies: air stripping, GAC adsorption, catalytic oxidation, and reinjection trenches. As discussed in the Technology Description Volume (Sections 5, 14.1, 14.2, 14.3, and 15), most of these technologies are currently being successfully used at RMA.

The equipment required is commercially available from several vendors. Transport systems and reinjection systems are implementable, time-proven technologies that are also currently in use at RMA. Horizontal well technology is considered innovative and is becoming more reliable and cost-effective with continued development of equipment and techniques for environmental applications (see Section 7.6.2.6).

The use of horizontal wells is expected to enhance the performance of the dewatering systems and reduce the potential for well damage and scheduling conflicts that may arise from construction of the soil alternatives. This results from the ability to construct horizontal wells from the perimeter of the proposed soil cap, keeping the area to be capped free from well heads and pipelines that could interfere with earth-moving equipment. The horizontal well heads could be located outside of the cap area and away from the earth-moving activity.

The water treatment system required for treating groundwater in the South Plants plumes during dewatering can be assembled on skids prior to shipment to the site. Startup and training can be performed in an acceptable period of time, and operators at RMA already have experience with most of the components of this system.

The alternative is expected to be reliable. In situ pilot-scale tracer and biodegradation studies are required to determine whether in situ biodegradation can be implemented. The in situ treatment system requires simple equipment that is easily installed. Operation is primarily associated with monitoring and feed adjustments. All systems allow temporary maintenance to be performed with minimal impacts to the schedule of operation. In many cases, maintenance can be performed without shutting down the system. The systems have automated controls that ensure continued operation with little supervision. The groundwater and the treatment system are adequately monitored during and after extraction/treatment.

GAC units and air strippers are produced and supplied in sufficient quantities by qualified vendors to be used for this alternative. The sediments from the wastewater tank are stabilized

and disposed along with filter cartridges in an off-post landfill. Precious metals are removed from spent catalyst by the supply vendor. GAC is sent off post for regeneration.

This alternative is administratively feasible. It requires an O&M program for the treatment system, contracts with GAC suppliers, periodic site monitoring, and 5-year reviews. The use of horizontal wells makes it more easily implemented prior to, or during, soil and structures remediation.

8.8.2.7 Costs

The capital cost of this treatment system (including both phases of operation) is estimated to be \$5,740,000. The annual O&M costs, including monitoring, are \$940,000 (years 1 to 5), \$807,000 (years 6 to 10), and \$564,000 (years 11 to 30). The present worth cost for construction and 30 years of extraction/treatment is \$19,900,000. A summary of costs is presented in greater detail in Appendix A, Table A5-8.

8.9 ALTERNATIVE SPC-6/SPT-3/SPT-5: DEWATERING, OXIDATION/SORPTION, IN SITU BIODEGRADATION

This alternative consists of dewatering the South Plants groundwater mound and controlling hydraulic gradients in the South Plants North Source and the South Plants Southeast Plumes. Concurrently, groundwater in the South Tank Farm Plume is treated by in situ biodegradation. The South Tank Farm Plume is monitored for the presence of LNAPL and, if necessary, freely drainable product is removed as described in Section 8.0. Dewatering is accomplished using a system of horizontal wells that are installed prior to the initiation of proposed soil and structures media remedial construction activities.

Extracted water is treated with oxidation and GAC adsorption (which differentiates this alternative from Alternative SPC-6/SPT-2/SPT-5) and is then reinjected into recharge trenches in Section 27 (or other suitable location). Three areas are being considered as possible sites for the injection trenches: Section 27 upgradient of the NWBCS, Sections 23 and 24 upgradient of the NBCS, and

Section 25 and 31 upgradient of North Plants and the NBCS. At this time the Section 27 option is preferred because it is located in a permeable aquifer that can accept the estimated flow volumes without significant impact to the aquifer or contaminant migration. The Section 27 location was used to develop costs for this report. Groundwater is extracted at a rate of 20 gpm for the first 10 years (Phase I) to draw down the water table and continues to be extracted at a similar rate (Phase II) for the remaining years after the soil cap is installed. The estimated chemical influent concentrations for Phase I and Phase II are listed in Tables 8.8-1 and 8.8-2.

8.9.1 Description of Alternative

8.9.1.1 Extraction/Reinjection

Alternative SPC-6/SPT-3/SPT-5 includes the same groundwater control systems that are used for Alternative SPC-6/SPT-2/SPT-5 (Sections 8.8.1.1) (see Figure 8.8-1).

8.9.1.2 Treatment

The groundwater is treated by a combination of in situ biodegradation of the South Tank Farm Plume and treatment of the remaining extracted water by oxidation and GAC adsorption.

This treatment system uses oxidation followed by GAC to remove contamination from the groundwater, which is treated at a rate of 20 gpm (Phase I) and 15 gpm (Phase II). Figure 8.9-1 is a process flow diagram showing the major pieces of treatment equipment as well as tanks, pumps, and filters used in this alternative.

Extracted water is stored in a collection tank prior to being treated. From there, the water is pumped first to the oxidation reactor and then to the GAC adsorption system. This consists of two GAC units connected in series and holding 2,000 lbs of carbon each. It is expected that 12 GAC units will be replaced every year during Phase I, and 9 units will be replaced every year during Phase II. All equipment is sized for the Phase I flow rate of 20 gpm, and it is anticipated that this plant can be adjusted to the lower flow rate of Phase II without resizing any of the

equipment. The in situ biotreatment of the South Tank Farm Plume is described in Section 8.7.12.

8.9.1.3 Sidestreams

Two sidestreams are produced by this treatment system: spent GAC units and used filter cartridges. Used filter cartridges are drummed and sent to an off-post RCRA landfill. Spent GAC is sent off post for regeneration. The wastewater in the wastewater tank is recirculated to the collection tank and the sediments from the wastewater tank are drummed and landfilled.

8.9.2 Analysis of Alternative

8.9.2.1 Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment off post as long as PRGs are met at the boundary. FFA restrictions on future use of groundwater provide protection of human health on post. Removal of VHOs, VAOs, DBCP, OCPs, and freely drainable LNAPL, if necessary, from the groundwater in the South Plants North Source and South Plants Southeast Plumes and biodegradation of the benzene in the South Tank Farm Plume result in a reduction in the contaminant mass. Together with the preferred soil alternative, contaminant migration between soil and groundwater is reduced and downward migration between the upper and lower aquifers is eliminated. Most of the contaminant mass is eventually removed from the aquifer. Lowering of the water table separates the groundwater from contaminated overlying soil, thereby further reducing the potential for contaminant migration.

8.9.2.2 Compliance with ARARs

Alternative SPC-6/SPT-3/SPT-5 is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls. The treatment systems were conceptually designed based on an earlier set of standards. Should this alternative be selected as the preferred alternative, it is expected to meet most of the revised CBSG-based, chemical-specific ARARs and with the FFA (EPA et al. 1989) that would be developed for it; however, some design parameter changes might be required. Appropriate siting of the groundwater

treatment facility ensures compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

8.9.2.3 Long-Term Effectiveness and Permanence

Alternative SPC-6/SPT-3/SPT-5 reduces the potential for future contaminant migration by permanently removing contamination from the groundwater, preventing continued contact between groundwater and contaminated soil, and controlling vertical and horizontal hydraulic gradients in the South Plants Plume Group area. The potential for off-post exposure is reduced by removal of contaminants from the South Plants Plume Group in conjunction with the continued operation of the boundary systems and Basin A Neck IRA. In situ biotreatment of the South Tank Farm Plume ensures that benzene concentrations are significantly and permanently reduced.

Contaminants are removed and treated close to the source. The proposed dewatering system lowers the groundwater levels approximately to the base of the unconfined aquifer in the South Plants Plume Group, further reducing the potential for migration. The amount of contaminated soil in contact with groundwater is reduced by lowering the water table.

The use of horizontal wells is expected to enhance the performance of the dewatering system and reduce the potential for well damage and scheduling conflicts with the construction of the soil alternative. Horizontal wells also increase the probability of cross-cutting vertical fractures and joints, thus increasing the amount of water and contamination extracted. A cap placed over the South Plants area as part of the soil medium preferred alternative prevents infiltration, thereby reducing both groundwater migration in the South Plants Plume Group and the leaching of the contaminants from the unsaturated soil column. Lowering the water table aquifer controls the gradient between the confined and unconfined flow systems, greatly reducing the potential for downward contaminant migration.

8.9.2.4 Reduction of TMV

Alternative SPC-6/SPT-3/SPT-5 reduces the TMV of contaminated groundwater by dewatering the South Plants area and treating the water to remove contaminants. The groundwater intercepted at the South Plants North Source and South Plants Southeast Plumes at a rate of approximately 20 gpm is treated by a combination of air stripping and GAC adsorption. Residual contaminants (OCPs and DBCP) in the water are adsorbed onto GAC, which is then disposed off post. Because the contaminants are removed from the groundwater prior to reinjection, the treatment is irreversible.

In situ biotreatment, involving recirculation of 10 gpm of water from the South Tank Farm Plume, significantly reduces the toxicity and volume of contaminants, thereby further reducing contaminant migration from the South Tank Farm area. If freely drainable LNAPL accumulates to a sufficient thickness, it is separated, drummed, and sent off post for disposal. Both of these processes are irreversible.

Contamination is also immobilized by dewatering, which includes removal of the South Plants groundwater mound. The water table is lowered due both to decreased man-made recharge and to dewatering, thereby reducing the amount of contaminated soil in contact with the groundwater. The migration of the contaminants is reduced by the control of hydraulic gradients.

8.9.2.5 Short-Term Effectiveness

In general, the construction, operation, and final demobilization of Alternative SPC-6/SPT-3/SPT-5 have minimal negative impact on the environment, workers, or the surrounding community. On-post workers are potentially exposed to contaminants through dermal and/or dust inhalation pathways when excavation and construction of the recharge trenches are performed. To minimize or prevent such exposure, dust-control measures and PPE are used. The use of horizontal wells, which are drilled from the periphery of South Plants, reduces the potential chemical exposures and risks to workers. Another advantage horizontal wells provide is that very few wellheads exist and they are located on the periphery of the South Plants complex area, therefore reducing the

probability of damage or interference during soil or structure remediation. Personnel must follow specified procedures when changing out the carbon. To reduce potential exposure, personnel are made aware of health and safety procedures and PPE is used.

In situ biotreatment has minimal negative impact on the environment, workers, or the surrounding community because treatment is carried out in the subsurface environment. Operation of the system involves some chemical handling that requires PPE.

RAOs are achieved under this alternative over an extended period of time. This remedial action may have to be operated for an indefinite period of time to maintain the lowered water table elevation.

8.9.2.6 Implementability

Alternative SPC-6/SPT-3/SPT-5 is composed of both well-developed technologies (extraction wells, air stripping, GAC adsorption, and reinjection trenches) and innovative technologies (horizontal extraction wells, in situ biological treatment, and UV/hydrogen peroxide oxidation). As discussed in the Technology Description Volume (Sections 5, 11.3, 14.1, 14.2, 14.3 and 15), most of these technologies are currently being successfully used at RMA. The equipment required is commercially available from several vendors, with the exception of oxidation, for which a limited number of vendors supply the equipment. Extraction systems for in situ treatment, transport systems, and reinjection systems are implementable, time-proven technologies currently in use at RMA.

Horizontal well technology is considered innovative but is becoming more reliable and cost-effective as equipment and techniques for environmental applications are developed (see Section 7.6.2.6).

The use of horizontal wells is expected to enhance the performance of the dewatering systems and reduce the potential for well damage and scheduling conflicts that may arise from

implementation of the soil alternatives. This results from the ability to construct horizontal wells from the perimeter of the proposed soil cap, keeping the area to be capped free from well heads and pipelines that could interfere with earth-moving equipment. The horizontal well heads could be located outside of the cap area and away from the earth-moving activity.

The water treatment system required for treating the South Plants groundwater during dewatering can be assembled on skids prior to shipment to the site. Startup and training can be performed in an acceptable period of time. Operators at RMA already have experience with most of the components of this system.

The alternative is expected to be reliable. In situ pilot-scale tracer and biodegradation studies are currently being performed to determine whether in situ biodegradation can be implemented. The in situ treatment system requires basic equipment that is easily installed. Operation is primarily associated with monitoring and feed adjustments. All systems allow temporary maintenance to be performed with minimal impacts to the schedule of operation. In many cases, maintenance can be performed without shutting down the system. The systems have automated controls that ensure continued operation with little supervision. The groundwater and the treatment system are adequately monitored during and after extraction/treatment.

GAC units and hydrogen peroxide to be used in this alternative are produced and supplied in sufficient quantities by qualified vendors. The advanced oxidation process, using hydrogen peroxide and UV light, is an innovative technology (Technology Description Volume, Section 14.1). Pilot-scale studies have been performed as follow up to the WES bench-scale treatability studies but results are not available for inclusion in this document. The sediments from the wastewater tank are stabilized and disposed, along with filter cartridges, in an off-post RCRA landfill.

This alternative is administratively feasible. It requires an O&M program for the treatment system, contracts with GAC suppliers, periodic site monitoring, and 5-year reviews. The use of horizontal wells makes it more easily implemented prior to, or during, soil and structures remediation.

8.9.2.7 Costs

The capital cost of this treatment system (including both phases of operation) is estimated to be \$5,890,000. The annual O&M costs, including monitoring, are \$1,100,000 (years 1 to 5), \$966,000 (years 6 to 10), and \$673,000 (years 11 to 30). The present worth cost for construction and 30 years of operation is \$22,600,000. A summary of cost is presented in Appendix A, Table A5-9.

8.10 ALTERNATIVE SPC-7/SPT-2/SPT-5: DEWATERING/CAP, STRIPPING/SORPTION, IN SITU BIODEGRADATION

This alternative consists of dewatering the South Plants groundwater mound, including the South Plants North Source and the South Plants Southeast Plumes, and installing a cap over parts of South Plants. Concurrently, groundwater in the South Tank Farm Plume is treated by in situ biodegradation. The South Tank Farm Plume is monitored for the presence of LNAPL and, if freely drainable product accumulates to a sufficient thickness, it is separated and treated as described in Section 8.0. Dewatering is accomplished using a system of horizontal wells that are installed prior to the initiation of proposed structures medium remedial activities. The addition of a cap, which reduces recharge, is what distinguishes this alternative from Alternative SPC-6. The cap will be installed under the soil remediation program.

Extracted water is treated using air stripping and GAC adsorption and is then reinjected into recharge trenches located in Section 27 (or other suitable location). Three areas are being considered as possible sites for the injection trenches: Section 27 upgradient of the NWBCS, Sections 23 and 24 upgradient of the NBCS, and Sections 25 and 31 upgradient of North Plants and the NBCS. At this time the Section 27 option is preferred because it is located in a

permeable aquifer that can accept the estimated flow volumes without significant impact to the aquifer or contaminant migration. The Section 27 location was used to develop costs for this report. This alternative is accomplished in conjunction with soil remedial activities, which include caps over the Basin A and South Plants areas. Groundwater is extracted at a rate of 20 gpm for the first 10 years (Phase I) to draw down the water table and then is extracted at a rate of 15 gpm (Phase II) for the remaining years. Tables 8.8-1 and 8.8-2 list the estimated chemical influent concentrations for Phase I and Phase II of this alternative.

8.10.1 Description of Alternative

8.10.1.1 Extraction/Reinjection

Alternative SPC-7/SPT-2/SPT-5 is identical to Alternative SPC-6 except that a cap is added to the South Plants Central Processing Area as part of the soil medium remediation (Figure 8.10-1). The construction and maintenance of a soil cap is further described in Section 6.2 of the Technology Description Volume of the DAA. The flow rate for dewatering is still approximately 20 gpm. The mound dewatering, in situ biodegradation, and reinjection systems are all described in Section 8.8.1.1.

8.10.1.2 Treatment

The extracted groundwater is treated by a combination of in situ biodegradation of the South Tank Farm Plume and of air stripping and GAC adsorption of the remaining extracted water. If freely drainable LNAPL accumulates to a sufficient thickness, it is separated, drummed, and sent off post for disposal.

Groundwater extracted by the dewatering system is treated in a plant that is identical to the treatment system described for Alternative SPC-6/SPT-2/SPT-5 (Section 8.8.1.2). It is anticipated that this plant can be adjusted to the lower flow rate of Phase II without resizing any of the permanent equipment. In situ biotreatment of the South Tank Farm Plume is also described in Section 8.8.1.2.

8.10.1.3 Sidestreams

The sidestreams generated by Alternative SPC-7/SPT-2/SPT-5 are the same as those described for Alternative SPC-6/SPT-2/SPT-5 (Section 8.8.1.3).

8.10.2 Analysis of Alternative

8.10.2.1 Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment off post as long as PRGs are met at the boundary. FFA restrictions on future use of groundwater provide protection of human health on post. Removal of VHOs, VAOs, DBCP, OCPs, and, if necessary, freely drainable LNAPL from the groundwater in the South Plants North Source and South Plants Southeast Plumes and biodegradation of the benzene in the South Tank Farm Plume result in a reduction in the contaminant mass. Together with the preferred soil alternative, contaminant migration between soil and groundwater is reduced and downward migration between the upper and lower aquifers is eliminated. Most of the contaminant mass is eventually removed from the aquifer. Lowering of the water table separates the groundwater from contaminated overlying soil, thereby further reducing the potential for contaminant migration. The leaching of contaminants from the South Plants Central Processing Area is reduced by the installation of a cap, thus containing contaminants in the vadose zone once dewatering is complete.

8.10.2.2 Compliance with ARARs

Alternative SPC-7/SPT-2/SPT-5 is in compliance with all action-specific ARARs, including those related to the extraction systems and air emission controls and with the FFA (EPA et al. 1989). The treatment systems were conceptually designed based on an earlier set of standards. Should this alternative be selected as the preferred alternative, it is expected to meet most of the revised CBSG-based, chemical-specific ARARs that would be developed for it; however, some design parameter changes might be required. Appropriate siting of the groundwater treatment facility ensures compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

8.10.2.3 Long-Term Effectiveness and Permanence

Alternative SPC-7/SPT-2/SPT-5 reduces the potential for future migration of contaminants by permanently removing contamination from the groundwater, preventing continued contact between groundwater and contaminated soil, controlling vertical and horizontal hydraulic gradients in the South Plants Plume Group area, and limiting infiltration of precipitation. The potential for off-post exposure is reduced by removal of contaminants from the South Plants Plume Group in conjunction with the continued operation of the boundary systems and Basin A Neck IRA. In situ biotreatment of the South Tank Farm Plume ensures that benzene concentrations are significantly and permanently reduced.

The proposed dewatering system lowers the groundwater levels in the South Plants Plume approximately to the base of the unconfined aquifer. Contaminants are suspended in the soil column when dewatering is complete and the water table is lowered.

The use of horizontal wells is expected to enhance the performance of the dewatering system and reduce the potential for well damage and scheduling conflicts with the implementation of the soil alternative. Horizontal wells increase the probability of cross-cutting vertical fractures and joints, thus increasing the amount of water and contamination extracted. The cap minimizes the leaching of those contaminants from the vadose zone and natural attenuation reduces contaminant levels in the aquifer. Long-term effectiveness and plume migration are evaluated through continued groundwater monitoring. Lowering the water table aquifer also controls the gradient between the confined and unconfined flow systems, greatly reducing the potential for downward contaminant migration.

8.10.2.4 Reduction of TMV

Alternative SPC-7/SPT-2/SPT-5 reduces the TMV of contaminated groundwater by dewatering the South Plants area and treating the water to remove contaminants. The groundwater intercepted at the South Plants North Source and South Plants Southeast Plumes is treated by a combination of air stripping and GAC adsorption at a rate of approximately 20 gpm. Air

stripping transfers volatile organics from the liquid phase to the vapor phase, in which they are subsequently destroyed by catalytic oxidation. Residual contaminants (OCPs, DBCP, and volatiles) in the water are adsorbed onto GAC, which is regenerated off post. Because the contaminants are removed from the groundwater prior to reinjection, the treatment is irreversible.

In situ biotreatment, involving recirculation of 10 gpm of water from the South Tank Farm Plume, significantly reduces the toxicity and volume of contaminants, thereby further reducing contaminant migration from the South Tank Farm area. If freely drainable LNAPL accumulates to a sufficient thickness, it is separated, drummed, and sent off post for treatment or disposal. Both of these processes are irreversible.

Contamination is also largely immobilized by dewatering, which includes removal of the South Plants groundwater mound. The water table is lowered due both to installing the cap and to dewatering, thereby reducing the amount of contaminated soil in contact with the groundwater. The cap reduces the leaching of the contaminants contained in the soil column under the South Plants Central Processing Area. Migration of contaminants is reduced when the hydraulic gradient is controlled.

8.10.2.5 Short-Term Effectiveness

In general, the construction, operation, and final demobilization of Alternative SPC-7/SPT-2/SPT-5 have minimal negative impact on the environment, workers, or the surrounding community. On-post workers would potentially be exposed to contaminants through dermal and/or dust inhalation pathways when excavation and construction of the recharge trenches are performed. To minimize or prevent such exposure, dust-control measures and PPE are used. The use of horizontal wells, which are drilled from the periphery of South Plants, reduces the potential chemical exposures and risks to workers. Another advantage horizontal wells provide is that very few wellheads exist and are located on the periphery of the South Plants complex area, therefore reducing the probability of damage or interference during soil or structure remediation. The GAC

system requires periodic changeout of spent carbon. To reduce the potential for exposure, personnel are made aware of health and safety procedures and PPE is used.

In situ biotreatment has minimal negative impact on the environment, workers, or the surrounding community because treatment is carried out in the subsurface environment. Operation of the system involves some chemical-handling activities that require PPE.

RAOs are achieved under this alternative. This remedial action may have to be operated for an indefinite period of time to maintain the lowered water table elevation, although at a reduced extraction rate.

8.10.2.6 Implementability

With the exception of in situ biological treatment and horizontal extraction wells, Alternative SPC-7/SPT-2/SPT-5 is composed of well-developed technologies: extraction wells for in situ treatment, air stripping, GAC adsorption, catalytic oxidation, and reinjection trenches. As discussed in the Technology Description Volume (Sections 5, 11.3, 14.2, 14.3, and 15), most of these technologies are currently being successfully used at RMA. The equipment required is commercially available from several vendors. Extraction systems, transport systems, and reinjection systems are implementable, time-proven technologies similar to those that are currently in use at RMA.

Horizontal well technology is considered innovative and is becoming more reliable and cost-effective with continued development of equipment and techniques for environmental applications (see Section 7.6.2.6).

The use of horizontal wells is expected to enhance the performance of the dewatering systems and reduce the potential for well damage and scheduling conflicts that may arise from implementation of the soil alternatives. This results from the ability to construct horizontal wells from the perimeter of the proposed soil cap, keeping the area to be capped free from well heads

and pipelines that could interfere with earth-moving equipment. The horizontal well heads could be located outside of the cap area and away from the earth-moving activity.

The water treatment system required for treating the South Plants groundwater during dewatering can be assembled on skids prior to shipment to the site. Startup and training can be performed in an acceptable period of time. Operators at RMA already have experience with most of the components of this system.

The alternative is expected to be reliable. In situ pilot-scale tracer and biodegradation studies are currently being performed to determine whether in situ biodegradation can be implemented. The in situ treatment system requires basic equipment that is easily installed, and operation primarily involves monitoring and feed adjustments. All systems allow temporary maintenance to be performed with minimal impacts to the schedule of operation. In many cases, maintenance can be performed without shutting down the system. The systems have automated controls that ensure continued operation with little supervision. The groundwater and the treatment system are adequately monitored during and after remediation.

GAC units and air strippers to be used in this alternative are produced and supplied in sufficient quantities by qualified vendors. Sediments from the wastewater tank are stabilized and disposed, along with filter cartridges, in an off-post RCRA landfill. GAC is sent off post to be regenerated. Precious metals are recovered from spent catalyst by the supply vendor.

This alternative is administratively feasible. It requires an O&M program for the treatment system, contracts with GAC suppliers, periodic site monitoring, and 5-year reviews. The use of horizontal wells makes it more easily implemented prior to, or during, soil and structures remediation.

8.10.2.7 Costs

The capital cost of this treatment system (including both phases of operation, but not including the cost of the cap) is estimated to be \$5,740,000. The annual O&M costs, including monitoring, are \$940,000 (years 1 to 5), \$807,000 (years 6 to 10), and \$564,000 (years 11 to 30). The present worth cost for construction and 30 years of operation is \$19,900,000. A cost summary is presented in Appendix A, Table A5-10.

8.11 ALTERNATIVE SPC-7/SPT-3/SPT-5: DEWATERING/CAP, OXIDATION/SORPTION, IN SITU BIODEGRADATION

This alternative consists of dewatering the South Plants groundwater mound and controlling hydraulic gradients, including the South Plants North Source and the South Plants Southeast Plumes, and installing a cap over portions of South Plants. Concurrently, groundwater in the South Tank Farm Plume is treated by in situ biodegradation. The South Tank Farm Plume is monitored for the presence of LNAPL. If drainable product accumulates to a sufficient thickness, it is separated and treated as described in Section 8.0. Dewatering is accomplished using a system of horizontal wells that are installed prior to the initiation of proposed soil and structures media remedial activities. The addition of a cap, which reduces recharge, is what distinguishes this alternative from Alternative SPC-6. The cap will be installed under the soil remediation program.

Extracted water is treated with oxidation and GAC adsorption and is then reinjected into recharge trenches located in Section 27 (or other suitable location). Three areas are being considered as possible sites for the injection trenches: Section 27 upgradient of the NWBCS, Sections 23 and 24 upgradient of the NBCS, and Sections 25 and 31 upgradient of North Plants and the NBCS. At this time the Section 27 option is preferred because it is located in a permeable aquifer that can accept the estimated flow volumes without significant impact to the aquifer or contaminant migration. The Section 27 location was used to develop costs for this report. Groundwater is extracted at a rate of 20 gpm for the first 10 years (Phase I) to draw down the water table and then is extracted at a rate of 15 gpm (Phase II) for the remaining years. Tables 8.8-1 and 8.8-2

list the estimated chemical influent concentrations for Phase I and Phase II of this alternative, including the cap. The concentrations are the same as those in Alternative SPC-7/SPT-2/SPT-5.

8.11.1 Description of Alternative

8.11.1.1 Extraction/Reinjection

Alternative SPC-7/SPT-3/SPT-5 includes the same groundwater control systems that are used for Alternative SPC-7/SPT-2/SPT-5 (Section 8.10.1.1) (see Figure 8.10.1).

8.11.1.2 Treatment

The extracted groundwater is treated using a combination of in situ biodegradation of the South Tank Farm Plume and treatment of the South Plants North Source and South Plants Southeast Plumes by oxidation and GAC adsorption. If any LNAPL is removed from the plumes, it is drummed and sent off post for disposal.

This treatment system uses oxidation followed by GAC adsorption at a rate of 20 gpm (Phase I) and is identical to the treatment system described for Alternative SPC-6/SPT-3/SPT-5 (Section 8.9.1.2). It is anticipated that this treatment plant can be adjusted to the lower flow rate of Phase II without resizing any of the equipment. The in situ biotreatment system for the South Tank Farm Plume is described in Section 8.7.1.2.

8.11.1.3 Sidestreams

The sidestreams generated by this alternative are the same sidestreams as those generated by Alternative SPC-6/SPT-3/SPT-5 (Section 8.9.1.3). These include spent GAC units and used filter cartridges.

8.11.2 Analysis of Alternative

8.11.2.1 Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment as long as PRGs are met at the boundary. FFA restrictions on future use of groundwater provide protection of human health

on post. Removal of VHOs, VAOs, DBCP, OCPs, and freely drainable LNAPL, if necessary, from the groundwater in the South Plants North Source and South Plants Southeast Plumes and biodegradation of the benzene in the South Tank Farm Plume result in a reduction in the contaminant mass. Together with the preferred soil alternative, contaminant migration between soil and groundwater is reduced and downward migration between the upper and lower aquifers is eliminated. Permanent lowering of the water table separates the groundwater from contaminated overlying soil, thereby further reducing the potential for future migration of contaminants. The leaching of contaminants from the South Plants Central Processing Area is reduced by the installation of a cap, thus containing contaminants in the vadose zone following dewatering.

8.11.2.2 Compliance with ARARS

Alternative SPC-7/SPT-3/SPT-5 is in compliance with all action-specific ARARs including those related to the extraction systems and air emission controls and with the FFA (EPA et al. 1989). The treatment systems were conceptually designed based on an earlier set of standards. Should this alternative be selected as the preferred alternative, it is expected to meet most of the revised CBSG-based, chemical-specific ARARs that would be developed for it; however, some design parameter changes might be required. Appropriate siting of the groundwater treatment plant ensures compliance with all location-specific ARARs. All ARARs are listed in Appendix A of the Technology Descriptions Volume of this report.

8.11.2.3 Long-Term Effectiveness and Permanence

Alternative SPC-7/SPT-3/SPT-5 reduces the potential for future contaminant migration by permanently removing contamination from the groundwater, preventing continued contact between groundwater and contaminated soils, controlling vertical and horizontal hydraulic gradients in the South Plants Plume Group area, and limiting infiltration of precipitation. The potential for off-post exposure is reduced by removal of contaminants from the South Plants Plume Group in conjunction with the continued operation of the boundary systems. In situ biotreatment of the

South Tank Farm Plume ensures that benzene concentrations are significantly and permanently reduced.

The proposed dewatering system lowers the groundwater levels in the South Plants Plume to approximately the base of the unconfined aquifer. Contaminants are suspended in the soil column when dewatering is complete and the water table is lowered.

The use of horizontal wells is expected to enhance the performance of the dewatering system and reduce the potential for well damage and scheduling conflicts with the implementation of the soil alternative. Horizontal wells maximize the horizontal screen area affecting a larger area of contamination (Wilson and Kaback 1993). Horizontal wells also increase the probability of cross-cutting vertical fractures and joints, thus increasing the amount of water and contamination extracted. The cap reduces the leaching of those contaminants contained in the vadose zone and natural attenuation reduces contaminant levels in the aquifer. Long-term effectiveness and plume migration are evaluated through continued groundwater monitoring. Lowering the water table also creates upward gradients between the confined and unconfined flow systems, greatly reducing the potential for downward contaminant migration.

8.11.2.4 Reduction of TMV

Alternative SPC-7/SPT-3/SPT-5 reduces the TMV of contaminated groundwater by dewatering the South Plants area and treating the water to remove contaminants. The groundwater extracted from the South Plants North Source and South Plants Southeast Plumes is treated by a combination of oxidation and GAC adsorption at a rate of approximately 20 gpm. Residual contaminants (OCPs, DBCP, and volatile organics) in the water are adsorbed onto GAC, which is regenerated off post. Because the contaminants are removed from the groundwater prior to reinjection, the treatment is irreversible.

In situ biotreatment, involving recirculation of 10 gpm of water from the South Tank Farm, significantly reduces the toxicity and volume of contaminants, thereby further reducing

contaminant migration from the South Tank Farm area. If freely drainable LNAPL accumulates to a sufficient thickness, it is separated and sent off-post for treatment or disposal. Both of these processes are irreversible.

Contamination is also largely immobilized by dewatering, which includes removal of the South Plants groundwater mound. The water table is lowered due to installation of the cap and to dewatering, thereby reducing the amount of contaminated soil in contact with the groundwater. The cap reduces the leaching of the contaminants contained in the soil column under the South Plants Central Processing Area. Migration of the contaminants is reduced when the hydraulic gradient is controlled.

8.11.2.5 Short-Term Effectiveness

In general, the construction, operation, and final demobilization of Alternative SPC-7/SPT-3/SPT-5 have minimal negative impact on the environment, workers, or the surrounding community. On-post workers would potentially be exposed to contaminants through dermal and/or dust inhalation pathways when excavation and construction of the recharge trenches are performed. To minimize or prevent such exposure, dust-control measures and PPE are used. The use of horizontal wells, which are drilled from the periphery of South Plants, reduces the potential chemical exposures and risks to workers. Another advantage horizontal wells provide is that very few wellheads exist and they are located on the periphery, therefore reducing the probability of damage or interference during soil or structure remediation. Personnel must follow specified procedures when changing out the GAC system. To reduce potential exposure, personnel are made aware of health and safety procedures and PPE is used.

In situ biotreatment has minimal negative impact on the environment, workers, or the surrounding community because treatment is carried out in the subsurface environment. Operation of the system involves some chemical-handling activities that require PPE.

RAOs are achieved under this alternative. This remedial action may have to be operated for an indefinite period of time to maintain the lowered water table elevations, although at a reduced extraction rate.

8.11.2.6 Implementability

Alternative SPC-7/SPT-3/SPT-5 is composed of both well-developed technologies (extraction wells for in situ treatment, air stripping, GAC adsorption, and reinjection trenches) and innovative technologies (horizontal extraction wells, in situ biological treatment and hydrogen peroxide-UV oxidation). As discussed in the Technology Description Volume (Sections 5, 11.3, 14.1, 14.2, 14.3, and 15), most of these technologies are currently being successfully used at RMA. The equipment required is commercially available from several vendors. The extraction systems, transport systems, and reinjection systems are implementable, time-proven technologies currently in use at RMA.

Horizontal well technology is considered innovative but is becoming more reliable and cost-effective with continued development of equipment and techniques for environmental applications (see Section 7.6.2.6).

The use of horizontal wells is expected to enhance the performance of the dewatering systems and reduce the potential for well damage and scheduling conflicts that may arise from construction of the soil alternatives. This results from the ability to construct horizontal wells from the perimeter of the proposed soil cap, keeping the area to be capped free from well heads and pipelines that could interfere with earth-moving equipment. The horizontal well heads could be located outside of the cap area and away from the earth-moving activity.

The water treatment system required for treating the South Plants groundwater during dewatering can be assembled on skids prior to shipment to the site. Startup and training can be performed in an acceptable period of time, and operators at RMA already have experience with most of the components of this system.

The alternative is expected to be reliable. In situ pilot-scale tracer and biodegradation studies are currently being performed to determine whether in situ biodegradation can be implemented. The in situ treatment system requires basic equipment that is easily installed. Operation is primarily associated with monitoring and feed adjustments. All systems allow temporary maintenance to be performed with minimal impacts to the schedule of operation. In many cases, maintenance can be performed without shutting down the system. The systems have automated controls that ensure continued operation with little supervision. The groundwater and the treatment system are adequately monitored during and after remediation.

GAC and hydrogen peroxide to be used for this alternative are produced and supplied in sufficient quantities by qualified vendors. Sediments from the wastewater tank are stabilized and disposed, along with filter cartridges, in an off-post RCRA landfill. Precious metals are recovered from spent catalyst by the supply vendor. GAC is sent off post to be regenerated.

This alternative is administratively feasible. It requires an O&M program for the treatment system, contracts with GAC suppliers, periodic site monitoring, and 5-year reviews. The use of horizontal wells makes it more easily implemented prior to, or during, soil and structures remediation.

8.11.2.7 Cost

The capital cost of this treatment system (including both phases of operation) is estimated to be \$5,890,000. The annual O&M costs, including monitoring, are \$1,100,000 (years 1 to 5), \$966,000 (years 6 to 10), and \$673,000 (years 11 to 30). The present worth cost for construction and 30 years of operation is \$22,600,000. A summary of cost is presented in Appendix A, Table A5-11.

8.12 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section describes the selection of preferred alternatives for the South Plants Plume Group. In this step of the DAA process, a comparative analysis of each of the retained alternatives against the EPA screening criteria, and one against another, is performed.

The South Plants alternatives include no action, continued existing action (monitoring), treatment, and mass reduction or dewatering approaches. Continued existing action (SPC-2) involves continued monitoring utilizing expanded monitoring near the lakes and in deeper aquifers. The mass reduction alternative (SPC-3) is combined with air stripping and GAC adsorption (SPT-2) or oxidation and GAC adsorption (SPT-3) for all plumes. Treatment alternatives SPT-2 and SPT-3 are also applied to the North Source and Southeast Plumes only when the South Tank Farm Plume is treated with direct biological treatment and GAC adsorption (SPT-4). In situ biodegradation of the South Tank Farm Plume is combined with mass reduction and air stripping/GAC adsorption of the other two plumes under Alternatives SPC-5/SPT-2/SPT-5. The dewatering alternative (SPC-6) is also combined with air stripping and GAC adsorption (SPT-2) or oxidation and GAC adsorption (SPT-3) for the North Source and Southeast Plumes, along with in situ biotreatment (SPT-5) for the South Tank Farm Plume. The dewatering alternatives are repeated with the addition of a cap under Alternative SPC-7. The only difference between Alternatives SPC-6 and SPC-7 is the cap in Alternative SPC-7.

8.12.1 Overall Protection of Human Health and the Environment

All of the alternatives evaluated for the South Plants Plume Group are protective of human health both on post and off post. Human health is protected off post as long as PRGs are met at the boundary. This is currently achieved through continued operation of the existing boundary systems. FFA restrictions on future use of groundwater provide protection of human health on post.

The potential for future migration of contaminants is reduced the most by alternatives that treat the greatest volume of contaminated water over the longest period of time and provide hydraulic

controls that limit migration. These are Alternatives SPC-6 and SPC-7, which actively dewater the South Plants area indefinitely and reduce contaminant migration both by removing contaminant mass from the groundwater and by controlling the hydraulic gradient to lower the hydraulic head in the South Plants groundwater mound area. An increase in hydraulic head and hydraulic gradients could result in migration of contaminants to the west and northwest as well as toward the south lakes. The SPC-7 alternatives are the same as the SPC-6 alternatives but with the addition of a cap over the South Plants Central Processing Area prior to, or during, dewatering. The cap prevents continued leaching of contaminants from soil to groundwater in the South Plants Central Processing Area. Groundwater is captured and treated during dewatering as in Alternative SPC-6. Because the cap limits contaminant leaching, the SPC-7 alternatives most effectively minimize contaminant migration.

The treatment options associated with these control alternatives are either air stripping/GAC or oxidation/GAC. In situ biodegradation of the South Tank Farm Plume is also included in all of the SPC-6 and SPC-7 alternatives. The SPC-6 and SPC-7 alternatives are designed to be effective in treating extracted contaminants and have the same in situ treatment system; therefore, the alternatives are best differentiated by how they control the groundwater as described above.

The third most protective alternative is Alternative SPC-5/SPT-2/SPT-5, which employs mass reduction in the South Plants North Source Plume and South Plants Southeast Plume for 20 years but does not include dewatering of the South Plants groundwater mound. This alternative also includes in situ biodegradation in the South Tank Farm Plume. In situ biodegradation of the South Tank Farm Plume produces slightly less waste from the treatment process than direct biological treatment and makes this alternative slightly more favorable than the remaining alternatives, which do not include in situ treatment.

The remaining alternatives that include active treatment of the South Plants Plume Group are the SPC-3 alternatives, which consist of groundwater extraction in a mass reduction configuration followed by treatment and reinjection. These alternatives are less effective than the SPC-6 and

SPC-7 alternatives because they do not remove as great a volume of water for treatment or permanently control the hydraulic gradient in the South Plants groundwater mound. The SPC-3 alternatives are only slightly less effective than Alternative SPC-5/SPT-2/SPT-5, which differs from the SPC-3 alternatives in that it includes in situ biodegradation of the South Tank Farm Plume rather than direct treatment of that plume. The in situ treatment is slightly more effective in the short term than the direct treatment because it produces less waste, although the degree to which contaminant TMV is reduced is less certain.

The SPC-3 alternatives include four options for direct treatment: air stripping/GAC, oxidation/GAC, air stripping/GAC with direct biological treatment of the South Tank Farm Plume, or oxidation/GAC with direct biological treatment of the South Tank Farm Plume. All of these treatment systems ensure the permanent removal of contaminants from the extracted water; therefore, all of the SPC-3 alternatives are equally effective.

The SPC-2 alternative provides protection when combined with the preferred soil alternative capping most of the South Plants area. Natural lowering of the water table will prevent further spreading of the contamination, thereby protecting human health and the environment.

Alternative SPC-1 provides no additional control over contaminant migration. Some of this contamination may slowly migrate to and be removed by existing treatment systems at RMA (e.g., the Basin A Neck and Basin F Groundwater IRAs and the boundary systems).

8.12.2 Compliance with ARARs

All of the alternatives developed for the South Plants Plume Group comply with relevant action-, location-, and chemical-specific ARARs.

8.12.3 Long-Term Effectiveness and Permanence

The long-term effectiveness of the alternatives developed for South Plants is primarily dependent on their means of controlling groundwater movement through extraction, injection, and containment. The alternatives that provide the greatest degree of long-term effectiveness are Alternatives SPC-7/SPT-2/SPT-5 and SPC-7/SPT-3/SPT-5. These include dewatering of the groundwater mound and controlling the hydraulic gradient beneath the South Plants North Source and South Plants Southeast Plumes, in situ biodegradation in the South Tank Farm Plume, and installation of a cap over the South Plants Central Processing Area. This approach reduces the potential for long-term contaminant migration through dewatering, gradient control, and installation of the cap.

The treatment options for these alternatives are air stripping (with catalytic oxidation of the vapor emissions) followed by GAC adsorption plus in situ biodegradation of the South Tank Farm Plume (Alternative SPC-7/SPT-2/SPT-5) or UV/hydrogen peroxide oxidation followed by GAC adsorption and in situ biodegradation (Alternative SPC-7/SPT-3/SPT-5). These technologies provide comparable long-term effectiveness because contaminants are irreversibly removed. Oxidation has an advantage in that the contaminants are destroyed in the oxidation unit. GAC treatment involves adsorption of the contaminants onto carbon, which is regenerated off post. Air stripping also involves transfer of contaminants from the water into the air stream and then destruction of the contaminants in the catalytic oxidation unit.

The next most effective alternatives are the SPC-6 alternatives, which are exactly the same as the SPC-7 alternatives, except that no cap is installed over the South Plants Central Processing Area. Alternatives SPC-6/SPT-2/SPT-5 and SPC-6/SPT-3/SPT-5 are slightly less effective than the SPC-7 alternatives because the cap in the SPC-7 alternatives reduces contaminant migration more effectively than does dewatering alone (as in the SPC-6 alternatives).

The remaining treatment alternatives involve a mass reduction approach, rather than dewatering, making them less effective than the SPC-6 and SPC-7 alternatives. Without dewatering, the

groundwater mound in South Plants is not reduced, and hydraulic gradients are not permanently controlled, which may allow additional groundwater migration to occur. The mass reduction approach does not remove as great a volume of contaminated groundwater for treatment as does the dewatering approach.

