DEPARTMENT OF THE ARMY
HEADQUARTERS, 3D INFANTRY DIVISION (MECHANIZED) AND FORT STEWART
DIRECTORATE OF PUBLIC WORKS
1550 FRANK COCHRAN DRIVE
FORT STEWART, GEORGIA 31314-4927

14 AUG 2000

REPLY TO
ATTENTION OF

AFZP-PWV-E (200-1a)

MEMORANDUM FOR HEADQUARTERS, FORSCOM, DCSPIM,
ATTN: STEPHANIE SIGLER, 1777 HARDEE AVENUE SW.,
FORT MCPHERSON, GA 30330-1062

SUBJECT: Decision Documents for Fort Stewart and Hunter Army Airfield, Georgia

1. The attached decision documents are provided for your use and convenience in documenting the distribution of fiscal year 99 through 01 funding for the:
   a. Interim Remedial Action (IRA) at FST-31, the Former DEH Asphalt Tanks (FY 99).
   b. Final Remedial Action (FRA) at FST-01, the Post South Central Landfill (FY00).
   c. IRA at HAA-12, the Old Property Disposal Yard (FY99).
   d. FRA at HAA-12, the Old Property Disposal Yard (FY00 or FY01).

2. As noted above, the IRA's for FST-31 and HAA-12 were funded in FY99, prior to the requirement to submit a decision document for interim remedial actions. However, at the request of FORSCOM, decision documents (DDs) were prepared for these two sites.
   a. The DD for FST-31 summarizes the site conditions prior to implementation of the IRA. In addition, the document provides justification for the actions taken at the site. Implementation of the IRA was conducted April 12-20, 1999, and the site is now pending approval by the Georgia Environmental Protection Division of a "No Further Action Required" status.
   b. The DD for HAA-12 incorporates information regarding the FY99 funded IRA into the document for the FRA. The FRA is programmed to be funded 4th QTR FY00 or 1st QTR FY01.

3. Mr. Joe King at the Army Environmental Center has received a copy of these decision documents for review and approval.

4. The point of contact for this memorandum is Ms. Melanie Little or Ms. Tressa Rutland, DPW Environmental Branch, at (405) 364-8461 or (912) 767-7919, respectively.

FOR THE COMMANDER:

Enclosures

GREGORY V. STANLEY
COL, EN
Director, Public Works

DOCUMENT 10

DECISION DOCUMENT FOR INTERIM AND FINAL REMEDIAL ACTIONS AT THE OLD PROPERTY DISPOSAL YARD (HAA-12) HUNTER ARMY AIRFIELD, GEORGIA

PURPOSE OF THE INTERIM & FINAL REMEDIAL ACTIONS

This decision document describes the selected Interim Remedial Action (IRA) and Final Remedial Action (FRA) for the Old Property Disposal (PDO) Yard (HAA-12) at Hunter Army Airfield (HAAF), Georgia. One decision document for both actions was approved by FORSCOM (April 2000). Specifically, the IRA, which was performed in June 1998, consisted of removal of three ASTs and approximately 450 cubic yards of soil. The proposed FRA for HAA-12 includes Geo-Cleanse® treatment of the PCE plume, monitored natural attenuation of the benzene plume, and implementation of the Operation & Maintenance (O&M) plan. The selected final remedial action is described in detail in the *Final Corrective Action Plan for the Old Property Disposal Yard (HAA-12)*, dated May 2000, and approved by GA EPD in correspondence dated July 25, 2000.