Alternative SPC-5/SPT-2/SPT-5 is expected to be somewhat more effective than the SPC-3 alternatives because the South Tank Farm Plume is remediated with in situ biodegradation rather than aboveground treatment. In situ treatment involves treatment in the aquifer and recirculation of water and is therefore expected to provide a higher degree of contaminant reduction in the long term in the aquifer than achieved through extraction and treatment. However, in situ biodegradation is less demonstrated and treatment rates are slower.

Of the remaining alternatives, those that include the SPC-3 controls provide somewhat lower long-term effectiveness to SPC-5. These alternatives use a mass reduction approach to extract contaminated groundwater near the contamination source in the South Plants North Source, South Plants Southeast, and South Tank Farm Plumes and thus reduce contaminant migration on post. The SPC-3-based treatment alternatives include air stripping, UV/hydrogen peroxide oxidation, GAC adsorption, and direct biological treatment. All of the treatment technologies are equally effective in the long term, making the SPC-3-based alternatives equal under this criterion.

Even though SPC-2 does not involve active treatment, the capping done in conjunction with this alternative results in lowering of the water table and reduced migration in the long term.

Alternative SPC-1 is substantially less effective in the long term than any of the other alternatives. The alternative allows continued contaminant migration on post, including potential vertical migration into deeper aquifer zones.

8.12.4 Reduction of TMV

The reduction in toxicity is dependent on the type of treatment that is being used, and reductions in mobility and volume are dependent on the groundwater controls that are being used.

Alternatives SPC-7/SPT-2/SPT-5 and SPC-7/SPT-3/SPT-5 result in the greatest decrease in mobility and volume because of the large volume of contaminated groundwater that is extracted and treated, which, combined with the cap, prevents further infiltration and reduces leaching of contaminants from the soil sources into the groundwater. Contaminant mobility is also controlled by dewatering because the latter prevents continued migration.

Both Alternatives SPC-7/SPT-2/SPT-5 and SPC-7/SPT-3/SPT-5 reduce the toxicity of the groundwater either by treatment with air stripping (with catalytic oxidation of the vapor emissions) followed by GAC adsorption or with UV/hydrogen peroxide oxidation followed by GAC adsorption, respectively. Both of these treatment processes irreversibly remove contaminants from the extracted water.

Oxidation has the advantage that the contaminants are destroyed in the oxidation unit, while the other processes involve transfer of the contaminants to a different medium where they may subsequently be destroyed. GAC treatment involves adsorption of the contaminant onto carbon, which is regenerated off post. Air stripping also involves transfer of the contaminants from the water into the air stream. Contaminants are subsequently destroyed in the catalytic oxidation unit. Therefore, Alternatives SPC-7/SPT-3/SPT-5 and SPC-7/SPT-2/SPT-5 have comparable efficiencies. Alternative SPC-7/SPT-3/SPT-5 consumes more carbon than Alternative SPC-7/SPT-2/SPT-5 and thereby produces more saturated GAC, which requires further treatment.

The next most effective alternatives are Alternatives SPC-6/SPT-2/SPT-5 and SPC-6/SPT-3/SPT-5, which are identical to Alternatives SPC-7/SPT-2/SPT-5 and SPC-7/SPT-3/SPT-5 except that they do not include a cap over the South Plants Central Processing Area. These alternatives also result in a large reduction in volume of contaminated water because of the dewatering. The

reduction in mobility is not as effective as for the SPC-7 alternatives because there is no cap to retard recharge in the South Plants Central Processing Area.

The treatment technologies are the same as those considered for the SPC-7 alternatives. As discussed above, both treatment alternatives irreversibly remove contaminants, but Alternative SPC-6/SPT-2/SPT-5 consumes less carbon than Alternative SPC-6/SPT-3/SPT-5.

Except for Alternative SPC-1 and SPC-2, the remaining alternatives consist of mass reduction systems. The SPC-3 alternatives and Alternative SPC-5/SPT-2/SPT-5 remove a smaller volume of contaminated groundwater overall than the SPC-6 and SPC-7 alternatives. In addition, the groundwater mound in South Plants is not removed, water levels are not lowered substantially, and hydraulic gradients are not permanently controlled as under the dewatering alternatives. The SPC-3 alternatives remove the next greatest volume of contaminated groundwater for treatment. Treatment alternatives include four treatment options: air stripping followed by GAC adsorption (SPC-3/SPT-2), UV/hydrogen peroxide oxidation followed by GAC adsorption (SPC-3/SPT-3), air stripping followed by GAC adsorption plus direct biological treatment followed by GAC adsorption (SPC-3/SPT-2/SPT-4), and UV/hydrogen peroxide oxidation followed by GAC adsorption plus direct biological treatment followed by GAC adsorption (SPC-3/SPT-3/SPT-4). All of these alternatives include catalytic oxidation of vapor emissions from the air strippers, and all remove or destroy contaminants irreversibly; however, Alternatives SPC-3/SPT-2/SPT-4 and SPC-3/SPT-3/SPT-4 generate slightly more waste due to the biological system, and Alternative SPC-3/SPT-3 has the greatest annual carbon consumption of all the alternatives.

Alternative SPC-5/SPT-2/SPT-5 is similar to Alternative SPC-3/SPT-2/SPT-4 except that the former includes in situ biodegradation rather than direct biological treatment in the South Tank Farm Plume. The result is that less groundwater is extracted and treated aboveground than in the SPC-3 alternatives, although the reduction in TMV is comparable for both alternatives.

Alternative SPC-2 does not reduce contaminant mass, but the capping done in conjunction with this alternative will cause a reduction in mobility and volume.

Alternative SPC-1 provides marginal reduction in TMV because it relies solely on natural attenuation. Leaving groundwater contamination in the South Plants area increases the potential for this contamination to migrate vertically into deeper aquifers where it is more difficult to remediate.

8.12.5 Short-Term Effectiveness

All of the alternatives considered for the South Plants Plume Group have minimal impact on the environment, surrounding communities, or workers. The two SPC-7 alternatives have the same potential for impact because they assume the demolition of structures and installation of a cap over the South Plants Central Processing Area as part of the soil remediation; the impact, however, is still expected to be negligible. The SPC-6 and SPC-7 alternatives employ the use of horizontal wells, which are drilled from the periphery of South Plants, thereby reducing the potential chemical exposures and risks to workers compared to vertical well installation. Another advantage horizontal wells provide is that very few wellheads exist and that they are located on the periphery of the South Plants area, thereby reducing the probability of damage or scheduling conflicts during soil or structure remediation.

RAOs are achieved at the RMA boundary by systems other than the South Plants groundwater alternatives. The SPC-3 alternatives and Alternative SPC-5/SPT-2/SPT-5 are expected to operate for 20 and 10 years, respectively, while the SPC-6 and SPC-7 alternatives are expected to operate for an indefinite period of time to maintain the lowered groundwater levels in South Plants. SPC-2 involves monitoring only and continues for an indefinite period. Alternative SPC-1 includes a reduced monitoring program and also continues for an indefinite period of time.

8.12.6 Implementability

All of the alternatives being considered for the South Plants Plume Group are administratively feasible. They are also technically feasible, although some are more easily implemented than others.

The control technologies used in the alternatives consist of extraction wells, injection wells and trenches, and a clay/soil cap. These are all proven, reliable, and available technologies that are currently in use at RMA.

Horizontal well technology is considered innovative and is becoming more reliable and cost-effective with continued development of equipment and techniques for environmental applications. The use of horizontal wells is expected to enhance the performance of the dewatering system and reduce the potential for well damage and scheduling conflicts with the construction of the soil alternative.

Treatment alternatives consist of various combinations of the following technologies: air stripping, GAC adsorption, oxidation (UV/hydrogen peroxide), direct biological treatment, and in situ biodegradation. Of these, air stripping and GAC adsorption are proven, reliable, and available technologies that are currently in use at RMA. Therefore, the only alternative that uses only these technologies, Alternative SPC-3/SPT-2, is the most readily implementable of the alternatives.

Chemical oxidation is considered innovative and requires treatability studies, making implementation and operation somewhat more complex than for the proven technologies. The alternatives that are more difficult to implement than those involving only proven technologies are Alternatives SPC-3/SPT-3/SPT-5, SPC-6/SPT-3/SPT-5, and SPC-7/SPT-3/SPT-5.

Direct biological treatment and in situ biodegradation both require close oversight and necessitate treatability studies and operator training. Alternatives that include biological treatment in

combination with air stripping and GAC adsorption are the least implementable. These are Alternatives SPC-3/SPT-2/SPT-4, SPC-5/SPT-2/SPT-5, SPC-6/SPT-2/SPT-5, and SPC-7/SPT-2/SPT-5.

Alternative SPC-2 is easily implemented because it only involves an expansion of the current monitoring program using existing wells.

Alternative SPC-1 involves continuation of current monitoring so this alternative is the most easily implemented of all the alternatives.

8.12.7 Costs

The alternatives tend to fall into three cost categories: high, medium, or low. Alternative SPC-1, with a present worth cost of \$2,340,000, Alternative SPC-2, with a present worth of \$5,180,000, and SPC-5/SPT-2/SPT-5, with a present worth of \$7,430,000, are significantly less costly than any of the other alternatives.

Alternatives that fall into the medium cost group are those that use mass reduction but not dewatering. In this group are Alternatives SPC-3/SPT-2, SPC-3/SPT-3, SPC-3/SPT-2/SPT-4, and SPC-3/SPT-3/SPT-4. For this group, capital costs range from \$2,420,000 to \$3,160,000 and present worth costs range from \$12,300,000 to \$14,900,000.

Alternatives in the highest cost group are those that include an extended dewatering phase. There are four alternatives in this group with capital costs ranging from \$5,740,000 to \$5,890,000; their present worth costs range from \$19,900,000 to \$22,600,000. Included in this group are Alternatives SPC-6/SPT-2/SPT-5, SPC-6/SPT-3/SPT-5, SPC-7/SPT-2/SPT-5, and SPC-7/SPT-3/SPT-5.

8.12.8 Summary

All of the alternatives for South Plants meet the basic requirements of protection of human health and compliance with ARARs as long as the boundary systems continue to operate.

Alternative SPC-1 is less effective and provides less TMV reduction than any of the other alternatives, but it is the most easily implementable and least costly alternative.

All the SPC-3 and SPC-5 alternatives involve mass reduction while the SPC-6 and SPC-7 alternatives use a dewatering approach. The dewatering alternatives are more effective than mass reduction in the long term because lowering of the mound in South Plants and operating for more than 30 years (for an indefinite period of time) provides a greater reduction in migration potential than the 20-year mass reduction approach. The TMV reduction is consequently also greater for the dewatering alternatives than for the mass reduction alternatives. The dewatering alternatives are more protective of workers and the environment during installation because of the use of horizontal wells that are installed from the periphery of the remediation area. The mass reduction alternatives, which utilize vertical wells, are more easily implemented because demonstrated well installation technologies are used as compared to the more innovative approach required for dewatering with horizontal wells. The overall costs of mass reduction are lower than for dewatering; however, these alternatives also represent a shorter treatment period for a lower volume of water.

In summary, dewatering is favored over mass reduction because of its greater long-term effectiveness and TMV reduction and an approach that is compatible with and supports the soil remedial alternatives in South Plants.

Alternative SPC-2 in conjunction with soil capping provides a significant reduction in contaminant migration with extensive monitoring at a cost only slightly higher than for No Action.

Among the treatment alternatives SPT-2 (Stripping and GAC Adsorption) is preferred over SPT-3 (Oxidation and GAC Adsorption) for all plumes but the South Tank Farm Plume because air stripping is a more effective treatment for the mixture of volatile contaminants that will be treated in the system than oxidation, and implementation of SPT-2 is easier because it only involves proven technologies. For the South Tank Farm benzene plume, SPT-5 (In Situ Biological Treatment) is preferred over SPT-4 (Biological Reactor) because it is less intrusive, does not generate sludge for disposal (as SPT-4 does), is less costly, and is easily implemented.

Based on the above discussion, three different alternatives, SPC-1, SPC-2, and SPC-7/SPT-2/SPT-5, were retained for consideration as part of the sitewide alternatives (which are developed in Section 9). SPC-1 (No Action) was selected because it satisfies the minimum compliance criteria and is the lowest cost alternative. SPC-2 was selected because it provides added benefit through capping and additional monitoring at low cost. SPC-7/SPT-2/SPT-5 (Dewatering/Cap, Stripping/Sorption, In Situ Biodegradation) was selected because of its effectiveness in reducing TMV in the long term and its compatibility with the soil capping alternative. The retained alternatives are summarized below:

- SPC-1: No Action
- SPC-2: Continued Existing Action with Additional Lake Area and Deep Well Monitoring
- SPC-7/SPT-2/SPT-5: Dewatering with Air Stripping and GAC Adsorption of Extracted Water and In Situ Biological Treatment for South Tank Farm Plume

Table 8.0-1 Comparative Analysis of Alternatives: South Plants
Plume Group

Page 1 of 6

Criteria	ALT SPC-1 No Action	ALT SPC-2 Continued Existing Action
1. Overall protection of human health and the environment	Contaminants free to migrate to boundary, are treated at boundary systems	Soil capping alternative reduces migration somewhat. Contaminants treated at boundary systems
2. Compliance with ARARs	Location-, chemical-specific and action-specific ARARs do not apply Action-specific ARARs do not apply	Location-, chemical-specific and action-specific ARARs do not apply Action-specific ARARs do not apply
3. Long-term effectiveness and permanence	Increases potential for exposure due to contaminant migration Monitoring continues No controls implemented	Soil capping lowers water table and reduces contaminant migration Groundwater monitoring continues with expanded monitoring in lake area and deep well monitoring
4. Reduction of TMV	No treatment or action undertaken, contaminants free to migrate TMV reduced slightly over time by natural attenuation	Soil cap reduces mobility and potentially volume TMV reduced slightly over time by natural attenuation
5. Short-term effectiveness	Minimal negative impact on the environment, surrounding community, or workers Contamination free to migrate RAOs achieved if boundary systems continue to operate	Minimal negative impact on the environment, surrounding community, or workers RAOs achieved if boundary systems continue to operate
6. Implementability	Technically and administratively feasible Easily implemented	Technically and administratively feasible Easily implemented
7. Costs		
-Capital Cost	\$0	\$80,000
-Annual O&M Cost	\$196,000 (yr 1-5) \$91,000 (yr 6-30)	\$355,000 (yr 1-5) \$225,000 (yr 6-30)
-Present Worth	\$2,340,000	\$5,180,000
Summary:	Retained: meets all basic requirements as long as boundary systems continue to operate	Retained: meets all basic requirements as long as boundary systems continue to operate and accomplishes dewatering through installation of soil cap

Table 8.0-1 Comparative Analysis of Alternatives: South Plants
Plume Group

Criteria	ALT SPC-3/SPT-2 Mass Reduction, Stripping/Sorption	ALT SPC-3/SPT-3 Mass Reduction, Oxidation/Sorption
1. Overall protection of human health and the environment	Removes contaminant mass and reduces migration	Removes contaminant mass and reduces migration
2. Compliance with ARARs	Action-, location- and chemical-specific ARARs do not apply	Complies with action- and location-specific ARARs. Chemical-specific ARARs would be developed if selected and necessary adjustments made
3. Long-term effectiveness and permanence	Minimizes potential for off-post exposure, contaminants removed and treated at source; does not significantly decrease groundwater mound	Minimizes potential for off-post exposure, contaminants removed and treated at source; does not significantly decrease groundwater mound
4. Reduction of TMV	Monitoring program continues Contaminants removed by air stripping and GAC adsorption; mass reduction system at source reduces potential migration through the aquifer 7 gpm removed and treated Contaminants irreversibly transferred to GAC, which requires regeneration, or transferred to vapor phase where destroyed by catalytic oxidation	Monitoring program continues Contaminants removed by oxidation and GAC adsorption; mass reduction system at source reduces potential migration through the aquifer 7 gpm removed and treated Contaminants destroyed by oxidation or transferred to GAC, which requires regeneration; lower GAC consumption than SPT-2
5. Short-term effectiveness	Minimal negative impact on the environment, surrounding community, or workers Achieves RAOs; operates for 20 years	Minimal negative impact on the environment, surrounding community, or workers Achieves RAOs; operates for 20 years
6. Implementability	Technically feasible: demonstrated, available technologies, reliable equipment, and experienced operators Administratively feasible	Technically feasible: GAC is a demonstrated, available technology, with reliable equipment and experienced operators; advanced oxidation process is innovative, requiring more oversight and operator training Administratively feasible
7. Costs		
–Capital Cost	\$2,420,000	\$2,550,000
–Annual O&M Cost	\$696,000 (yr 1-5) \$563,000 (yr 6-20) \$122,000 (yr 21-30)	\$801,000 (yr 1-5) \$667,000 (yr 6-20) \$122,000 (yr 21-30)
–Present Worth	\$12,300,000	\$14,000,000
Summary:	Not retained: does not provide significant hydraulic control even though contaminant mass is reduced	Not retained: does not provide significant hydraulic control even though contaminant mass is reduced

Table 8.0-1 Comparative Analysis of Alternatives: South Plants
Plume Group

Criteria	ALT SPC-3/SPT-2/SPT-4 Mass Reduction, Stripping/Sorption, Biological Reactor/Sorption	ALT SPC-3/SPT-3/SPT-4 Mass Reduction, Oxidation/Sorption, Biological Reactor/Sorption
1. Overall protection of human health and the environment	Removes contaminant mass and reduces migration	Removes contaminant mass and reduces migration
2. Compliance with ARARs	Complies with action- and location-specific ARARs. Chemical-specific ARARs would be developed if selected and necessary adjustments made	Complies with action- and location-specific ARARs. Chemical-specific ARARs will be developed if selected and necessary design adjustments made
3. Long-term effectiveness and permanence	Minimizes potential for off-post exposure, contaminants removed and treated at source; does not decrease groundwater mound Monitoring program continues	Minimizes potential for off-post exposure, contaminants removed and treated at source; does not decrease groundwater mound Monitoring program continues
4. Reduction of TMV	Contaminants removed by air stripping and GAC adsorption at South Plants North Source and South Plants Southeast Plumes; direct biological treatment of the contaminants in the South Tank Farm Plume; mass reduction system at source reduces potential migration through the aquifer 2 gpm from South Plants North Source and South Plants Southeast Plumes and 5 gpm from South Tank Farm Plume removed and treated Contaminants irreversibly transferred to GAC, which requires regeneration, transferred to vapor phase by air stripping, or destroyed in biological reactor, creating sludge that requires disposal; emissions from air stripper and biological reactor destroyed by catalytic oxidation	Contaminants destroyed by oxidation and removed by GAC adsorption at South Plants North Source and South Plants Southeast Plumes; direct biological treatment of contaminants in the South Tank Farm Plume; mass removal at source reduces potential migration through the aquifer 2 gpm from South Plants North Source and South Plants Southeast Plumes and 5 gpm from South Tank Farm Plume removed and treated Contaminants destroyed in oxidation or biological reactor or transferred to GAC, which requires regeneration; biological treatment creates sludge, which requires disposal; lower GAC consumption than SPT-2; biological reactor gaseous emissions destroyed by catalytic oxidation
5. Short-term effectiveness	Minimal negative impact on the environment, surrounding community, or workers Achieves RAOs; both systems operate for 20 years	Minimal negative impact on the environment, surrounding community, or workers Achieves RAOs; both systems operate for 20 years
6. Implementability	Technically feasible: demonstrated, available technologies; most equipment reliable except biological process requires close oversight and additional training for operators Administratively feasible	Technically feasible: GAC adsorption is a demonstrated, available technology with reliable equipment and experienced operators; advanced oxidation process is innovative; oxidation and biological reactors require more oversight and additional operator training Administratively feasible
7. Costs		
-Capital Cost	\$2,980,000	\$3,160,000
-Annual O&M Cost	\$823,000 (yr 1-5) \$690,000 (yr 6-20) \$122,000 (yr 21-30)	\$817,000 (yr 1-5) \$685,000 (yr 6-20) \$122,000 (yr 21-30)
-Present Worth	\$14,800,000	\$14,900,000
Summary:	Not retained: does not provide significant hydraulic control even though contaminant mass is reduced	Not retained: does not provide significant hydraulic control even though contaminant mass is reduced

Table 8.0-1 Comparative Analysis of Alternatives: South Plants
Plume Group

Criteria	ALT SPC-5/SPT-2/SPT-5 Mass Reduction, Stripping/Sorption, In Situ Biodegradation
1. Overall protection of human health and the environment	Removes contaminant mass and reduces migration
2. Compliance with ARARs	Complies with action- and location-specific ARARs. Chemical-specific ARARs will be developed if selected and necessary design adjustments made
3. Long-term effectiveness and permanence	Minimizes potential for off-post exposure, contaminants removed and treated at source; does not decrease groundwater mound Monitoring program continues
4. Reduction of TMV through treatment	Contaminants removed from South Plants North Source and South Plants Southeast Plumes; in situ biological treatment of the contaminants in the South Tank Farm Plume; mass reduction system at source reduces potential migration through the aquifer 1.0 gpm each from South Plants North Source and South Plants Southeast Plumes extracted and treated and 10 gpm from South Tank Farm Plume recirculated and treated by in situ biodegradation Contaminants from South Tank Farm Plume destroyed by in situ biodegradation
5. Short-term effectiveness	Minimal negative impact on the environment, surrounding community, or workers Achieves RAOs; both systems operate for 20 years
6. Implementability	Technically feasible: demonstrated, available technologies except in situ biological treatment; biological process requires close oversight Administratively feasible
7. Costs	
-Capital Cost	\$1,470,000
-Annual O&M Cost	\$550,000 (yr 1-5) \$412,000 (yr 6-20) \$120,000 (yr 21-30)
-Present Worth	\$7,430,000
Summary:	Not retained: does not provide significant hydraulic control even though contaminant mass is reduced

Table 8.0-1 Comparative Analysis of Alternatives: South Plants
Plume Group

Criteria	ALT SPC-6/SPT-2/SPT-5 Dewatering, Stripping/Sorption, In Situ Biodegradation	ALT SPC-6/SPT-3/SPT-5 Dewatering, Oxidation/Sorption, In Situ Biodegradation
1. Overall protection of human health and the environment	Removes contaminant mass and provides long-term control of contaminant migration	Removes contaminant mass and provides long-term control of contaminant migration
2. Compliance with ARARs	Complies with action- and location-specific ARARs. Chemical-specific ARARs will be developed if selected and necessary design adjustments made	Complies with action- and location-specific ARARs. Chemical-specific ARARs will be developed if selected and necessary design adjustments made
3. Long-term effectiveness and permanence	Minimizes potential for off-post exposure, contaminants removed and treated near source; decreases groundwater mound, reducing potential for long-term migration	Minimizes potential for off-post exposure, contaminants removed and treated near source; decreases groundwater mound, reducing potential for long-term migration
4. Reduction of TMV	Monitoring program continues Benzene destroyed by in situ biodegradation in the South Tank Farm Plume; contaminants from South Plants North Source and South Plants Southeast Plumes removed by air stripping and GAC adsorption; dewatering reduces potential migration through the aquifer 10 gpm recirculated for in situ biotreatment and 20 gpm extracted and treated for dewatering Contaminants irreversibly destroyed by biodegradation; transferred to GAC, which requires regeneration; or transferred to vapor-phase and destroyed by catalytic oxidation	Monitoring program continues Benzene destroyed by in situ biodegradation in the South Tank Farm Plume; contaminants from South Plants North Source and South Plants Southeast Plumes removed by oxidation and GAC adsorption; dewatering reduces potential migration through the aquifer 10 gpm recirculated for in situ biotreatment and 20 gpm extracted and treated for dewatering Contaminants irreversibly destroyed by biodegradation or oxidation or transferred to GAC, which requires regeneration; lower GAC consumption than SPT-2
5. Short-term effectiveness	Minimal negative impact on the environment, surrounding community, or workers; horizontal wells exist on periphery of remediation area reducing chance of interference or damage Achieves RAOs; dewatering may be required for more than 30 years	Minimal negative impact on the environment, surrounding community, or workers; horizontal wells exist on periphery of remediation area reducing chance of interference or damage Achieves RAOs; dewatering may be required for more than 30 years
6. Implementability	Technically feasible: demonstrated, available treatment technologies, reliable equipment, and experienced operators; horizontal wells are innovative requiring special drillers Administratively feasible	Technically feasible: GAC is a demonstrated, available technology; advanced oxidation is innovative, requiring more oversight and additional training for operators; horizontal wells are innovative requiring special drillers Administratively feasible
7. Costs		
–Capital Cost	\$5,740,000	\$5,890,000
–Annual O&M Cost	\$940,000 (yr 1-5) \$807,000 (yr 6-10) \$564,000 (yr 11-30)	\$1,100,000 (yr 1-5) \$966,000 (yr 6-10) \$673,000 (yr 11-30)
–Present Worth	\$19,900,000	\$22,600,000
Summary:	Not retained: does not incorporate soil cap alternatives proposed for this area, as SPC-7 does	Not retained: does not incorporate soil cap alternatives proposed for this area, as SPC-7 does

Criteria	SPC-7/SPT-2/SPT-5 Dewatering/Cap, Stripping/Sorption, In Situ Biodegradation	ALT SPC-7/SPT-3/SPT-5 Dewatering/Cap, Oxidation/Sorption, In Situ Biodegradation
1. Overall protection of human health and the environment	Removes contaminant mass and provides long-term control of contaminant migration	Removes contaminant mass and provides long-term control of contaminant migration
2. Compliance with ARARs	Complies with action- and location-specific ARARs. Chemical-specific ARARs will be developed if selected and necessary design adjustments made	Complies with action- and location-specific ARARs. Chemical-specific ARARs will be developed if selected and necessary design adjustments made
3. Long-term effectiveness and permanence	Minimizes potential for off-post exposure, contaminants removed and treated near source; decreases groundwater mound, reducing potential for long-term migration; reduces infiltration; monitoring program continues	Minimizes potential for off-post exposure, contaminants removed and treated near source; decreases groundwater mound, reducing potential for long-term migration; reduces infiltration; monitoring program continues
4. Reduction of TMV	Benzene destroyed by in situ biodegradation in the South Tank Farm Plume; contaminants removed by air stripping and GAC adsorption in the remainder of the South Plants plumes; dewatering reduces potential migration through the aquifer; cap reduces recharge and contaminant mobility 10 gpm recirculated for in situ biotreatment and 20 gpm extracted and treated for dewatering Contaminants irreversibly destroyed by biodegradation and transferred to GAC, which requires regeneration, or transferred to vapor phase and destroyed by catalytic oxidation	Benzene destroyed by in situ biodegradation in the South Tank Farm Plume; contaminants removed by oxidation and GAC adsorption in the remainder of the South Plants plumes; dewatering reduces potential migration through the aquifer; cap reduces recharge and contaminant mobility 10 gpm recirculated for in situ biotreatment and 20 gpm extracted and treated for dewatering Contaminants irreversibly destroyed by biodegradation and transferred to GAC, which requires regeneration or destroyed by oxidation; lower GAC consumption than SPT-2
5. Short-term effectiveness	Minimal negative impact on the environment, surrounding community, or workers; horizontal wells exist on periphery of remediation area reducing chance of interference or damage Achieves RAOs; dewatering may be required for more than 30 years	Minimal negative impact on the environment, surrounding community, or workers; horizontal wells exist on periphery of remediation area reducing chance of interference or damage Achieves RAOs; dewatering may be required for more than 30 years
6. Implementability	Technically feasible: demonstrated, available treatment technologies, reliable equipment, and experienced operators; horizontal wells are innovative requiring trained drillers Administratively feasible	Technically feasible: demonstrated, available technologies; reliable equipment; advanced oxidation process is innovative and requires increased oversight and additional training for operators; horizontal wells are innovative requiring trained drillers Administratively feasible
7. Costs		
–Capital Cost	\$5,740,000*	\$5,890,000*
–Annual O&M Cost	\$940,000 (yr 1-5) \$807,000 (yr 6-10) \$564,000 (yr 11-30)	\$1,100,000 (yr 1-10) \$966,000 (yr 6-10) \$673,000 (yr 11-30)
–Present Worth	\$19,900,000	\$22,600,000
Summary:	Retained: provides hydraulic control, removes contaminant mass, is compatible with soil cap, and utilizes easily implementable technologies	Not retained: provides same hydraulic control and mass reduction as SPC-7/SPT-2/SPT-5, but treatment not as easily implemented

* Does not include cost of cap

ARARs Applicable or Relevant and Appropriate Requirements
 FFA Federal Facility Agreement
 GAC Granular Activated Carbon
 LNAPL Light Nonaqueous Phase Liquid

O&M Operation and Maintenance
 RAO Remedial Action Objective
 TMV Toxicity, Mobility, or Volume

Table 8.3-1 SPC-3 South Plants North Source, South Plants Southeast, and South Tank Farm Plumes Estimated Influent Concentrations

Chemical Group/Compound	Estimated Influent Concentration (µg/l)
Volatile Halogenated Organic Compounds (VHOs)	
Carbon tetrachloride	26
Chloroform	830
Methylene chloride	11
Trichloroethylene	7.7
Volatile Hydrocarbon Compounds (VHCs)	
Dicyclopentadiene (DCPD)	13
Volatile Aromatic Organic Compounds (VAOs)	
Benzene	100,000
Organosulfur Compounds, Mustard Agent Related (OSCMs)	
Dithiane	3.1
Organosulfur Compounds, Herbicide Related (OSCHs)	
Chlorophenylmethyl sulfoxide	2.6
Organophosphorous Compounds, GB-Agent Related (OPHGBs)	
Diisopropylmethyl phosphonate (DIMP)	0.80
Organophosphorus Compounds, Pesticide Related (OPHPs)	
Atrazine	4.3
Dibromochloropropane (DBCP)	
Dibromochloropropane	9.2
Organochlorine Pesticides (OCPs)	
Chlordane	0.15
Dieldrin	0.18
Hydrazine Related Compounds	
N-nitrosodimethylamine (NDMA)	0.082
Arsenic	
Arsenic	1.9

Table 8.5-1 South Plants North Source and Southeast Plumes Estimated Influent Concentrations

Chemical Group/Compound	Estimated Influent Concentration (µg/l)
Volatile Halogenated Organic Compounds (VHOs)	
Carbon tetrachloride	88
Chloroform	2,900
Methylene chloride	32
Trichloroethylene	25
Volatile Hydrocarbon Compounds (VHCs)	
Dicyclopentadiene (DCPD)	24
Volatile Aromatic Organic Compounds (VAOs)	
Benzene	400
Organosulfur Compounds, Mustard Agent Related (OSCMs)	
Dithiane	7.3
Organosulfur Compounds, Herbicide Related (OSCHs)	
Chlorophenylmethyl sulfoxide	5.6
Organophosphorous Compounds, GB-Agent Related (OPHGBs)	
Diisopropylmethyl phosphonate (DIMP)	2.2
Organophosphorus Compounds, Pesticide Related (OPHPs)	
Atrazine	4.0
Dibromochloropropane (DBCP)	
Dibromochloropropane	32
Organochlorine Pesticides (OCPs)	
Chlordane	0.21
Dieldrin	0.41
Hydrazine Related Compounds	
N-nitrosodimethylamine (NDMA)	0.082
Arsenic	
Arsenic	3.7

µg/L micrograms per liter

Table 8.5-2 South Tank Farm Direct Biological Treatment Estimated Influent Concentrations

Chemical Group/Compound	Estimated Influent Concentration (µg/l)
Volatile Halogenated Organic Compounds (VHOs)	
Chloroform	0.80
Volatile Hydrocarbon Compounds (VHCs)	
Dicyclopentadiene (DCPD)	8.5
Volatile Aromatic Organic Compounds (VAOs)	
Benzene	140,000
Organophosphorus Compounds, Pesticide Related (OPHPs)	
Atrazine	4.4
Dibromochloropropane (DBCP)	
Dibromochloropropane	0.18
Organochlorine Pesticides (OCPs)	
Chlordane	0.12
Dieldrin	0.09

Table 8.7-1 South Tank Farm Plume In Situ Biological Treatment Estimated Influent Concentrations

Page 1 of 1

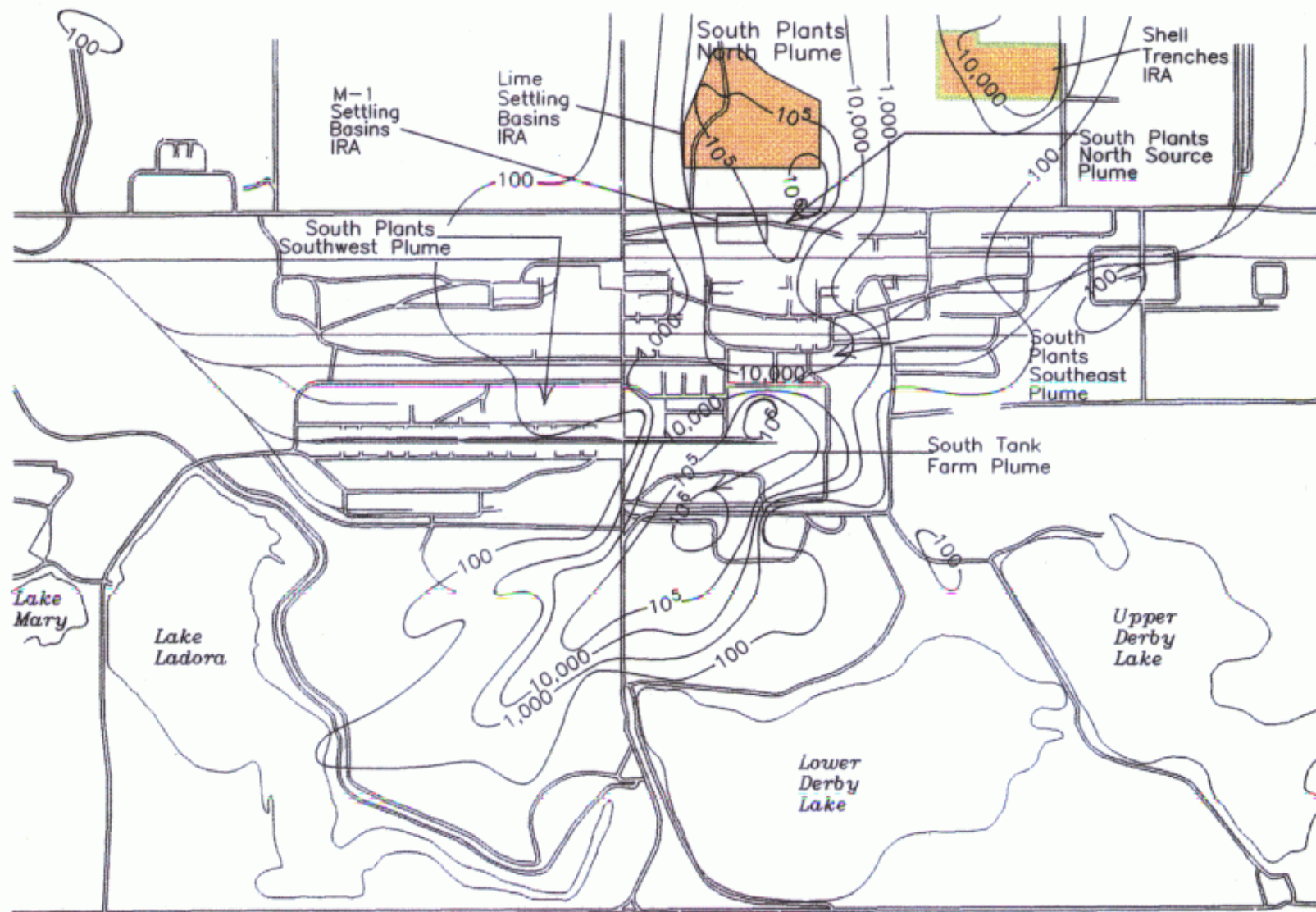
Chemical Group/Compound	Estimated Influent Concentration (µg/l)
Volatile Halogenated Organic Compounds (VHOs)	
Chloroform	1.9
Methylene Chloride	1.5
Trichloroethylene	1.2
Volatile Hydrocarbon Compounds (VHCs)	
Dicyclopentadiene (DCPD)	46
Volatile Aromatic Organic Compounds (VAOs)	
Benzene	30,000
Organosulfur Compounds, Mustard Agent Related (OSCMs)	
Dithiane	2.1
Organophosphorous Compounds, Pesticide Related (OPHPs)	
Atrazine	1.2
Dibromochloropropane (DBCP)	
Dibromochloropropane	2.3
Organochlorine Pesticides (OCPs)	
Chlordane	0.092
Dieldrin	0.19

Table 8.8-1 South Plants Dewatering SPC-6 and Dewatering with a Cap SPC-7 Estimated Influent Concentrations Phase I

Chemical Group/Compound	Estimated Influent Concentration (µg/l)
Volatile Halogenated Organic Compounds (VHOs)	
Carbon tetrachloride	21
Chloroform	1,066
Methylene chloride	11
Trichloroethylene	6.3
Volatile Hydrocarbon Compounds (VHCs)	
Dicyclopentadiene (DCPD)	43
Volatile Aromatic Organic Compounds (VAOs)	
Benzene	15,000
Organosulfur Compounds, Mustard Agent Related (OSCMs)	
Dithiane	22
Organosulfur Compounds, Herbicide Related (OSCHs)	
Chlorophenylmethyl sulfoxide	2.6
Organophosphorous Compounds, GB-Agent Related (OPHGBs)	
Diisopropylmethyl phosphonate (DIMP)	1.5
Organophosphorus Compounds, Pesticide Related (OPHPs)	
Atrazine	1.7
Dibromochloropropane (DBCP)	
Dibromochloropropane	1.2
Organochlorine Pesticides (OCPs)	
Chlordane	0.12
Dieldrin	0.10
Hydrazine Related Compounds	
N-nitrosodimethylamine (NDMA)	0.31
Arsenic	
Arsenic	1.8

Table 8.8-2 South Plants Dewatering SPC-6 and Dewatering with Cap SPC-7 Estimated
Influent Concentrations Phase II

Chemical Group/Compound	Estimated Influent Concentration (µg/l)
Volatile Halogenated Organic Compounds (VHOs)	
Carbon tetrachloride	21
Chloroform	1,100
Methylene chloride	11
Trichloroethylene	6.3
Volatile Hydrocarbon Compounds (VHCs)	
Dicyclopentadiene (DCPD)	43
Volatile Aromatic Organic Compounds (VAOs)	
Benzene	15,000
Organosulfur Compounds, Mustard Agent Related (OSCMs)	
Dithiane	22
Organosulfur Compounds, Herbicide Related (OSCHs)	
Chlorophenylmethyl sulfoxide	2.6
Organophosphorous Compounds, GB-Agent Related (OPHGBs)	
Diisopropylmethyl phosphonate (DIMP)	1.5
Organophosphorus Compounds, Pesticide Related (OPHPs)	
Atrazine	1.7
Dibromochloropropane (DBCP)	
Dibromochloropropane	1.2
Organochlorine Pesticides (OCPs)	
Chlordane	0.12
Dieldrin	0.10
Hydrazine Related Compounds	
N-nitrosodimethylamine (NDMA)	0.31
Arsenic	
Arsenic	1.8



LEGEND



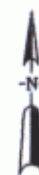
Cap



Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)