This decision document presents the justification for the selected IRA and FRA and specifically provides details on the following:

- Site History
- Nature and Extent of Soil Contamination
- Nature and Extent of Groundwater Contamination
- Nature & Extent of Surface Water and Sediment Contamination
- Contaminant Fate and Transport
- Human Health Risk Assessment
- Ecological Risk Assessment
- Supplemental Sampling
- Justification and Purpose of Corrective Action
- Identification of Remedial Levels
- Screening of Corrective Action Alternatives
- Conceptual Design and Implementation
- Public Notification
- Declaration

SITE HISTORY

HAAF is located in Savannah, Chatham County, Georgia, and covers approximately 5,400 acres. HAAF is a sub-installation to the Fort Stewart Military Reservation, which is located approximately 30 miles to the southwest. The PDO Yard is located near the northwestern boundary of HAAF and consists of a parcel containing approximately 0.955 acres. The fenced area of the site is approximately 136 feet by 300 feet. Much of the site is paved with the remainder covered in crushed stone. The PDO Yard contains three newly installed aboveground storage tanks (ASTs) that serve as an accumulation point for used oil and off-specification jet propulsion (JP-4) fuel, a 90-day hazardous waste storage area, and several paved open storage bays.

Prior to 1998, the PDO Yard contained three ASTs set within a bermed area in the southeast corner of the fenced site area. Those ASTs included two 20,000-gallon tanks for storage of waste oil and one 18,000-gallon tank for storage of off-specification JP-8. These tanks were removed in 1998 as part of the IRA and replaced with the three new ASTs set in a concrete-lined tank area on the northwest side of the fenced PDO Yard area. The new ASTs were funded with OMA funds, and were not part of IRA activities.

NATURE AND EXTENT OF SOIL CONTAMINATION

Previous investigations had revealed petroleum hydrocarbon and organic solvent contamination within the former bermed AST area, which was the suspected source of benzene and PCE identified in the groundwater. During Phase I RFI activities in 1996, 20 shallow soil samples were collected from 10 hand auger locations, 4 monitoring well boreholes, and 15 soil boring locations. Although benzene was not detected in any of those samples, PCE as high as 43 µg/kg was reported in a single soil sample from within the bermed area. As a result, GA EPD highly recommended that the Installation perform an IRA to remove the ASTs and berm, and resubmit the RFI report documenting the IRA activities. Therefore, the contaminated soil in the former AST area was removed during IRA activities that were conducted at the PDO Yard in July 1998. The ASTs were removed from the facility, cleaned, and taken offsite for recycling. The soil around the former AST locations, including the berms, was excavated to a depth of about 3 feet below ground surface (bgs) with the exception of the northeast corner where the depth was 4.2 feet bgs. The excavation pit was approximately 50 feet by 75 feet and produced about 450 cubic yards of soil. Eight confirmatory soil samples were collected from the excavation prior to backfilling, and no elevated concentrations of target compounds were present in the confirmatory soil samples.

Soil samples were collected from seven new monitoring well boreholes during Phase II RFI activities in July and August 1998 (i.e., after the IRA activities). No organic target analyte exceeded screening criteria in soil. Although human health contaminants of potential concern (HHCOPCs) were identified in the screening value comparison for surface and subsurface soil, none were retained as human health contaminants of concern (HHCOCs) following further quantitative evaluation in the Revised Final RFI Report (Metcalf & Eddy, September 1999).

NATURE AND EXTENT OF GROUNDWATER CONTAMINATION

Benzene was detected in the following monitoring wells during Phase II sampling activities: MW01 (64 ug/L), MW02 (4 ug/L), MW06 (36 ug/L), MW1-23 (13 ug/L), and MW1-25 (29 ug/L). The suspected source of benzene was near the former bermed AST area; the benzene plume extends to the north-northwest (downgradient) from the source area. The concentration of benzene in MW01 increased slightly when compared to Phase I sample results; however, benzene in all other wells decreased slightly since the Phase I investigation. The maximum contaminant level (MCL) for benzene of 5 ug/L was exceeded at 4 of 18 groundwater monitoring wells.

PCE was detected in groundwater samples from MW02 (16 ug/L), MW05 (47 ug/L), MW1-22 (11 ug/L), and MW1-24 (15 ug/L). PCE was not detected in MW03 during the Phase II RFI sampling, although PCE was detected in MW03 during Phase I RFI sampling at 4.8 ug/L. PCE detections seem to be localized outside the fenced site area and extend to the west-northwest, in the area between the storage bays, the railroad tracks, and Lamar Canal. The MCL for PCE is 5 ug/L.

Neither benzene nor PCE was detected in any of the deep monitoring wells located on the site.

NATURE AND EXTENT OF SURFACE WATER AND SEDIMENT CONTAMINATION

No HHCOPCs were identified in surface water or sediment in Lamar Canal. Benzene was not identified in any surface water sample. The benzene plume indicates that benzene-contaminated groundwater is reaching Lamar Canal at concentrations below the In-stream Water Quality Standard (IWQS) for benzene (71.28 µg/L). Similarly, PCE was not identified in any surface water sample collected from Lamar Canal; however, the PCE plume suggests that PCE-contaminated groundwater may be reaching the banks of Lamar Canal at concentrations exceeding its IWQS (8.85 µg/L).

CONTAMINANT FATE AND TRANSPORT

At the PDO Yard, benzene and PCE in groundwater were the only organic compounds consistently identified at concentrations above their respective screening criteria. Benzene is a volatile aromatic hydrocarbon that can migrate readily through the soil column toward groundwater. Benzene is less dense than water and as a non-aqueous phase liquid (NAPL) tends to float on top of the water table. Benzene is biodegradable under aerobic conditions with a biodegradation half-life of approximately 2 years.

PCE is a chlorinated aliphatic hydrocarbon that is very mobile. Being denser than water, PCE may migrate vertically (downward) through a saturated medium as a separate phase. PCE is somewhat biodegradable under anaerobic conditions with a biodegradation half-life of approximately 4 years.

Both benzene and PCE are highly volatile; therefore, volatilization is a major mechanism for removal of these constituents from groundwater and surface waters.

HUMAN HEALTH RISK ASSESSMENT

A Human Health Baseline Risk Assessment (HHBRA) was completed during the Phase II RFI. Although four public/commercial supply wells were identified within a 1-mile radius of the site, human exposure to contaminants identified in the shallow groundwater at the PDO Yard through these wells is unlikely. The groundwater use investigation conducted as part of the potential receptor survey (PRS) indicated that no shallow groundwater is used for potable water supply within 0.5 miles of the site. The PRS indicated that a potential exists for exposure to HHCOPCs in the open drainage ditch (Lamar Canal) located north of the PDO Yard. The sides of the ditch, being heavily vegetated and steep, are not conducive to casual human contact. Therefore, the potential for human exposure to water or sediment in the ditch is remote.

No current groundwater exposure exists. Risk calculations indicate that even under the highly unlikely future residential exposure scenario, the levels of contamination are within acceptable risk ranges determined by the EPA and GA EPD. The calculated levels were based on the highest contaminant concentrations at the PDO Yard and very conservative assumptions resulting in a risk estimation strongly biased toward the protection of human health. However, concentrations of both benzene and PCE in groundwater exceed their respective MCLs, and GA EPD requires that groundwater be remediated to MCLs regardless of the risk associated with the site. This is due to the fact that the state of Georgia views every water source (i.e., surficial aquifer, surface water body, etc.) as a potential source of drinking water.

ECOLOGICAL RISK ASSESSMENT

A Preliminary Risk Evaluation (PRE) was conducted during the Phase II RFI. There are no identified ecological contaminants of potential concern (ECOPCs) in surface soil, surface water, or groundwater. Although barium was found in sediment, it does not pose a risk to potential receptors near the PDO Yard.

An ecological risk assessment (ERA) is not required for the PDO Yard based on the data evaluation conducted in the PRE, and no corrective action is required for protection of ecological receptors.

SUPPLEMENTAL SAMPLING

Supplemental Groundwater Sampling. The Installation elected to sample groundwater, surface water, and sediment on a quarterly basis to monitor potential contaminant migration associated with former releases from the PDO Yard. A total of four quarters of sampling events were conducted at the PDO Yard between August 1998 and May 1999. The first quarter data were evaluated and presented in the Revised Final RFI Report. Data from the three additional quarterly sampling events (which have also been submitted to GA EPD) show no significant changes in the potentiometric surface, flow direction, or gradient.