Slurry Wall

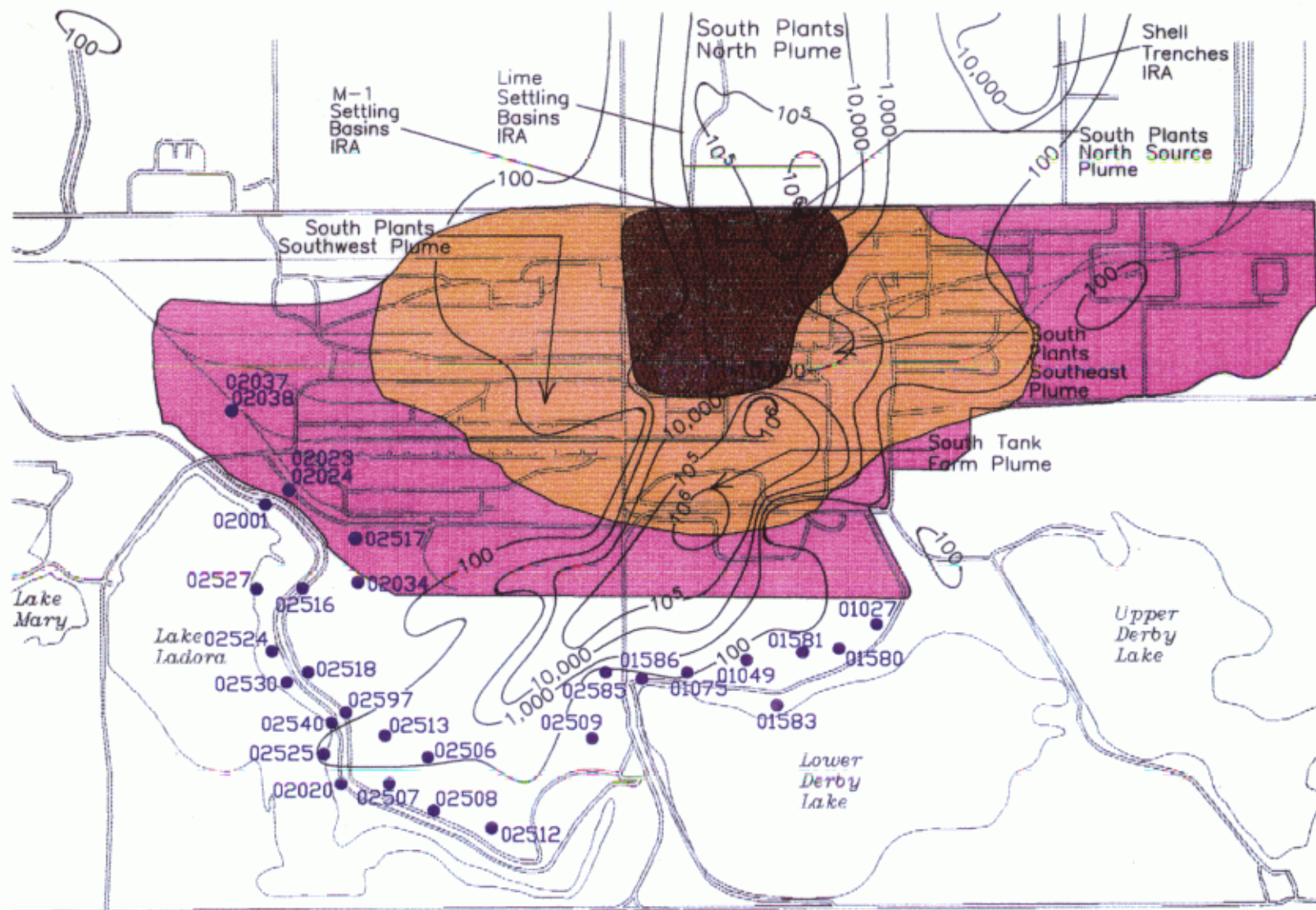


Not To Scale

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

FIGURE 8.1-1
Schematic for South Plants Plume Group
Control Alternative SPC-1

Prepared by:
Foster Wheeler Environmental Corporation



LEGEND

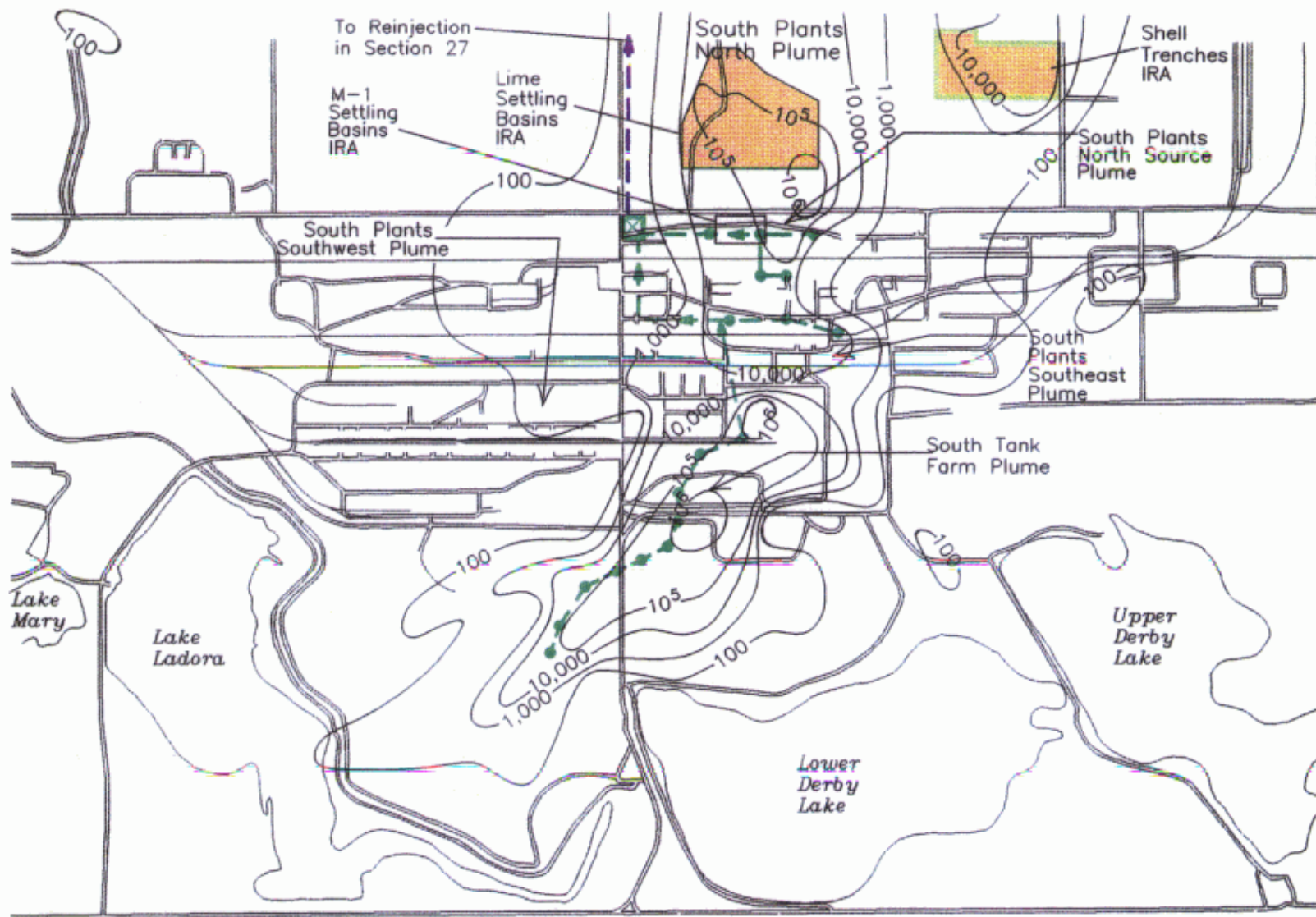
- 4 ft. Thick or Greater Soil Cover
- 3 ft. Thick Soil Cover
- 1 to 3 ft. Thick Soil Cover
- 10 - Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)
- Groundwater Well with ID
- 02507



Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

FIGURE 8.2-1
Schematic for South Plants Plume Group
Control Alternative SPC-2

Prepared by:
Foster Wheeler Environmental Corporation



LEGEND



Cap

-100-

Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)



Extraction Well

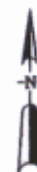
Reinjection Pipe

Slurry Wall

Transport Pipe



Treatment Plant

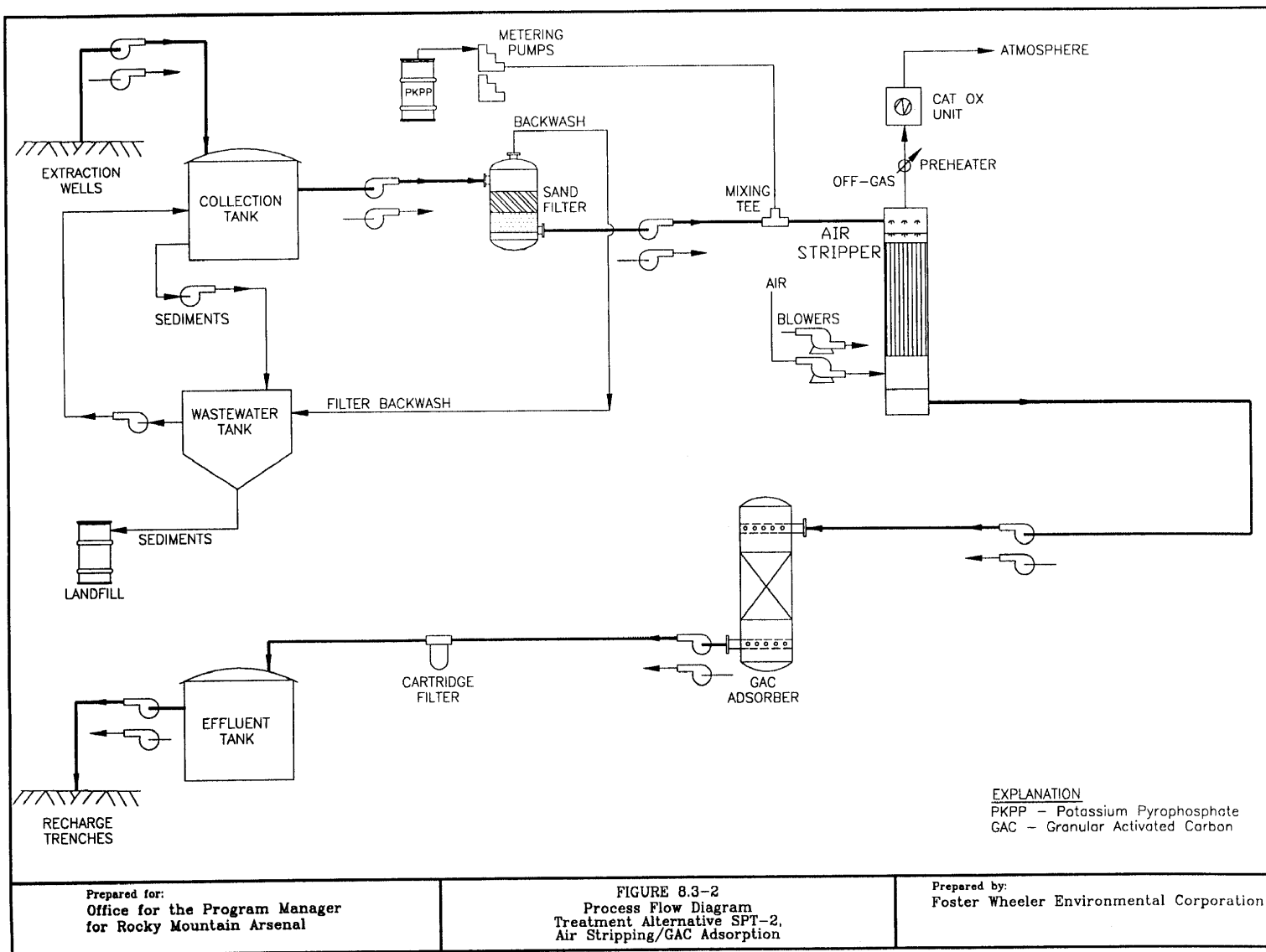


Not To Scale

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for Rocky Mountain Arsenal

FIGURE 8.3-1
Schematic for South Plants Plume Group
Control Alternative SPC-3

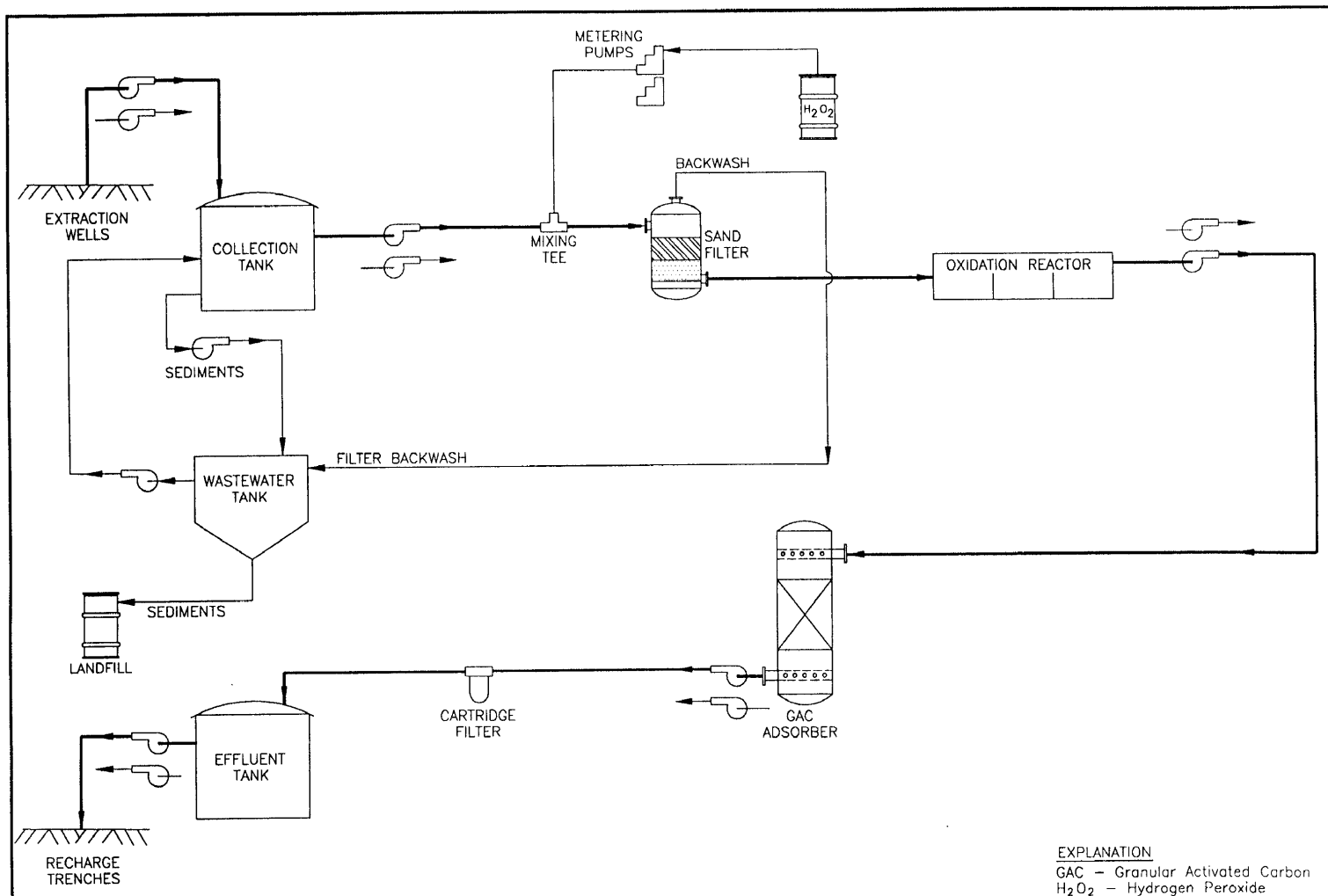
Prepared by:
Foster Wheeler Environmental Corporation



Prepared for:
 Office for the Program Manager
 for Rocky Mountain Arsenal

FIGURE 8.3-2
 Process Flow Diagram
 Treatment Alternative SPT-2,
 Air Stripping/GAC Adsorption

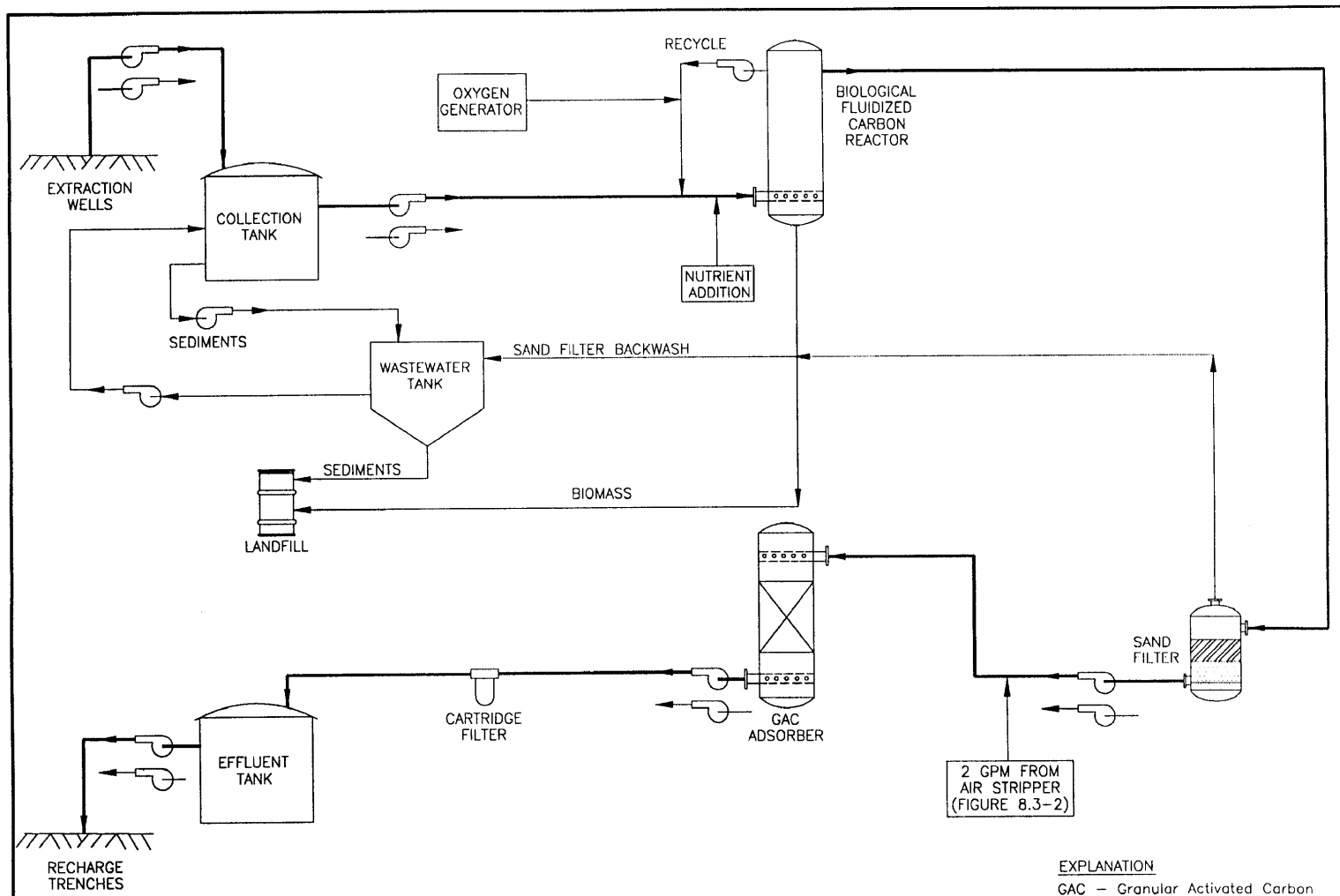
Prepared by:
 Foster Wheeler Environmental Corporation



Prepared for:
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 for Rocky Mountain Arsenal

FIGURE 8.4-1
 Process Flow Diagram
 Treatment Alternative SPT-3 (SPC-6 or SPC-7)
 UV/ H_2O_2 Oxidation/GAC Adsorption

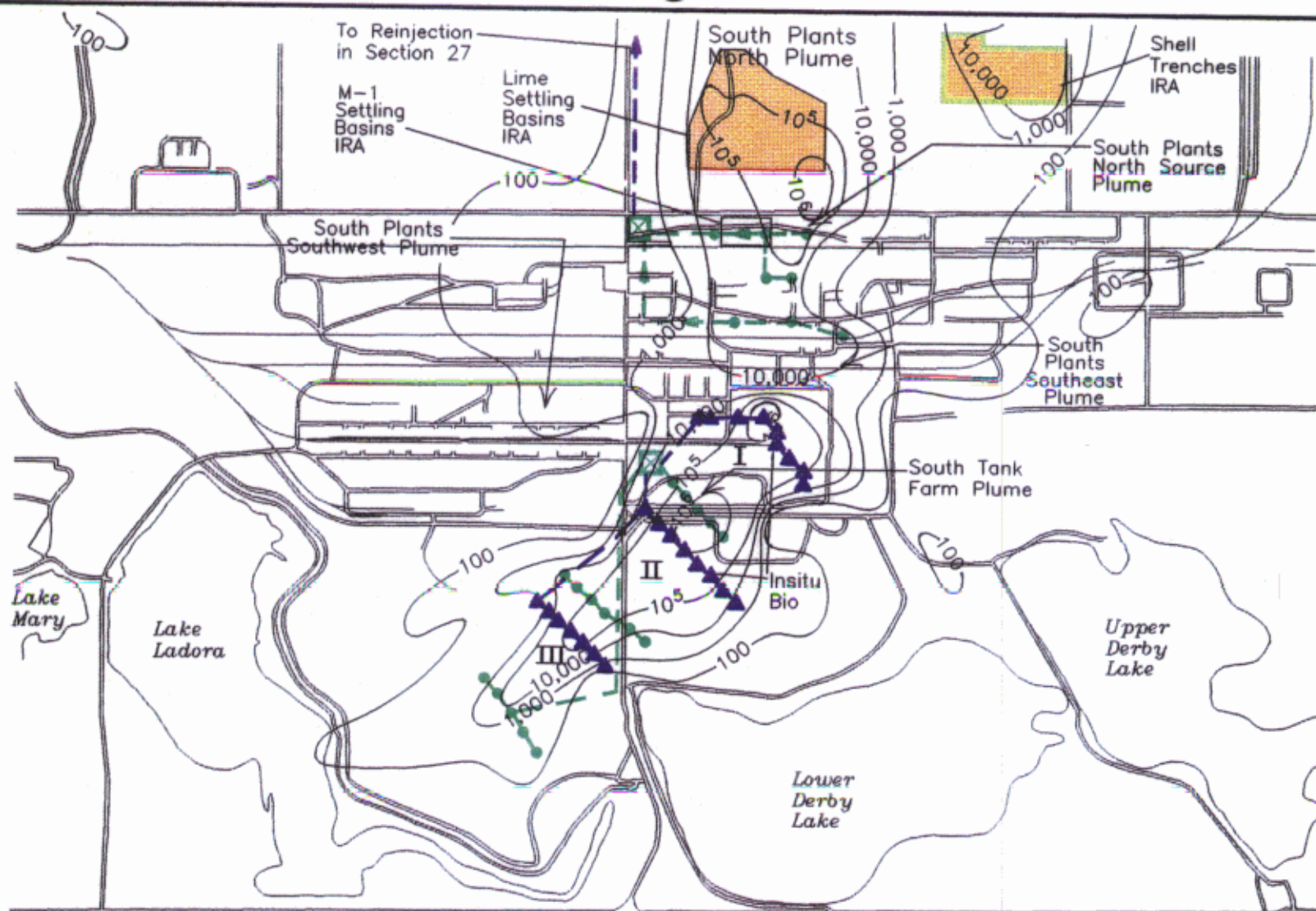
Prepared by:
 Foster Wheeler Environmental Corporation



Prepared for:
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FIGURE 8.5-1
 Process Flow Diagram
 Treatment Alternative SPT-4,
 Direct Biological Treatment/GAC Adsorption

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LEGEND

-  Cap
-  Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)
-  Extraction Well
-  Injection Well
-  Slurry Wall
-  Transport Pipe
-  Treatment Plant
-  Cell Number



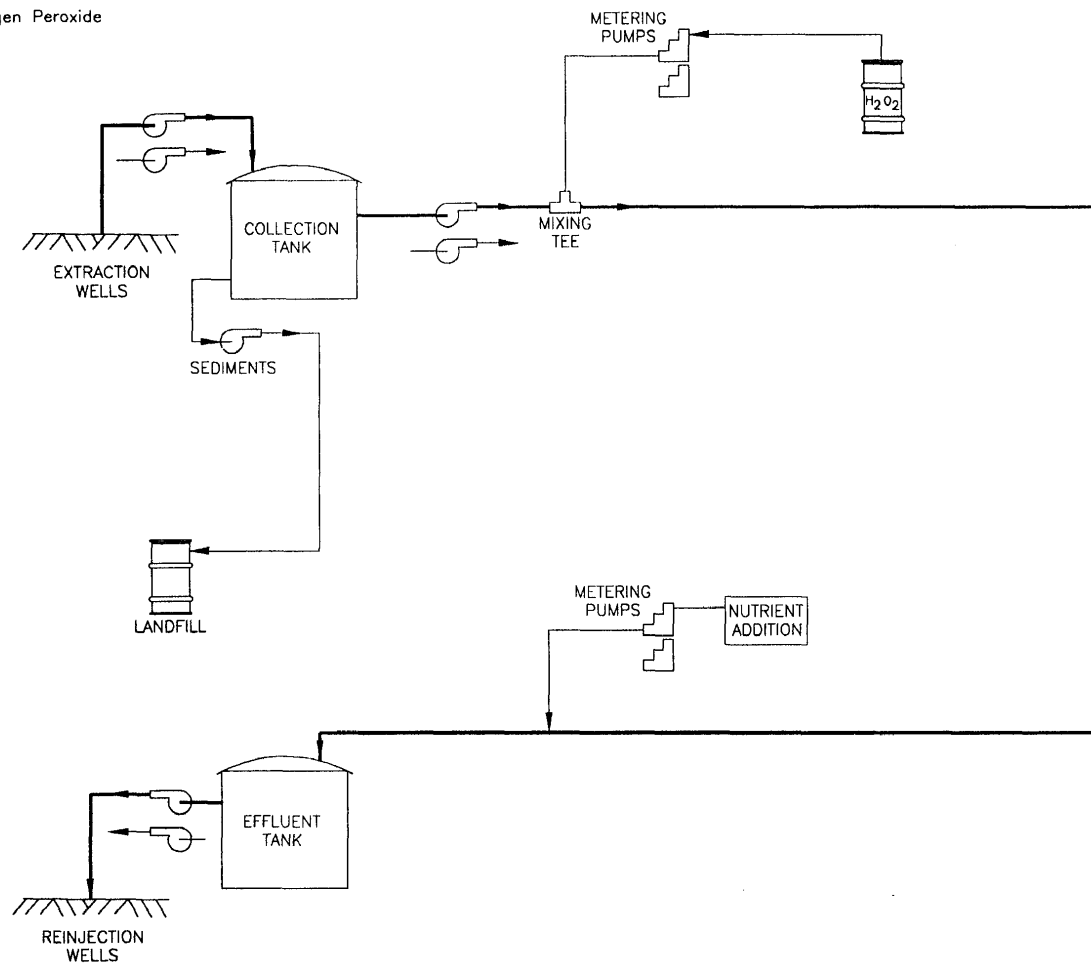
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FIGURE 8.7-1
Schematic for South Plants Plume Group
Control Alternative SPC-5

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Foster Wheeler Environmental Corporation

EXPLANATION

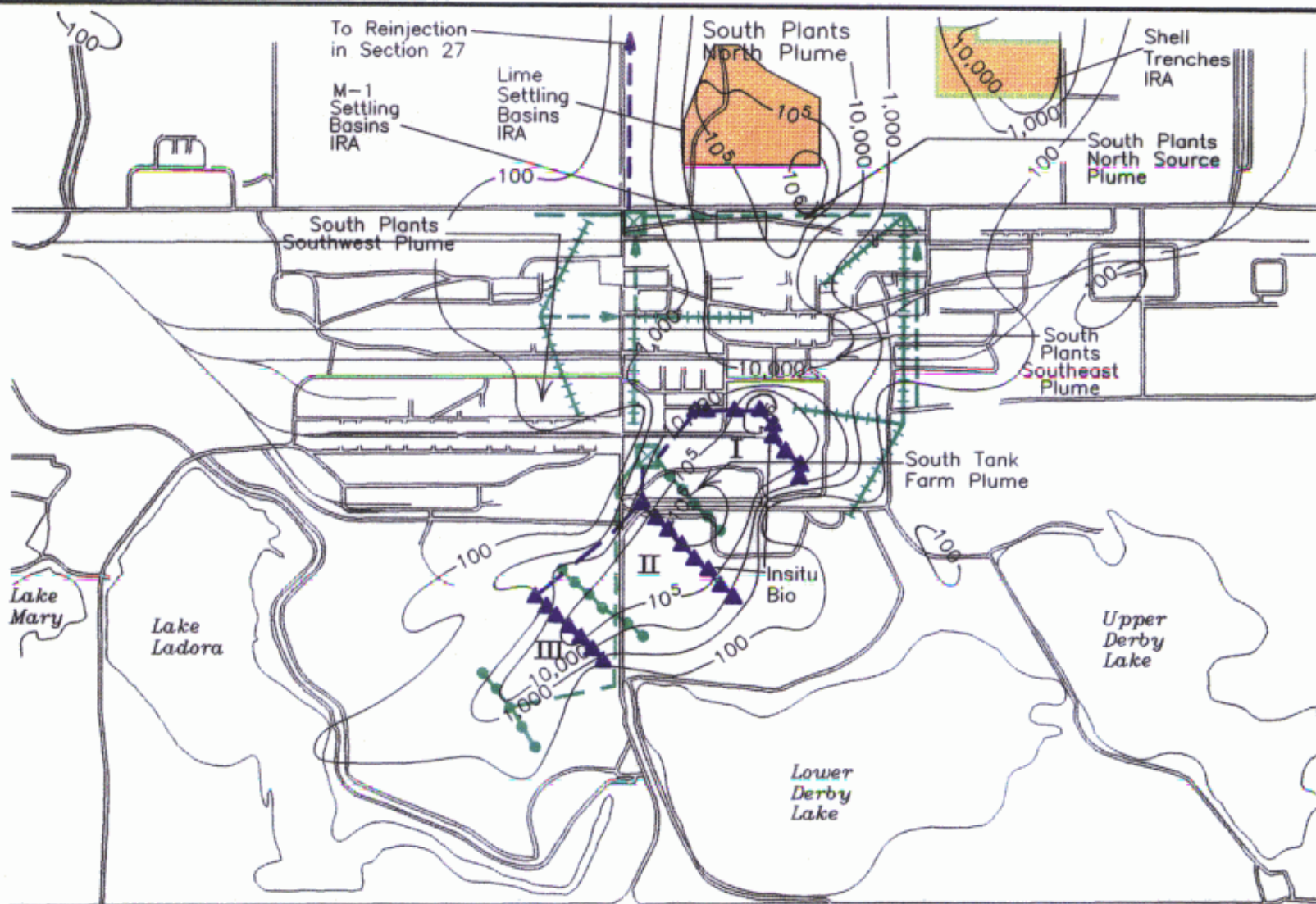
H₂O₂ - Hydrogen Peroxide



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FIGURE 8.7-2
Process Flow Diagram
Treatment Alternative SPT-5,
In Situ Biodegradation

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Foster Wheeler Environmental Corporation



LEGEND



Cap

-100-

Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)



Extraction Well



Injection Well



Horizontal Extraction Well



Slurry Wall



Transport Pipe



Treatment Plant

I

Cell Number

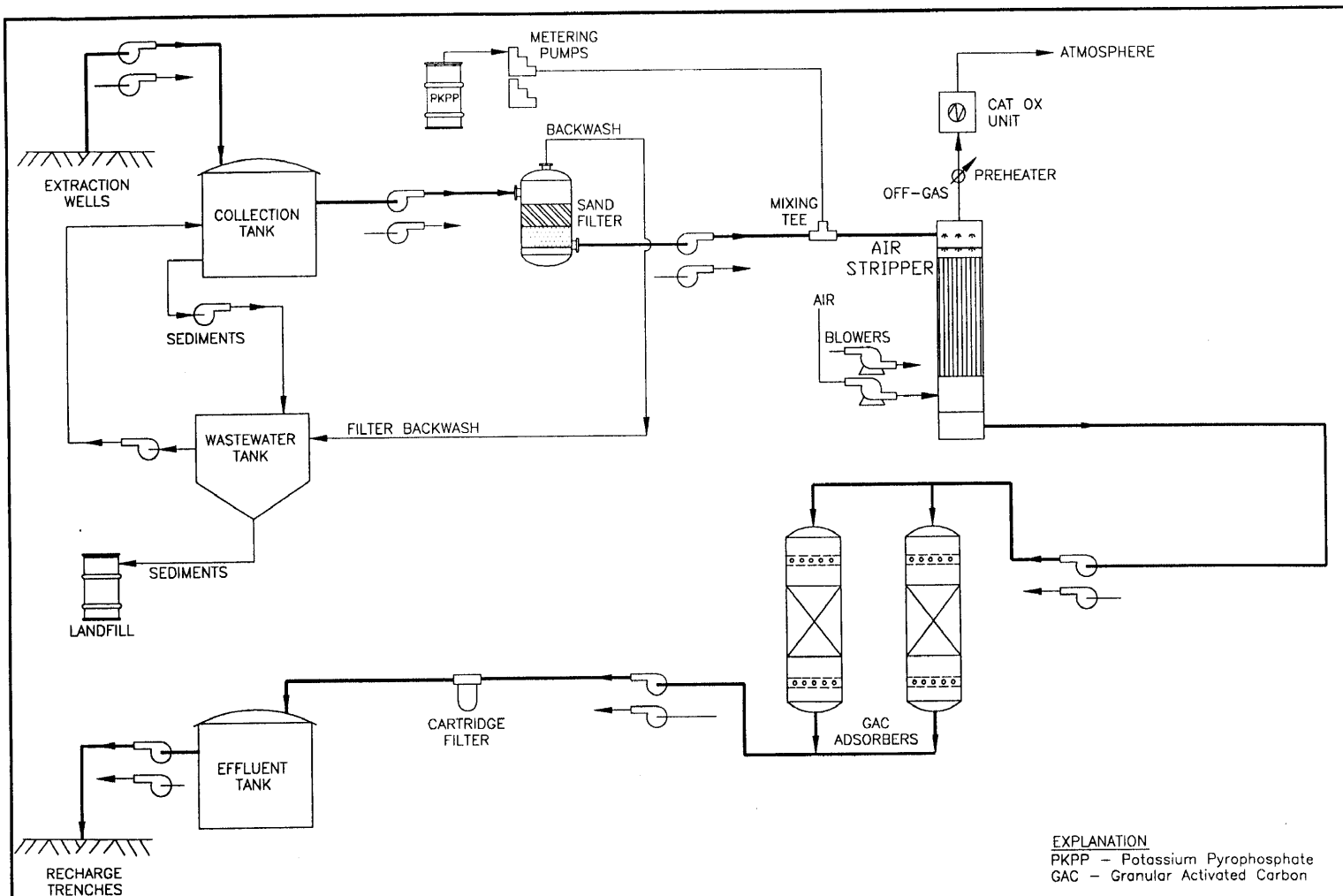


Not To Scale

Prepared for:
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FIGURE 8.8-1
Schematic for South Plants Plume Group
Control Alternative SPC-6

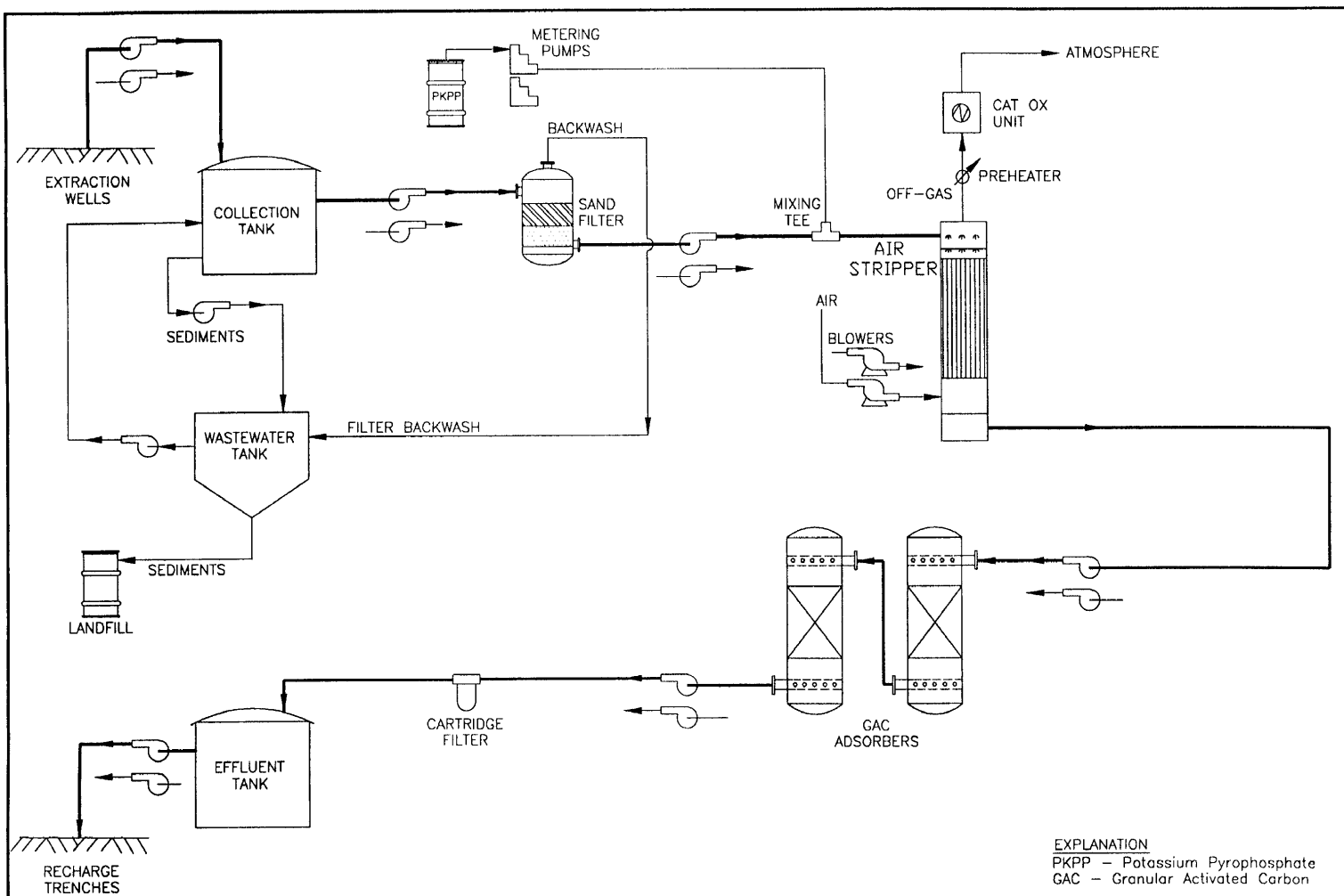
Prepared by:
Foster Wheeler Environmental Corporation



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FIGURE 8.8-2
Process Flow Diagram
Treatment Alternative SPT-6, SPT-7
Air Stripping/GAC Adsorption

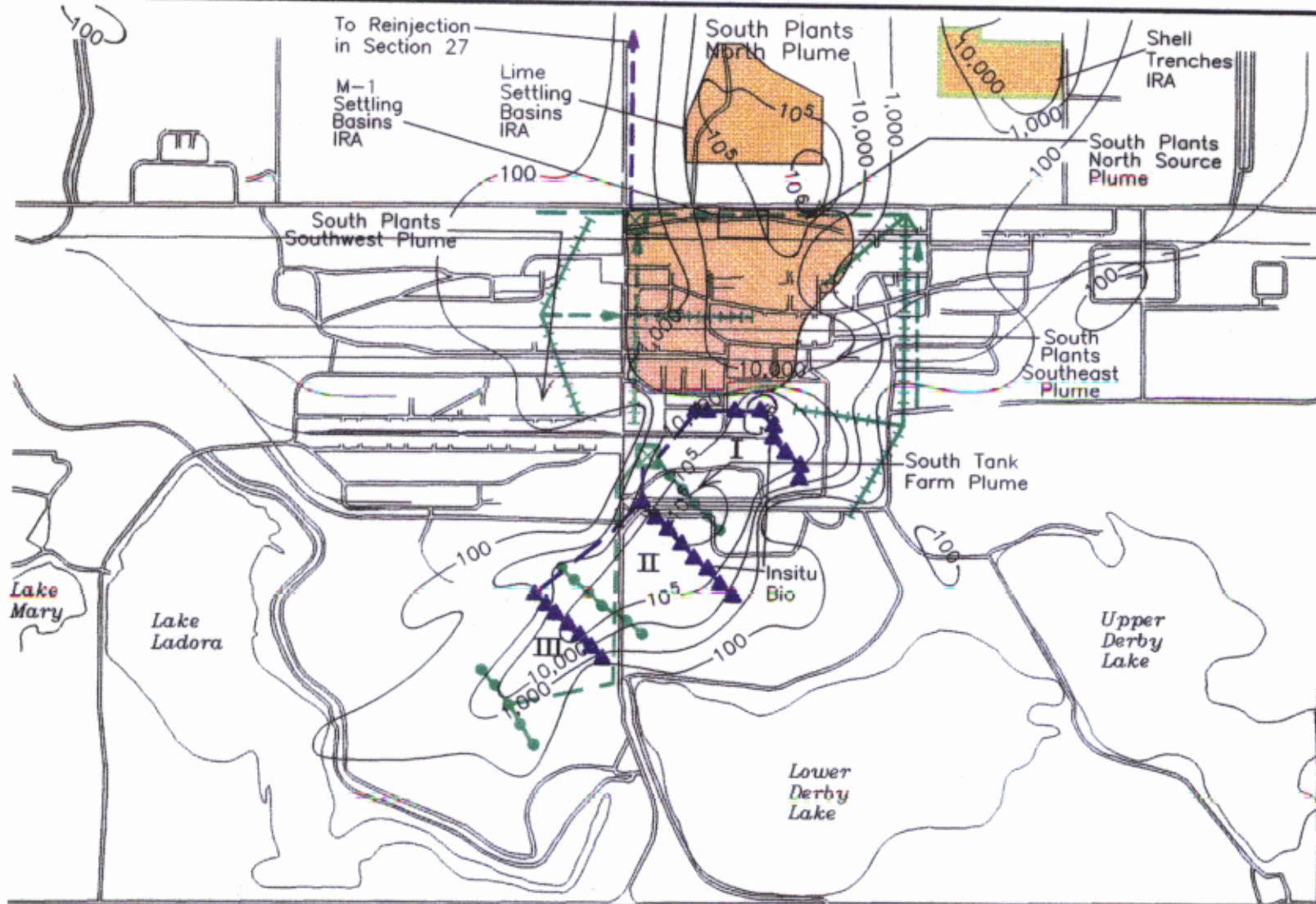
Prepared by:
Foster Wheeler Environmental Corporation



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FIGURE 8.9-1
 Process Flow Diagram
 Treatment Alternative SPT-8, SPT-7
 Air Stripping/GAC Adsorption

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 Foster Wheeler Environmental Corporation



LEGEND



Cap

100

Summed Concentration of organic analytes (Table 3.1-2) in unconfined aquifer (ug/L)



Extraction Well



Injection Well



Horizontal Extraction Well



Slurry Wall



Transport Pipe



Treatment Plant

I

Cell Number



Not To Scale

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for Rocky Mountain Arsenal

FIGURE 8.10-1
Schematic for South Plants Plume Group
Control Alternative SPC-7

Prepared by:
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Section 9

9.0 DEVELOPMENT AND SELECTION OF SITEWIDE ALTERNATIVES

9.1 COMBINATION OF PLUME GROUP ALTERNATIVES

This section describes how the alternatives retained for the individual plume groups in Sections 4 through 8 (listed in Table 9.1-1) are combined into sitewide alternatives for comparison and discusses the selection of one preferred groundwater sitewide alternative for RMA. On a sitewide basis, these alternatives were divided into the following four levels of groundwater control and treatment:

- Boundary System Control/Treatment—Alternative 1: Continued Operation of Existing Boundary Systems
- Boundary System/IRA Control/Treatment—Alternative 2: Continued Operation of Existing Boundary Systems and IRAs, Limited Deep Well Monitoring
- Additional On-Post Control/Treatment—Alternative 3: Continued Operation of Existing Boundary Systems and IRAs, On-Post Treatment, South Plants/Basin A Dewatering and Treatment, and South Tank Farm Plume In Situ Treatment, Limited Deep Well Monitoring
- Additional On-Post Control—Alternative 4: Continued Operation of Existing Boundary Systems and IRAs, On-Post Extraction from the Section 36 Bedrock Ridges, Deep Well Monitoring

These four sitewide alternatives under consideration are described and explained below.