Benzene concentrations are observed to be increasing in two downgradient wells (MW01 and MW06), which is consistent with the expected plume migration following removal of the source area soils (i.e., 1998 IRA activities). Benzene concentrations in two wells peripheral to the groundwater plume (MW02 and MW1-23) have shown consistent decline over the sampling period. Benzene concentrations in one well (MW1-25) have remained relatively constant. In the most recent quarterly sampling event (May 1999), the maximum benzene concentrations were reported at MW01 (68 µg/L) and MW06 (62 µg/L), exceeding the MCL of 5 µg/L).

PCE concentrations have remained relatively constant in four wells (MW03, MW05, MW1-22, and MW1-24) and have shown a slight decline in well MW02. In the most recent quarterly sampling event, the maximum PCE concentration was reported at MW05 at 40 µg/L, exceeding its MCL of 5 µg/L.

Supplemental Soil Sampling. Due to the fact that the areas encompassing the respective benzene and PCE plumes do not coincide and because PCE concentrations have remained relatively constant in many of the monitoring wells, the Installation elected to conduct supplemental soil sampling in November 1999 to evaluate whether a secondary source of PCE contamination is present in soil. Six soil samples were taken in the vicinity and upgradient of MW05. PCE was not detected in any of the soil samples, indicating that a secondary source of the PCE could not be found.

JUSTIFICATION AND PURPOSE OF CORRECTIVE ACTION

The purpose of corrective actions are to (1) protect human health and the environment, (2) attain MCLs, (3) control the source of the releases, (4) comply with any applicable waste management standards, and (5) other factors. The remedial response objectives for the PDO Yard are to reduce concentrations of benzene and PCE in groundwater to the RLs presented in the GA EPD approved Revised Final RFI Report.

IDENTIFICATION OF REMEDIAL LEVELS

Groundwater RLs for both benzene and PCE are their respective MCLs of 5 µg/L. The groundwater RLs are protective of direct exposure to hypothetical future residents by hazardous constituents in groundwater, and take into consideration both human health and technological limitations. However, it is recognized that groundwater is not used at this site as a source of drinking water and that exposure by a future resident is highly unlikely. The groundwater RLs are also lower than the respective IWQSs for benzene (71.28 μg/L) and PCE (8.85 μg/L), so that they are protective of any direct exposure to these constituents within Lamar Canal. Table 1 summarizes the RLs for groundwater at the PDO Yard.

Table 1. Remedial Levels for Groundwater, PDO Yard, Hunter Army Airfield, Georgia

Analyte	Groundwater Remedial Level (μg/L)	Maximum Observed Level in Groundwater in Most Recent Sampling (μg/L)
Benzene	5	68
Tetrachloroethene (PCE)	5	40

SCREENING OF CORRECTIVE ACTION ALTERNATIVES

Several technologies for remediating contamination in groundwater for benzene and PCE were identified and screened. Technologies applicable to general response actions (no action, institutional controls, natural attenuation and long-term monitoring, and active source remediation) were identified and evaluated with respect to their suitability in meeting the remedial response objectives. Technologies were screened using three evaluation criteria: effectiveness, implementability, and cost (Tables 2 and 3).

The "No Action" alternative was not considered to be viable due to the need to ensure that the MCLs are being met for the site. Institutional controls were not considered further as the sole remedial alternative since they are appropriate for this site only when combined with other technologies, such as Monitored Natural Attenuation.

Each of the following alternatives for benzene and PCE is considered applicable to the site, cost-effective, and implementable. Therefore, two primary evaluation factors were used in the selection of the preferred corrective action alternative: time to implement and life-cycle cost. Time to implement the action is an important evaluation factor for this site; preferably, the site would be remediated to meet RLs in the shortest possible time. Life-cycle cost estimates are budget estimates based on conceptual design and are not adjusted to present worth costs or for escalation.

Benzene. The following three corrective action alternatives were evaluated for benzene (Table 4):
Alternative 1: Monitored Natural Attenuation,
Alternative 2: Air Sparging, and
Alternative 3: Enhanced Bioremediation.

PCE. The following four corrective action alternatives were evaluated for PCE (Table 5):
Alternative 1: Monitored Natural Attenuation,
Alternative 2: Air Sparging,
Alternative 3: Geo-Cleanse® with Monitored Natural Attenuation
Alternative 4: Geo-Cleanse® Full Plume Treatment.

CONCEPTUAL DESIGN AND IMPLEMENTATION PLAN

Justification of Selection

Benzene. Monitored Natural Attenuation (Alternative 1) has been selected as the most appropriate corrective action for benzene in groundwater at the PDO Yard because the source of soil contamination has been removed. Additionally, contaminant levels in groundwater will attenuate to concentrations below the MCL of 5 ug/L in approximately 2 years. Geochemical conditions in the groundwater at the site indicate aerobic conditions are present that are conducive to biodegradation of benzene. The presence of elevated methane gas in monitoring well MW01 suggests that active biodegradation of benzene is occurring. The site will be monitored during the 2-year attenuation period to ensure that attenuation of benzene in the groundwater continues.

PCE. An in-situ chemical oxidation treatment system has been determined to be the most appropriate corrective action for PCE in groundwater at the PDO Yard because PCE concentrations in groundwater have not decreased significantly over time, suggesting that biodegradation of PCE is not occurring. The aerobic conditions in groundwater are not conducive to biodegradation of PCE, and its daughter compounds have not been observed in groundwater at the site. Chemical oxidation using the Geo-Cleanse® system was selected because it is a proven in-situ technology to remediate chlorinated hydrocarbons, such as PCE, in a matter of days. The effectiveness of chemical oxidation is more reliable than Monitored Natural Attenuation because any unidentified source of PCE contamination in soil would also be eliminated, and because PCE concentrations in groundwater adjacent to Lamar Canal would be reduced to below their IWQS.

The decision to implement an in-situ chemical oxidation treatment system resulted in the Installation having two options for the FRA: Alternative #3 or Alternative #4 (see Table 5 for specifics/differences). Since the site has shown no biodegradation of PCE in four years, Alternative #4 was chosen over Alternative #3 to ensure that the site is remediated to less than 5 ug/L in the appropriate timeframes. Furthermore, there was justifiable concern that choosing Alternative #3, which would allow PCE <15 ug/L to "naturally attenuate", would result in a notice of non-compliance with the approved CAP. GA EPD requires PCE to be remediated to <5 ug/L, therefore contingencies would be required if natural attenuation did not occur at the site and concentrations of PCE remained at ~15 ug/L in the groundwater. As the site has shown no natural biodegradation in four years, the Installation determined it was more cost effective to remediate the entire plume to less than 5 ug/L in one FRA.

Conceptual Design

Geo-Cleanse® will be injected into the shallow PCE plume using 29 separate injection points covering an area approximately 200 feet wide by 100 feet long. A 15-foot radius of influence is used for the conceptual design, based upon a similar pilot test conducted at the Wright Army Airfield Bulk Fuel System (FST-35) at Fort Stewart, Georgia, in September 1998. Each injection point will consist of 1-1/4-inch-diameter carbon steel pipe having a 3-foot-long stainless steel screen. Fenton's reagent, a mixture of hydrogen peroxide and ferrous iron catalyst, will be injected into the subsurface at 2 separate levels (10 feet and 20 feet bgs). Chemical injection is anticipated to reduce concentrations of PCE by 90 percent with application of Geo-Cleanse® reagent, so that residual PCE concentrations in groundwater will not exceed 5 μg/L. A "polishing step" may be required based on site-specific conditions.