9.2 DESCRIPTION OF ALTERNATIVES

Alternative 1 (Figure 9.2-1) involves continued operation of the three boundary systems (the NWBCS, NBCS, and ICS) and discontinuation of the existing IRAs (the Motor Pool, Rail yard, Basin F Groundwater, and Basin A Neck IRAs). Alternative 1 meets all necessary requirements by ensuring that no contaminants migrate beyond the RMA boundary. The present worth costs for all four sitewide alternatives are presented in Table 9.2-1. For all the sitewide alternatives presented in this document an on-post supply of water must be provided. An assessment of the specific water needs and costs is ongoing. For the purposes of this document, a water supply cost of \$15,000,000 has been added to each of the sitewide alternatives. The capital cost for Alternative 1, which includes demolition of the Basin A Neck IRA slurry wall and on-post water

supply, is \$15,000,000. The annual O&M costs are \$4,170,000 for the first 4 years and \$3,040,000 for the remaining years, and the present worth cost is \$80,000,000.

Alternative 2 (Figure 9.2-2) involves continued operation of all boundary systems and IRAs as they currently exist. This alternative ensures, through operation of the three boundary systems, that contaminants do not migrate off post. The two IRAs in the Western Plume Group accelerate the cleanup through source extraction in the Motor Pool and Rail Yard areas. The Basin F Groundwater IRA reduces contaminant migration to the North Boundary, and the Basin A Neck IRA treats contaminants migrating from Basin A, thereby accelerating the cleanup and reducing the contaminant loading on the NWBCS. The capital cost associated with Alternative 2 is due to the on-post water supply and comes to \$15,000,000. The annual O&M costs are \$5,180,000 for the first 4 years and \$3,950,000 for the remaining 26 years, and present worth cost is \$98,400,000.

Alternative 3 (Figure 9.2-3) includes all of the existing boundary and IRA control and treatment systems as well as capture and treatment in the Basin A and South Plants areas. Contaminant capture beneath Basin A and South Plants is accomplished through removal of groundwater to lower the water table to bedrock and results in dewatering the area. Extracted water is treated at a combined treatment plant in the northwest corner of Section 1, and the South Tank Farm Plume is treated with in situ biological treatment. Another consideration for these areas is that the planned soil remediation activities include installation of caps in both Basin A and in South Plants, which impacts the hydrology in these areas. In addition to removing groundwater for treatment, dewatering provides hydraulic control under the source areas where capping is planned. Dewatering prevents the groundwater from coming into contact with the more contaminated soils, thereby minimizing migration.

Alternative 3 uses the groundwater extraction systems that are included in groundwater control alternatives AC-8 and SPC-7 and are described in Sections 7.6 and 8.10, respectively. Horizontal wells are installed before the caps are in place, and the wells extend into the areas that will be

capped. Phase I of the extraction process lasts 10 years and consists of high pumping rates to lower the water table to the level of bedrock. Phase II begins in year 11, continues indefinitely, and consists of reduced pumping rates to maintain the water table at the level of bedrock. During Phase I, 60 gpm is extracted from Basin A and 20 gpm is extracted from South Plants for a combined flow of 80 gpm; during Phase II, 20 gpm is extracted from Basin A and 15 gpm is extracted from South Plants for a combined flow of 35 gpm. The extracted water is combined at the treatment plant prior to treatment. The influent concentration estimates for the combined flow are listed in Table 9.2-2 for Phase I and Table 9.2-3 for Phase II. Treated water is pumped to recharge trenches in Section 27, as described in Section 7.3.1 of this report.

In addition to the dewatering and treatment activities, in situ biodegradation is used to reduce the contaminant mass in the South Tank Farm Plume. This system is exactly the same as that described for Alternative SPT-5 in Section 8.7. The system consists of a series of extraction and injection wells, which are used to extract a portion of the water and then reinject it after oxygen and nutrients are added. This system operates for approximately 10 years and then some of the wells will be incorporated into the dewatering system in South Plants.

The capital cost of Alternative 3, including the additional systems and on-post water supply, is \$28,400,000. The annual O&M costs for years 1 through 4 are \$6,190,000, for years 5 through 10 are \$4,920,000, and for years 11 through 30 are \$4,630,000. The present worth cost is \$128,000,000.

Alternative 4 (Figure 9.2-4) includes continued operation of all the existing boundary systems and IRAs, addition of an extraction system for the Section 36 Bedrock Ridge Plume, and hydraulic control of the south lakes, and it is combined with extensive soil containment approaches. The boundary systems will operate as long as deemed necessary according to the criteria for shutting them down as defined in Section 1.3.3. The ICS has already reached an adequate cleanup level and is scheduled for shutdown after 4 more years of operation. The Rail Classification Yard and Motor Pool System will be shut off at the same time. The Basin A Neck System will continue

to operate under this alternative and provide treatment for the small additional flow generated by the Section 36 Bedrock Ridge Extraction System. Complete or partial shutdown of the system occurs when the criteria defined in Section 1.3.3 are met. This alternative also provides monitoring and, if necessary, hydraulic controls for the lakes to prevent negative impacts on biota in the lakes.

This alternative is implemented in conjunction with installation of soil caps in the Basin F area, South Plants, and Basin A as depicted in Figure 9.2-4. These caps provide an additional benefit for the water medium in terms of limiting infiltration and thereby lowering the water table over time so that contact between contaminated soil and water is minimized.

The capital cost for Alternative 4 is \$19,000,000 and the annual O&M costs are \$5,280,000 for years 1 through 4 and \$4,060,000 for years 6 through 30. The total present worth is \$105,000,000.

Alternatives 1, 2, 3, and 4 are all in compliance with the FFA and meet the RAOs.

9.3 SELECTION OF THE PREFERRED ALTERNATIVE

The selection of a preferred alternative for water is strongly dependent upon the alternatives selected for the soil and structures media in addition to the EPA criteria. The FFA (EPA et al. 1989) states that there should be no use of groundwater as drinking water on post. Therefore, all required treatment is accomplished through operation of boundary systems that ensure that any water leaving RMA meets off-post PRGs. Additional IRAs (Rail Classification Yard, Motor Pool, Basin F Groundwater and Basin A Neck) were either installed to speed up the cleanup of certain sources or to capture contamination to prevent it from reaching the boundary systems. The primary reason for considering additional on-post remedial alternatives for groundwater is the potential positive impact groundwater action can have on the overall sitewide remedial solution. Table 9.3-1 summarizes a comparative analysis of sitewide water alternatives.

All four sitewide alternatives being considered are protective of human health as long as PRGs are met and because of FFA restrictions on future use of groundwater on post.

Alternative 3 is the most protective of the environment because it removes the largest mass of contaminants from the environment and also minimizes migration of contaminants from soil in the most contaminated area. Alternative 4 is slightly more protective than Alternative 2, which is somewhat more protective than Alternative 1. All alternatives are in compliance with applicable ARARs with the exceptions made for NDMA, chloride, and sulfate as described in Section 6.

All four sitewide alternatives reduce the risk for off-post exposure by achieving PRGs at the boundary. Alternative 3 is more effective than the other three in that it reduces contact between contaminated soil and groundwater and treats contaminants closer to the source. Alternative 4, which includes a capture system in the Section 36 Bedrock Ridge Plume, is somewhat more protective than Alternative 2. Alternative 2, which involves source interception at the IRA locations, is slightly more effective than Alternative 1 in that it provides additional capture closer to on-post sources.

Alternative 3 provides significantly higher TMV reduction than Alternatives 1 and 2 because it reduces contact between contaminated soil and groundwater, removes a large volume of water and a correspondingly large mass of contaminants from the most contaminated plumes, and significantly limits migration of contaminants through the aquifer. Alternative 4 provides a slightly higher TMV reduction than Alternative 2 due to the Section 36 Bedrock Ridge Plume Extraction System. Alternative 2 reduces TMV more than Alternative 1 due to the on-post IRAs.

Alternative 2 is the most protective of workers because all systems operating under this alternative are currently in place and because it has the least negative impact on the environment. Alternative 3, being the most intrusive, is the least protective of workers and has the most short-

term impacts on the environment; however, it does not pose any hazard. Alternatives 1 and 4 pose low but similar impacts due to the respective addition or destruction of systems. All alternatives achieve RAOs.

Alternative 2, which is already in place, is the most easily implemented alternative, and Alternatives 1 and 4 are slightly more difficult to implement than Alternative 2 due to the additional activities. Alternative 3 is the most difficult to implement because it involves fairly large extraction and treatment systems, which include innovative technologies such as horizontal wells and in situ biological treatment. Alternative 3 is significantly more costly than the other three alternatives due to the added on-post systems.

The soil medium is the driving medium for RMA remediation; therefore, the selected sitewide soil alternative is the most important deciding factor in the selection of a preferred alternative for water aside from the requirement to meet off-post PRGs at the RMA boundary. The sitewide soil alternative involves construction of caps in Basin A and in the South Plants area to contain the contaminated soil and prevent infiltration. Because the contaminated soil is left in place, it is important that groundwater does not act as a migration pathway and that hydraulic control is maintained. Alternative 3 accomplishes this in the short term through active dewatering of the capped areas, which minimizes contact between contaminated soil and groundwater. However, the soil alternative involving large capped areas, in Basin A and South Plants, which will be implemented in conjunction with Alternative 4, leads to a significant lowering of the water table and reduced potential for migration of contaminants in the long term. Alternative 3 is more effective than Alternative 4 (in conjunction with soil capping) in preventing migration but is significantly more expensive. Alternative 3 is significantly more effective than Alternatives 1 and 2 in preventing horizontal and vertical migration and in removing and treating a substantial amount of the contamination that has already migrated into groundwater. This alternative is the most protective of the on-post environment and ensures reduction in TMV for both the groundwater and the soil media. However, Alternative 3 is significantly more expensive than either of the other three alternatives. Alternative 4, in conjunction with the selected soil capping

alternative, limits contact between contaminated soil and groundwater through lowering of the water table. It does not involve a controlled action to reverse gradients but includes extensive monitoring to identify any contaminant migration that might occur in the deeper aquifer and the lakes. It is much more easily implemented than Alternative 3 at a much lower cost.

Alternative 4 is the selected alternative for groundwater. The preferred sitewide alternative selected in conjunction with the preferred soil remedy was designed and selected based on currently available information about site conditions. It was determined that Alternative 3, after considering proposed soil actions and the continuing operation of boundary systems, provides limited added benefit at a higher cost.

Table 9.1-1 Summary of Sitewide Alternatives

Page 1 of 1

Plume Group	Selected Plume Group Alternative	Sitewide Alternatives			
		Alt. 1	Alt. 2	Alt. 3	Alt. 4
Northwest Boundary	<u>NWC-2</u> : Continued Operation of NWBCS	X	X	X	X
Western	<u>WC-2</u> : Continued Operation of ICS and IRAs		X	X	X
	<u>WC-2A</u> : Continued Operation of ICS Only	X			
North Boundary	<u>NC-2</u> : Continued Operation of NBCS and IRA		X	X	X
	<u>NC-2A</u> : Continued Operation of NBCS Only	X			
Basin A	<u>AC-1</u> : No Action	X			
	<u>AC-2</u> : Continued Operation of IRA		X		
	<u>AC-8/AT-2</u> : Dewatering and Treatment			X	
	<u>AC-9/AT-2</u> : Bedrock Ridge Treatment at Basin A Neck				X
South Plants	<u>SPC-1</u> : No Action	X	X		
	<u>SPC-2</u> : Monitoring, South Lakes Control				X
	<u>SPC-7/SPT-2/SPT-5</u> : Dewatering and Treatment; Mass Reduction by In Situ Biotreatment			X	

NWBCS - Northwest Boundary Containment System
 ICS - Irondale Containment System
 NBCS - North Boundary Containment System
 IRA - Interim Remedial Action

Table 9.2-1 Cost Summary for Sitewide Alternatives for Groundwater

Page 1 of 1

Plume Group	Alternative 1 ¹		Alternative 2 ²		Alternative 3 ¹		Alternative 4 ⁴	
	<u>1995 \$</u>	<u>Present Worth</u>	<u>1995 \$</u>	<u>Present Worth</u>	<u>1995 \$</u>	<u>Present Worth</u>	<u>1995 \$</u>	<u>Present Worth</u>
Northwest Boundary	33,000,000	22,000,000	33,000,000	22,000,000	33,000,000	22,000,000	33,000,000	22,000,000
Western	5,900,000	4,900,000	5,900,000	4,900,000	5,900,000	4,900,000	5,900,000	4,900,000
North Boundary	51,000,000	34,000,000	52,000,000	34,000,000	52,000,000	34,000,000	52,000,000	34,000,000
Basin A	3,300,000	2,400,000	31,000,000	21,000,000	48,000,000	35,000,000	33,000,000	23,000,000
South Plants	3,300,000	2,300,000	3,300,000	2,300,000	26,000,000	20,000,000	7,500,000	5,200,000
On-Post Water Supply	15,000,000	15,000,000	15,000,000	15,000,000	15,000,000	15,000,000	15,000,000	15,000,000
Total	111,000,000 ⁵	80,000,000 ⁵	139,000,000 ⁵	98,000,000 ⁵	175,000,000 ⁶	128,000,000 ⁶	146,000,000	105,000,000 ⁵

1 Alternative 1: Continued operation of boundary systems

2 Alternative 2: Continued operation of boundary systems and IRAs

3 Alternative 3: Continued operation of boundary systems and IRAs, dewatering/treatment in Basin A, and dewatering/treatment and in situ biotreatment of South Plants

4 Alternative 4: Continued operation of boundary systems and IRAs, extraction, Section 36 Bedrock Ridge

5 This number appears low due to rounding

6 This number was rounded down to reflect cost savings from combining Basin A and South Plants groundwater treatment

Table 9.2-2 Basin A and South Plants Dewatering SP-7, Phase I

Page 1 of 1

Chemical Group/Compound	Estimated Influent Concentration (µg/l)
Volatile Halogenated Organic Compound (VHOs)	
Carbon tetrachloride	7.8
Chloroform	440
Methylene chloride	77
Tetrachloroethylene	11
Volatile Hydrocarbon Compounds (VHCs)	
Dicyclopentadiene (DCPD)	24
Volatile Aromatic Organic Compounds (VAOs)	
Benzene	3,900
Organosulfur Compounds, Mustard Agent Related (OSCMs)	
Dithiane	30
Organosulfur Compounds, Herbicide Related (OSCHs)	
Chlorophenylmethyl sulfoxide	8.3
Organophosphorous Compounds, GB-Agent Related (OPHGBs)	
Diisopropylmethyl phosphonate (DIMP)	66
Organophosphorus Compounds, Pesticide Related (OPHPs)	
Atrazine	27
Dibromochloropropane	
Dibromochloropropane (DBCP)	8.3
Organochlorine Pesticides (OCPs)	
Chlordane	0.36
Dieldrin	0.25
Hydrazine-Related Compounds	
N-nitrosodimethylamine (NDMA)	0.085
Arsenic	
Arsenic	16

Table 9.2-3 Basin A and South Plants Dewatering SPC-7, Phase II

Page 1 of 1

Chemical Group/Compound	Estimated Influent Concentration (µg/l)
Volatile Halogenated Organic Compound (VHOs)	
Carbon tetrachloride	11
Chloroform	590
Methylene chloride	61
Trichloroethylene	21
Volatile Hydrocarbon Compounds (VHCs)	
Dicyclopentadiene (DCPD)	29
Volatile Aromatic Organic Compounds (VAOs)	
Benzene	6,600
Organosulfur Compounds, Mustard Agent Related (OSCMs)	
Dithiane	28
Organosulfur Compounds, Herbicide Related (OSCHs)	
Chlorophenylmethyl sulfoxide	6.9
Organophosphorous Compounds, GB-Agent Related (OPHGBs)	
Diisopropylmethyl phosphonate (DIMP)	51
Organophosphorus Compounds, Pesticide Related (OPHPs)	
Atrazine	21
Dibromochloropropane	
Dibromochloropropane (DBCP)	6.6
Organochlorine Pesticides (OCPs)	
Chlordane	0.30
Dieldrin	0.21
Hydrazine-Related Compounds	
N-nitrosodimethylamine (NDMA)	0.14
Arsenic	
Arsenic	13

Table 9.3-1 Comparative Analysis of Sitewide Water Alternatives

Page 1 of 2

Criteria	Alternative 1: Continued Operation of Existing Boundary Systems	Alternative 2: Continued Operation of Existing Boundary Systems and IRAs	Alternative 3: Continued Operation of Existing Boundary Systems and IRAs	Alternative 4: Combined Operation of Existing Boundary Systems and IRAs, On-Post Extraction from Section 36 Bedrock Ridges, Deep Well Monitoring
Protection of Human Health and the Environment	<i>Protective.</i> Provides protection through operation of boundary systems.	<i>Protective.</i> Provides protection through operation of boundary systems and limits on-post migration through operation of IRAs.	<i>Protective.</i> Provides protection through boundary systems and minimizes on-post migration through operation of IRAs and additional on-post systems.	<i>Protective.</i> Provides protection through boundary systems and minimizes on-post migration through operation of IRAs and additional on-post systems.
Compliance with ARARs	<i>Complies</i> with action-, chemical-, and location-specific ARARs.	<i>Complies</i> with action-, chemical-, and location-specific ARARs.	<i>Complies</i> with action-, chemical-, and location-specific ARARs.	<i>Complies</i> with action-, chemical-, and location-specific ARARs.
Long-Term Effectiveness and Permanence	<i>Low residual risk.</i> Potential for off-post exposure is lowered. Long-term monitoring required; contaminant migration reduced through natural dewatering.	<i>Low residual risk.</i> Potential for off-post exposure is lowered. Long-term monitoring required; contaminant migration reduced through IRAs, source capture, and natural dewatering.	<i>Low residual risk.</i> Potential for off-post exposure is lowered. Long-term monitoring required; contaminant migration reduced through IRAs, source capture, and natural dewatering.	<i>Low residual risk.</i> Potential for off-post exposure is lowered. Long-term monitoring required; contaminant migration reduced through IRAs, source capture, and natural dewatering.
Reduction of Toxicity, Mobility, or Volume	<i>Reduced.</i> Contaminants removed by GAC adsorption, reducing toxicity and volume.	<i>Reduced.</i> Contaminants removed by GAC adsorption and air stripping, reducing toxicity and volume; source capture at Basin A Neck and natural dewatering limit migration.	<i>Reduced.</i> Contaminants removed by GAC adsorption and air stripping, reducing toxicity and volume; dewatering and source capture significantly limit migration and mobility.	<i>Reduced.</i> Contaminants removed by GAC adsorption and air stripping, reducing toxicity and volume; source capture and natural dewatering limit mobility.
Short-Term Effectiveness	<i>Effective.</i> Minimal negative impact; achieves RAOs.	<i>Effective.</i> No additional impact associated with continued operation; achieves RAOs.	<i>Effective.</i> Minimal negative impact associated with installation of dewatering system; achieves RAOs.	<i>Effective.</i> Minimal negative impact associated with installation of extraction system.

Table 9.3-1 Comparative Analysis of Sitewide Water Alternatives

Criteria	Alternative 1: Continued Operation of Existing Boundary Systems	Alternative 2: Continued Operation of Existing Boundary Systems and IRAs	Alternative 3: Continued Operation of Existing Boundary Systems and IRAs	Alternative 4: Combined Operation of Existing Boundary Systems and IRAs, On-Post Extraction from Section 36 Bedrock Ridges, Deep Well Monitoring
Implementability	<i>Technically and administratively feasible.</i>	<i>Technically and administratively feasible.</i>	<i>Technically and administratively feasible.</i> Dewatering involves innovative horizontal wells; treatment by proven technologies except for in situ biological treatment in South Plants.	<i>Technically and administratively feasible.</i> Extraction by innovative horizontal wells.
Cost	\$80,000,000	\$98,000,000	\$128,000,000	\$105,000,000
Conclusion	<i>Not selected.</i> Meets evaluation criteria but provides less protection than other alternatives.	<i>Not selected.</i> Meets evaluation criteria but does not provide additional control and protection beyond what is currently in place.	<i>Not selected.</i> Meets evaluation criteria and provides additional on-post controls but at significantly higher cost than other alternatives.	<i>Selected.</i> Meets evaluation criteria and is consistent with soil remedial alternative; provides additional on-post controls with minimal added cost.



LEGEND

- **Boundary Systems**
- **Treatment Systems**
- **Summed Concentration of Organic Analytes in Unconfined Aquifer 100ug/l Contour Limit**



0 3000
Scale in Feet

Prepared for:
Office of the Program Manager
for Rocky Mountain Arsenal

FIGURE 9.2-1

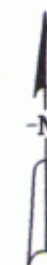
Alternative 1: Continued Operation of
Existing Boundary Systems

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Foster Wheeler Environmental Corporation



LEGEND

- Boundary Systems
- Treatment Systems
- Existing IRAs
- Summed Concentration of Organic Analytes in Unconfined Aquifer 100ug/l Contour Limit



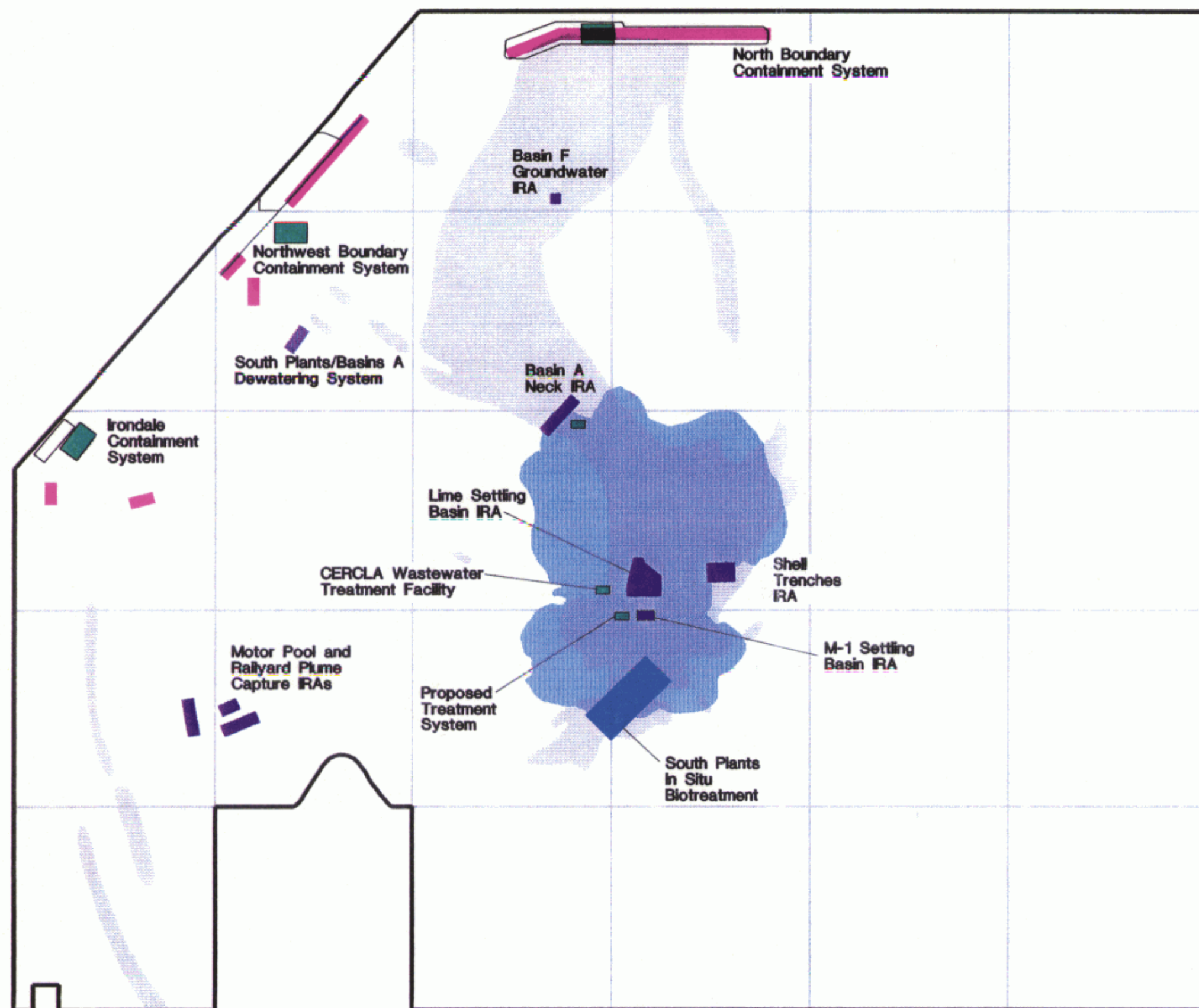
0 3000
Scale in Feet

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FIGURE 9.2-2

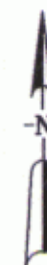
Alternative 2: Continued Operation of
Existing Boundary Systems and IRAs

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Foster Wheeler Environmental Corporation



LEGEND

- Boundary System
- Treatment System
- Existing IRA
- Area Affected by the South Plants/Basin A Dewatering Systems
- South Plants In Situ Biotreatment Systems
- South Plants Basin A Recharge System
- Summed Concentration of Organic Analytes in Unconfined Aquifer 100ug/l Contour Limit



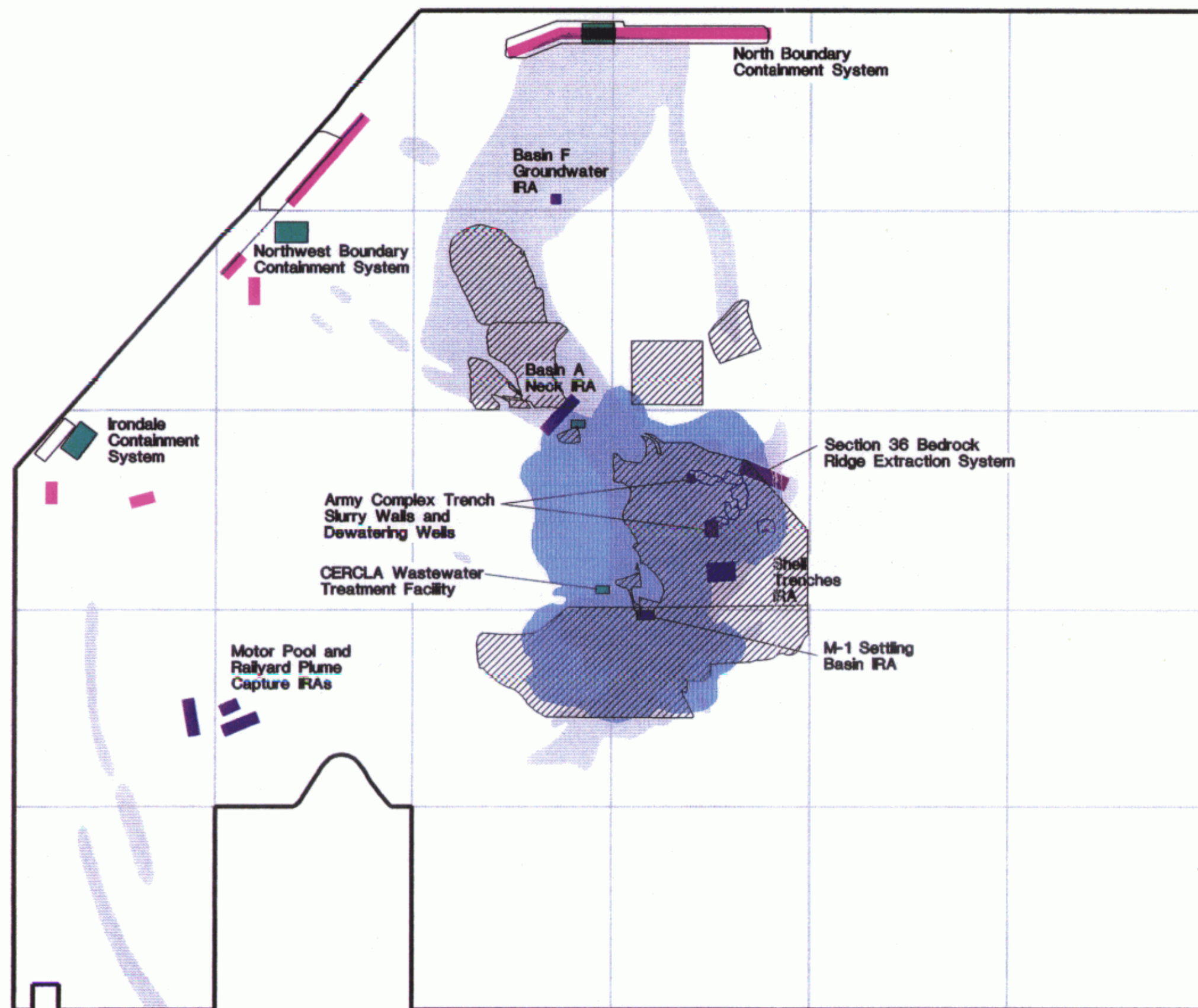
0 3000
Scale in Feet

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for Rocky Mountain Arsenal

FIGURE 9.2-3

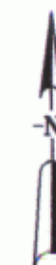
Alternative 3: Continued Operation of Existing
Boundary Systems and IRAs and Capture/
Treatment in Basin A and South Plants

Prepared by:
Foster Wheeler Environmental Corporation



LEGEND

- Boundary System**
- Treatment System**
- Existing IRA**
- Area Affected by the South Plants/Basin A**
- Summed Concentration of Organic Analytes in Unconfined Aquifer 100ug/l Contour Limit**
- Slurry Wall**
- Groundwater Extraction Well**
- Capped Area**



0 3000
Scale in Feet

Prepared for:
Office of the Program Manager
for Rocky Mountain Arsenal

FIGURE 9.2-4

Alternative 4: Continued Operation of Existing
Boundary Systems and IRAs and Extraction from
Section 36 Bedrock Ridge

Prepared by:
Foster Wheeler Environmental Corporation

Section 10

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Appendix A

APPENDIX A
COST ESTIMATES

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A1.0 INTRODUCTION

This appendix contains the cost estimates for the alternatives evaluated in the Detailed Analysis of Alternatives (DAA) for the Northwest Boundary, Western, North Boundary, Basin A, South Plants Plume Groups, and the combined sitewide alternatives in the water medium.

Cost estimates for each of the groundwater alternatives were developed from the bottom up using a series of linked spreadsheets. After the Draft Final DAA was released (July 1993) (EBASCO) two commercially available cost estimating programs were obtained in order to perform an independent check on the DAA costing, and to evaluate whether other cost estimating systems give more usable or more reliable results. These programs are MCACES (MicroComputer Aided Cost Engineering Support System), which was developed by Building Systems Design Co. for the Corps of Engineers and can be linked to the Primavera scheduling system, and RACER (Remedial Action Cost Engineering and Requirements system), which was developed by Delta Research Corp. for the USAF.

For water, the Draft Final DAA preferred alternative was costed in RACER and compared to the DAA costing spreadsheets. A comparison showed that the total RACER costs for the Basin A/South Plants extraction and treatment system were 4 percent lower than the Draft Final DAA (EBASCO 1993) estimate. Individual line item costs varied by up to 43 percent, but only 6 of 15 independently estimated line item costs varied by more than 20 percent. Alternatives were not costed (bottom up) in MCACES because MCACES is designed more for large earth moving projects than for water pump-and-treat systems.

The comparison showed that RACER provides a useful check on the DAA cost spreadsheet estimates; however, the alternative-specific spreadsheets provide more detail and are compatible with the Primavera scheduling system. It was decided that the three site-wide alternatives being developed for water would be costed using the DAA cost spreadsheets. These costs would then be imported into MCACES/Primavera for overall RMA remediation cost and schedule comparisons.

The cost estimates for alternatives developed for the Northwest Boundary Plume Group are presented in Tables A1-1 and A1-2, those for the Western Plume Group in Tables A2-1 through A2-2A, those for the North Boundary Plume Group in Tables A3-1 through A3-6, those for the Basin A Plume Group in Tables A4-1 through A4-8, those for the South Plants Plume Group in Tables A5-1 through A5-11, and those for the combined sitewide alternatives in Tables A6-1 through A6-4

The following sections explain the format of the cost estimate tables and discuss the methodology used to develop the unit rates and indirect cost factors appearing in the tables.

A2.0 COST ESTIMATE TABLES

The cost estimates presented in the tables of this appendix detail the following four cost categories:

- Direct Capital Costs
- Indirect Capital Costs
- Direct Operations and Maintenance Costs
- Indirect Operations and Maintenance Costs

Capital costs are those costs incurred to purchase and install the control and treatment systems (e.g., the purchase of an air stripping unit). Operations and Maintenance (O&M) costs are those incurred to actually extract and treat the groundwater (e.g., the operation and maintenance of the air stripper).

Direct costs include costs to purchase, build, and operate equipment at the site. Indirect costs include the following:

- Mobilization and demobilization
- Indirects, overhead, and profit
- Engineering design
- Resident engineering
- Contingency

The headings across the top of each cost estimate are explained as follows:

Cost Item: Represents a unit operation and its associated direct cost.

Cost Type: Represents the cost incurred: "LS" for lump sum for a unit operation that occurs in only year 1, or "A" for annual cost for a unit operation that occurs in only year 1.

Start Year: Represents the starting year for the unit operation. Cardinal numbers are used to specify the calendar year with year 1 representing 1995.

End Year: Represents the ending year for the unit operation. Note that no ending year is specified for the lump sum cost type. Cardinal numbers are used to specify the calendar year with year 1 representing 1995.

Unit Cost: Represents unit cost for the particular unit operation in 1995 dollars.

Units: Represents units associated with the 1995 (\$) unit cost. Each unit begins with a slash (/), indicating the units are in the denominator of the 1995 (\$) Unit Cost and Units pair.

Quantity: Represents quantity of each unit.

Units: Represents units associated with the Quantity.

1995 (\$)

Annual Cost: Represents the annual costs for the O&M portion of the cost estimates for the time period indicated (e.g., YR 1-10, YR 11-30)

1995 (\$)

Total Cost: Represents total cost in 1995 dollars, which is calculated by multiplying these factors as follows:

- 5(\$ Unit Cost
- Quantity

1995 (\$)

PW Cost: Represents present worth cost in 1995 dollars, which is calculated by applying the appropriate fraction of the 1995 (\$) Total Cost to the specified years, then discounting the applied value at each year back to Year 1 1995 (\$) using a 4.5 percent discount rate.

Explanations for calculations for all subtotals and all indirect costs are given on the estimate tables in the form of alphabetical references to computed values. It should be noted, these cost estimates are structured solely to represent a comparative cost between site-wide alternatives and not as stand alone estimates. Caution should be exercised in comparing individual alternative costs such as design; resident engineering; and indirects, overhead and profit since these costs represent only a comparative percentage of any one individual alternative. Prior to implementation of the preferred alternatives developed in this document it will be necessary to re-evaluate the total estimated cost to provide a more detailed cost assessment.

A3.0 UNIT RATE DEVELOPMENT

A3.1 NO ACTION

No Action line item costs include the plume evaluation monitoring and slurry wall demolition.

A3.1.1 Plume Evaluation Monitoring

Costs for plume evaluation monitoring include the disposal of purge water and the analysis of groundwater samples (including quality assurance/quality control (QA/QC) samples).

A3.1.2 Slurry Wall Demolition

Since the trenches used to demolish the slurry wall are similar in design to reinjection trenches (i.e., 10 ft long with a depth to the base of the slurry wall), the same unit cost per square foot for installation cost is used. Approximately nine trenches are to be constructed through the North Boundary Containment System (NBCS) and approximately four through the Northwest Boundary Containment System (NWBCS) and Basin A Neck Interim Response Action (IRA) slurry walls each.

A3.2 CONTINUED OPERATION OF EXISTING SYSTEMS

Costs associated with operation of the existing boundary systems and groundwater IRAs are included as separate line items. These costs were obtained from PMRMA and include costs for basic O&M, special projects, analytical, technical support, carbon, utilities, and other (not plant specific). The costs range from \$355,857 annually for the continued operation of the Irondale Control System (ICS) with the IRAs to \$840,905 annually for the NBCS.

A3.3 MONITORING

Monitoring line item costs include performance monitoring of the extraction and reinjection systems and plume evaluation monitoring and process monitoring of the treatment system. Monitoring is calculated as annual O&M costs.

A3.3.1 Performance Monitoring Well Installation

Costs for performance monitoring well installation include materials, drill rig, labor for an operator and helper, and mobilization/demobilization. Additional costs include labor for a decontamination technician, geologist, and health and safety technician, personal protective equipment (PPE) for drilling and well development personnel, and waste handling.

Well installation was assumed to be completed in Level C protection and to require approximately 12 hours (hrs)/well. Well development requires a geologist and health and safety technician and takes approximately 4 hrs/well.

PPE costs cover a four-man crew for drilling operations and a two-man crew for well development, including monitoring equipment.

Waste-handling costs include Toxicity Characteristic Leaching Procedure (TCLP) analysis for each well and disposal of six drums containing well cuttings and development water.

For costing purposes, well installation for Basin A was assumed to require Level B protection. This requires additional health and safety monitoring equipment and personnel, and increases by 25 percent the per-foot rate for drilling and hours required for well installation and development. Well installation in all other areas was assumed to be in Level C. This is for costing only and work in Level B installation may occur in other areas besides Basin A, but it was assumed the higher percentage of work is conducted be in Level C. The actual level of protection is determined in the workplace prior to performance of work.

A3.3.2 Plume Monitoring

The number of monitoring wells proposed reflects estimates made strictly for costing purposes. The actual number of monitoring wells required will be determined during the design phase. In addition, the initial number of monitoring wells sampled during system operation may decrease over time depending on system performance.

Plume monitoring includes only the wells that are used specifically to monitor the performance of extraction and reinjection systems. The number of wells varies depending on the alternative. Costs for performance well monitoring were derived by estimating the number of wells required for adequate evaluation of system performance. These wells were assumed to be sampled quarterly for 5 years for target analytes and annually for 25 years for full-suite analysis. Quality assurance/quality control (QA/QC) sampling includes an additional 30 percent of the total number of samples taken and includes trip blanks, rinse blanks, and duplicates. Additional costs include labor, transportation, handling, and disposal. It was assumed that three well purge volumes per well require three drums for disposal. The number of years required for monitoring varies depending on system performance.

Deep well monitoring costs were derived by assuming 20 wells are monitored annually for 5 years and once every 5 years for the next 25 years. These wells are divided on a percentage basis between Alternatives NC-2, AC-9, and SPC-2. Costs include sampling and purge water disposal, including 30 percent additional samples for QA/QC purposes. Purge water disposal costs include labor, transportation, handling, disposal, and drum purchase. The actual number of monitoring wells needed will be specified in the work plan for the monitoring program.

A3.3.3 Process Monitoring

The Process Monitoring line item includes the costs of monitoring the treatment plant influent and effluent streams to ensure proper operation of the treatment system.

Process monitoring includes the costs to analyze different contaminants. The contaminants that are to be monitored were determined on the basis of Target Effluent Concentration (TEC) exceedances. The total cost per sampling event is the sum of the analytical costs, sample containers, and shipping.

Process monitoring includes one influent and one effluent sample per week. In the case of in situ biodegradation, where no treatment takes place aboveground, only one sample is collected per

week. Labor is included in this line item as operation and supervisory labor. The operator requires 1 hr/week to complete the sampling required. Supervisory labor is included at 130 percent of the operator's wages and 15 percent of the operator's time. The supervisor's functions consist of overseeing the sampling and preparing the report.

A3.4 CONTROL SYSTEM INSTALLATION

Control system installation costs include extraction well and pump installation, reinjection pipe and system installation, and recharge trench installation.

Extraction and reinjection pipe costs include controls and system hookups.

Extraction and reinjection wells are of similar design in that both are constructed of 6-inch Schedule 40 polyvinyl chloride (PVC) and placed in a 12-inch borehole to enhance water flow to and from the well.

A3.4.1 Extraction Wells and Pump Installation

Costs for vertical extraction well installation include materials, drill rig, labor for an operator and helper, and mobilization/demobilization. Additional costs include labor for a decontamination technician, geologist, and health and safety technician, PPE for drilling and well development, waste handling, pump installation, and geotechnical analysis.

Vertical well installation was assumed to be in Level C protection and to require approximately 12 hrs/well. Well development requires a geologist and health and safety technician for approximately 4 hrs/well.

PPE costs for vertical extraction wells cover a four-man crew for drilling operations and a two-man crew for well development, including monitoring equipment.

Waste-handling costs for vertical extraction wells include TCLP analysis for each well and disposal of six drums containing well cuttings and development water.

Costs for horizontal extraction well installation include materials, drill rig, labor for an operator and helper, and mobilization/demobilization. Additional costs include labor for a decontamination technician, geologist, and health and safety technician, PPE for drilling and well development, waste handling, pump installation, and geotechnical analysis.

Horizontal well installation was assumed to be in Level C protection and proceed at a rate of 500 ft/day. Well development requires a geologist and health and safety technician for approximately 12 hrs/well.

PPE costs for horizontal well installation cover a four-man crew for drilling operations and a two-man crew for well development, including monitoring equipment.

Waste-handling costs for horizontal well installation include TCLP analysis for each well and disposal of well cuttings and development water.

Pump installation costs include a one-third-horsepower pump with teflon seals. The material and labor costs for the installation of these pumps are included in the cost of the extraction system installation.

Geotechnical analysis includes two samples per well for permeability testing, sieve analysis (using a 200-micron sieve), and a hydrometer test.

For costing purposes, well installation for Basin A was assumed to require Level B protection. This requires additional health and safety monitoring equipment and personnel, and increases by 25 percent the per-foot rate for drilling and hours required for well installation and development.

Well installation in all other areas was assumed to be in Level C. This is for costing only, and work in Level B may occur in other areas besides Basin A, but it was assumed the higher percentage of work is performed in Level C. The actual level of protection is determined in the work plan prior to performance of work.

Costs for extraction pipe and system installation include labor and materials for extraction and booster pump installation including controls and power line, pipe installation, and PPE for pipe burial.

Extraction pump installation costs include the labor costs for one electrician, trenching for conduit burial, controls, collection tanks, and the hookup and installation of a submersible pump for each well. It was assumed that installation of each pump requires an average of 4 hours.

Booster system costs include the purchase of two 1.5 horsepower pumps. One pump is used as a backup should repairs be required to the primary pump. Materials for booster system installation were assumed to be 15 percent of the total extraction pipe and system installation. Labor costs for booster pump installation include one electrician for 4 hrs per pump.