Following chemical oxidation within the PCE plume area, confirmation groundwater sampling will be conducted 6 months following the treatment period(s) to verify that the MCLs for PCE have been reached and maintained at the PDO Yard.

Two additional shallow monitoring wells (MW26 and MW27) and one additional deep monitoring well (MW28) will be installed within the contamination plume where PCE concentrations in existing wells have consistently exceeded their MCLs. The shallow wells will be screened to bisect the water table, for a total depth of less than 20 feet. The deep well will be screened between a depth of 35 and 45 feet, similar to the adjacent deep wells. The wells will be constructed using carbon steel casing and stainless steel screens to withstand the high temperatures during Geo-Cleanse® treatment. The cost estimate also includes costs for replacement of the existing monitoring wells with steel casings and stainless steel screens in the event the existing PVC wells become damaged during Geo-Cleanse® treatment. The monitoring wells will be used to verify the effectiveness of Geo-Cleanse® treatment and to more accurately observe the reduction in PCE concentrations during the treatment period.

PUBLIC NOTIFICATION

GA EPD has determined that a public notification period for this site is not required since the remedial action is required to comply with the Consent Order issued in 1994. Therefore, Fort Stewart will not pursue public notification and/or public involvement in implementing the FRA for HAA-12. The effectiveness of the FRA will be documented in required Progress and Completion Reports to be submitted to GA EPD. If Fort Stewart is made aware of any public interest in the remediation of this site, copies of the Progress and/or Completion Reports can be provided to interested parties with GA EPD concurrence.

DECLARATION

The selected remedies are protective of human health and the environment, attains Federal and State requirements that are applicable or relevant and appropriate to both the IRA and FRA, and is cost-effective. Although the selected remediation for PCE in groundwater (i.e., Alternative #4) is approximately 25% more expensive than Alternative #3, it is highly probable that if Alternative #3 were chosen for remediation of the PCE plume, additional contingency actions would be required, ultimately eliminating what appears to be a "cost savings" (see Conceptual Design and Implementation section for specifics/justification).

As the selected course of actions will be implemented in accordance with the GA EPD approved documents, the five-year review will not apply to either the completed IRA and/or the proposed FRA.

This decision document was developed by the Directorate of Public Works at Fort Stewart, with support from the U.S. Army Corps of Engineers, and Science Applications International Corporation.

Table 2. Evaluation of Corrective Actions/Technologies for Benzene

Action/ Technology	Description	Effectiveness	Implementability	Costs
No Action	The "No Action" alternative provides a baseline against which other actions can be compared. Under the "No Action" alternative, the groundwater would be left "as is," without implementing any removal, treatment, or other mitigating actions to reduce existing or potential future exposure.	This alternative would not address the remedial response objectives of the site. This alternative does not provide protection of human health or the environment because attainment of MCLs would not be confirmed.	There is no implementability involved for this alternative because no action is taken.	There would be no cost associated with the "No Action" alternative.
Institutional Controls	Technologies associated with institutional controls will reduce potential hazards by limiting exposure of humans to contaminated surface water and/or groundwater. Groundwater use restrictions would prohibit use of groundwater as a drinking water supply. Excavation permit restrictions would prohibit any construction at the site that might disturb the soil or allow contact with groundwater.	This technology alone would not meet the site objectives (i.e., RLs). Assuming compliance with groundwater use restrictions, this technology would be effective and provide reliability with respect to eliminating human exposure to contaminated groundwater within the boundaries of the site. Use of surficial groundwater at this site for drinking water is unlikely.	Very few factors limit implementability of the institutional controls. The property is not expected to be developed in the near future and will remain under Federal ownership. This alternative is readily implementable.	Low; to establish groundwater use restrictions, approximately $5,000.
Monitored Natural Attenuation	This action would require the monitoring of contaminant levels to ensure that the mass of contamination is being reduced over time in accordance with OSWER Directive 9200.4-17P. A total of 6 wells would be sampled annually for 2 years and analyzed for benzene and natural attenuation parameters (e.g., methane).	Natural attenuation of benzene constituents through biodegradation is known to be occurring at the site and would be effective. This action would require approximately 2 years to successfully meet the site objectives (i.e., RLs).	This alternative is readily implementable and would only require monitoring of a total of 6 wells at the site for approximately 2 years.	Low; monitoring of 6 wells is required for approximately 2 years.
Air Sparging	Air sparging involves injecting a gas, usually air, under pressure, into the subsurface to volatilize groundwater contaminants and to promote biodegradation by increasing subsurface oxygen concentrations. Volatilized vapors migrate into the vadose zone where they can be extracted via vacuum, generally by a soil vapor extraction system.	Technology proven for light petroleum products, such as benzene, present at the site.	Equipment readily available. Air injection system components would be operated for two or more years. Approximately nine injection wells would have to be installed. Monitoring and maintenance of the wells would be required. UIC permit would be required for injection of air.	Moderate; $20 to $50 per ton of saturated soil (EPA 1995).
Enhanced Bioremediation (Pure Oxygen Injection)	Enhanced biodegradation is the enhancement of one aspect of natural attenuation. The activity of naturally occurring microbes is stimulated by injecting 98 percent pure oxygen to enhance in-situ biological degradation of organic contaminants. Nutrients or other additives may be used to encourage the natural biodegradation processes, as is done using the patented PHOSter II® system.	Technology proven for benzene; site geochemical conditions are aerobic, which is conducive to biodegradation of benzene.	Equipment readily available, applicable to a small site. Approximately 45 injection points would be installed. Bioremediation process may require continuous monitoring and maintenance to prevent plugging of injection wells by microbial growth or mineral precipitation. UIC permit would be required for injection of oxygen or nutrients.	Moderate; similar to air sparging based on quote from manufacturer.
Oxygen-releasing Compounds (ORC)	Use of formulations that release oxygen when they contact water to promote biodegradation.	Technology proven for treatment of fuel-related constituents, such as benzene, in groundwater.	Equipment and ORC formulation readily available. Approximately 18 injection points would be installed. Time to reach MCLs only nominally faster than natural attenuation. UIC permit would be required for injection of reagent.	High; capital costs of $50,000, with minimal O&M costs.
Geo-Cleanse®	The Geo-Cleanse® process is an aggressive, pressurized injection of concentrated hydrogen peroxide and ferrous iron catalyst (together known as Fenton's reagent) that generates a hydroxyl-free radical that acts as the active oxidizing agent. Oxidation of an organic compound by Fenton's reagent is a rapid and exothermic (heat-producing) reaction.	Expected to provide accelerated performance over air sparging. However, more than one application may be required to achieve RLs. Chemical oxidation would temporarily destroy the natural bioremediation processes observed at the site.	Would be compatible with any Geo-Cleanse® treatment for the adjacent PCE plume. Approximately 15 injection points would be installed. Time to reach MCLs would be a matter of days. UIC permit would be required for injection of reagent.	High; requires injection of a minimum volume of peroxide per injection point for small contaminant mass.

COC = Chemical/contaminant of concern.
MCL = Maximum contaminant level.
OSWER = Office of Solid Waste and Emergency Response.
RFI = Resource Conservation and Recovery Act (RCRA) Facility Investigation.
UIC = Underground Injection Control (Program).

EPA = U.S. Environmental Protection Agency.
O&M = Operation and maintenance.
PCE = Tetrachloroethene.
RL = Remedial level.