The cost for power line installation, including materials and labor, is included. Pipe materials and installation costs include a 2-inch carrier pipe inside a 3-inch containment pipe. The unit cost for piping installation in Basin A, Basins C and F, and South Plants areas were increased to cover PPE requirements.

A3.4.2 Reinjection Pipe and System Installation

Costs for Injection Well Installation line items are identical to the costs for extraction wells, excluding pump installation and geotechnical analysis.

Costs for reinjection pipe and system installation include labor and materials for booster pump installation, including controls and pipe installation.

Booster system costs include the purchase of two 1.5-horsepower pumps. One pump is to be used as a backup should repairs be required to the primary pump. Materials for booster system installation were assumed to be 15 percent of the total reinjection pipe and system installation. Labor costs for booster pump installation include one electrician for 4 hrs per pump.

Pipe materials and installation costs include 2-inch Schedule 40 PVC pipe. The unit cost for installation of the pipe, pumps, and controls is increased by a factor of 25 percent for Basin A since this area is more highly contaminated.

A3.4.3 Recharge Trench Installation

The costs for recharge trench installation include mobilization/demobilization and materials and labor. The costs for excavation, burial, bioslurry, gravel pack, geotextile, perforated pipe for injection and monitoring, and labor are included in the unit cost per square foot.

A3.5 WELL PUMP OPERATIONS AND MAINTENANCE

The well pump operations and maintenance costs include well and pump operations and maintenance and repair.

A3.5.1 Well and Pump Operations

Well and Pump Operations line item costs include the utility costs for operation of booster and submersible pumps. The pumps were assumed to operate 24 hrs/day for 330 days/yr.

A3.5.2 Maintenance and Repair

Maintenance and Repair line item costs include labor, well cleaning, pump replacement, and maintenance vehicle. Costs for labor are derived by assuming that one person is able to perform the required periodic checks and adjustments in 2 hrs/day or 520 hrs/year(yr). Well cleaning

costs include yearly backflushing of the sand pack, additives for limiting biological growth, sediment removal from the sand trap, and brushing of the casing. Pump replacement for each well is expected to take place every 5 years. The project vehicle costs include 65 days/yr/system.

A3.6 CLAY/SOIL CAP

The unit cost for capping is being estimated as part of the development of alternatives for the soils medium and is detailed in the soils DAA.

A3.7 TREATMENT

A3.7.1 Treatment Facility

The Treatment Facility line item involves the costs of constructing the building that houses the process equipment, utility connections, electricity for the office, site and road preparation materials, and personnel to maintain the facility once it is constructed.

The building costs are based on estimated square footage required for a given treatment system, including secondary containment for tanks. The costs include the prefabricated building and concrete foundation.

Electrical connection costs include the cost of power lines and transformers. Other utility connections, such as water and sewer, are approximately equivalent to 100 percent of the power line and transformer costs. Office electricity includes the costs of electricity to maintain normal office functions such as lighting. The site preparation and road costs are based on an assumed requirement of 100 ft of road per treatment facility. Labor for the facility includes routine maintenance on the building and utilities at 2 hrs/week.

A3.7.2 Tanks, Filters, and Pumps

The Collection System line item includes the cost of all tanks and pads, pumps, filters, and labor to operate and maintain the equipment.

Influent tanks are sized based on an 8-hour holding time and effluent tanks are sized based on a 4-hour holding time. The tank material and cost is dependent on the tank size. Wastewater tanks are sized based on the amount of wastewater generated by the sand filters. Tanks designed for volumes less than 3,000 gallons are fiber reinforced plastic (FRP), and tanks larger than 3,000 gallons are prefabricated of crosslinked polyethylene for increased strength. The tanks are placed on concrete pads that are 1 ft thick and sized 2 ft larger than the tank diameter.

Also included in this line item are feed pumps for each treatment unit, an effluent pump, a wastewater transfer pump, a sediment pump, and chemical metering pumps, if needed. The pumps are cast iron, totally enclosed, fan-cooled (TEFC) pumps due to their required horsepower. Annual O&M costs include pump replacement every 3 years and the power required to operate the pumps. The feed pumps operate continuously, 24 hrs/day, 330 days/yr. The sediment pump operates for 2 hours, four times per year to transfer sediments that collect in the influent tank. Metering pump costs are based on a 0.167-horsepower stainless-steel pump that runs continuously and requires replacement every other year.

Sand filters and cartridge filters are sized based on flow rate. The O&M costs for the cartridge filters are based on cartridge replacement 3 to 4 times per year. The disposal costs for the filter solids and cartridges are based on the costs of using the on-post hazardous waste landfill. The volumes of waste generated are based on flow rates, backwash rates, duration, and frequency for the sand filter and cartridge volume and replacement frequency for the cartridge filter.

Labor for tanks, filters, and pumps includes operation of the tanks, pumps, and filters and maintenance. Annual maintenance materials are also included.

A3.7.3 Hardness/Iron Pretreatment

The Hardness/Iron Pretreatment line item includes the costs of adding sequesterant to water. This line item includes the costs of the required sequesterant and labor. The chemical sequesterant, potassium pyrophosphate is added to the system at a rate that provides a concentration in the

process stream of 10 micrograms/liter of water treated. The labor involved in adding sequesterant addition includes 1 hr/day for operation.

A3.7.4 Air Stripping Unit

The Air Stripping Unit line item includes the cost of a shallow-tray air stripper, a catalytic oxidation air emissions treatment unit, air monitoring, and labor.

The costs of shallow tray air strippers for the various flow rates were obtained from several vendors. These are low-profile, low maintenance units that do not contain packing material, and therefore do not generate packing material/waste. Labor requirements are estimated to be 1.25 hours per day for operation and 111 hours per year for maintenance.

Catalytic oxidation is used to destroy contaminants in the vapor-phase emissions from the air strippers. Catalytic oxidation capital costs include the cost of the unit and annual O&M costs include costs of power for both the blower and auxiliary heater.

Air monitoring costs include both weekly and monthly samples of off-gas emissions. The monthly sampling is more comprehensive than the weekly sampling. These costs are included in the annual O&M costs. Labor requirements to operate the air treatment unit and to monitor the emissions are included with the air stripper labor requirements.

A3.7.5 Oxidation

The Oxidation Unit line item includes the cost of the oxidation reactor and labor to operate and maintain the equipment. The oxidation systems being used are ultraviolet (UV)/hydrogen peroxide reactors.

UV/hydrogen peroxide reactor capital costs include the cost of the reactor and UV lamps. The annual O&M costs to maintain these reactors include hydrogen peroxide feedstock, electricity for the UV lamps, and UV lamp replacement.

The oxidation reactors require 1 hour of operating labor daily. The UV/hydrogen peroxide reactors require 2 hours of maintenance labor for every 30,000 gallons treated. The annual O&M costs for labor includes operations, maintenance, and supervisory labor and associated maintenance materials.

A3.7.6 GAC Adsorption Unit

This GAC Adsorption Unit line item includes the GAC adsorbers, GAC replacement, and labor to operate and maintain the units.

The GAC adsorber(s) are designed to treat from 7 to 80 gpm each and are included in the capital costs. The cost of regenerating and replacing the spent carbon varies, depending upon the usage requirement for a given system. The cost of transporting the carbon for regeneration is included in the annual O&M costs.

The O&M costs associated with treating a 2-gpm flow from Alternative SPC-5 with the Basin A groundwater in the Basin A/South Plants combined treatment plant are based on the additional GAC usage.

A3.7.7 Additional Loading on North Boundary Systems

The costs of additional loading on the NBCS, Basin A Neck IRA, and Basin F Groundwater IRA were calculated and found to be negligible compared to the cost of operating the existing systems.

A3.7.8 In Situ Biodegradation Unit

The costs involved in the In Situ Biodegradation line item are the costs of nutrients, hydrogen peroxide, and labor. Capital costs associated with the chemical addition pumps and tanks are included in the Tanks, Filters, and Pumps line item.

Annual O&M costs include nutrient and hydrogen peroxide consumption. Labor for this item consists of 0.5 hr/day for system operation and 176 hours/year for maintenance.

A3.7.9 Direct Biological Treatment Unit

The items included in the Direct Biological Treatment Unit line item are the biological reactor, sand filter, tanks, pumps and labor.

The cost for the biological reactor designed for this application was obtained from a vendor. The annual O&M costs involved in operation of this reactor include GAC, nutrients and oxygen addition. The biomass produced by the reactor is removed by a sand filter, which is included in the capital cost. The solids from the filter are disposed in the on-post hazardous waste landfill.

The tanks required for this unit (influent, effluent, and thickener tanks) are constructed of fiberglass. The tanks are installed on concrete pads.

The pumps required to operate this system are bioreactor feed and recycle pumps, post-filter feed pumps, sediment pump, and filter backwash pump. The capital cost for these pumps is included and annual O&M costs include power and replacement costs.

Operating labor requirements for this unit were estimated at 2 hrs/day and maintenance labor at 350 hrs/yr. Annual costs include supervision and associated maintenance materials.

A3.7.10 Balance of Capital

The Balance of Capital line item includes the cost of additional capital items that were not part of any specific treatment unit. These costs were estimated as percentages of the direct capital treatment equipment costs. Balance of capital specifically includes instrumentation (35 percent), freight and handling (6 percent), installation (45 percent), site development (10 percent), electrical (11 percent), and piping and insulation (60 percent).

A4.0 INDIRECT COSTS

Indirect costs are applied to the sum of the two main cost groups which include direct capital costs and direct O&M operating costs. The indirect costs include:

- mobilization/demobilization
- indirects, overhead, and profit
- engineering design
- resident engineering
- contingency

The indirect costs vary due to four factors: medium group contamination; technologies selected; size of the project; and the duration. Based on the characteristics of each alternative as it applies to medium group characteristics, these factors assist in the development of indirect percentages as explained below. These indirect percentages are then applied to the direct costs to determine an overall total cost.

In order to provide a uniform basis of estimate, a cost markup matrix was developed to determine indirect cost percentages for direct capital and O&M costs and is presented in Table A4.0-1. In some instances, these factors were individually adjusted to be more representative of the individual alternative's complexity. The following sections explain the indirect markup factors and the application rationale.

A4.1 MOBILIZATION/DEMOBILIZATION

Mobilization activities include construction/setup of contractor support facilities, mobilization of heavy equipment, and relocation of management/supervisory personnel. Demobilization consists of decontamination and removal of contractor's equipment and facilities from the site. Costs for these activities are applied as a percentage of direct cost. The percentages applied vary from 2 to 7 percent as shown in the markup matrix.

A4.2 INDIRECTS, OVERHEAD AND PROFIT

Indirect Costs are calculated as a percentage of the sum of direct and mobilization/demobilization costs. Indirect costs cover on-site management, administrative, technical, health and safety, and supervisory staff, utilities for site support facilities (excluding production facilities), engineering tests, QA/QC program, preparation of work plans, submittals and as-built drawings, bonding costs, support facilities, and vehicle maintenance and operation. The range of percentages applied vary between 34 to 44 percent.

A4.3 DESIGN ENGINEERING

The engineering design costs are estimated as a percentage of the sum of direct costs; mobilization/demobilization costs; and indirects, overhead, and profits. In general, engineering percentages were developed based on past experience of engineering costs on similar projects. These percentages are dependent upon the degree of complexity associated with the particular alternative and the complexity of the treatment technology selected. Standard percentages ranging between 3 to 6 percent are applied to the estimates, however, certain alternatives required adjustments to reflect extenuating circumstances in the required design effort and were adjusted accordingly.

A4.4 RESIDENT ENGINEERING

The resident engineering costs are estimated as a percentage of the sum of direct costs: mobilization/demobilization costs; and indirects, overhead, and profits. The actual percentage used is based on the alternative size, estimated project duration, and the extent to which the selected remedial technology would require thorough, full-time inspection and field engineering support by a multi-member staff to assure conformance and verification with the approved remedial design. Standard percentages ranging between 1 and 3 percent are applied to the estimates.

A4.5 CONTINGENCY

Contingency is applied as a percentage of the sum of direct costs; mobilization/demobilization costs; and indirect, overhead, and profit costs; and design and resident engineering costs. Contingency is a specific provision for unforeseeable costs within the defined project scope; it is particularly important where previous experience relating estimates and actual costs (e.g., complexity of the treatment technology, unforeseen and unpredictable conditions, and/or uncertainties within the scope of this project) has shown that unforeseeable events that increase costs are likely to occur. Other considerations that may affect the selection of contingency are levels of contamination; environmental media and climatic conditions; scheduling; changes in federal, state, or local regulations; and other considerations unique to the project such as waste management permits and regulatory reviews.

Separate contingency costs were developed for capital expenditures and O & M, both of which are illustrated in the markup matrix. A contingency range for this level of detail is typically 20 to 50 percent, which was applied to these estimates. The contingency to be provided for the current estimates was developed based on four cost parameters: the levels of contamination, the complexity of the treatment technology, the size of the project, and the estimated duration of the activity. The amount of contingency applied to the estimates in this document ranged between 25 to 40 percent based on these consideration factors and on professional experience and knowledge with similar remedial projects.

A5.0 REFERENCES

EBASCO (Ebasco Services, Incorporated)

1993 (July) Detailed Analysis of Alternatives Report, Draft Final, Version 2.0, 7 v. RTIC
93200R05.

Table A1-1

Cost Estimate - Northwest Boundary Plume Group
Alternative NWC-1: No Action

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Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Slurry Wall Demolition	LS	1	--	22,320	/EA	1	EA	22,000	22,000
Subtotal (A)								22,000	22,000
COST CODE LLSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	3.3%	B = 0.033 * (A)						1,000	1,000
Indirects, Overhead & Profit	39.0%	C = 0.390 * (A+B)						9,000	9,000
Engineering Design	3.0%	D = 0.030 * (A+B+C)						1,000	1,000
Resident Engineering	1.3%	E = 0.013 * (A+B+C)						400	400
Contingency	27.5%	F = 0.275 * (A+B+C+D+E)						9,200	9,200
Subtotal (G =B+C+D+E+F)								20,000	20,000
TOTAL CAPITAL COSTS (H = A+G)								43,000	43,000

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Table A1-1 Cost Estimate - Northwest Boundary Plume Group
Alternative NWC-1: No Action

Cost Item	Cost Type	Start Year	End Year	1995 (\$)		----- 1995 (\$) Annual Cost -----			1995 (\$)	1995 (\$)			
DIRECT O&M COSTS (OPERATIONS)													
Plume Monitoring, Quarterly	A	1	5	51,751	/EA-YR	1	EA	51,800		259,000			
Plume Monitoring, Annually	A	6	30	24,600	/EA-YR	1	EA		24,600	615,000			
Subtotal (I)								51,800	24,600	24,600	874,000	625,000	
INDIRECT O&M COSTS (OPERATIONS)													
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						20,000	10,000	10,000	341,000	244,000	
Resident Engineering	1.8%	K = 0.018 * (I+J)						1,000	1,000	1,000	21,000	15,000	
Contingency	32.5%	L = 0.325 * (I+J+K)						24,000	12,000	12,000	402,000	287,000	
Subtotal (O = J+K+L)								45,000	23,000	23,000	764,000	546,000	
TOTAL O&M COSTS (T = I+O)								96,800	47,600	47,600	1,637,000	1,171,000	
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)												1,680,000	1,210,000

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Table A1-2 Cost Estimate - Northwest Boundary Plume Group
Alternative NWC-2: Continued Existing Action

Cost Item	Cost Type	Start Year	End Year	1995 (\$)		Quantity	Units	----- 1995 (\$) Annual Cost -----			1995 (\$)	1995 (\$)
				Unit Cost	Units			Yr 1-5	Yr 6-10	Yr 11-30	Total Cost	PW Cost
DIRECT O&M COSTS (OPERATIONS)												
Continued Operation of NWBCS	A	1	30	542,930	/EA-YR	1	EA	543,000	543,000	543,000	16,288,000	10,731,000
Plume Monitoring, Quarterly	A	1	5	51,751	/EA-YR	1	EA	52,000			259,000	244,000
Plume Monitoring, Annually	A	6	30	24,600	/EA-YR	1	EA		25,000	25,000	615,000	381,000
Subtotal (I)								595,000	568,000	568,000	17,162,000	11,355,000
COST CODE LMSL												
INDIRECT O&M COSTS (OPERATIONS)												
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						232,000	222,000	222,000	6,693,000	4,429,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						17,000	16,000	16,000	477,000	316,000
Contingency	33.8%	L = 0.338 * (I+J+K)						285,000	272,000	272,000	8,212,000	5,434,000
Subtotal (O = J+K+L)								534,000	510,000	510,000	15,382,000	10,178,000
TOTAL O&M COSTS (T = I+O)								1,129,000	1,078,000	1,078,000	32,544,000	21,533,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)											32,500,000	21,500,000

Table A2-1 Cost Estimate - Western Plume Group
Alternative WC-1: No Action

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									

COST CODE LLSS			Subtotal (A)	0	0
INDIRECT CAPITAL COSTS					
Mob/Demob	3.3%	B = 0.033 * (A)		0	0
Indirects, Overhead & Profit	39.0%	C = 0.390 * (A+B)		0	0
Engineering Design	3.0%	D = 0.030 * (A+B+C)		0	0
Resident Engineering	1.3%	E = 0.013 * (A+B+C)		0	0
Contingency	27.5%	F = 0.275 * (A+B+C+D+E)		0	0
			Subtotal (G =B+C+D+E+F)	0	0
TOTAL CAPITAL COSTS (H = A+G)				0	0

Table A2-1 Cost Estimate - Western Plume Group
Alternative WC-1: No Action

Cost Item	Cost Type	Start Year	End Year	1995 (\$)				1995 (\$)		1995 (\$)	1995 (\$)
				Unit Cost	Units	Quantity	Units	Yr 1-5	Yr 6-30	Total Cost	PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Plume Monitoring, Quarterly	A	1	5	79,399	/EA-YR	1	EA	79,400		397,000	375,000
Plume Monitoring, Annually	A	6	30	36,399	/EA-YR	1	EA		36,400	910,000	563,000

				Subtotal (I)	79,400	36,400	1,307,000	938,000	
COST CODE	LLSL								
INDIRECT O&M COSTS (OPERATIONS)									
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)			31,000	14,000	510,000	366,000	
Resident Engineering	1.8%	K = 0.018 * (I+J)			2,000	1,000	32,000	23,000	
Contingency	32.5%	L = 0.325 * (I+J+K)			37,000	17,000	601,000	431,000	
				Subtotal (O = J+K+L)	70,000	32,000	1,142,000	820,000	
TOTAL O&M COSTS (T = I+O)					149,400	68,400	2,449,000	1,757,000	
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)								2,450,000	1,760,000

Table A2-2 Cost Estimate - Western Plume Group
Alternative WC-2: Continued Existing Action

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost

DIRECT CAPITAL COSTS

			Subtotal (A)	0	0
COST CODE	LLSS				
INDIRECT CAPITAL COSTS					
Mob/Demob	3.3%	B = 0.033 * (A)		0	0
Indirects, Overhead & Profit	39.0%	C = 0.390 * (A+B)		0	0
Engineering Design	3.0%	D = 0.030 * (A+B+C)		0	0
Resident Engineering	1.3%	E = 0.013 * (A+B+C)		0	0
Contingency	27.5%	F = 0.275 * (A+B+C+D+E)		0	0
			Subtotal (G =B+C+D+E+F)	0	0
TOTAL CAPITAL COSTS (H = A+G)				0	0

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Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Annual Cos Yr 1-4	Yr 5-30	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Continued Operation of ICS and IRAs	A	1	4	375,080	/EA-YR	1	EA	375,000		1,500,000	1,436,000
Plume Monitoring, Quarterly	A	1	4	96,899	/EA-YR	1	EA	97,000		388,000	371,000
Plume Monitoring, Annually	A	5	30	47,830	/EA-YR	1	EA		48,000	1,244,000	782,000
Subtotal (I)								472,000	48,000	3,131,000	2,590,000
COST CODE LMSL											
INDIRECT O&M COSTS (OPERATIONS)											
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						184,000	19,000	1,221,000	1,010,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						13,000	1,000	87,000	72,000
Contingency	33.8%	L = 0.338 * (I+J+K)						226,000	23,000	1,498,000	1,239,000
Subtotal (O = J+K+L)								423,000	43,000	2,807,000	2,321,000
TOTAL O&M COSTS (T = I+O)								895,000	91,000	5,938,000	4,911,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)										5,940,000	4,910,000
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Table A2-2A Cost Estimate - Western Plume Group
Alternative WC-2A: Boundary Systems Only

Cost Item	Cost Type	Start Year	End Year	1994 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Subtotal (A)								0	0
INDIRECT CAPITAL COSTS									
Mob/Demob	3.3%	B = 0.033 * (A)						0	0
Indirects, Overhead & Profit	39.0%	C = 0.390 * (A+B)						0	0
Engineering Design	3.0%	D = 0.030 * (A+B+C)						0	0
Resident Engineering	1.3%	E = 0.013 * (A+B+C)						0	0
Contingency	27.5%	F = 0.275 * (A+B+C+D+E)						0	0
Subtotal (G =B+C+D+E+F)								0	0
TOTAL CAPITAL COSTS (H = A+G)								0	0

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Table A2-2A Cost Estimate - Western Plume Group
Alternative WC-2A: Boundary Systems Only

Cost Item	Cost Type	Start Year	End Year	1994 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Annual Cos Yr 1-4	1995 (\$) Annual Cos Yr 5-30	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Continued Operation of ICS	A	1	4	355,857	/EA-YR	1	EA	365,000		1,462,000	1,399,000
Plume Monitoring, Quarterly	A	1	4	96,699	/EA-YR	1	EA	99,000		397,000	380,000
Plume Monitoring, Annually	A	5	30	47,630	/EA-YR	1	EA		49,000	1,272,000	800,000
Subtotal (I)								464,000	49,000	3,131,000	2,580,000
COST CODE LMSL											
INDIRECT O&M COSTS (OPERATIONS)											
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						181,000	19,000	1,221,000	1,006,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						13,000	1,000	87,000	72,000
Contingency	33.8%	L = 0.338 * (I+J+K)						222,000	23,000	1,498,000	1,234,000
Subtotal (O = J+K+L)								416,000	43,000	2,806,000	2,312,000
TOTAL O&M COSTS (T = I+O)								880,000	92,000	5,937,000	4,892,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)										5,940,000	4,890,000

Table A3-1 Cost Estimate - North Boundary Plume Group
Alternative NC-1: No Action

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Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Slurry Wall Demolition	LS	1	--	80,880	/EA	1	EA	81,000	81,000
Subtotal (A)								81,000	81,000
COST CODE LLSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	3.3%	B = 0.033 * (A)						3,000	3,000
Indirects, Overhead & Profit	39.0%	C = 0.390 * (A+B)						33,000	33,000
Engineering Design	3.0%	D = 0.030 * (A+B+C)						3,500	3,500
Resident Engineering	1.3%	E = 0.013 * (A+B+C)						1,500	1,500
Contingency	27.5%	F = 0.275 * (A+B+C+D+E)						33,300	33,300
Subtotal (G =B+C+D+E+F)								73,000	73,000
TOTAL CAPITAL COSTS (H = A+G)								154,000	154,000

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Table A3-1 Cost Estimate - North Boundary Plume Group
Alternative NC-1: No Action

Cost Item	Cost Type	Start Year	End Year	1995 (\$)		Quantity	Units	1995 (\$) Annual Cos		1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Plume Monitoring, Quarterly	A	1	5	103,501	/EA-YR	1	EA	103,500		518,000	488,000
Plume Monitoring, Annually	A	6	30	49,199	/EA-YR	1	EA		49,200	1,230,000	761,000
Subtotal (I)								103,500	49,200	1,747,000	1,249,000
COST CODE LLSL											
INDIRECT O&M COSTS (OPERATIONS)											
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						40,000	19,000	682,000	487,000
Resident Engineering	1.8%	K = 0.018 * (I+J)						3,000	1,000	43,000	30,000
Contingency	32.5%	L = 0.325 * (I+J+K)						48,000	22,000	803,000	574,000
Subtotal (O = J+K+L)								91,000	42,000	1,527,000	1,092,000
TOTAL O&M COSTS (T = I+O)								194,500	91,200	3,275,000	2,341,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)										3,430,000	2,500,000

Table A3-2 Cost Estimate - North Boundary Plume Group
Alternative NC-2: Continued Existing Action

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Deep Well Abandonment	LS	1	--	42,000	/EA	1	EA	42,000	42,000
Subtotal (A)								42,000	42,000
COST CODE LLSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	3.3%	B = 0.033 * (A)						1,000	1,000
Indirects, Overhead & Profit	39.0%	C = 0.390 * (A+B)						17,000	17,000
Engineeering Design	3.0%	D = 0.030 * (A+B+C)						1,800	1,800
Resident Engineering	1.3%	E = 0.013 * (A+B+C)						800	800
Contingency	27.5%	F = 0.275 * (A+B+C+D+E)						17,300	17,300
Subtotal (G =B+C+D+E+F)								38,000	38,000
TOTAL CAPITAL COSTS (H = A+G)								80,000	80,000

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Table A3-2 Cost Estimate - North Boundary Plume Group
Alternative NC-2: Continued Existing Action

Cost Item	Cost Type	Start Year	End Year	1995 (\$)				1995 (\$) Annual Cos		1995 (\$)	1995 (\$)
				Unit Cost	Units	Quantity	Units	Yr 1-5	Yr 6-30	Total Cost	PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Continued Operation of NBCS	A	1	30	840,905	/EA-YR	1	EA	841,000	841,000	25,227,000	16,620,000
Plume Monitoring, Quarterly	A	1	5	103,501	/EA-YR	1	EA	104,000		518,000	488,000
Plume Monitoring, Annually	A	6	30	49,199	/EA-YR	1	EA		49,000	1,230,000	761,000
Deep Well Monitoring, Annually	A	1	5	12,914	/EA-YR	1	EA	13,000		65,000	61,000
Deep Well Monitoring, Every 5 Years	A	6	30	2,583	/EA-YR	1	EA		3,000	65,000	40,000
Subtotal (I)								958,000	893,000	27,104,000	17,970,000
COST CODE LMSL											
INDIRECT O&M COSTS (OPERATIONS)											
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						374,000	348,000	10,570,000	7,008,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						27,000	25,000	753,000	500,000
Contingency	33.8%	L = 0.338 * (I+J+K)						459,000	427,000	12,969,000	8,599,000
Subtotal (O = J+K+L)								860,000	800,000	24,293,000	16,107,000
TOTAL O&M COSTS (T = I+O)								1,818,000	1,693,000	51,397,000	34,077,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)										51,500,000	34,200,000

Table A3-2A Cost Estimate - North Boundary Plume Group
Alternative NC-2A: Boundary Systems Only

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost

DIRECT CAPITAL COSTS

			Subtotal (A)	0	0
COST CODE	LLSS				
INDIRECT CAPITAL COSTS					
Mob/Demob	3.3%	B = 0.033 * (A)	0	0	
Indirects, Overhead & Profit	39.0%	C = 0.390 * (A+B)	0	0	
Engineering Design	3.0%	D = 0.030 * (A+B+C)	0	0	
Resident Engineering	1.3%	E = 0.013 * (A+B+C)	0	0	
Contingency	27.5%	F = 0.275 * (A+B+C+D+E)	0	0	
			Subtotal (G =B+C+D+E+F)	0	0
TOTAL CAPITAL COSTS (H = A+G)				0	0

Table A3-2A Cost Estimate - North Boundary Plume Group
Alternative NC-2A: Boundary Systems Only

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Yr 1-5	1995 (\$) Yr 6-30	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Continued Operation of NBCS	A	1	30	840,905	/EA-YR	1	EA	841,000	841,000	25,227,000	16,620,000
Plume Monitoring, Quarterly	A	1	5	103,501	/EA-YR	1	EA	104,000		518,000	488,000
Plume Monitoring, Annually	A	6	30	49,199	/EA-YR	1	EA		49,000	1,230,000	761,000
Subtotal (I)								945,000	890,000	26,975,000	17,869,000
COST CODE LMSL											
INDIRECT O&M COSTS (OPERATIONS)											
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						369,000	347,000	10,520,000	6,969,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						26,000	25,000	750,000	497,000
Contingency	33.8%	L = 0.338 * (I+J+K)						452,000	426,000	12,908,000	8,551,000
Subtotal (O = J+K+L)								847,000	798,000	24,178,000	16,016,000
TOTAL O&M COSTS (T = I+O)								1,792,000	1,688,000	51,152,000	33,885,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)										51,200,000	33,900,000

Table A3-3 Cost Estimate - North Boundary Plume Group
Alternative NC-3/NT-2: Interception, Treatment at NBCS

Cost Item	Cost Type	Start Year	End Year	1995 (\$)				1995 (\$)	1995 (\$)
				Unit Cost	Units	Quantity	Units	Total Cost	PW Cost
DIRECT CAPITAL COSTS									
Extraction Wells & Pump Installation	LS	1	--	90,462	/EA	1	EA	90,000	90,000
Performance Monitoring Well Installation	LS	1	--	83,688	/EA	1	EA	84,000	84,000
Subtotal (A)								174,000	174,000
COST CODE MLSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	3.9%	B = 0.039 * (A)						7,000	7,000
Indirects, Overhead & Profit	40.3%	C = 0.403 * (A+B)						73,000	73,000
Engineering Design	3.0%	D = 0.030 * (A+B+C)						7,600	7,600
Resident Engineering	1.5%	E = 0.015 * (A+B+C)						3,800	3,800
Contingency	30.0%	F = 0.300 * (A+B+C+D+E)						79,500	79,500
Subtotal (G = B+C+D+E+F)								171,000	171,000
TOTAL CAPITAL COSTS (H = A+G)								345,000	345,000

Table A3-3 Cost Estimate - North Boundary Plume Group
Alternative NC-3/NT-2: Interception, Treatment at NBCS

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Annual Cost Yr 1-5	1995 (\$) Annual Cost Yr 6-30	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Continued Operation of NBCS	A	1	30	840,905	/EA-YR	1	EA	841,000	841,000	25,227,000	16,620,000
Maintenance & Repair	A	1	30	14,615	/EA-YR	1	EA	15,000	15,000	438,000	289,000
Well & Pump Operations	A	1	30	3,445	/EA-YR	1	EA	3,000	3,000	103,000	68,000
Plume Monitoring, Quarterly	A	1	5	134,551	/EA-YR	1	EA	135,000		673,000	635,000
Plume Monitoring, Annually	A	6	30	63,959	/EA-YR	1	EA		63,960	1,599,000	990,000

				Subtotal (I)	994,000	922,960	28,041,000	18,601,000	
COST CODE	LMSL								
INDIRECT O&M COSTS (OPERATIONS)									
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)			388,000	360,000	10,936,000	7,254,000	
Resident Engineering	2.0%	K = 0.020 * (I+J)			28,000	26,000	780,000	517,000	
Contingency	33.8%	L = 0.338 * (I+J+K)			476,000	442,000	13,418,000	8,901,000	
				Subtotal (O = J+K+L)	892,000	828,000	25,133,000	16,672,000	
TOTAL O&M COSTS (T = I+O)					1,886,000	1,751,000	53,174,000	35,273,000	
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)								53,500,000	35,600,000

Table A3-4 Cost Estimate - North Boundary Plume Group
Alternative NC-3/NT-3: Interception, Treatment at Basin A Neck IRA

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Extraction Wells & Pump Installation	LS	1	--	90,462	/EA	1	EA	90,000	90,000
Performance Monitoring Well Installation	LS	1	--	83,688	/EA	1	EA	84,000	84,000
Subtotal (A)								174,000	174,000
INDIRECT CAPITAL COSTS									
Mob/Demob	4.5%	B = 0.045 * (A)						8,000	8,000
Indirects, Overhead & Profit	40.3%	C = 0.403 * (A+B)						73,000	73,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)						11,500	11,500
Resident Engineering	1.8%	E = 0.018 * (A+B+C)						4,500	4,500
Contingency	31.3%	F = 0.313 * (A+B+C+D+E)						84,700	84,700
Subtotal (G =B+C+D+E+F)								182,000	182,000
TOTAL CAPITAL COSTS (H = A+G)								356,000	356,000

Table A3-4

Cost Estimate - North Boundary Plume Group
Alternative NC-3/NT-3: Interception, Treatment at Basin A Neck IRA

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Cost Item	Cost Type	Start Year	End Year	1995 (\$)				1995 (\$) Annual Cos		1995 (\$)	1995 (\$)
				Unit Cost	Units	Quantity	Units	Yr 1-5	Yr 6-30	Total Cost	PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Continued Operation of NBCS	A	1	30	840,905	/EA-YR	1	EA	841,000	841,000	25,227,000	16,620,000
Maintenance & Repair	A	1	30	14,615	/EA-YR	1	EA	15,000	15,000	438,000	289,000
Well & Pump Operations	A	1	30	3,445	/EA-YR	1	EA	3,000	3,000	103,000	68,000
Plume Monitoring, Quarterly	A	1	5	134,551	/EA-YR	1	EA	135,000		673,000	635,000
Plume Monitoring, Annually	A	6	30	63,959	/EA-YR	1	EA		64,000	1,599,000	990,000

				Subtotal (I)		994,000	923,000	28,041,000	18,601,000
COST CODE	LMSL								
INDIRECT O&M COSTS (OPERATIONS)									
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)				388,000	360,000	10,936,000	7,254,000
Resident Engineering	2.0%	K = 0.020 * (I+J)				28,000	26,000	780,000	517,000
Contingency	33.8%	L = 0.338 * (I+J+K)				476,000	442,000	13,418,000	8,901,000
				Subtotal (O = J+K+L)		892,000	828,000	25,133,000	16,672,000
TOTAL O&M COSTS (T = I+O)						1,886,000	1,751,000	53,174,000	35,273,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)								53,500,000	35,600,000

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Table A3-5 Cost Estimate - North Boundary Plume Group
Alternative NC-3/NT-4: Interception, Oxidation

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Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Control System									
Extraction Wells & Pump Installation	LS	1	--	90,462 /EA		1	EA	90,000	90,000
Performance Monitoring Well Installation	LS	1	--	83,688 /EA		1	EA	84,000	84,000
Treatment System									
Balance of Capital Costs	LS	1	--	245,068 /EA		1	EA	245,000	245,000
Oxidation Unit	LS	1	--	156,094 /EA		1	EA	156,000	156,000

			Subtotal (A)	575,000	575,000
COST CODE	MMSS				
INDIRECT CAPITAL COSTS					
Mob/Demob	4.5%	B = 0.045 * (A)		26,000	26,000
Indirects, Overhead & Profit	40.3%	C = 0.403 * (A+B)		242,000	242,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)		37,900	37,900
Resident Engineering	1.8%	E = 0.018 * (A+B+C)		14,800	14,800
Contingency	31.3%	F = 0.313 * (A+B+C+D+E)		280,000	280,000
			Subtotal (G =B+C+D+E+F)	601,000	601,000
TOTAL CAPITAL COSTS (H = A+G)				1,176,000	1,176,000

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Table A3-5 Cost Estimate - North Boundary Plume Group
Alternative NC-3/NT-4: Interception, Oxidation

Cost Item	Cost Type	Start Year	End Year	1995 (\$)				1995 (\$) Annual Co		1995 (\$)	1995 (\$)
				Unit Cost	Units	Quantity	Units	Yr 1-5	Yr 6-30	Total Cost	PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Control System											
Maintenance & Repair	A	1	30	14,615	/EA-YR	1	EA	15,000	15,000	438,000	289,000
Well & Pump Operations	A	1	30	3,445	/EA-YR	1	EA	3,000	3,000	103,000	68,000
Plume Monitoring, Quarterly	A	1	5	134,551	/EA-YR	1	EA	135,000		673,000	635,000
Plume Monitoring, Annually	A	6	30	63,959	/EA-YR	1	EA		64,000	1,599,000	990,000
Treatment System											
Continued Operation of NBCS	A	1	30	840,905	/EA-YR	1	EA	841,000	841,000	25,227,000	16,620,000
Oxidation Unit	A	1	30	61,764	/EA-YR	1	EA	62,000	62,000	1,853,000	1,221,000

				Subtotal (I)		1,056,000	985,000	29,894,000	19,822,000
COST CODE LMSL									
INDIRECT O&M COSTS (OPERATIONS)									
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)				412,000	384,000	11,659,000	7,730,000
Resident Engineering	2.0%	K = 0.020 * (I+J)				29,000	27,000	831,000	551,000
Contingency	33.8%	L = 0.338 * (I+J+K)				505,000	471,000	14,304,000	9,485,000
				Subtotal (O = J+K+L)		946,000	882,000	26,794,000	17,766,000
TOTAL O&M COSTS (T = I+O)						2,002,000	1,867,000	56,687,000	37,588,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)								57,900,000	38,800,000

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Cost Item				1995 (\$)	1995 (\$)	1995 (\$)	1995 (\$)	1995 (\$)	1995 (\$)
Cost Type	Start Year	End Year	Unit Cost	Units	Quantity	Units	Total Cost	PW Cost	
DIRECT CAPITAL COSTS									
Soil Capping	LS	I	--	8,413,746	/EA	I	EA	8,414,000	8,414,000
Subtotal (A)								8,414,000	8,414,000
COST CODE L.L.M.S									
INDIRECT CAPITAL COSTS									
Mob/Demob	3.3%	B = 0.033 * (A)					273,000	273,000	
Indirects, Overhead & Profit	37.8%	C = 0.378 * (A+B)					3,279,000	3,279,000	
Engineering Design	3.0%	D = 0.030 * (A+B+C)					359,000	359,000	
Resident Engineering	1.3%	E = 0.013 * (A+B+C)					149,600	149,600	
Contingency	28.8%	F = 0.288 * (A+B+C+D+E)					3,586,600	3,586,600	
Subtotal (G =B+C+D+E+F)								7,648,000	7,648,000
TOTAL CAPITAL COSTS (H = A+G)								16,062,000	16,062,000
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Table A3-6 Cost Estimate - North Boundary Plume Group
Alternative NC-6: Clay/Soil Cap

Cost Item	Cost Type	Start Year	End Year	1995 (\$)				1995 (\$) Annual Cost			1995 (\$)	1995 (\$)
				Unit Cost	Units	Quantity	Units	Yr 1-5	Yr 6-10	Yr 11-30	Total Cost	PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS												
Continued Operation of NBCS	A	1	30	840,905	/EA-YR	1	EA	841,000	841,000	841,000	25,227,000	16,620,000
Soil Capping	A	1	30	31,372	/EA-YR	1	EA	31,000	31,000	31,000	941,000	620,000
Plume Monitoring, Quarterly	A	1	5	103,501	/EA-YR	1	EA	104,000			518,000	488,000
Plume Monitoring, Annually	A	6	30	49,199	/EA-YR	1	EA		49,000	49,000	1,230,000	761,000
Subtotal (I)								976,000	921,000	921,000	27,916,000	18,489,000
COST CODE LMSL												
INDIRECT O&M COSTS (OPERATIONS)												
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						381,000	359,000	359,000	10,887,000	7,211,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						27,000	26,000	26,000	776,000	514,000
Contingency	33.8%	L = 0.338 * (I+J+K)						467,000	441,000	441,000	13,358,000	8,847,000
Subtotal (O = J+K+L)								875,000	826,000	826,000	25,021,000	16,572,000
TOTAL O&M COSTS (T = I+O)								1,851,000	1,747,000	1,747,000	52,937,000	35,061,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)											69,000,000	51,100,000

Table A4-1 Cost Estimate - Basin A Plume Group
Alternative AC-1: No Action

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Slurry Wall Demolition	LS	1	--	14,940	/EA	1	EA	14,900	14,900

				Subtotal (A)				14,900	14,900
COST CODE	LLSS								
INDIRECT CAPITAL COSTS									
Mob/Demob	3.3%	B = 0.033 * (A)						500	500
Indirects, Overhead & Profit	39.0%	C = 0.390 * (A+B)						6,000	6,000
Engineering Design	3.0%	D = 0.030 * (A+B+C)						600	600
Resident Engineering	1.3%	E = 0.013 * (A+B+C)						300	300
Contingency	27.5%	F = 0.275 * (A+B+C+D+E)						6,100	6,100
				Subtotal (G = B+C+D+E+F)				13,600	13,600
TOTAL CAPITAL COSTS (H = A+G)								28,500	28,500

Table A4-1

Cost Estimate - Basin A Plume Group
Alternative AC-1: No Action

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Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Annual Co Yr 1-5	1995 (\$) Annual Co Yr 6-30	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Plume Monitoring, Quarterly	A	1	5	103,501	/EA-YR	1	EA	103,500		518,000	488,000
Plume Monitoring, Annually	A	6	30	49,199	/EA-YR	1	EA		49,200	1,230,000	761,000

				Subtotal (I)		103,500	49,200	1,747,000	1,249,000
COST CODE LLSL									
INDIRECT O&M COSTS (OPERATIONS)									
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)				40,000	19,000	682,000	487,000
Resident Engineering	1.8%	K = 0.018 * (I+J)				3,000	1,000	43,000	30,000
Contingency	32.5%	L = 0.325 * (I+J+K)				48,000	22,000	803,000	574,000
				Subtotal (O = J+K+L)		91,000	42,000	1,527,000	1,092,000
TOTAL O&M COSTS (T = I+O)						194,500	91,200	3,275,000	2,341,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)								3,300,000	2,370,000

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Table A4-2 Cost Estimate - Basin A Plume Group
Alternative AC-2: Continued Existing Action

Cost Item	Cost Type	Start Year	End Year	1995 (\$)				1995 (\$) Annual Cost		1995 (\$)	1995 (\$)
				Unit Cost	Units	Quantity	Units	Yr 1-5	Yr 6-30	Total Cost	PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Continued Operation of Basin A Neck IRA	A	1	30	464,170	/EA-YR	1	EA	464,000	464,000	13,925,000	9,174,000
Plume Monitoring, Quarterly	A	1	5	137,033	/EA-YR	1	EA	137,000		685,000	646,000
Plume Monitoring, Annually	A	6	30	63,105	/EA-YR	1	EA		63,000	1,578,000	976,000
Subtotal (I)								601,000	527,000	16,188,000	10,797,000
COST CODE LMSL											
INDIRECT O&M COSTS (OPERATIONS)											
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						234,000	206,000	6,313,000	4,211,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						17,000	15,000	450,000	300,000
Contingency	33.8%	L = 0.338 * (I+J+K)						288,000	252,000	7,746,000	5,166,000
Subtotal (O = J+K+L)								539,000	473,000	14,509,000	9,677,000
TOTAL O&M COSTS (T = I+O)								1,140,000	1,000,000	30,697,000	20,474,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)										30,700,000	20,500,000

Table A4-3 Cost Estimate - Basin A Plume Group
Alternative AC-3/AT-2: Mass Reduction, Stripping/Sorption

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Control System									
Extraction Wells & Pump Installation	LS	1	--	676,118	/EA	1	EA	676,000	676,000
Performance Monitoring Well Installation	LS	1	--	218,736	/EA	1	EA	219,000	219,000
Recharge Trench	LS	1	--	414,000	/EA	1	EA	414,000	414,000
Treatment System									
Balance of Capital Costs	LS	1	--	365,295	/EA	1	EA	365,000	365,000
Treatment Facility, 3200 Square Feet	LS	1	--	108,725	/EA	1	EA	109,000	109,000
Tanks, Filters, & Pumps	LS	1	--	39,495	/EA	1	EA	39,000	39,000
Air Stripping Unit	LS	1	--	56,944	/EA	1	EA	57,000	57,000
Granular Activated Carbon Adsorption Unit	LS	1	--	13,576	/EA	1	EA	14,000	14,000
Subtotal (A)								1,893,000	1,893,000
COST CODE HMSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	5.1%	B = 0.051 * (A)						97,000	97,000
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)						826,000	826,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)						126,700	126,700
Resident Engineering	2.0%	E = 0.020 * (A+B+C)						56,300	56,300
Contingency	33.8%	F = 0.338 * (A+B+C+D+E)						1,012,100	1,012,100
Subtotal (G =B+C+D+E+F)								2,118,000	2,118,000
TOTAL CAPITAL COSTS (H = A+G)								4,011,000	4,011,000

Table A4-3 Cost Estimate - Basin A Plume Group
Alternative AC-3/AT-2: Mass Reduction, Stripping/Sorption

Cost Item	Cost Type	Start Year	End Year	1995 (\$)		----- 1995 (\$) Annual Cost -----				1995 (\$)	1995 (\$)	
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS												
Control System												
Maintenance & Repair	A	1	20	41,462	/EA-YR	1	EA	41,000	41,000		829,000	635,000
Well & Pump Operations	A	1	20	5,391	/EA-YR	1	EA	5,000	5,000		108,000	83,000
Plume Monitoring, Quarterly	A	1	5	139,936	/EA-YR	1	EA	140,000			700,000	660,000
Plume Monitoring, Annually	A	6	30	67,659	/EA-YR	1	EA		68,000	68,000	1,691,000	1,047,000
Treatment System												
Continued Operation of Basin A Neck IRA	A	1	30	464,170	/EA-YR	1	EA	464,000	464,000	464,000	13,925,000	9,174,000
Treatment Facility, 3200 Square Feet	A	1	20	4,770	/EA-YR	1	EA	5,000	5,000		95,000	73,000
Tanks, Filters, & Pumps	A	1	20	62,899	/EA-YR	1	EA	63,000	63,000		1,258,000	964,000
Hardness/Iron Treatment Unit	A	1	20	3,723	/EA-YR	1	EA	4,000	4,000		74,000	57,000
Air Stripping Unit	A	1	20	44,181	/EA-YR	1	EA	44,000	44,000		884,000	677,000
Granular Activated Carbon Adsorption Unit	A	1	20	13,373	/EA-YR	1	EA	13,000	13,000		267,000	205,000
Process Monitoring	A	1	20	78,235	/EA-YR	1	EA	78,000	78,000		1,565,000	1,199,000
Subtotal (I)								857,000	785,000	532,000	21,397,000	14,774,000
COST CODE LMSL												
INDIRECT O&M COSTS (OPERATIONS)												
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						334,000	306,000	207,000	8,345,000	5,762,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						24,000	22,000	15,000	595,000	411,000
Contingency	33.8%	L = 0.338 * (I+J+K)						410,000	376,000	254,000	10,239,000	7,069,000
Subtotal (O = J+K+L)								768,000	704,000	476,000	19,178,000	13,242,000
TOTAL O&M COSTS (T = I+O)								1,625,000	1,489,000	1,008,000	40,575,000	28,015,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)											44,600,000	32,000,000

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Cost Item				Cost Type	Start Year	End Year	1995 (\$)		1995 (\$)		
							Unit Cost	Units	Quantity	Units	
DIRECT CAPITAL COSTS											
Control System											
Extraction Wells & Pump Installation				LS	1	--	676,118	/EA	1	EA	
Performance Monitoring Well Installation				LS	1	--	218,736	/EA	1	EA	
Recharge Trench				LS	1	--	414,000	/EA	1	EA	
Treatment System											
Balance of Capital Costs				LS	1	--	495,171	/EA	1	EA	
Treatment Facility, 3200 Square Feet				LS	1	--	108,725	/EA	1	EA	
Tanks, Filters, & Pumps				LS	1	--	42,265	/EA	1	EA	
Air Stripping Unit				LS	1	--	56,944	/EA	1	EA	
Oxidation Unit				LS	1	--	75,000	/EA	1	EA	
Granular Activated Carbon Adsorption Unit				LS	1	--	13,576	/EA	1	EA	
Subtotal (A)										2,101,000	2,101,000
COST CODE HMSS											
INDIRECT CAPITAL COSTS											
Mob/Demob				5.1%	B = 0.051 * (A)					108,000	108,000
Indirects, Overhead & Profit				41.5%	C = 0.415 * (A+B)					916,000	916,000
Engineering Design				4.5%	D = 0.045 * (A+B+C)					140,600	140,600
Resident Engineering				2.0%	E = 0.020 * (A+B+C)					62,500	62,500
Contingency				33.8%	F = 0.338 * (A+B+C+D+E)					1,123,100	1,123,100
Subtotal (G =B+C+D+E+F)										2,350,000	2,350,000
TOTAL CAPITAL COSTS (H = A+G)										4,451,000	4,451,000
BA-03A4.WQ1											
WATER DAA											
04-Oct-95											

Table A4-4 Cost Estimate - Basin A Plume Group
Alternative AC-3/AT-4: Mass Reduction, Stripping/Oxidation/Sorption

Cost Item	Cost Type	Start Year	End Year	1995 (\$)		----- 1995 (\$) Annual Cost -----			1995 (\$)	1995 (\$)		
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											Total Cost	PW Cost
Control System												
Maintenance & Repair	A	1	20	41,462	/EA-YR	1	EA	41,000	41,000	829,000	635,000	
Well & Pump Operations	A	1	20	5,391	/EA-YR	1	EA	5,000	5,000	108,000	83,000	
Plume Monitoring, Quarterly	A	1	5	139,936	/EA-YR	1	EA	140,000		700,000	660,000	
Plume Monitoring, Annually	A	6	30	67,659	/EA-YR	1	EA		68,000	68,000	1,691,000	1,047,000
Treatment System												
Continued Operation of Basin A Neck IRA	A	1	30	464,170	/EA-YR	1	EA	464,000	464,000	464,000	13,925,000	9,174,000
Treatment Facility, 1200 Square Feet	A	1	20	4,770	/EA-YR	1	EA	5,000	5,000		95,000	73,000
Tanks, Filters, & Pumps	A	1	20	76,970	/EA-YR	1	EA	77,000	77,000		1,539,000	1,179,000
Hardness/Iron Treatment Unit	A	1	20	3,723	/EA-YR	1	EA	4,000	4,000		74,000	57,000
Air Stripping Unit	A	1	20	44,181	/EA-YR	1	EA	44,000	44,000		884,000	677,000
Oxidation Unit	A	1	20	55,832	/EA-YR	1	EA	56,000	56,000		1,117,000	856,000
Granular Activated Carbon Adsorption Unit	A	1	20	13,373	/EA-YR	1	EA	13,000	13,000		267,000	205,000
Process Monitoring	A	1	20	78,235	/EA-YR	1	EA	78,000	78,000		1,565,000	1,199,000
Subtotal (I)								927,000	855,000	532,000	22,795,000	15,845,000
COST CODE LLSL												
INDIRECT O&M COSTS (OPERATIONS)												
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						362,000	333,000	207,000	8,890,000	6,179,000
Resident Engineering	1.8%	K = 0.018 * (I+J)						23,000	21,000	13,000	554,000	385,000
Contingency	32.5%	L = 0.325 * (I+J+K)						426,000	393,000	244,000	10,478,000	7,283,000
Subtotal (O = J+K+L)								811,000	747,000	464,000	19,922,000	13,848,000
TOTAL O&M COSTS (T = I+O)								1,738,000	1,602,000	996,000	42,717,000	29,693,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)											47,200,000	34,100,000

Table A4-5 Cost Estimate - Basin A Plume Group
Alternative AC-7: Capping

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									

COST CODE		HLSS	Subtotal (A)				0	0
INDIRECT CAPITAL COSTS								
Mob/Demob	4.5%	B = 0.045 * (A)					0	0
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)					0	0
Engineering Design	3.0%	D = 0.030 * (A+B+C)					0	0
Resident Engineering	1.8%	E = 0.018 * (A+B+C)					0	0
Contingency	32.5%	F = 0.325 * (A+B+C+D+E)					0	0
		Subtotal (G = B+C+D+E+F)					0	0
TOTAL CAPITAL COSTS (H = A+G)							0	0

Table A4-5 Cost Estimate - Basin A Plume Group
Alternative AC-7: Capping

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Annual Cos Yr 1-5	1995 (\$) Annual Cos Yr 6-30	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Continued Operation of Basin A Neck IRA	A	1	30	464,170	/EA-YR	1	EA	464,000	464,000	13,925,000	9,174,000
Plume Monitoring, Quarterly	A	1	5	134,522	/EA-YR	1	EA	135,000		673,000	635,000
Plume Monitoring, Annually	A	6	30	63,524	/EA-YR	1	EA		64,000	1,588,000	983,000
Subtotal (I)								599,000	528,000	16,186,000	10,791,000
COST CODE LLSL											
INDIRECT O&M COSTS (OPERATIONS)											
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						234,000	206,000	6,312,000	4,209,000
Resident Engineering	1.8%	K = 0.018 * (I+J)						15,000	13,000	394,000	262,000
Contingency	32.5%	L = 0.325 * (I+J+K)						276,000	243,000	7,440,000	4,960,000
Subtotal (O = J+K+L)								525,000	462,000	14,146,000	9,431,000
TOTAL O&M COSTS (T = I+O)								1,124,000	990,000	30,332,000	20,223,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)										30,300,000	20,200,000

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Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Control System									
Extraction Wells & Pump Installation	LS	1	--	1,641,371	/EA	1	EA	1,641,000	1,641,000
Performance Monitoring Well Installation	LS	1	--	152,111	/EA	1	EA	152,000	152,000
Recharge Trench	LS	1	--	414,000	/EA	1	EA	414,000	414,000
Phase I, Treatment System									
Balance of Capital Costs	LS	1	--	562,613	/EA	1	EA	563,000	563,000
Treatment Facility, 8700 Square Feet	LS	1	--	162,810	/EA	1	EA	163,000	163,000
Tanks, Filters, & Pumps	LS	1	--	78,485	/EA	1	EA	78,000	78,000
Air Stripping Unit	LS	1	--	75,235	/EA	1	EA	75,000	75,000
Granular Activated Carbon Adsorption Unit	LS	1	--	20,364	/EA	1	EA	20,364	20,364
Phase II, Treatment System									
Balance of Capital Costs	LS	10	--	134,375	/EA	1	EA	134,000	103,000
Tanks, Filters, & Pumps	LS	10	--	24,069	/EA	1	EA	24,000	18,000
Air Stripping Unit	LS	10	--	47,944	/EA	1	EA	48,000	37,000
Granular Activated Carbon Adsorption Unit	LS	10	--	13,576	/EA	1	EA	13,576	10,405
Subtotal (A)								3,327,000	3,276,000
COST CODE HMSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	5.1%	B = 0.051 * (A)						171,000	168,000
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)						1,451,000	1,429,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)						222,700	219,300
Resident Engineering	2.0%	E = 0.020 * (A+B+C)						99,000	97,400
Contingency	33.8%	F = 0.338 * (A+B+C+D+E)						1,778,800	1,751,400
Subtotal (G = B+C+D+E+F)								3,722,000	3,665,000
TOTAL CAPITAL COSTS (H = A+G)								7,049,000	6,941,000
AC-0802.WQ1									04-Oct-95
WATER DAA									

Table A4-6 Cost Estimate - Basin A Plume Group
Alternative AC-8/AT-2: Dewatering, Stripping/Sorption

Cost Item	Cost Type	Start Year	End Year	1995 (\$)					----- 1995 (\$) Annual Cost -----			1995 (\$)	1995 (\$)
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS													
Control System													
Maintenance & Repair	A	1	30	13,685	/EA-YR	1	EA	14,000	14,000	14,000	411,000	270,000	
Well & Pump Operations	A	1	30	1,961	/EA-YR	1	EA	2,000	2,000	2,000	59,000	39,000	
Plume Monitoring, Quarterly	A	1	5	62,651	/EA-YR	1	EA	63,000			313,000	296,000	
Plume Monitoring, Annually	A	6	30	30,069	/EA-YR	1	EA		30,000	30,000	752,000	465,000	
Phase I, Treatment													
Continued Operation of Basin A Neck IRA	A	1	30	464,170	/EA-YR	1	EA	464,000	464,000	464,000	13,925,000	9,174,000	
Treatment Facility, 8700 Square Feet	A	1	10	4,770	/EA-YR	1	EA	5,000	5,000		48,000	42,000	
Tanks, Filters, & Pumps	A	1	10	65,977	/EA-YR	1	EA	66,000	66,000		660,000	580,000	
Hardness/Iron Treatment Unit	A	1	10	3,740	/EA-YR	1	EA	4,000	4,000		37,000	33,000	
Air Stripping Unit	A	1	10	51,290	/EA-YR	1	EA	51,000	51,000		513,000	451,000	
Granular Activated Carbon Adsorption Unit	A	1	10	24,107	/EA-YR	1	EA	24,000	24,000		241,000	212,000	
Process Monitoring	A	1	10	78,235	/EA-YR	1	EA	78,000	78,000		782,000	687,000	
Phase II, Treatment System													
Treatment Facility, 8700 Square Feet	A	11	30	4,770	/EA-YR	1	EA			5,000	95,000	54,000	
Tanks, Filters, & Pumps	A	11	30	62,899	/EA-YR	1	EA			63,000	1,258,000	717,000	
Hardness/Iron Treatment Unit	A	11	30	3,723	/EA-YR	1	EA			4,000	74,000	42,000	
Air Stripping Unit	A	11	30	40,135	/EA-YR	1	EA			40,000	803,000	458,000	
Granular Activated Carbon Adsorption Unit	A	11	30	13,373	/EA-YR	1	EA			13,000	267,000	152,000	
Process Monitoring	A	11	30	78,235	/EA-YR	1	EA			78,000	1,565,000	892,000	
Subtotal (I)								771,000	738,000	713,000	21,803,000	14,564,000	
COST CODE LMSL													
INDIRECT O&M COSTS (OPERATIONS)													
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						301,000	288,000	278,000	8,503,000	5,680,000	
Resident Engineering	2.0%	K = 0.020 * (I+J)						21,000	21,000	20,000	606,000	405,000	
Contingency	33.8%	L = 0.338 * (I+J+K)						369,000	353,000	341,000	10,433,000	6,969,000	
Subtotal (O = J+K+L)								691,000	662,000	639,000	19,543,000	13,054,000	
TOTAL O&M COSTS (T = I+O)								1,462,000	1,400,000	1,352,000	41,346,000	27,619,000	
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)												48,400,000	34,600,000

Table A4-7 Cost Estimate - Basin A Plume Group
Alternative AC-8/AT-4: Dewatering, Stripping/Oxidation/Sorption

Cost Item	Cost Type	Start Year	End Year	1995 (\$)				1995 (\$)	1995 (\$)
				Unit Cost	Units	Quantity	Units	Total Cost	PW Cost
DIRECT CAPITAL COSTS									
Control System									
Extraction Wells & Pump Installation	LS	1	--	1,641,371	/EA	1	EA	1,641,000	1,641,000
Performance Monitoring Well Installation	LS	1	--	152,111	/EA	1	EA	152,000	152,000
Recharge Trench	LS	1	--	414,000	/EA	1	EA	414,000	414,000
Phase I, Treatment System									
Balance of Capital Costs	LS	1	--	692,619	/EA	1	EA	693,000	693,000
Treatment Facility, 8700 Square Feet	LS	1	--	162,810	/EA	1	EA	163,000	163,000
Tanks, Filters, & Pumps	LS	1	--	81,333	/EA	1	EA	81,000	81,000
Air Stripping Unit	LS	1	--	75,235	/EA	1	EA	75,000	75,000
Oxidation Unit	LS	1	--	75,000	/EA	1	EA	75,000	75,000
Granular Activated Carbon Adsorption Unit	LS	1	--	20,364	/EA	1	EA	20,000	20,000
Phase II, Treatment System									
Balance of Capital Costs	LS	10	--	138,724	/EA	1	EA	139,000	106,000
Tanks, Filters, & Pumps	LS	10	--	26,839	/EA	1	EA	27,000	21,000
Air Stripping Unit	LS	10	--	47,944	/EA	1	EA	48,000	37,000
Granular Activated Carbon Adsorption Unit	LS	10	--	13,576	/EA	1	EA	13,576	10,405
Subtotal (A)								3,542,000	3,489,000
COST CODE HMSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	5.1%	B = 0.051 * (A)						182,000	179,000
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)						1,545,000	1,522,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)						237,100	233,500
Resident Engineering	2.0%	E = 0.020 * (A+B+C)						105,400	103,800
Contingency	33.8%	F = 0.338 * (A+B+C+D+E)						1,893,800	1,865,400
Subtotal (G =B+C+D+E+F)								3,963,000	3,904,000
TOTAL CAPITAL COSTS (H = A+G)								7,505,000	7,393,000

Table A4-7 Cost Estimate - Basin A Plume Group
Alternative AC-8/AT-4: Dewatering, Stripping/Oxidation/Sorption

Cost Item	Cost Type	Start Year	End Year	1995 (\$)		----- 1995 (\$) Annual Cost -----				1995 (\$)	1995 (\$)			
						Unit Cost	Units	Quantity	Units	Yr 1-5	Yr 6-10	Yr 11-30	Total Cost	PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS														
Control System														
Maintenance & Repair	A	1	30	13,685	/EA-YR	1	EA			14,000	14,000	14,000	411,000	270,000
Well & Pump Operations	A	1	30	1,961	/EA-YR	1	EA			2,000	2,000	2,000	59,000	39,000
Plume Monitoring, Quarterly	A	1	5	62,651	/EA-YR	1	EA			63,000			313,000	296,000
Plume Monitoring, Annually	A	6	30	30,069	/EA-YR	1	EA				30,000	30,000	752,000	465,000
Phase I, Treatment														
Continued Operation of Basin A Neck IRA	A	1	30	464,170	/EA-YR	1	EA			464,000	464,000	464,000	13,925,000	9,174,000
Treatment Facility, 8700 Square Feet	A	1	10	4,770	/EA-YR	1	EA			5,000	5,000		48,000	42,000
Tanks, Filters, & Pumps	A	1	10	80,431	/EA-YR	1	EA			80,000	80,000		804,000	707,000
Hardness/Iron Treatment Unit	A	1	10	3,740	/EA-YR	1	EA			4,000	4,000		37,000	33,000
Air Stripping Unit	A	1	10	51,290	/EA-YR	1	EA			51,000	51,000		513,000	451,000
Oxidation Unit	A	1	10	132,782	/EA-YR	1	EA			133,000	133,000		1,328,000	1,167,000
Granular Activated Carbon Adsorption Unit	A	1	10	28,707	/EA-YR	1	EA			29,000	29,000		287,000	252,000
Process Monitoring	A	1	10	78,235	/EA-YR	1	EA			78,000	78,000		782,000	687,000
Phase II, Treatment System														
Treatment Facility, 8700 Square Feet	A	11	30	4,770	/EA-YR	1	EA					5,000	95,000	54,000
Tanks, Filters, & Pumps	A	11	30	76,970	/EA-YR	1	EA					77,000	1,539,000	878,000
Hardness/Iron Treatment Unit	A	11	30	3,723	/EA-YR	1	EA					4,000	74,000	42,000
Air Stripping Unit	A	11	30	40,135	/EA-YR	1	EA					40,000	803,000	458,000
Oxidation Unit	A	11	30	55,832	/EA-YR	1	EA					56,000	1,117,000	637,000
Granular Activated Carbon Adsorption Unit	A	11	30	13,373	/EA-YR	1	EA					13,000	267,000	152,000
Process Monitoring	A	11	30	78,235	/EA-YR	1	EA					78,000	1,565,000	892,000
Subtotal (I)										923,000	890,000	783,000	24,720,000	16,695,000
COST CODE LMSL														
INDIRECT O&M COSTS (OPERATIONS)														
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)								360,000	347,000	305,000	9,641,000	6,511,000
Resident Engineering	2.0%	K = 0.020 * (I+J)								26,000	25,000	22,000	687,000	464,000
Contingency	33.8%	L = 0.338 * (I+J+K)								442,000	426,000	375,000	11,829,000	7,989,000
Subtotal (O = J+K+L)										828,000	798,000	702,000	22,157,000	14,964,000
TOTAL O&M COSTS (T = I+O)										1,751,000	1,688,000	1,485,000	46,876,000	31,660,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)													54,400,000	39,100,000

Table A4-8 Cost Estimate - Basin A Plume Group
Alternative AC-9/AT-2: Bedrock Ridge Extraction, Stripping/Sorption

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Extraction Wells & Pump Installation	LS	1	--	1,594,989	/EA	1	EA	1,595,000	1,595,000
Performance Monitoring Well Installation	LS	1	--	152,111	/EA	1	EA	152,000	152,000
Deep Well Abandonment	LS	1	--	42,000	/EA	1	EA	42,000	42,000
Subtotal (A)								1,789,000	1,789,000
COST CODE MLSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	3.9%	B = 0.039 * (A)						69,000	69,000
Indirects, Overhead & Profit	40.3%	C = 0.403 * (A+B)						748,000	748,000
Engineering Design	3.0%	D = 0.030 * (A+B+C)						78,200	78,200
Resident Engineering	1.5%	E = 0.015 * (A+B+C)						39,100	39,100
Contingency	30.0%	F = 0.300 * (A+B+C+D+E)						817,100	817,100
Subtotal (G =B+C+D+E+F)								1,752,000	1,752,000
TOTAL CAPITAL COSTS (H = A+G)								3,541,000	3,541,000

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Table A4-8 Cost Estimate - Basin A Plume Group
Alternative AC-9/AT-2: Bedrock Ridge Extraction, Stripping/Sorption

Cost Item	Cost Type	Start Year	End Year	1995 (\$)		Quantity	Units	1995 (\$) Annual Cost		1995 (\$)	1995 (\$)	
								Yr 1-5	Yr 6-30	Total Cost	PW Cost	
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS												
Continued Operation of Basin A Neck IRA	A	1	30	464,170	/EA-YR	1	EA	464,000	464,000	13,925,000	9,174,000	
Maintenance & Repair	A	1	30	13,685	/EA-YR	1	EA	14,000	14,000	411,000	270,000	
Well & Pump Operations	A	1	30	1,961	/EA-YR	1	EA	2,000	2,000	59,000	39,000	
Plume Monitoring, Quarterly	A	1	5	68,974	/EA-YR	1	EA	69,000		345,000	325,000	
Plume Monitoring, Annually	A	6	30	30,181	/EA-YR	1	EA		30,000	755,000	467,000	
Deep Well Monitoring, Annually	A	1	5	20,662	/EA-YR	1	EA	21,000		103,000	97,000	
Deep Well Monitoring, Every 5 Years	A	6	30	4,132	/EA-YR	1	EA		4,000	103,000	64,000	
Subtotal (I)								570,000	514,000	15,700,000	10,437,000	
COST CODE LMSL												
INDIRECT O&M COSTS (OPERATIONS)												
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						222,000	200,000	6,123,000	4,070,000	
Resident Engineering	2.0%	K = 0.020 * (I+J)						16,000	14,000	436,000	290,000	
Contingency	33.8%	L = 0.338 * (I+J+K)						273,000	246,000	7,513,000	4,994,000	
Subtotal (O = J+K+L.)								511,000	460,000	14,072,000	9,355,000	
TOTAL O&M COSTS (T = I+O)								1,081,000	974,000	29,773,000	19,791,000	
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)										33,300,000	23,300,000	

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Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									

COST CODE		LLSS	Subtotal (A)	0	0
INDIRECT CAPITAL COSTS					
Mob/Demob	3.3%	B = 0.033 * (A)		0	0
Indirects, Overhead & Profit	39.0%	C = 0.390 * (A+B)		0	0
Engineering Design	3.0%	D = 0.030 * (A+B+C)		0	0
Resident Engineering	1.3%	E = 0.013 * (A+B+C)		0	0
Contingency	27.5%	F = 0.275 * (A+B+C+D+E)		0	0
			Subtotal (G =B+C+D+E+F)	0	0
TOTAL CAPITAL COSTS (H = A+G)				0	0

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Table A5-2 Cost Estimate - South Plants Plume Group
Alternative SPC-2: South Lakes Monitoring

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Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Deep Well Abandonment	LS	1	--	42,000	/EA	1	EA	42,000	42,000
Subtotal (A)								42,000	42,000
COST CODE LLSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	3.3%	B = 0.033 * (A)						1,000	1,000
Indirects, Overhead & Profit	39.0%	C = 0.390 * (A+B)						17,000	17,000
Engineering Design	3.0%	D = 0.030 * (A+B+C)						1,800	1,800
Resident Engineering	1.3%	E = 0.013 * (A+B+C)						800	800
Contingency	27.5%	F = 0.275 * (A+B+C+D+E)						17,300	17,300
Subtotal (G =B+C+D+E+F)								38,000	38,000
TOTAL CAPITAL COSTS (H= A+G)								80,000	80,000

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Table A5-2 Cost Estimate - South Plants Plume Group
Alternative SPC-2: South Lakes Monitoring

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Cost Item	Cost Type	Start Year	End Year	1995 (\$)		Quantity	Units	1995 (\$) Annual Cos		1995 (\$)	1995 (\$)
				Unit Cost	Units			Yr 1-5	Yr 6-30	Total Cost	PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Plume Monitoring, Quarterly	A	1	5	103,501	/EA-YR	1	EA	104,000		518,000	488,000
Plume Monitoring, Annually	A	6	30	49,200	/EA-YR	1	EA		49,000	1,230,000	761,000
Plume Monitoring, Annually, South Lakes	A	1	30	67,360	/EA-YR	1	EA	67,000	67,000	2,021,000	1,331,000
Deep Well Monitoring, Annually	A	1	5	18,080	/EA-YR	1	EA	18,000		90,000	85,000
Deep Well Monitoring, Every 5 Years	A	6	30	3,616	/EA-YR	1	EA		4,000	90,000	56,000
Subtotal (I)								189,000	120,000	3,949,000	2,722,000
COST CODE LLSL											
INDIRECT O&M COSTS (OPERATIONS)											
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						74,000	47,000	1,540,000	1,062,000
Resident Engineering	1.8%	K = 0.018 * (I+J)						5,000	3,000	96,000	66,000
Contingency	32.5%	L = 0.325 * (I+J+K)						87,000	55,000	1,815,000	1,251,000
Subtotal (O = J+K+L)								166,000	105,000	3,451,000	2,379,000
TOTAL O&M COSTS (T = I+O)								355,000	225,000	7,401,000	5,101,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)										7,480,000	5,180,000

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Cost Item	Cost Type	Start Year	End Year	1995 (\$)				1995 (\$)	1995 (\$)
				Unit Cost	Units	Quantity	Units	Total Cost	PW Cost
DIRECT CAPITAL COSTS									
Control System									
Extraction Wells & Pump Installation	LS	1	--	270,108	/EA	1	EA	270,000	270,000
Performance Monitoring Well Installation	LS	1	--	240,968	/EA	1	EA	241,000	241,000
Recharge Trench	LS	1	--	158,400	/EA	1	EA	158,000	158,000
Treatment System									
Balance of Capital Costs	LS	1	--	295,116	/EA	1	EA	295,000	295,000
Treatment Facility, 1200 Square Feet	LS	1	--	78,939	/EA	1	EA	79,000	79,000
Tanks, Filters, & Pumps	LS	1	--	30,937	/EA	1	EA	31,000	31,000
Air Stripping Unit	LS	1	--	55,944	/EA	1	EA	56,000	56,000
Granular Activated Carbon Adsorption Unit	LS	1	--	10,896	/EA	1	EA	11,000	11,000
Subtotal (A)								1,141,000	1,141,000
COST CODE HMSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	5.1%	B = 0.051 * (A)						58,000	58,000
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)						498,000	498,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)						76,400	76,400
Resident Engineering	2.0%	E = 0.020 * (A+B+C)						34,000	34,000
Contingency	33.8%	F = 0.338 * (A+B+C+D+E)						610,200	610,200
Subtotal (G = B+C+D+E+F)								1,277,000	1,277,000
TOTAL CAPITAL COSTS (H = A+G)								2,418,000	2,418,000
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Table A5-3 Cost Estimate - South Plants Plume Group
Alternative SPC-3/SPT-2: Mass Reduction, Stripping/Sorption

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	----- 1995 (\$) Annual Cost -----			1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS												
Control System												
Maintenance & Repair	A	1	20	23,791	/EA-YR	1	EA	24,000	24,000		476,000	365,000
Well & Pump Operations	A	1	20	3,445	/EA-YR	1	EA	3,000	3,000		69,000	53,000
Plume Monitoring, Quarterly	A	1	5	134,329	/EA-YR	1	EA	134,000			672,000	634,000
Plume Monitoring, Annually	A	6	30	64,440	/EA-YR	1	EA		64,000	64,000	1,611,000	997,000
Treatment System												
Treatment Facility, 1200 Square Feet	A	1	20	4,770	/EA-YR	1	EA	5,000	5,000		95,000	73,000
Tanks, Filters, & Pumps	A	1	20	62,741	/EA-YR	1	EA	63,000	63,000		1,255,000	961,000
Hardness/Iron Treatment Unit	A	1	20	3,718	/EA-YR	1	EA	4,000	4,000		74,000	57,000
Air Stripping Unit	A	1	20	43,689	/EA-YR	1	EA	44,000	44,000		874,000	669,000
Granular Activated Carbon Adsorption Unit	A	1	20	11,979	/EA-YR	1	EA	12,000	12,000		240,000	184,000
Process Monitoring	A	1	20	78,235	/EA-YR	1	EA	78,000	78,000		1,565,000	1,199,000
Subtotal (I)								367,000	297,000	64,000	6,930,000	5,191,000
COST CODE LMSL												
INDIRECT O&M COSTS (OPERATIONS)												
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						143,000	116,000	25,000	2,703,000	2,025,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						10,000	8,000	2,000	193,000	144,000
Contingency	33.8%	L = 0.338 * (I+J+K)						176,000	142,000	31,000	3,316,000	2,484,000
Subtotal (O = J+K+L)								329,000	266,000	58,000	6,211,000	4,653,000
TOTAL O&M COSTS (T = I+O)								696,000	563,000	122,000	13,141,000	9,844,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)											15,600,000	12,300,000

Table A5-4 Cost Estimate - South Plants Plume Group
Alternative SPC-3/SPT-3: Mass Reduction, Oxidation/Sorption

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Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Control System									
Extraction Wells & Pump Installation	LS	1	--	270,108	/EA	1	EA	270,000	270,000
Performance Monitoring Well Installation	LS	1	--	240,968	/EA	1	EA	241,000	241,000
Recharge Trench	LS	1	--	158,400	/EA	1	EA	158,000	158,000
Treatment System									
Balance of Capital Costs	LS	1	--	333,656	/EA	1	EA	334,000	334,000
Treatment Facility, 1200 Square Feet	LS	1	--	78,939	/EA	1	EA	79,000	79,000
Tanks, Filters, & Pumps	LS	1	--	32,279	/EA	1	EA	32,000	32,000
Oxidation Unit	LS	1	--	75,000	/EA	1	EA	75,000	75,000
Granular Activated Carbon Adsorption Unit	LS	1	--	13,576	/EA	1	EA	14,000	14,000
Subtotal (A)								1,203,000	1,203,000
COST CODE HMSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	5.1%	B = 0.051 * (A)						62,000	62,000
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)						525,000	525,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)						80,500	80,500
Resident Engineering	2.0%	E = 0.020 * (A+B+C)						35,800	35,800
Contingency	33.8%	F = 0.338 * (A+B+C+D+E)						643,200	643,200
Subtotal (G = B+C+D+E+F)								1,346,000	1,346,000
TOTAL CAPITAL COSTS (H = A+G)								2,549,000	2,549,000

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Table A5-4 Cost Estimate - South Plants Plume Group
Alternative SPC-3/SPT-3: Mass Reduction, Oxidation/Sorption

Cost Item	Cost Type	Start Year	End Year	1995 (\$)				----- 1995 (\$) Annual Cost -----			1995 (\$)	1995 (\$)
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS												
Control System												
Maintenance & Repair	A	1	20	23,791	/EA-YR	1	EA	24,000	24,000		476,000	365,000
Well & Pump Operations	A	1	20	3,445	/EA-YR	1	EA	3,000	3,000		69,000	53,000
Plume Monitoring, Quarterly	A	1	5	134,329	/EA-YR	1	EA	134,000			672,000	634,000
Plume Monitoring, Annually	A	6	30	64,440	/EA-YR	1	EA		64,000	64,000	1,611,000	997,000
Treatment System												
Treatment Facility, 1200 Square Feet	A	1	20	4,770	/EA-YR	1	EA	5,000	5,000		95,000	73,000
Tanks, Filters, & Pumps	A	1	20	69,722	/EA-YR	1	EA	70,000	70,000		1,394,000	1,068,000
Hardness/Iron Treatment Unit	A	1	20	3,718	/EA-YR	1	EA	4,000	4,000		74,000	57,000
Oxidation Unit	A	1	20	34,272	/EA-YR	1	EA	34,000	34,000		685,000	525,000
Granular Activated Carbon Adsorption Unit	A	1	20	70,109	/EA-YR	1	EA	70,000	70,000		1,402,000	1,074,000
Process Monitoring	A	1	20	78,235	/EA-YR	1	EA	78,000	78,000		1,565,000	1,199,000
Subtotal (I)								422,000	352,000	64,000	8,044,000	6,045,000
COST CODE LMSL												
INDIRECT O&M COSTS (OPERATIONS)												
Indirects, Overhead & Profit	39.0%	J = 0.390 • (I)						165,000	137,000	25,000	3,137,000	2,357,000
Resident Engineering	2.0%	K = 0.020 • (I+J)						12,000	10,000	2,000	224,000	168,000
Contingency	33.8%	L = 0.338 • (I+J+K)						202,000	168,000	31,000	3,849,000	2,892,000
Subtotal (O = J+K+L)								379,000	315,000	58,000	7,210,000	5,418,000
TOTAL O&M COSTS (T = I+O)								801,000	667,000	122,000	15,254,000	11,463,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)											17,800,000	14,000,000

Table A5-5 Cost Estimate - South Plants Plume Group
Alternative SPC-3/SPT-2/SPT-4: Mass Reduction, Stripping/Sorption, Biological Reactor/Sorption

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Control System									
Extraction Wells & Pump Installation	LS	1	--	270,108	/EA	1	EA	270,000	270,000
Performance Monitoring Well Installation	LS	1	--	240,968	/EA	1	EA	241,000	241,000
Recharge Trench	LS	1	--	158,400	/EA	1	EA	158,000	158,000
Treatment System									
Balance of Capital Costs	LS	1	--	279,008	/EA	1	EA	279,000	279,000
Treatment Facility, 1200 Square Feet	LS	1	--	78,939	/EA	1	EA	79,000	79,000
Tanks, Filters, & Pumps	LS	1	--	29,612	/EA	1	EA	30,000	30,000
Air Stripping Unit	LS	1	--	44,944	/EA	1	EA	45,000	45,000
Granular Activated Carbon Adsorption Unit	LS	1	--	10,896	/EA	1	EA	11,000	11,000
Balance of Capital Costs, Direct Biological Treatment	LS	1	--	180,457	/EA	1	EA	180,000	180,000
Direct Biological Treatment Unit	LS	1	--	114,941	/EA	1	EA	115,000	115,000
Subtotal (A)								1,408,000	1,408,000
COST CODE HMSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	5.1%	B = 0.051 * (A)						72,000	72,000
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)						614,000	614,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)						94,300	94,300
Resident Engineering	2.0%	E = 0.020 * (A+B+C)						41,900	41,900
Contingency	33.8%	F = 0.338 * (A+B+C+D+E)						753,000	753,000
Subtotal (G =B+C+D+E+F)								1,576,000	1,576,000
TOTAL CAPITAL COSTS (H = A+G)								2,984,000	2,984,000

Table A5-5

Cost Estimate - South Plants Plume Group

Alternative SPC-3/SPT-2/SPT-4: Mass Reduction, Stripping/Sorption, Biological Reactor/Sorption

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Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	----- 1995 (\$) Annual Cost -----			1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS												
Control System												
Maintenance & Repair	A	1	20	23,791	/EA-YR	1	EA	24,000	24,000		476,000	365,000
Well & Pump Operations	A	1	20	3,445	/EA-YR	1	EA	3,000	3,000		69,000	53,000
Plume Monitoring, Quarterly	A	1	5	134,329	/EA-YR	1	EA	134,000			672,000	634,000
Plume Monitoring, Annually	A	6	30	64,440	/EA-YR	1	EA		64,000	64,000	1,611,000	997,000
Treatment System												
Treatment Facility, 1200 Square Feet	A	1	20	4,770	/EA-YR	1	EA	5,000	5,000		95,000	73,000
Tanks, Filters, & Pumps	A	1	20	62,636	/EA-YR	1	EA	63,000	63,000		1,253,000	960,000
Hardness/Iron Treatment Unit	A	1	20	3,716	/EA-YR	1	EA	4,000	4,000		74,000	57,000
Air Stripping Unit	A	1	20	39,889	/EA-YR	1	EA	40,000	40,000		798,000	611,000
Granular Activated Carbon Adsorption Unit	A	1	20	11,979	/EA-YR	1	EA	12,000	12,000		240,000	184,000
Process Monitoring	A	1	20	78,235	/EA-YR	1	EA	78,000	78,000		1,565,000	1,199,000
Direct Biological Treatment Unit	A	1	20	41,534	/EA-YR	1	EA	42,000	42,000		831,000	636,000
Process Monitoring, Direct Bio	A	1	20	29,355	/EA-YR	1	EA	29,000	29,000		587,000	450,000
Subtotal (I)								434,000	364,000	64,000	8,270,000	6,218,000
COST CODE LMSL												
INDIRECT O&M COSTS (OPERATIONS)												
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						169,000	142,000	25,000	3,225,000	2,425,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						12,000	10,000	2,000	230,000	173,000
Contingency	33.8%	L = 0.338 * (I+J+K)						208,000	174,000	31,000	3,957,000	2,975,000
Subtotal (O = J+K+L)								389,000	326,000	58,000	7,412,000	5,573,000
TOTAL O&M COSTS (T = I+O)								823,000	690,000	122,000	15,682,000	11,791,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)											18,700,000	14,800,000

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Table A5-6

Cost Estimate - South Plants Plume Group

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Alternative SPC-3/SPT-3/SPT-4: Mass Reduction, Oxidation/Sorption, Biological Reactor/Sorption

Cost Item	Cost Type	Start Year	End Year	1995 (\$)				1995 (\$)	1995 (\$)
				Unit Cost	Units	Quantity	Units	Total Cost	PW Cost
DIRECT CAPITAL COSTS									
Control System									
Extraction Wells & Pump Installation	LS	1	--	270,108	/EA	1	EA	270,000	270,000
Performance Monitoring Well Installation	LS	1	--	240,968	/EA	1	EA	241,000	241,000
Recharge Trench	LS	1	--	158,400	/EA	1	EA	158,000	158,000
Treatment System									
Balance of Capital Costs	LS	1	--	331,443	/EA	1	EA	331,000	331,000
Treatment Facility, 1200 Square Feet	LS	1	--	78,939	/EA	1	EA	79,000	79,000
Tanks, Filters, & Pumps	LS	1	--	30,954	/EA	1	EA	31,000	31,000
Oxidation Unit	LS	1	--	75,000	/EA	1	EA	75,000	75,000
Granular Activated Carbon Adsorption Unit	LS	1	--	10,876	/EA	1	EA	11,000	11,000
Balance of Capital Costs, Direct Biological Treatment	LS	1	--	180,457	/EA	1	EA	180,000	180,000
Direct Biological Treatment Unit	LS	1	--	114,941	/EA	1	EA	115,000	115,000
Subtotal (A)								1,492,000	1,492,000
COST CODE HMSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	5.1%	B = 0.051 * (A)						76,000	76,000
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)						651,000	651,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)						99,900	99,900
Resident Engineering	2.0%	E = 0.020 * (A+B+C)						44,400	44,400
Contingency	33.8%	F = 0.338 * (A+B+C+D+E)						797,800	797,800
Subtotal (G =B+C+D+E+F)								1,669,000	1,669,000
TOTAL CAPITAL COSTS (H = A+G)								3,162,000	3,162,000

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Table A5-6

Cost Estimate - South Plants Plume Group

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Alternative SPC-3/SPT-3/SPT-4: Mass Reduction, Oxidation/Sorption, Biological Reactor/Sorption

Cost Item	Cost Type	Start Year	End Year	1995 (\$)				----- 1995 (\$) Annual Cost -----			1995 (\$)	1995 (\$)
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS												
Control System												
Maintenance & Repair	A	1	20	23,791	/EA-YR	1	EA	24,000	24,000		476,000	365,000
Well & Pump Operations	A	1	20	3,445	/EA-YR	1	EA	3,000	3,000		69,000	53,000
Plume Monitoring, Quarterly	A	1	5	134,329	/EA-YR	1	EA	134,000			672,000	634,000
Plume Monitoring, Annually	A	6	30	64,440	/EA-YR	1	EA		64,000	64,000	1,611,000	997,000
Treatment System												
Treatment Facility, 1200 Square Feet	A	1	20	4,770	/EA-YR	1	EA	5,000	5,000		95,000	73,000
Tanks, Filters, & Pumps	A	1	20	69,616	/EA-YR	1	EA	70,000	70,000		1,392,000	1,067,000
Hardness/Iron Treatment Unit	A	1	20	3,716	/EA-YR	1	EA	4,000	4,000		74,000	57,000
Oxidation Unit	A	1	20	25,802	/EA-YR	1	EA	26,000	26,000		516,000	395,000
Granular Activated Carbon Adsorption Unit	A	1	20	16,371	/EA-YR	1	EA	16,000	16,000		327,000	251,000
Process Monitoring	A	1	20	78,235	/EA-YR	1	EA	78,000	78,000		1,565,000	1,199,000
Direct Biological Treatment Unit	A	1	20	41,534	/EA-YR	1	EA	42,000	42,000		831,000	636,000
Process Monitoring, Direct Bio	A	1	20	29,355	/EA-YR	1	EA	29,000	29,000		587,000	450,000
Subtotal (I)								431,000	361,000	64,000	8,215,000	6,176,000
COST CODE	LMSL											
INDIRECT O&M COSTS (OPERATIONS)												
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						168,000	141,000	25,000	3,204,000	2,409,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						12,000	10,000	2,000	228,000	172,000
Contingency	33.8%	L = 0.338 * (I+J+K)						206,000	173,000	31,000	3,931,000	2,955,000
Subtotal (O = J+K+L)								386,000	324,000	58,000	7,363,000	5,536,000
TOTAL O&M COSTS (T = I+O)								817,000	685,000	122,000	15,579,000	11,712,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)											18,700,000	14,900,000

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Table A5-7

Cost Estimate - South Plants Plume Group
Alternative SPC-5/SPT-2/SPT-5: Mass Reduction, Stripping/Sorption, In-Situ Biodegradation

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Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	----- 1995 (\$) Annual Cost -----			1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS												
Control System												
Maintenance & Repair	A	1	20	23,791	/EA-YR	1	EA	24,000	24,000		476,000	365,000
Well & Pump Operations	A	1	20	3,445	/EA-YR	1	EA	3,000	3,000		69,000	53,000
Plume Monitoring, Quarterly	A	1	5	135,944	/EA-YR	1	EA	136,000			680,000	641,000
Plume Monitoring, Annually	A	6	30	62,572	/EA-YR	1	EA		63,000	63000	1,564,000	968,000
Treatment System												
Tanks, Filters, & Pumps	A	1	20	142	/EA-YR	1	EA	0	0		3,000	2,000
Granular Activated Carbon Adsorption Unit	A	1	20	210	/EA-YR	1	EA	0	0		4,000	3,000
In Situ Biodegradation System												
Treatment Facility, In Situ Bio	A	1	10	4,770	/EA-YR	1	EA	5,000	5,000		48,000	42,000
Tanks, Filters, & Pumps, In Situ Bio	A	1	10	32,872	/EA-YR	1	EA	33,000	33,000		329,000	289,000
In Situ Biodegradation	A	1	10	10,618	/EA-YR	1	EA	11,000	11,000		106,000	93,000
Process Monitoring, In Situ Bio	A	1	10	78,235	/EA-YR	1	EA	78,000	78,000		782,000	687,000
Subtotal (I)								290,000	217,000	63,000	4,061,000	3,143,000
COST CODE LMSL												
INDIRECT O&M COSTS (OPERATIONS)												
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						113,000	85,000	25,000	1,584,000	1,226,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						8,000	6,000	2,000	113,000	87,000
Contingency	33.8%	L = 0.338 * (I+J+K)						139,000	104,000	30,000	1,943,000	1,504,000
Subtotal (O = J+K+L)								260,000	195,000	57,000	3,640,000	2,818,000
TOTAL O&M COSTS (T = I+O)								550,000	412,000	120,000	7,700,000	5,961,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)											9,170,000	7,430,000

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WATER DAA

04-Oct-95

Table A5-8 Cost Estimate - South Plants Plume Group
Alternative SPC-6/SPT-2/SPT-5: Dewatering, Stripping/Sorption, In Situ Biodegradation

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Control System									
Recharge Trench	LS	1	--	158,400	/EA	1	EA	158,000	158,000
Extraction Wells & Pump Installation	LS	1	--	2,032,598	/EA	1	EA	2,033,000	2,033,000
Reinjection Pipe & System Installation	LS	1	--	116,882	/EA	1	EA	117,000	117,000
Performance Monitoring Well Installation	LS	1	--	240,968	/EA	1	EA	241,000	241,000
Phase I Treatment System									
Balance of Capital Costs	LS	1	--	365,295	/EA	1	EA	365,000	365,000
Treatment Facility, 3200 Square Feet	LS	1	--	108,725	/EA	1	EA	109,000	109,000
Tanks, Filters, & Pumps	LS	1	--	39,495	/EA	1	EA	39,000	39,000
Air Stripping Unit	LS	1	--	56,944	/EA	1	EA	57,000	57,000
Granular Activated Carbon Adsorption Unit	LS	1	--	13,576	/EA	1	EA	14,000	14,000
Phase II Treatment System									
Balance of Capital Costs	LS	1	--	21,314	/EA	1	EA	21,000	21,000
Granular Activated Carbon Adsorption Unit	LS	1	--	10,896	/EA	1	EA	11,000	11,000
In Situ Biodegradation System									
Balance of Capital Costs, In Situ Treatment	LS	1	--	137,729	/EA	1	EA	138,000	138,000
Treatment Facility, In Situ Bio	LS	1	--	72,974	/EA	1	EA	73,000	73,000
Tanks, Filters, & Pumps, In Situ Bio	LS	1	--	9,499	/EA	1	EA	9,000	9,000
COST CODE HMSS Subtotal (A)								3,385,000	3,385,000
INDIRECT CAPITAL COSTS									
Mob/Demob	5.1%	B = 0.051 * (A)						173,000	173,000
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)						1,477,000	1,477,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)						74,300	74,300
Resident Engineering	2.0%	E = 0.020 * (A+B+C)						33,000	33,000
Contingency	33.8%	F = 0.338 * (A+B+C+D+E)						593,200	593,200
Subtotal (G =B+C+D+E+F)								2,351,000	2,351,000
TOTAL CAPITAL COSTS (H = A+G)								5,736,000	5,736,000

Table A5-8 Cost Estimate - South Plants Plume Group
Alternative SPC-6/SPT-2/SPT-5: Dewatering, Stripping/Sorption, In Situ Biodegradation

Cost Item	Cost Type	Start Year	End Year	1995 (\$)		Quantity	Units	----- 1995 (\$) Annual Cost -----			1995 (\$)	1995 (\$)
								Yr 1-5	Yr 6-10	Yr 11-30	Total Cost	PW Cost
DIRECT O&M COSTS (OPERATIONS)												
Control System												
Maintenance & Repair	A	1	30	23,791	/EA-YR	1	EA	24,000	24,000	24,000	714,000	470,000
Well & Pump Operations	A	1	30	3,445	/EA-YR	1	EA	3,000	3,000	3,000	103,000	68,000
Plume Monitoring, Quarterly	A	1	5	134,551	/EA-YR	1	EA	135,000			673,000	635,000
Plume Monitoring, Annually	A	6	30	63,959	/EA-YR	1	EA		64,000	64,000	1,599,000	990,000
Phase I Treatment System												
Treatment Facility, 3200 Square Feet	A	1	10	4,770	/EA-YR	1	EA	5,000	5,000		48,000	42,000
Tanks, Filters, & Pumps	A	1	10	62,978	/EA-YR	1	EA	63,000	63,000		630,000	553,000
Hardness/Iron Treatment Unit	A	1	10	3,723	/EA-YR	1	EA	4,000	4,000		37,000	33,000
Air Stripping Unit	A	1	10	44,181	/EA-YR	1	EA	44,000	44,000		442,000	388,000
Granular Activated Carbon Adsorption Unit	A	1	10	13,373	/EA-YR	1	EA	13,000	13,000		134,000	117,000
Process Monitoring	A	1	10	78,235	/EA-YR	1	EA	78,000	78,000		782,000	687,000
Phase II Treatment System												
Treatment Facility, 3200 Square Feet	A	11	30	4,770	/EA-YR	1	EA			5,000	95,000	54,000
Tanks, Filters, & Pumps	A	11	30	62,872	/EA-YR	1	EA			63,000	1,257,000	717,000
Hardness/Iron Treatment Unit	A	11	30	3,721	/EA-YR	1	EA			4,000	74,000	42,000
Air Stripping Unit	A	11	30	44,181	/EA-YR	1	EA			44,000	884,000	504,000
Granular Activated Carbon Adsorption Unit	A	11	30	13,234	/EA-YR	1	EA			13,000	265,000	151,000
Process Monitoring	A	11	30	78,235	/EA-YR	1	EA			78,000	1,565,000	892,000
In Situ Biodegradation System												
Treatment Facility, In Situ Bio	A	1	10	4,770	/EA-YR	1	EA	5,000	5,000		48,000	42,000
Tanks, Filters, & Pumps, In Situ Bio	A	1	10	32,872	/EA-YR	1	EA	33,000	33,000		329,000	289,000
In Situ Biodegradation	A	1	10	10,618	/EA-YR	1	EA	11,000	11,000		106,000	93,000
Process Monitoring, In Situ Bio	A	1	10	78,235	/EA-YR	1	EA	78,000	78,000		782,000	687,000
Subtotal (I)								496,000	425,000	298,000	10,567,000	7,455,000
COST CODE LMSL												
INDIRECT O&M COSTS (OPERATIONS)												
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						193,000	166,000	116,000	4,121,000	2,908,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						14,000	12,000	8,000	294,000	207,000
Contingency	33.8%	L = 0.338 * (I+J+K)						237,000	204,000	142,000	5,056,000	3,567,000
Subtotal (O = J+K+L)								444,000	382,000	266,000	9,471,000	6,682,000
TOTAL O&M COSTS (T = I+O)								940,000	807,000	564,000	20,038,000	14,138,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)											25,800,000	19,900,000

Table A5-9 Cost Estimate - South Plants Plume Group
Alternative SPC-6/SPT-3/SPT-5: Dewatering, Oxidation/Sorption, In Situ Biodegradation

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Control System									
Recharge Trench	LS	1	--	158,400	/EA	1	EA	158,000	158,000
Extraction Wells & Pump Installation	LS	1	--	2,032,598	/EA	1	EA	2,033,000	2,033,000
Performance Monitoring Well Installation	LS	1	--	240,968	/EA	1	EA	241,000	241,000
Reinjection Pipe & System Installation	LS	1	--	116,882	/EA	1	EA	117,000	117,000
Phase I Treatment System									
Balance of Capital Costs	LS	1	--	409,026	/EA	1	EA	409,000	409,000
Treatment Facility, 3200 Square Feet	LS	1	--	108,725	/EA	1	EA	109,000	109,000
Tanks, Filters, & Pumps	LS	1	--	40,837	/EA	1	EA	41,000	41,000
Oxidation Unit	LS	1	--	75,000	/EA	1	EA	75,000	75,000
Granular Activated Carbon Adsorption Unit	LS	1	--	20,364	/EA	1	EA	20,000	20,000
Phase II Treatment System									
Balance of Capital Costs	LS	1	--	31,971	/EA	1	EA	32,000	32,000
Granular Activated Carbon Adsorption Unit	LS	1	--	20,364	/EA	1	EA	20,000	20,000
In Situ Biodegradation System									
Balance of Capital Costs, In Situ Treatment	LS	1	--	137,729	/EA	1	EA	138,000	138,000
Treatment Facility, In Situ Bio	LS	1	--	72,974	/EA	1	EA	73,000	73,000
Tanks, Filters, & Pumps, In Situ Bio	LS	1	--	9,499	/EA	1	EA	9,000	9,000
COST CODE HMSS Subtotal (A)								3,475,000	3,475,000
INDIRECT CAPITAL COSTS									
Mob/Demob	5.1%	B = 0.051 * (A)						178,000	178,000
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)						1,516,000	1,516,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)						76,200	76,200
Resident Engineering	2.0%	E = 0.020 * (A+B+C)						33,900	33,900
Contingency	33.8%	F = 0.338 * (A+B+C+D+E)						609,000	609,000
Subtotal (G =B+C+D+E+F)								2,413,000	2,413,000
TOTAL CAPITAL COSTS (H = A+G)								5,889,000	5,889,000

Table A5-9 Cost Estimate - South Plants Plume Group
Alternative SPC-6/SPT-3/SPT-5: Dewatering, Oxidation/Sorption, In Situ Biodegradation

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Cost Item	Cost Type	Start Year	End Year	1995 (\$)		Quantity	Units	----- 1995 (\$) Annual Cost -----			1995 (\$) Total Cost	1995 (\$) PW Cost
				Unit Cost	Units			Yr 1-5	Yr 6-10	Yr 11-30		
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS												
Control System												
Maintenance & Repair	A	1	30	23,791	/EA-YR	1	EA	24,000	24,000	24,000	714,000	470,000
Well & Pump Operations	A	1	30	3,445	/EA-YR	1	EA	3,000	3,000	3,000	103,000	68,000
Plume Monitoring, Quarterly	A	1	5	134,551	/EA-YR	1	EA	135,000			673,000	635,000
Plume Monitoring, Annually	A	6	30	63,959	/EA-YR	1	EA		64,000	64,000	1,599,000	990,000
Phase I Treatment System												
Treatment Facility, 3200 Square Feet	A	1	10	4,770	/EA-YR	1	EA	5,000	5,000		48,000	42,000
Tanks, Filters, & Pumps	A	1	10	69,958	/EA-YR	1	EA	70,000	70,000		700,000	615,000
Hardness/Iron Treatment Unit	A	1	10	3,721	/EA-YR	1	EA	4,000	4,000		37,000	33,000
Oxidation Unit	A	1	10	55,832	/EA-YR	1	EA	56,000	56,000		558,000	491,000
Granular Activated Carbon Adsorption Unit	A	1	10	77,776	/EA-YR	1	EA	78,000	78,000		778,000	683,000
Process Monitoring	A	1	10	78,235	/EA-YR	1	EA	78,000	78,000		782,000	687,000
Phase II Treatment System												
Treatment Facility, 3200 Square Feet	A	11	30	4,770	/EA-YR	1	EA			5,000	95,000	54,000
Tanks, Filters, & Pumps	A	11	30	69,853	/EA-YR	1	EA			70,000	1,397,000	796,000
Hardness/Iron Treatment Unit	A	11	30	3,721	/EA-YR	1	EA			4,000	74,000	42,000
Oxidation Unit	A	11	30	46,802	/EA-YR	1	EA			47,000	936,000	534,000
Granular Activated Carbon Adsorption Unit	A	11	30	60,142	/EA-YR	1	EA			60,000	1,203,000	686,000
Process Monitoring	A	11	30	78,235	/EA-YR	1	EA			78,000	1,565,000	892,000
In Situ Biodegradation System												
Treatment Facility, In Situ Bio	A	1	10	4,770	/EA-YR	1	EA	5,000	5,000		48,000	42,000
Tanks, Filters, & Pumps, In Situ Bio	A	1	10	32,872	/EA-YR	1	EA	33,000	33,000		329,000	289,000
In Situ Biodegradation	A	1	10	10,618	/EA-YR	1	EA	11,000	11,000		106,000	93,000
Process Monitoring, In Situ Bio	A	1	10	78,235	/EA-YR	1	EA	78,000	78,000		782,000	687,000
Subtotal (I)								580,000	509,000	355,000	12,527,000	8,829,000
COST CODE LMSL												
INDIRECT O&M COSTS (OPERATIONS)												
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						226,000	199,000	138,000	4,886,000	3,443,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						16,000	14,000	10,000	348,000	245,000
Contingency	33.8%	L = 0.338 * (I+J+K)						277,000	244,000	170,000	5,994,000	4,225,000
Subtotal (O = J+K+L)								519,000	457,000	318,000	11,228,000	7,914,000
TOTAL O&M COSTS (T = I+O)								1,099,000	966,000	673,000	23,755,000	16,743,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)											29,600,000	22,600,000

Table A5-10 Cost Estimate - South Plants Plume Group
Alternative SPC-7/SPT-2/SPT-5: Dewatering, Stripping/Sorption, In Situ Biodegradation

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Control System									
Recharge Trench	LS	1	--	158,400	/EA	1	EA	158,000	158,000
Extraction Wells & Pump Installation	LS	1	--	2,032,598	/EA	1	EA	2,033,000	2,033,000
Reinjection Pipe & System Installation	LS	1	--	116,882	/EA	1	EA	117,000	117,000
Performance Monitoring Well Installation	LS	1	--	240,968	/EA	1	EA	241,000	241,000
Phase I Treatment System									
Balance of Capital Costs	LS	1	--	365,295	/EA	1	EA	365,000	365,000
Treatment Facility, 3200 Square Feet	LS	1	--	108,725	/EA	1	EA	109,000	109,000
Tanks, Filters, & Pumps	LS	1	--	39,495	/EA	1	EA	39,000	39,000
Air Stripping Unit	LS	1	--	56,944	/EA	1	EA	57,000	57,000
Granular Activated Carbon Adsorption Unit	LS	1	--	13,576	/EA	1	EA	14,000	14,000
Phase II Treatment System									
Balance of Capital Costs	LS	1	--	21,314	/EA	1	EA	21,000	21,000
Granular Activated Carbon Adsorption Unit	LS	1	--	10,896	/EA	1	EA	11,000	11,000
In Situ Biodegradation System									
Balance of Capital Costs, In Situ Treatment	LS	1	--	137,729	/EA	1	EA	138,000	138,000
Treatment Facility, In Situ Bio	LS	1	--	72,974	/EA	1	EA	73,000	73,000
Tanks, Filters, & Pumps, In Situ Bio	LS	1	--	9,499	/EA	1	EA	9,000	9,000
COST CODE HMSS Subtotal (A)								3,385,000	3,385,000
INDIRECT CAPITAL COSTS									
Mob/Demob	5.1%	B = 0.051 * (A)						173,000	173,000
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)						1,477,000	1,477,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)						74,300	74,300
Resident Engineering	2.0%	E = 0.020 * (A+B+C)						33,000	33,000
Contingency	33.8%	F = 0.338 * (A+B+C+D+E)						593,200	593,200
Subtotal (G =B+C+D+E+F)								2,351,000	2,351,000
TOTAL CAPITAL COSTS (H = A+G)								5,736,000	5,736,000

Table A5-10 Cost Estimate - South Plants Plume Group
Alternative SPC-7/SPT-2/SPT-5: Dewatering, Stripping/Sorption, In Situ Biodegradation

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Cost Item	Cost Type	Start Year	End Year	1995 (\$)		Quantity	Units	----- 1995 (\$) Annual Cost -----			1995 (\$)	1995 (\$)
				Unit Cost	Units			Yr 1-5	Yr 6-10	Yr 11-30	Total Cost	PW Cost
DIRECT O&M COSTS (OPERATIONS)												
Control System												
Maintenance & Repair	A	1	30	23,791	/EA-YR	1	EA	24,000	24,000	24,000	714,000	470,000
Well & Pump Operations	A	1	30	3,445	/EA-YR	1	EA	3,000	3,000	3,000	103,000	68,000
Plume Monitoring, Quarterly	A	1	5	134,551	/EA-YR	1	EA	135,000			673,000	635,000
Plume Monitoring, Annually	A	6	30	63,959	/EA-YR	1	EA		64,000	64,000	1,599,000	990,000
Phase I Treatment System												
Treatment Facility, 3200 Square Feet	A	1	10	4,770	/EA-YR	1	EA	5,000	5,000		48,000	42,000
Tanks, Filters, & Pumps	A	1	10	62,978	/EA-YR	1	EA	63,000	63,000		630,000	553,000
Hardness/Iron Treatment Unit	A	1	10	3,723	/EA-YR	1	EA	4,000	4,000		37,000	33,000
Air Stripping Unit	A	1	10	44,181	/EA-YR	1	EA	44,000	44,000		442,000	388,000
Granular Activated Carbon Adsorption Unit	A	1	10	13,373	/EA-YR	1	EA	13,000	13,000		134,000	117,000
Process Monitoring	A	1	10	78,235	/EA-YR	1	EA	78,000	78,000		782,000	687,000
Phase II Treatment System												
Treatment Facility, 3200 Square Feet	A	11	30	4,770	/EA-YR	1	EA			5,000	95,000	54,000
Tanks, Filters, & Pumps	A	11	30	62,872	/EA-YR	1	EA			63,000	1,257,000	717,000
Hardness/Iron Treatment Unit	A	11	30	3,721	/EA-YR	1	EA			4,000	74,000	42,000
Air Stripping Unit	A	11	30	44,181	/EA-YR	1	EA			44,000	884,000	504,000
Granular Activated Carbon Adsorption Unit	A	11	30	13,234	/EA-YR	1	EA			13,000	265,000	151,000
Process Monitoring	A	11	30	78,235	/EA-YR	1	EA			78,000	1,565,000	892,000
In Situ Biodegradation System												
Treatment Facility, In Situ Bio	A	1	10	4,770	/EA-YR	1	EA	5,000	5,000		48,000	42,000
Tanks, Filters, & Pumps, In Situ Bio	A	1	10	32,872	/EA-YR	1	EA	33,000	33,000		329,000	289,000
In Situ Biodegradation	A	1	10	10,618	/EA-YR	1	EA	11,000	11,000		106,000	93,000
Process Monitoring, In Situ Bio	A	1	10	78,235	/EA-YR	1	EA	78,000	78,000		782,000	687,000
Subtotal (I)								496,000	425,000	298,000	10,567,000	7,455,000
COST CODE LMSL												
INDIRECT O&M COSTS (OPERATIONS)												
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						193,000	166,000	116,000	4,121,000	2,908,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						14,000	12,000	8,000	294,000	207,000
Contingency	33.8%	L = 0.338 * (I+J+K)						237,000	204,000	142,000	5,056,000	3,567,000
Subtotal (O = J+K+L)								444,000	382,000	266,000	9,471,000	6,682,000
TOTAL O&M COSTS (T = I+O)								940,000	807,000	564,000	20,038,000	14,138,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)											25,800,000	19,900,000

Table A5-11 Cost Estimate - South Plants Plume Group
Alternative SPC-7/SPT-3/SPT-5: Dewatering, Oxidation/Sorption, In Situ Biodegradation

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Control System									
Recharge Trench	LS	1	--	158,400	/EA	1	EA	158,000	158,000
Extraction Wells & Pump Installation	LS	1	--	2,032,598	/EA	1	EA	2,033,000	2,033,000
Performance Monitoring Well Installation	LS	1	--	240,968	/EA	1	EA	241,000	241,000
Reinjection Pipe & System Installation	LS	1	--	116,882	/EA	1	EA	117,000	117,000
Phase I Treatment System									
Balance of Capital Costs	LS	1	--	409,026	/EA	1	EA	409,000	409,000
Treatment Facility, 3200 Square Feet	LS	1	--	108,725	/EA	1	EA	109,000	109,000
Tanks, Filters, & Pumps	LS	1	--	40,837	/EA	1	EA	41,000	41,000
Oxidation Unit	LS	1	--	75,000	/EA	1	EA	75,000	75,000
Granular Activated Carbon Adsorption Unit	LS	1	--	20,364	/EA	1	EA	20,000	20,000
Phase II Treatment System									
Balance of Capital Costs	LS	1	--	31,971	/EA	1	EA	32,000	32,000
Granular Activated Carbon Adsorption Unit	LS	1	--	20,364	/EA	1	EA	20,000	20,000
In Situ Biodegradation System									
Balance of Capital Costs, In Situ Treatment	LS	1	--	137,729	/EA	1	EA	138,000	138,000
Treatment Facility, In Situ Bio	LS	1	--	72,974	/EA	1	EA	73,000	73,000
Tanks, Filters, & Pumps, In Situ Bio	LS	1	--	9,499	/EA	1	EA	9,000	9,000
COST CODE HMSS Subtotal (A)								3,475,000	3,475,000
INDIRECT CAPITAL COSTS									
Mob/Demob	5.1%	B = 0.051 * (A)						178,000	178,000
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)						1,516,000	1,516,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)						76,200	76,200
Resident Engineering	2.0%	E = 0.020 * (A+B+C)						33,900	33,900
Contingency	33.8%	F = 0.338 * (A+B+C+D+E)						609,000	609,000
Subtotal (G =B+C+D+E+F)								2,413,000	2,413,000
TOTAL CAPITAL COSTS (H = A+G)								5,889,000	5,889,000

Table A5-11 Cost Estimate - South Plants Plume Group
Alternative SPC-7/SPT-3/SPT-5: Dewatering, Oxidation/Sorption, In Situ Biodegradation

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Cost Item	Type	Start Year	End Year	1995 (\$)		Quantity	Units	1995 (\$) Annual Cost			1995 (\$) Total Cost	1995 (\$) PW Cost
				Unit Cost	Units			Yr 1-5	Yr 6-10	Yr 11-30		
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS												
Control System												
Maintenance & Repair	A	1	30	23,791	/EA-YR	1	EA	24,000	24,000	24,000	714,000	470,000
Well & Pump Operations	A	1	30	3,445	/EA-YR	1	EA	3,000	3,000	3,000	103,000	68,000
Plume Monitoring, Quarterly	A	1	5	134,551	/EA-YR	1	EA	135,000			673,000	635,000
Plume Monitoring, Annually	A	6	30	63,959	/EA-YR	1	EA		64,000	64,000	1,599,000	990,000
Phase I Treatment System												
Treatment Facility, 3200 Square Feet	A	1	10	4,770	/EA-YR	1	EA	5,000	5,000		48,000	42,000
Tanks, Filters, & Pumps	A	1	10	69,958	/EA-YR	1	EA	70,000	70,000		700,000	615,000
Hardness/Iron Treatment Unit	A	1	10	3,721	/EA-YR	1	EA	4,000	4,000		37,000	33,000
Oxidation Unit	A	1	10	55,832	/EA-YR	1	EA	56,000	56,000		558,000	491,000
Granular Activated Carbon Adsorption Unit	A	1	10	77,776	/EA-YR	1	EA	78,000	78,000		778,000	683,000
Process Monitoring	A	1	10	78,235	/EA-YR	1	EA	78,000	78,000		782,000	687,000
Phase II Treatment System												
Treatment Facility, 3200 Square Feet	A	11	30	4,770	/EA-YR	1	EA			5,000	95,000	54,000
Tanks, Filters, & Pumps	A	11	30	69,853	/EA-YR	1	EA			70,000	1,397,000	796,000
Hardness/Iron Treatment Unit	A	11	30	3,721	/EA-YR	1	EA			4,000	74,000	42,000
Oxidation Unit	A	11	30	46,802	/EA-YR	1	EA			47,000	936,000	534,000
Granular Activated Carbon Adsorption Unit	A	11	30	60,142	/EA-YR	1	EA			60,000	1,203,000	686,000
Process Monitoring	A	11	30	78,235	/EA-YR	1	EA			78,000	1,565,000	892,000
In Situ Biodegradation System												
Treatment Facility, In Situ Bio	A	1	10	4,770	/EA-YR	1	EA	5,000	5,000		48,000	42,000
Tanks, Filters, & Pumps, In Situ Bio	A	1	10	32,872	/EA-YR	1	EA	33,000	33,000		329,000	289,000
In Situ Biodegradation	A	1	10	10,618	/EA-YR	1	EA	11,000	11,000		106,000	93,000
Process Monitoring, In Situ Bio	A	1	10	78,235	/EA-YR	1	EA	78,000	78,000		782,000	687,000
Subtotal (I)								580,000	509,000	355,000	12,527,000	8,829,000
COST CODE LMSL												
INDIRECT O&M COSTS (OPERATIONS)												
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						226,000	199,000	138,000	4,886,000	3,443,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						16,000	14,000	10,000	348,000	245,000
Contingency	33.8%	L = 0.338 * (I+J+K)						277,000	244,000	170,000	5,994,000	4,225,000
Subtotal (O = J+K+L)								519,000	457,000	318,000	11,228,000	7,914,000
TOTAL O&M COSTS (T = I+O)								1,099,000	966,000	673,000	23,755,000	16,743,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)											29,600,000	22,600,000

Table A6-1 Cost Estimate - Arsenal-Wide Alternative
Minimum Treatment - Boundary Systems Only

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Slurry Wall Demolition	LS	1	--	14,940	/EA	1	EA	14,900	14,900
On-Post Water Supply	LS	1	--	7,079,000	/EA	1	EA	7,079,000	7,079,000

Subtotal (A)				7,094,000	7,094,000
COST CODE HMSS					
INDIRECT CAPITAL COSTS					
Mob/Demob	5.1%	B = 0.051 * (A)			364,000 364,000
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)			3,095,000 3,095,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)			474,900 474,900
Resident Engineering	2.0%	E = 0.020 * (A+B+C)			211,000 211,000
Contingency	33.8%	F = 0.338 * (A+B+C+D+E)			3,792,900 3,792,900
Subtotal (G = B+C+D+E+F)				7,937,000	7,937,000
TOTAL CAPITAL COSTS (H = A+G)				15,031,000	15,031,000

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Cost Estimate - Arsenal-Wide Alternative
Minimum Treatment - Boundary Systems Only

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Yr 1-5	1995 (\$) Yr 6-30	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Continued Operation of NWBCS	A	1	30	542,930	/EA-YR	1	EA	543,000	543,000	16,288,000	10,731,000
Continued Operation of ICS	A	1	4	355,857	/EA-YR	1	EA	356,000		1,423,000	1,362,000
Continued Operation of NBCS	A	1	30	840,905	/EA-YR	1	EA	841,000	841,000	25,227,000	16,620,000
Plume Monitoring, Quarterly	A	1	5	458,953	/EA-YR	1	EA	459,000		2,295,000	2,165,000
Plume Monitoring, Annually	A	6	30	219,828	/EA-YR	1	EA		220,000	5,496,000	3,401,000
Subtotal (I)								2,199,000	1,604,000	50,729,000	34,279,000
COST CODE LMSL											
INDIRECT O&M COSTS (OPERATIONS)											
Indirects, Overhead & Profit	39.0%	J = 0.390 • (I)						858,000	626,000	19,784,000	13,369,000
Resident Engineering	2.0%	K = 0.020 • (I+J)						61,000	45,000	1,410,000	953,000
Contingency	33.8%	L = 0.338 • (I+J+K)						1,052,000	768,000	24,274,000	16,403,000
Subtotal (O = J+K+L)								1,971,000	1,439,000	45,469,000	30,724,000
TOTAL O&M COSTS (T = I+O)								4,170,000	3,043,000	96,198,000	65,003,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)										111,000,000	80,000,000
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Table A6-2 Cost Estimate - Arsenal-Wide Alternative
Existing Treatment

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Annual Cost Yr 1-5	1995 (\$) Annual Cost Yr 6-30	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Continued Operation of Basin A Neck IRA	A	1	30	464,170	/EA-YR	1	EA	464,000	464,000	13,925,000	9,174,000
Continued Operation of NWBCS	A	1	30	542,930	/EA-YR	1	EA	543,000	543,000	16,288,000	10,731,000
Continued Operation of ICS and IRAs	A	1	4	375,080	/EA-YR	1	EA	375,000		1,500,000	1,436,000
Continued Operation of NBCS	A	1	30	840,905	/EA-YR	1	EA	841,000	841,000	25,227,000	16,620,000
Plume Monitoring, Quarterly	A	1	5	492,685	/EA-YR	1	EA	493,000		2,463,000	2,324,000
Plume Monitoring, Annually	A	6	30	233,934	/EA-YR	1	EA		234,000	5,848,000	3,619,000
Deep Well Monitoring, Annually	A	1	5	12,914	/EA-YR	1	EA	13,000		65,000	61,000
Deep Well Monitoring, Every 5 Years	A	6	30	2,583	/EA-YR	1	EA		3,000	65,000	40,000
Subtotal (I)								2,729,000	2,085,000	65,381,000	44,004,000
COST CODE LMSL											
INDIRECT O&M COSTS (OPERATIONS)											
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						1,064,000	813,000	25,499,000	17,162,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						76,000	58,000	1,818,000	1,223,000
Contingency	33.8%	L = 0.338 * (I+J+K)						1,306,000	998,000	31,285,000	21,056,000
Subtotal (O = J+K+L)								2,446,000	1,869,000	58,602,000	39,441,000
TOTAL O&M COSTS (T = I+O)								5,175,000	3,954,000	123,983,000	83,446,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)										139,000,000	98,400,000

Table A6-3 Cost Estimate - Arsenal-Wide Alternative
Additional On-Post Treatment

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Control System									
Extraction Wells & Pump Installation	LS	1	--	3,228,450	/EA	1	EA	3,228,000	3,228,000
Performance Monitoring Well Installation	LS	1	--	670,627	/EA	1	EA	671,000	671,000
Reinjection Pipe & System Installation	LS	1	--	140,910	/EA	1	EA	141,000	141,000
Recharge Trench	LS	1	--	427,244	/EA	1	EA	427,000	427,000
Deep Well Abandonment	LS	1	--	126,000	/EA	1	EA	126,000	126,000
On-Post Water Supply	LS	1	--	7,079,000	/EA	1	EA	7,079,000	7,079,000
Phase I, Treatment System									
Balance of Capital Costs, Combined Phase I	LS	1	--	769,301	/EA	1	EA	769,000	769,000
Treatment Facility, 11000 Square Feet	LS	1	--	180,739	/EA	1	EA	181,000	181,000
Tanks, Filters, & Pumps	LS	1	--	101,863	/EA	1	EA	102,000	102,000
Air Stripping Unit, Phase I	LS	1	--	144,117	/EA	1	EA	144,000	144,000
Granular Activated Carbon Adsorption Unit, Phase I	LS	1	--	33,940	/EA	1	EA	34,000	34,000
Phase II, Treatment System									
Balance of Capital Costs, Combined Phase II	LS	10	--	163,647	/EA	1	EA	164,000	125,000
Tanks, Filters, & Pumps	LS	10	--	8,635	/EA	1	EA	8,635	6,618
Air Stripping Unit, Phase II	LS	10	--	75,235	/EA	1	EA	75,000	58,000
Granular Activated Carbon Adsorption Unit, Phase II	LS	10	--	20,364	/EA	1	EA	20,000	16,000
In Situ Biodegradation System									
Balance of Capital Costs, In Situ Treatment	LS	1	--	137,729	/EA	1	EA	138,000	138,000
Treatment Facility, In Situ Bio	LS	1	--	72,974	/EA	1	EA	73,000	73,000
Tanks, Filters, & Pumps, In Situ Bio	LS	1	--	9,499	/EA	1	EA	9,000	9,000
Subtotal (A)								13,390,000	13,328,000
COST CODE HMSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	5.1%	B = 0.051 * (A)						686,000	683,000
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)						5,842,000	5,814,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)						896,300	892,100
Resident Engineering	2.0%	E = 0.020 * (A+B+C)						398,400	396,500
Contingency	33.8%	F = 0.338 * (A+B+C+D+E)						7,159,400	7,125,900
Subtotal (G =B+C+D+E+F)								14,982,000	14,912,000
TOTAL CAPITAL COSTS (H = A+G)								28,372,000	28,240,000

Table A6-3 Cost Estimate - Arsenal-Wide Alternative
Additional On-Post Treatment

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost Units Quantity Units				1995 (\$) Annual Cost Yr 1-5 Yr 6-10 Yr 11-30			1995 (\$) Total Cost	1995 (\$) PW Cost	
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS													
Control System													
Continued Operation of Basin A Neck IRA	A	1	30	464,170	/EA-YR	1	EA	464,000	464,000	464,000	13,925,000	9,174,000	
Continued Operation of NWBCS	A	1	30	542,930	/EA-YR	1	EA	543,000	543,000	543,000	16,288,000	10,731,000	
Continued Operation of ICS and IRAs	A	1	4	375,080	/EA-YR	1	EA	375,000			1,500,000	1,436,000	
Continued Operation of NBCS	A	1	30	840,905	/EA-YR	1	EA	841,000	841,000	841,000	25,227,000	16,620,000	
Maintenance & Repair	A	1	30	149,650	/EA-YR	1	EA	150,000	150,000	150,000	4,490,000	2,958,000	
Well & Pump Operations	A	1	30	7,744	/EA-YR	1	EA	8,000	8,000	8,000	232,000	153,000	
Plume Monitoring, Quarterly	A	1	5	449,353	/EA-YR	1	EA	449,000			2,247,000	2,120,000	
Plume Monitoring, Annually	A	6	30	215,657	/EA-YR	1	EA		216,000	216,000	5,391,000	3,337,000	
Deep Well Monitoring, Annually	A	1	5	12,914	/EA-YR	1	EA	13,000			65,000	61,000	
Deep Well Monitoring, Every 5 Years	A	6	30	2,583	/EA-YR	1	EA		3,000	3,000	65,000	40,000	
Phase I, Treatment													
Treatment Facility, 11000 Square Feet	A	1	10	4,770	/EA-YR	1	EA	5,000	5,000		48,000	42,000	
Tanks, Filters, & Pumps	A	1	10	66,736	/EA-YR	1	EA	67,000	67,000		667,000	586,000	
Hardness/Iron Treatment Unit	A	1	10	3,748	/EA-YR	1	EA	4,000	4,000		37,000	33,000	
Air Stripping Unit, Phase I	A	1	10	59,534	/EA-YR	1	EA	60,000	60,000		595,000	523,000	
Granular Activated Carbon Adsorption Unit, Phase I	A	1	10	29,474	/EA-YR	1	EA	29,000	29,000		295,000	259,000	
Process Monitoring	A	1	10	78,235	/EA-YR	1	EA	78,000	78,000		782,000	687,000	
Phase II, Treatment System													
Treatment Facility, 11000 Square Feet	A	11	30	4,770	/EA-YR	1	EA			5,000	95,000	54,000	
Tanks, Filters, & Pumps	A	11	30	63,695	/EA-YR	1	EA			64,000	1,274,000	726,000	
Hardness/Iron Treatment Unit	A	11	30	3,729	/EA-YR	1	EA			4,000	75,000	43,000	
Air Stripping Unit, Phase II	A	11	30	51,290	/EA-YR	1	EA			51,000	1,026,000	585,000	
Granular Activated Carbon Adsorption Unit, Phase II	A	11	30	16,439	/EA-YR	1	EA			16,000	329,000	187,000	
Process Monitoring	A	11	30	78,235	/EA-YR	1	EA			78,000	1,565,000	892,000	
In Situ Biodegradation System													
Treatment Facility, In Situ Bio	A	1	10	4,770	/EA-YR	1	EA	5,000	5,000		48,000	42,000	
Tanks, Filters, & Pumps, In Situ Bio	A	1	10	32,872	/EA-YR	1	EA	33,000	33,000		329,000	289,000	
In Situ Biodegradation	A	1	10	10,618	/EA-YR	1	EA	11,000	11,000		106,000	93,000	
Process Monitoring, In Situ Bio	A	1	10	78,235	/EA-YR	1	EA	78,000	78,000		782,000	687,000	
Subtotal (I)								3,213,000	2,595,000	2,443,000	77,483,000	52,358,000	
COST CODE LMSL													
INDIRECT O&M COSTS (OPERATIONS)													
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						1,253,000	1,012,000	953,000	30,218,000	20,419,000	
Resident Engineering	2.0%	K = 0.020 * (I+J)						89,000	72,000	68,000	2,154,000	1,456,000	
Contingency	33.8%	L = 0.338 * (I+J+K)						1,537,000	1,242,000	1,169,000	37,076,000	25,053,000	
Subtotal (O = J+K+L)								2,879,000	2,326,000	2,190,000	69,448,000	46,928,000	
TOTAL O&M COSTS (T = I+O)								6,092,000	4,921,000	4,633,000	146,931,000	99,286,000	
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)											175,000,000	128,000,000	

Table A6-4 Cost Estimate - Arsenal-Wide Alternative
Existing Treatment, Bedrock Ridge Control

Cost Item	Cost Type	Start Year	End Year	1995 (\$) Unit Cost	Units	Quantity	Units	1995 (\$) Total Cost	1995 (\$) PW Cost
DIRECT CAPITAL COSTS									
Extraction Wells & Pump Installation	LS	1	--	1,594,989	/EA	1	EA	1,595,000	1,595,000
Performance Monitoring Well Installation	LS	1	--	152,111	/EA	1	EA	152,000	152,000
Deep Well Abandonment	LS	1	--	126,000	/EA	1	EA	126,000	126,000
On-Post Water Supply	LS	1	--	7,079,000	/EA	1	EA	7,079,000	7,079,000
Subtotal (A)								8,952,000	8,952,000
COST CODE HMSS									
INDIRECT CAPITAL COSTS									
Mob/Demob	5.1%	B = 0.051 * (A)						459,000	459,000
Indirects, Overhead & Profit	41.5%	C = 0.415 * (A+B)						3,906,000	3,906,000
Engineering Design	4.5%	D = 0.045 * (A+B+C)						599,200	599,200
Resident Engineering	2.0%	E = 0.020 * (A+B+C)						266,300	266,300
Contingency	33.8%	F = 0.338 * (A+B+C+D+E)						4,786,400	4,786,400
Subtotal (G =B+C+D+E+F)								10,016,000	10,016,000
TOTAL CAPITAL COSTS (H = A+G)								18,968,000	18,968,000

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Table A6-4 Cost Estimate - Arsenal-Wide Alternative
Existing Treatment, Bedrock Ridge Control

Cost Item	Cost Type	Start Year	End Year	1995 (\$)				1995 (\$) Annual Cost		1995 (\$)	1995 (\$)
				Unit Cost	Units	Quantity	Units	Yr 1-5	Yr 6-30	Total Cost	PW Cost
DIRECT OPERATIONS AND MAINTENANCE (O&M) COSTS											
Continued Operation of NWBCS	A	1	30	542,930	/EA-YR	1	EA	543,000	543,000	16,288,000	10,731,000
Continued Operation of ICS and IRAs	A	1	4	375,080	/EA-YR	1	EA	375,000		1,500,000	1,436,000
Continued Operation of NBCS	A	1	30	840,905	/EA-YR	1	EA	841,000	841,000	25,227,000	16,620,000
Continued Operation of Basin A Neck IRA	A	1	30	464,170	/EA-YR	1	EA	464,000	464,000	13,925,000	9,174,000
Maintenance & Repair	A	1	30	13,685	/EA-YR	1	EA	14,000	14,000	411,000	270,000
Well & Pump Operations	A	1	30	1,961	/EA-YR	1	EA	2,000	2,000	59,000	39,000
Plume Monitoring, Quarterly	A	1	5	424,626	/EA-YR	1	EA	425,000		2,123,000	2,003,000
Plume Monitoring, Annually	A	6	30	201,010	/EA-YR	1	EA		201,000	5,025,000	3,110,000
Plume Monitoring, Annually, South Lakes	A	1	30	67,360	/EA-YR	1	EA	67,000	67,000	2,021,000	1,331,000
Deep Well Monitoring, Annually	A	1	5	51,656	/EA-YR	1	EA	52,000		258,000	244,000
Deep Well Monitoring, Every 5 Years	A	6	30	10,331	/EA-YR	1	EA		10,000	258,000	160,000
Subtotal (I)								2,783,000	2,142,000	67,096,000	45,117,000
COST CODE LMSL											
INDIRECT O&M COSTS (OPERATIONS)											
Indirects, Overhead & Profit	39.0%	J = 0.390 * (I)						1,085,000	835,000	26,167,000	17,596,000
Resident Engineering	2.0%	K = 0.020 * (I+J)						77,000	60,000	1,865,000	1,254,000
Contingency	33.8%	L = 0.338 * (I+J+K)						1,331,000	1,025,000	32,106,000	21,589,000
Subtotal (O = J+K+L)								2,493,000	1,920,000	60,138,000	40,439,000
TOTAL O&M COSTS (T = I+O)								5,276,000	4,062,000	127,234,000	85,556,000
TOTAL CAPITAL COSTS AND TOTAL O&M COSTS (U = H+T)										146,000,000	105,000,000

Appendix B

Appendix B: Groundwater Quality Data

These data, which were used in TSGM calculations and TSGM results, are available upon request. Please contact the Program Manager for Rocky Mountain Arsenal for details.

Appendix C

APPENDIX C

MASS BALANCE AND TRAVEL TIME ESTIMATION

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C.3-1 Selected Contaminant Migration Flow Path

C.1 DESIGN FLOW RATE ESTIMATION FOR CONTROL SYSTEMS

C.1.1 BASIN F CONTROL SYSTEM FLOW ESTIMATES

The design flow rate for the Basin F IRA groundwater control/treatment system was estimated from existing data using analytical methods. Initial estimates of the groundwater flow rate through the cross-sectional aquifer area were made during the Development and Screening of Alternatives (DSA) (EBASCO 1992). The flow rate calculated at that time from existing information indicated that up to 15 gpm could flow through the area. Further evaluation of alternatives and the availability of new detailed data for the depth to bedrock in this area led to re-estimation of groundwater flow. The current estimates of groundwater flow are presented here.

The current estimate of flux through the Basin F IRA area north of Former Basin F is based on analytical methods. The bedrock surface in the targeted area was reviewed and locally reinterpreted based on new well logs and a new land and well survey completed for the area by MKE (Shell 1992). Approximately 20 to 30 drilling logs were also reviewed in critical areas to determine whether bedrock picks listed in the MKE database were reasonable. This review indicated that the data set was a reasonable interpretation of the hydrostratigraphy and bedrock configuration, with a few exceptions that could not be resolved with the existing information. In general, the MKE data set suggested that the depth to bedrock in the IRA area is much shallower than previously thought, resulting in a thinner saturated thickness for the alluvium than that used in previous calculations. This in turn represents a smaller cross-sectional area through which groundwater can flow in this area.

A simple Darcy's Law calculation was made from the standard equation:

$$Q = K i A$$

where Q is volumetric discharge (ft³/day) through the cross-sectional area (A; ft²), under hydraulic gradient (i; ft/ft), and through materials having a hydraulic conductivity (K; ft/day).

The hydraulic conductivity of alluvium was 244 ft/day (MK 1989) and 3 ft/day for the weathered Denver Formation (EBASCO 1989). The hydraulic gradients at each of three subsections were derived from water-level contour maps for several quarters in 1992 and 1993 and ranged from 0.0071 to 0.0131. The cross-sectional area for the alluvium was 375 ft² and the weathered Denver materials, was 12,050 ft² for assuming that the weathered zone was 10 feet thick. The calculated flow through the whole 1,300 foot-long section was 6.3 gpm.

C.2 DESIGN CONCENTRATION ESTIMATION FOR CONTROL/TREATMENT SYSTEMS

C.2.1 DEFINITION OF CONTROL SYSTEM CAPTURE AREAS

In the Basin F IRA area, the existing water-level contours and flow-net concepts were used to estimate and delineate on a map the width of the stream tube or capture zone extending upgradient from the proposed groundwater extraction system. The representative average linear velocity of groundwater was calculated using an analytical approach

$$\bar{v} = \frac{-Ki}{n_e}$$

where:

$\bar{v}$	=	mean groundwater velocity (ft/day)
K	=	hydraulic conductivity (ft/day)
i	=	hydraulic gradient (ft/ft)
n_e	=	effective porosity

employing the best available estimates of local hydraulic gradient, hydraulic conductivity, and effective porosity (Freeze and Cherry 1979). The distance traveled by groundwater at this velocity during a 5-year time period was calculated, and the stream tube capture zone was extended that distance upgradient from the proposed extraction system location.

If the 5-year travel distance reached back to the original source location, then the stream tube or capture zone was assumed to end at the margin of the source area. Only water quality data from wells lying within the prescribed capture zone were used for calculation of the TSGM.

If, however, a given capture zone did not contain a minimum of three sampling points, the capture zone was extended upgradient to include an additional well to reach a minimum of three sampling points within the zone.

For groundwater plumes falling within the boundaries of the South Plants/Basin A groundwater model (Foster Wheeler Environmental 1995), the particle tracking module was utilized to define the effective capture zones of individual mass reduction systems. This was accomplished by simulating the release of particles into the groundwater flow field in the vicinity of the pumping wells for a steady-state drawdown condition and identifying which particles were drawn in and captured by wells in the well field. A boundary was drawn around the well field to contain the area from which released particles were captured. This area then defined the capture zone of the given mass reduction system. Results of these capture zone definition simulations are summarized in the South Plants/Basin A Modeling Report (Foster Wheeler Environmental 1995). The capture zones defined for the mass reduction systems are depicted in Figure C.2-1.

C.2.2 ESTIMATION OF EXPECTED MEAN CONCENTRATIONS

The TSGM of a compound within a given capture zone or stream tube segment was computed as follows. In the first step, the geometric mean of all samples collected throughout a given time period for each individual well was estimated as:

$$GM_1 = \sqrt[n]{(V_1)(V_2)...(V_n)}$$

where:

GM_1	=	geometric mean of analytes in a given well number 1 throughout sampling period t
n	=	number of samples collected and analyzed
$V_1... V_2$	=	individually detected contaminant concentration values. If a value was below the Certified Reporting Limit (CRL), a value was calculated using the Robust Method (Helsel 1990). If the detection ratio for a given well was less than 50 percent (number of detections to number of total samples), one-half of the CRL was

used. One-half of the CRL was also used if there were fewer than three total detections in a given well.

In the second step, the geometric mean concentration between all wells in the capture zone was calculated. This required estimating the overall geometric mean for the stream tube or capture zone (GM_s) for all wells (m) located within the capture zone, based on the GM_i for each of these wells:

where:

$$GM_s = \sqrt[m]{(GM_1)(GM_2)\dots(GM_m)}$$

GM_s = geometric mean of the GM values for all wells 1 through m located within the capture zone

m = number of wells in the capture zone

$GM_1 \dots GM_m$ = individual values of GM, for all wells 1 through m

The TSGM method was used to estimate influent concentrations because it is resistant to outliers and anomalies and thus provides a representative estimate of the mean concentration. The wells that were used to estimate influent concentrations for the system considered in the DAA are listed in Table C.2-1. The data sets used for calculation of TSGM and the results of the calculations are provided in Appendix B of the Water DAA.

C.3 ESTIMATION OF CONTAMINANT TRANSPORT RATES AND TRAVEL TIMES

C.3.1 SELECTION OF REPRESENTATIVE FLOW PATHS

The selection of flow paths along which migration of contaminants could be of potential interest was guided by a simple procedure. The contaminated groundwater plumes, which are of interest due to potential migration, were identified. The most likely pathways along which migration could occur from each plume were defined by examination of water table elevation maps. The streamlines defined in this manner were then broken into segments for convenience and labeled for further reference. Each potential flow path of interest could then be referred to as a series

of streamline segments. Figure C.3-1 indicates the location and designation of each of the flow paths discussed in this section.

C.3.2 SELECTION OF REPRESENTATIVE COMPOUNDS

As part of the DAA, extraction systems have been evaluated for each of the plumes in question. To estimate the composition of the extracted water, statistical analyses were performed on analytical data from wells in the areas that would be influenced by the extraction systems. This water quality was assumed to be representative of the water quality in the plumes.

Representative compounds were chosen for each plume group, based on an evaluation of the list of compounds present in each plume and their concentrations, as identified by the statistical calculations. This list was compared against the groundwater quality standards that were in effect at that time to determine whether any compounds exceeded the current standards. Up to five compounds were chosen as being representative for each plume group.

An attempt was also made to choose compounds from different analyte groups. For example, if the three top exceedances for a particular plume were OCPs, the next three were VHOs and the next two were VAOs, the representative compounds would consist of the top two OCPs, the top two VHOs, and the top VAO. Dropping some compounds with fairly high exceedances, such as the third OCP in the above example, was considered to be acceptable because compounds in the same analyte group tend to show similar behavior. The advantage of this approach was that a wider range of analyte groups could be included.

The list of contaminants that were chosen is presented in Table C.3-1.

C.3.3 ESTIMATION OF CONTAMINANT TRANSPORT RATES

Contaminant transport rates were estimated by first calculating a groundwater velocity for each flow path that is likely to transport contaminants and then by applying a retardation factor to

each compound of interest. The mean linear groundwater velocities were calculated as described in Section C.2.1.

The values of the parameters that were used to calculate the mean linear groundwater velocity, V , for each segment are presented in Table C.3-2. Note that many of the parameters that were used in the calculation were actually represented as a range of values. The parameters used to calculate the groundwater flow velocities such as hydraulic conductivities and hydraulic gradients are from data collected at RMA. The range of values of hydraulic conductivity for a particular flow path are from aquifer tests conducted in the vicinity of that flow path or from aquifer tests conducted in similar aquifer materials at RMA. Hydraulic gradients were measured from a map of the summer 1992 water table. Site specific data does not exist for values of effective porosity for aquifer materials at RMA. The effective porosities used for these calculations are ranges of values for similar type materials described in the hydrogeologic literature.

The maximum and minimum values of parameter ranges were used to calculate a maximum and minimum groundwater velocity for each segment by selecting the combination of component factors that produced the minimum and maximum overall travel times for each path. For example, the maximum groundwater velocity for a flow path would be calculated using the maximum hydraulic conductivity and the minimum effective porosity, since the velocity is inversely proportional to the effective porosity.

Once the average linear groundwater velocity was calculated, retardation factors for each individual compound were applied to determine the contaminant transport rates. Retardation factors were calculated based on the soil bulk density, total porosity, fraction of organic carbon, and the partition coefficient for organic carbon, using the following equations.

$$R_i = 1 + (B \times K_p)/n$$

and

$$K_p = K_{oc} \times f_{oc}$$

where:

R_i	= retardation factor (dimensionless)
B	= soil density (g/cm^3)
K_p	= partitioning coefficient for soil (ml/g)
n	= total porosity (decimal fraction)
K_{oc}	= partition coefficient for organic carbon (ml/g)
f_{oc}	= fraction organic carbon in the soil (decimal fraction)

Values that were used for these parameters are also presented in Table C.3-2. Partition coefficients for organic carbon, K_{oc} , are included at the bottom of the table and are the only parameters used that are contaminant specific. All other parameters relate to the aquifer characteristics. Values for bulk densities and fraction of organic carbon are from data collected at RMA. The range of values for a particular flow path are from samples collected in the vicinity of that flow path or from samples collected in similar aquifer materials at RMA. The total porosities used for these calculations are ranges of values for similar type materials described in the hydrogeologic literature. Maximum and minimum retardation factors were determined for each segment by selecting the appropriate combination of parameters. For example, the maximum retardation factor for a flow path would be calculated using the maximum partition coefficient and fraction of organic carbon while using minimum total porosity, since the retardation is inversely proportional to the total porosity. The resulting retardation factors are specific to the particular contaminant and to the particular segment in the aquifer.

C.3.4 TRAVEL TIME ESTIMATION

Travel times for individual compounds were estimated by applying that compound's retardation factor to the groundwater velocity in the segment under consideration. The retardation factors were applied to the groundwater velocities through the following equation:

$$V_i = V / R_i$$

where:

V_i = velocity of component i in the aquifer (units)
 V = groundwater velocity
 R_i = retardation factor

The results of these calculations are presented in Table C.3-3. This table summarizes the range of travel times for individual compounds to reach control systems that are downgradient of the different plumes. Minimum and maximum values are presented for the travel times and can represent a range of several orders of magnitude. Contaminant travel times decrease as the groundwater velocity and contaminant migration rate increase. It should be noted that the calculated travel times only pertain to contaminants that have entered the groundwater in dissolved form.

The compounds of greatest concern listed in Table C.3-1 come from a few analyte groups: OCPs, VHOs, organophosphorus pesticides, VAOs, and DBCP. Of these, all but the OCPs have low retardation factors and therefore move with higher velocities, so that their maximum travel times are generally less than 20 years.

The OCPs are the only compounds with very high retardation factors. These compounds tend to be less water soluble than the others and therefore may be controlled more by the rate of release into the aquifer than by the theoretical time it takes to move from a source to the boundary. This mechanism, along with the high retardation factors, appear to cause the concentrations of these compounds to be relatively constant over time.

Based on a review of contaminant migration rates and the proximity of dissolved contaminants to the boundary systems, it appears that no compounds are likely to arrive at the boundary systems in the next 5 years other than those already found in the influent groundwater. As a result, it is anticipated that the current boundary treatment facilities will be able to continue to effectively treat influent at the boundaries.

C.4 ESTIMATION OF GROUNDWATER PLUME VOLUMES AND CONTAMINANT MASS

C.4.1 CALCULATION OF PLUME AND CAPTURE ZONE VOLUMES

The volumes of aquifer and groundwater contained within the limits of each groundwater plume and targeted capture zone in the Basin A and South Plants area were calculated. The resulting volumes were then used in the contaminant mass calculations.

The area of interest for each plume was defined on a plume and control system basis. The boundaries of the large, well-defined plumes were represented by the 100- $\mu\text{g/l}$ concentration contour for total organic contaminants as displayed on the Total Organic Plume Map (Plate 1). The plumes for which this boundary was used were the Basin A Plume, the South Plants North Plume, and the South Tank Farm Plume. The boundaries of the other, smaller plumes that have less well-defined perimeters were represented by the margins of their respective mass reduction capture zones.

The capture zones for mass reduction systems were delineated by evaluating the simulated capture of particles which were introduced into the groundwater flow field within the area of a given plume (See Section C.2.1). The South Plants/ Basin A groundwater flow model (Foster Wheeler Environmental 1995) was utilized for these mass reduction system and particle tracking simulations. The results of the model runs are presented in the Draft Final South Plants/Basin A Groundwater Flow Model Report (Foster Wheeler Environmental 1995). The plume boundaries and capture zone areas that have been defined are indicated on Figure C.2-1.

The first step in the plume volume calculation involved the identification of the finite difference grid cells in the groundwater flow model that fall within each plume boundary or capture area. For each of these cells, the water table elevation, the elevation of the top of the bedrock, and the estimated elevation of the base of the unconfined flow system have already been defined at the center of each cell as components of the model. The dimensions of each grid cell are known and generally measure 100 feet by 100 feet horizontally in most of the area of interest. The

water table elevation from spring 1993 defined the assumed water table surface for these calculations. Given these data, the volume of aquifer present in each grid cell was calculated directly. The volumes of all cells within an individual plume or capture zone were summed to determine the total aquifer volume in the given area. The resulting volumes are summarized in Table C.4-1.

The volume of contaminated groundwater within each plume or capture area was calculated as the product of the mean aquifer effective porosity and aquifer volume. The porosity values applied are listed in Table C.4-1. These values are generally 0.10 for alluvial materials and 0.05 for the weathered Denver Formation bedrock and fall within the ranges of properties reported for these materials (HLA 1992; EBASCO 1989). In general the porosities are lower than the reported total porosities and greater than the specific yields reported from pumping tests. The specific yield typical of weathered bedrock is approximately 0.01, representing primarily the drainable fracture porosity of the aquifer. A larger effective porosity of 0.05 was estimated to represent fracture porosity and adjacent primary porosity within the claystone bedrock matrix. The selection of 0.05 was based on engineering judgement and experience with the drainage characteristics of similar geologic materials.

C.4.2 ESTIMATION OF DISSOLVED CONTAMINANT MASS

The total dissolved mass of each contaminant plume and capture area was calculated as the product of the estimated contaminant concentration within each finite difference grid cell and the volume of groundwater in that cell. The total organic contaminant plume map served as the basis for estimating the concentrations associated with each grid cell location. For this estimate, the total organic map concentration contours were interpolated to yield point concentrations at each cell within the spatial limits of the plume or capture zone. The products of each cell concentration and groundwater volume were summed to obtain the total dissolved mass of organic contaminants. The resulting dissolved masses are listed in Table C.4-1.

C.4.3 ESTIMATION OF CONTAMINANT MASS SORBED ONTO AQUIFER MATERIAL

The mass of organic contaminants that is expected to be sorbed onto the aquifer materials was estimated from the dissolved mass of selected constituents that were considered to be representative of the bulk of the dissolved organic mass in each plume or capture zone. The selection of contaminants was performed by comparison of the calculated TSGM concentrations in each area. The partitioning coefficients of contaminants that appeared to constitute the greatest share of the dissolved mass (Section C.3.3) were also compared, and the compound having the K_p most representative of the dominant contaminants was selected for sorption calculations in that area. The chemical constituents selected as the representative compounds in each aquifer area are listed in Table C.4-1. The total mass sorbed into aquifer materials was estimated from the following equation:

$$\text{MassSoluteSorbed} = \frac{(K_p)(\text{MassSoluteDissolved})(\text{MassAquifer})}{(\text{GroundwaterVolume})}$$

The results from these calculations and the total estimated mass in each aquifer area are summarized in Table C.4-1. The results indicate that a large fraction of the contaminant mass may reside in the sorbed phase within each of the aquifer areas. The estimated percentage of mass that is dissolved has also been calculated for each plume area. The mass of contaminants in the dissolved phase ranges from approximately 4 percent in the Section 36 Bedrock Ridge North capture zone to 32 percent in the South Plants North Plume capture zone. Most of the dissolved contaminant mass falls within the 10 to 23 percent range, suggesting that approximately 4 to 10 times as much contaminant mass is sorbed onto aquifer materials as is dissolved in groundwater in these targeted areas. In the South Plants North Plume capture zone, this suggests that more than 80,000 kg of contamination is present as a sorbed phase. In the South Tank Farm Plume mass reduction system capture zone, there may be as much as 30,000 kg of dissolved and 245,000 kg of sorbed benzene present in the aquifer. For the same plume,

the in situ biotreatment system capture zone may encompass as much as 35,000 kg of dissolved and 285,000 kg of sorbed benzene.

The simplified approach employed here for the estimation of sorbed mass assumes that the K_p selected is representative of the mixture of compounds present in the aquifer. This approach has several advantages over attempting to compute the sum of all sorbed contaminants on an individual basis. If individual contaminant sorption calculations were performed, the K_p of each individual compound would have to be known or inferred for the Arsenal aquifers. This could not be accomplished for many of these compounds with great certainty. For the uncommon compounds, no defensible K_p value could be estimated without undertaking site-specific experiments to measure sorption parameters. Even if these parameters were known, it is not likely that the sum of individual constituent sorbed mass estimates would be significantly different than the current estimate made by the simplified approach described above based on a representative K_p value.

Note that the dissolved mass estimates here were those made by integration of the total organic contaminants as described in Section C.4.2 above and not by use of the TSGM values.

C.4.4 CALCULATION OF DISSOLVED MASS REMOVED FROM AQUIFER BY MASS REDUCTION SYSTEMS

The total volume of contaminated groundwater in each targeted plume area was calculated to establish the pumping rate that would be required in order to remove all of the contaminated groundwater in a 20-year period of operation. This would be equivalent to the removal of all currently dissolved contaminant mass in the same time period assuming plug flow displacement and that no additional mass entered solution by desorption from the sorbed phase on the aquifer solids. The derived pumping rate was then evaluated to determine whether the rate could be sustained over an extended period with a reasonable number of extraction wells in the wellfield. The actual extraction well systems that were capable of these requirements are discussed in the appropriate sections of the DAA Report (Sections 7.0 and 8.0). Based on these extraction rates and the 20-year time period, all of the dissolved contaminant mass within the targeted plume

areas could be removed. The resulting dissolved mass removal estimates have been summarized in Table C.4-2 along with the proposed pumping rates and the total volume of groundwater removed during the twenty years for each of the capture areas.

C.5 REFERENCES

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Table C.2-1 Wells Used to Calculate TSGM Values

Plume	Well Number
Basins C and F Plume	23049, 23237, 23530, 26041, 26133, 26148, 26149, 26157, 26161, 26162, 26163, 26166, 26171, 26173, 23006
Section 36 Bedrock Ridge North Plume	36184, 36191, 36204
Section 36 Bedrock Ridge South Plume	36185, 36200, 36207
South Plants North Plume	36054, 36055, 36056, 36058, 36076, 36109, 36167, 36168, 36193, 36511, 36512, 36210, 36212, 36181, 36001,
Basin A Plume	36080, 36187, 36188, 36189, 36190, 36202, 36088, 36090, 36203, 36180, 36204, 36205, 36523, 36509, 36510, 36515, 36590
South Plants North Plume Source	01078, 01083, 01507, 01513, 01524, 01525, 01572, 01573, 01516
South Plants Southeast Plume	01061, 01517, 01511
Block 1, Basin A Dewatering	36146, 36108, 36177, 36123, 36094, 36169, 36001, 36181, 36109, 36212, 36210, 36076, 36056, 36187, 36188, 36088, 36085, 36084, 36074, 36521, 36508, 36514, 36522, 36509, 36590, 36510, 36523, 36506, 36164
Block 2, Basin A Dewatering	36202, 36542, 36543, 36090, 36203, 36180, 36158, 36281, 36191, 36184, 36204, 36207
Block 3, Basin A Dewatering	36109, 36056, 36074
Block 4, Basin A Dewatering	36205, 36189, 36198, 36080, 36190, 36063, 36515, 36524, 36525, 36507, 36518
Block 1, South Plants Dewatering	02003, 02005, 02545, 02594
Block 2, South Plants Dewatering	01083, 01524, 01516, 01078, 01517, 01007, 01068, 01084
Block 3, South Plants Dewatering	36193, 36054, 01513, 01525, 36168, 01572, 01507, 01573, 01511, 36512, 36511, 36513, 01020, 01510
Block 4, South Plants Dewatering	01061, 01101, 01017
Block 5 and 6, South Plants Dewatering	01535, 01534, 01565, 01540, 01539, 01533, 01554, 01618, 01552, 01547, 01100, 01089

Table C.2-1 Wells Used to Calculate TSGM Values

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Plume	Well Number
South Tank Farm Plume	01089, 01533, 01534, 01539, 01540, 01541, 01559, 01565, 02561, 02584, 01094, 01560, 02585, 01014, 02522
South Tank Farm - In Situ	01094, 01533, 01534, 01089, 01540, 01047, 01100, 01565, 01539, 01540, 01541, 01559, 02561, 02584, 01560, 02585, 01014, 01552, 01554, 02501, 02562, 02575, 02502, 02576, 01618, 02583, 01587, 01604, 01605, 02522, 01588, 01547

Table C.3-1 Transport Plumes, Paths, and Contaminants

1 of 1

Plume	Segments	Contaminants
North Plants NPLANTS	A	Dieldrin, 1,1-Dichloroethylene
Section 36 North SECT36N	C,B,A	1,1-Dichloroethylene, Carbon tetrachloride, Methylene chloride, Chloroform, Trichloroethylene
Section 36 South SECT36S	E,B,A	Tetrachloroethylene
Basin A		
North Pathway BASINA_N	D,C,B,A	Benzene, Chloroform, Chlordane, DBCP, Dieldrin
South Pathway BASINA_N	F,E,B,A	Benzene, Chloroform, Chlordane, DBCP, Dieldrin
Basins C & F BASINC&F	H,G	Atrazine, Chloroform, DIMP, Dieldrin, Tetrachloroethylene
South Plants North SPLANTSN	K,J	Aldrin, Atrazine, Chloroform, DIMP, Dieldrin
Basin A Neck ANECK	I	Aldrin, Atrazine, Chloroform, DIMP, Dieldrin
South Tank Farm Plume STFP	L	Benzene, Carbon tetrachloride, Chloroform, Chlordane, DBCP
Western Tier WESTERN	M	DBCP, Trichloroethylene

Table C.3-2 TRAVEL TIME CALCULATION PARAMETERS

Segment	Description	Geology	Length x (feet)	Hydraulic Conductivity Ks (ft/day)	Hydraulic Gradient i (ft/ft)	Effective Porosity ne (fraction)	Avg. Linear Groundwater Velocity V (ft/day)	Soil Bulk Density B (lb/ft ³)	Total Porosity n (fraction)	Fraction Organic Carbon Foc (fraction)	
A	Flowing north from N. Plants to the NBCS.	Alluvium	8000	396.9	0.006	0.30	23.814	107.00	0.40	0.001	MAX
				31.2	0.006	0.10	0.624		0.15	0.001	MIN
B	Flowing north from Sect. 36 to North Plants.	Alluvium	3500	396.9	0.005	0.30	19.845	105.85	0.40	0.001	MAX
				195.6	0.005	0.10	3.260		0.15	0.001	MIN
C	Flowing NE from N. Bedrock High.	Bedrock	1500	2.5	0.02	0.20	5.000	72.77	0.70	0.018	MAX
				2.5	0.02	0.01	0.250		0.40	0.003	MIN
D	Flowing NE from Basin A to N. Bedrock High.	Alluvium	500	11.9	0.006	0.30	0.714	103.80	0.40	0.014	MAX
				4.2	0.006	0.10	0.084		0.15	0.001	MIN
E	Flowing NE from S. Bedrock High.	Bedrock	2000	2.5	0.014	0.20	3.500	72.77	0.70	0.018	MAX
				2.5	0.014	0.01	0.175		0.40	0.003	MIN
F	Flowing NE from Basin A to S. Bedrock High.	Alluvium	1500	11.9	0.006	0.30	0.714	103.80	0.40	0.014	MAX
				4.2	0.006	0.10	0.084		0.15	0.001	MIN
G	Flowing NNE in Sect 23 from Basin F to NBCS.	Alluvium	4500	229.6	0.001	0.30	2.296	107.00	0.40	0.001	MAX
				226.8	0.001	0.10	0.756		0.15	0.001	MIN
H	Flowing N from Basin F to Sect. 23.	Alluvium	2200	229.6	0.004	0.30	9.184	107.00	0.40	0.001	MAX
				226.8	0.004	0.10	3.024		0.15	0.001	MIN
I	Flowing NW from Basin A Neck to NWBCS.	Alluvium	9500	250	0.01	0.30	25.000	107.40	0.40	0.014	MAX
				106	0.01	0.10	3.533		0.15	0.001	MIN
J	Flowing N and W from South Plants to Basin A Neck.	Alluvium	6500	11.9	0.01	0.30	1.190	107.40	0.40	0.014	MAX
				4.2	0.01	0.10	0.140		0.15	0.001	MIN
K	Flowing N from S. Plants to Sect. 36.	Alluvium	600	10.8	0.012	0.30	1.296	107.40	0.40	0.014	MAX
				3.7	0.012	0.10	0.148		0.15	0.001	MIN
L	Flowing SW from S. Plants to the lakes.	Bedrock	3200	3.4	0.011	0.20	3.740	72.77	0.70	0.051	MAX
				1	0.011	0.01	0.055		0.40	0.001	MIN
M	Flowing N from Sect. 9 to the ICS.	Alluvium	10200	963.8	0.004	0.30	38.552	107.40	0.40	0.001	MAX
				396.9	0.004	0.10	5.292		0.15	0.001	MIN

	1,1-dichloro-ethylene	Aldrin	Atrazine	Benzene	Carbon tetra-chloride	Methylene chloride	Chloroform	Chlordane	DBCP	DIMP	Dieldrin	Tetrachloro-ethylene	Trichloro-ethylene
Koc MAX	123	372000	162	912	813	17	151	794000	257	123	245000	955	1740
Koc MIN	29	17000	162	34	224	10	43	33100	126	123	7240	166	145

TABLE C.3-3 SUMMARY OF CONTAMINANT TRANSPORT TIMES

*** ALL VALUES ARE IN YEARS ***

NORTH BOUNDARY CONTROL SYSTEM

Plume	11DCE	ALDRN	ATZ	C6H6	CCL4	CH2CL2	CHCL3	CLRDAN	DBCP	DIMP	DLDRN	TCLEE	TRCLE	
North Plants A	84 1										98000 29			MAX MIN
Sect 36 North C, B, A	210 2.5				1100 4.5	77 2.3	250 2.7						2300 3.7	MAX MIN
Sect 36 South E, B, A												2100 5.3		MAX MIN
Basin A North D, C, B, A				3600 4.8			650 4.9		1100 6.4	540 6.4	940000 140			MAX MIN
Basin A South F, E, B, A				8200 9.1			1400 9.4		2400 12	1200 12	2200000 250			MAX MIN
Basins C & F H, G			52 10				50 7.1			44 9.2	51000 190	220 10		MAX MIN

SOUTH PLANTS NORTH PLUME

Plume	11DCE	ALDRN	ATZ	C6H6	CCL4	CH2CL2	CHCL3	CLRDAN	DBCP	DIMP	DLDRN	TCLEE	TRCLE	
S Plants North K, J		8300000 1200	3700 28				3500 19			2900 25	5400000 520			MAX MIN

BASIN A NECK IRA CONTROL SYSTEM TO NORTHWEST BOUNDARY CONTROL SYSTEM

Plume	11DCE	ALDRN	ATZ	C6H6	CCL4	CH2CL2	CHCL3	CLRDAN	DBCP	DIMP	DLDRN	TCLEE	TRCLE	
Basin A Neck I		31000 77	21 1.8				20 1.2			18 1.6	21000 33			MAX MIN

SOUTH TANK FARM PLUME

Plume	11DCE	ALDRN	ATZ	C6H6	CCL4	CH2CL2	CHCL3	CLRDAN	DBCP	DIMP	DLDRN	TCLEE	TRCLE	
S Tank Farm L				22000 2.5	19000 3.2		3700 2.5	18800000 130	6200 2.8					MAX MIN

IRONDALE CONTROL SYSTEM

Plume	11DCE	ALDRN	ATZ	C6H6	CCL4	CH2CL2	CHCL3	CLRDAN	DBCP	DIMP	DLDRN	TCLEE	TRCLE	
Western M													110 1.2	MAX MIN

Table C.4-1 Groundwater Volume, Dissolved Mass, and Sorbed Mass Data

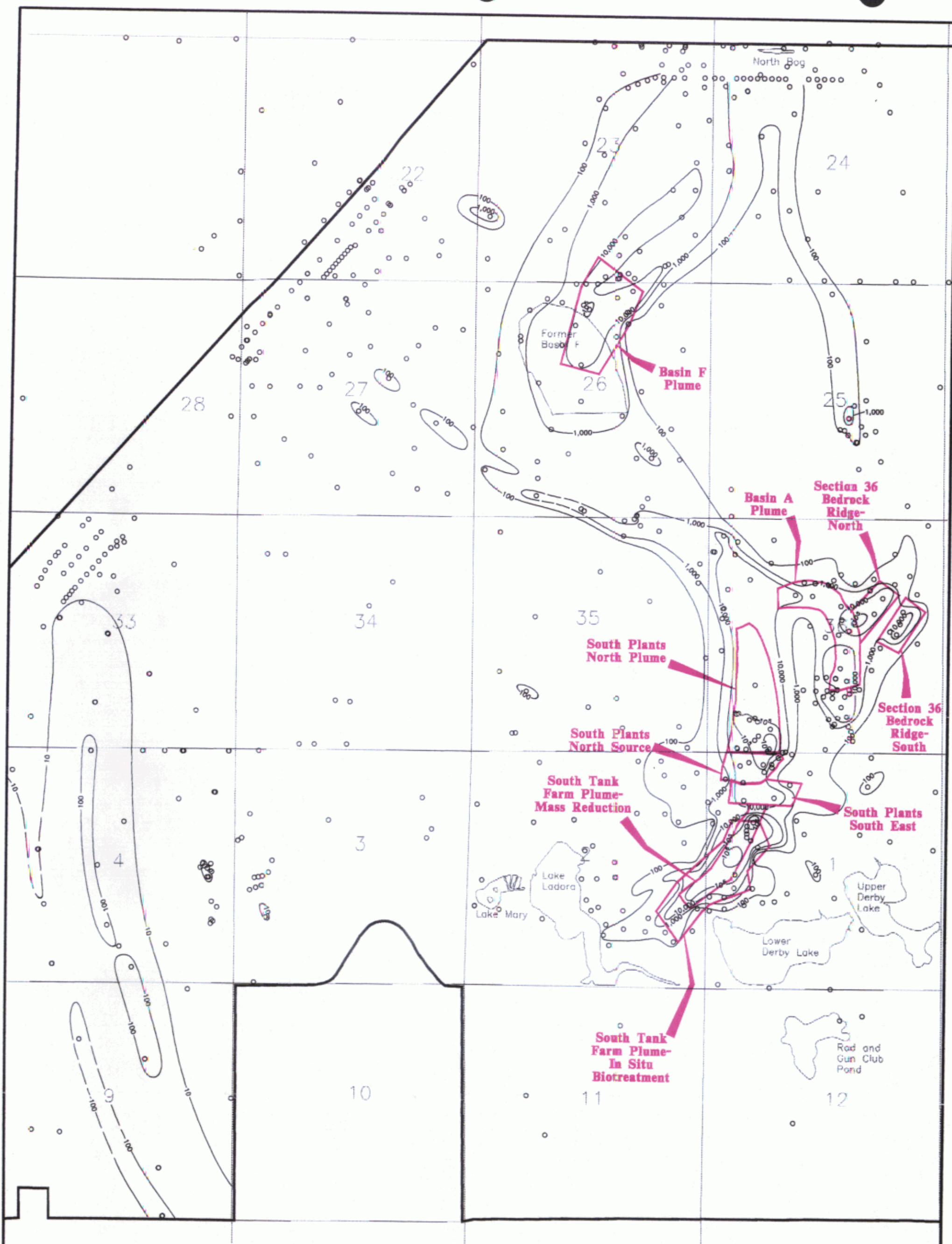
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Capture Zone ID	Aquifer Volume (ft ³)	Average Effective Porosity	Groundwater Volume (ft ³)	Total Dissolved Organic Contaminant Mass (kg)	Representative Contaminant	Representative K _p (L/kg)	Total Sorbed Contaminant Mass (kg)	Total Estimated Contaminant Mass (kg)
South Plants North	110 x 10 ⁶	0.1	11 x 10 ⁶	38,000	Chloroform	0.1164	80,000	118,000
Basin A Plume	94 x 10 ⁶	0.1	9.4 x 10 ⁶	3,400	DIMP	0.1845	11,000	14,400
Section 36 Bedrock Ridge North	24 x 10 ⁶	0.05	1.2 x 10 ⁶	930	1,1-Dichloroethylene	0.1086	3,700	4,630
Section 36 Bedrock Ridge South	20 x 10 ⁶	0.05	1.0 x 10 ⁶	130	Tetrachloroethylene	0.6705	3,100	3,230
South Plants North Source	28 x 10 ⁶	0.05	1.4 x 10 ⁶	2,400	Chloroform	0.1164	10,000	12,400
South Plants Southeast	30 x 10 ⁶	0.05	1.5 x 10 ⁶	430	Chloroform	0.1164	1,800	2,230
South Tank Farm Mass Reduction	56 x 10 ⁶	0.05	2.8 x 10 ⁶	30,000	Benzene	0.2265	245,000	275,000
South Tank Farm In Situ Bioremediation	94 x 10 ⁶	0.05	4.7 x 10 ⁶	35,000	Benzene	0.2265	285,000	320,000

Table C.4-2 Mass Removal Estimates for Mass Reduction Systems

Page 1 of 1

Capture Zone ID	Design Pumping Rate (gpm)	Volume Groundwater Removed (ft ³)	Volume Groundwater in Area (ft ³)	Fraction of Dissolved Mass Removed	Total Dissolved Organic Contaminant Mass Removed (kg)
Basin Alternative AC-3					
South Plants North	10	14 x 10 ⁶	11 x 10 ⁶	1.3	38,000
Basin A Plume	8	11.2 x 10 ⁶	9.4 x 10 ⁶	1.2	3,400
Section 36 Bedrock Ridge North	1	1.4 x 10 ⁶	1.2 x 10 ⁶	1.2	930
Section 36 Bedrock Ridge South	1	1.4 x 10 ⁶	1.0 x 10 ⁶	1.3	130
South Plants Alternative SPC-3					
South Plants North Source	2.5	3.5 x 10 ⁶	1.4 x 10 ⁶	2.5	2,400
South Plants Southeast	2.5	3.5 x 10 ⁶	1.5 x 10 ⁶	2.3	430
South Tank Farm	5	7.0 x 10 ⁶	2.8 x 10 ⁶	2.5	30,000
South Plants Alternative SPC-3/SPT-5					
South Plants North Source	2.5	3.5 x 10 ⁶	1.4 x 10 ⁶	2.5	2,400
South Plants Southeast	2.5	3.5 x 10 ⁶	1.5 x 10 ⁶	2.3	430
South Tank Farm	5	7.0 x 10 ⁶	2.8 x 10 ⁶	2.5	35,000
South Plants Alternative SPC-5					
South Plants North Source	2.5	3.5 x 10 ⁶	1.4 x 10 ⁶	2.5	2,400
South Plants Southeast	2.5	3.5 x 10 ⁶	1.5 x 10 ⁶	2.3	430



Legend

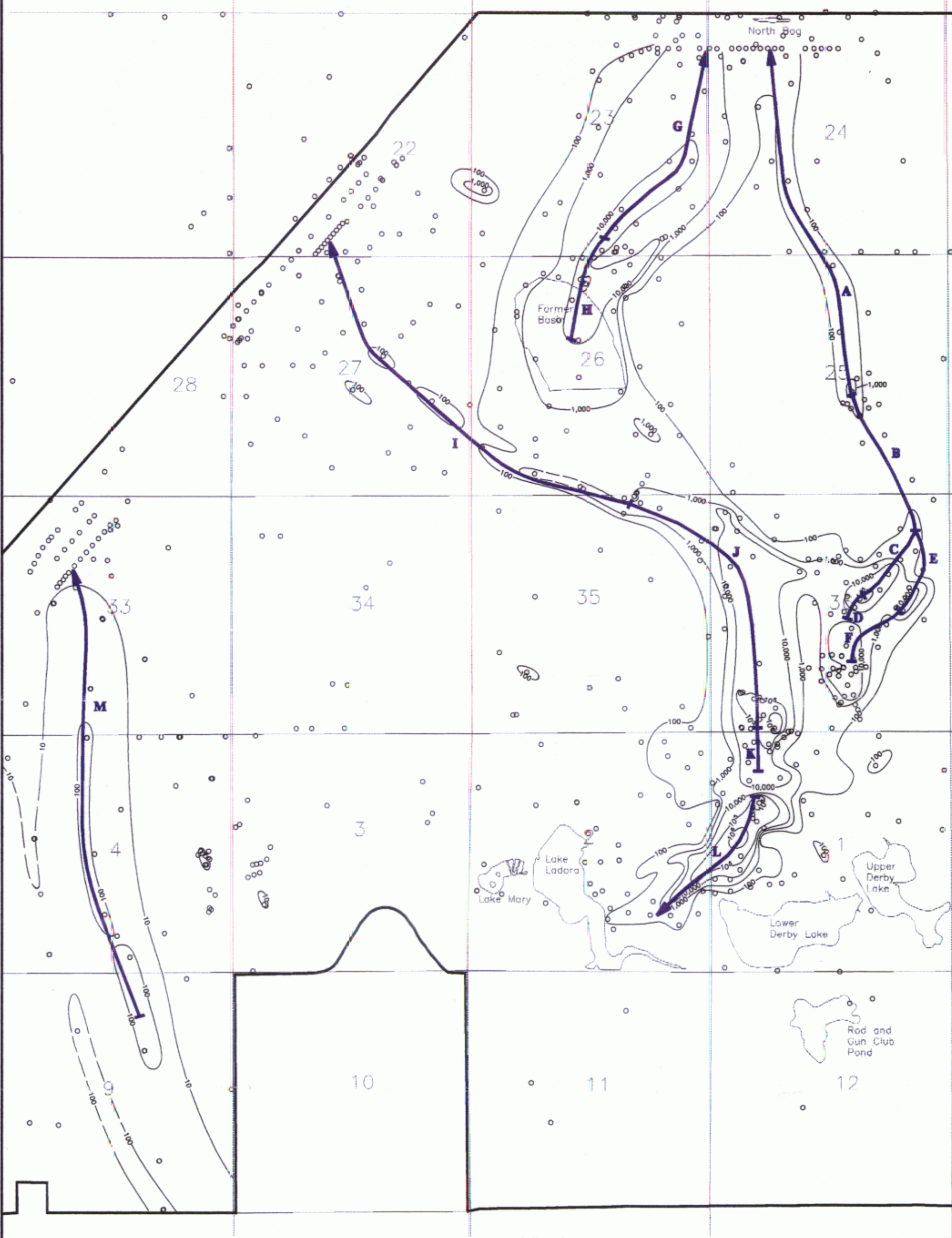
- Monitoring Well
- Summed Target Organic Analyte Concentration ug/L (Table 3.1-2)
- Mass Reduction Units



Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared October 1995

FIGURE C.2-1
Location of Mass Reduction
System Capture Areas

Rocky Mountain Arsenal
Prepared by: Foster Wheeler Environmental Corporation



Legend

- Monitoring Well
- Summed Target Organic Analyte Concentration
- ➔ Flow Direction



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 for Rocky Mountain Arsenal
 Prepared October 1995

FIGURE C.3-1
 Selected Contaminant Migration
 Flow Paths

Rocky Mountain Arsenal
 Prepared by: Foster Wheeler Environmental Corporation