Table 3. Evaluation of Corrective Actions/Technologies for PCE

Action/ Technology	Description	Effectiveness	Implementability	Costs
No Action	The "No Action" alternative provides a baseline against which other actions can be compared. Under the "No Action" alternative, the groundwater would be left "as is," without implementing any removal, treatment, or other mitigating actions to reduce existing or potential future exposure.	This alternative would not address the remedial response objectives of the site. This alternative does not provide protection of human health or the environment because attainment of MCLs would not be confirmed.	There is no implementability involved for this alternative because no action is taken.	There would be no cost associated with the "No Action" alternative.
Institutional Controls	Technologies associated with institutional controls will reduce potential hazards by limiting exposure of humans to contaminated surface water and/or groundwater. Groundwater use restrictions would prohibit use of groundwater as a drinking water supply. Excavation permit restrictions would prohibit any construction at the site that might disturb the soil or allow contact with groundwater.	This technology alone would not meet the site objectives (i.e., RLs). Assuming compliance with groundwater use restrictions, this technology would be effective and provide reliability with respect to eliminating human exposure to contaminated groundwater within the boundaries of the site. Use of surficial groundwater at this site for drinking water is unlikely.	Very few factors limit implementability of the institutional controls. The property is not expected to be developed in the near future and will remain under Federal ownership. This alternative is readily implementable.	Low; to establish deed restrictions, approximately $5,000.
Monitored Natural Attenuation	This action would require the monitoring of contaminant levels to ensure that the mass of contamination is being reduced over time in accordance with OSWER Directive 9200.4-17P. A total of 10 wells would be sampled annually for 5 years and analyzed for PCE and natural attenuation parameters (e.g., methane).	Natural attenuation of PCE through biodegradation is not occurring at the site. However, the AT123D model predicts degradation through advection and dispersion would require approximately 5 years to successfully meet the site objectives (i.e., RL).	This alternative is readily implementable; would involve installation of three new monitoring wells and monitoring of a total of 10 wells at the site for approximately 5 years.	Moderate; installation of 3 new wells and annual sampling/ monitoring of a total of 10 wells.
Air Sparging	Air sparging involves injecting a gas, usually air, under pressure, into the subsurface to volatilize groundwater contaminants. Volatilized vapors migrate into the vadose zone where they can be extracted via vacuum, generally by a soil vapor extraction system.	Technology proven for remediation of volatile organic compounds such as PCE by means of volatilization. Air sparging would not promote biodegradation of PCE.	Equipment readily available. Air injection system components would be operated for two or more years. Approximately 8 injection wells would be installed. Monitoring and maintenance of the wells would be required. UIC permit would be required for injection of air.	Moderate; $20 to $50 per ton of saturated soil (EPA 1995).
Enhanced Bioremediation (Methane Injection)	Enhanced biodegradation is the enhancement of one aspect of natural attenuation. The activity of naturally occurring microbes is stimulated by injecting methane to enhance in-situ biological degradation of organic contaminants by methanotropic bacteria. Oxygen may be injected simultaneously to encourage the natural biodegradation of less chlorinated daughter products.	Biodegradation is not considered to be effective since conditions are naturally aerobic. Technology has been demonstrated for removal of PCE, but is not proven. Removal by volatilization alone (air sparging) would be just as effective.	Equipment available, although limited field demonstrations have been performed on this technology. Approximately 40 injection points would be installed. Time to reach MCLs only nominally faster than air sparging. UIC permit would be required for injection of methane.	High; similar to air sparging plus additional cost of methane.
Geo-Cleanse®	The Geo-Cleanse® Process is an aggressive, pressurized injection of concentrated hydrogen peroxide and ferrous iron catalyst (together known as Fenton's reagent) that generates a hydroxyl free radical that acts as the active oxidizing agent. Oxidation of an organic compound by Fenton's reagent is a rapid and exothermic (heat-producing) reaction.	Expected to provide accelerated performance over air sparging. Technology proven for site contaminant (PCE).	Equipment readily available. Approximately 15 injection points would be installed for hot spot treatment; 29 points for full plume treatment. Time to reach MCLs would be a matter of days UIC permit would be required for injection of reagent.	High; requires injection of a minimum volume of peroxide per injection point for small contaminant mass.

AT123D = Analytical Transient 1-, 2-, 3-Dimensional (Model).
MCL = Maximum contaminant level.
PCE = Tetrachloroethene.
UIC = Underground Injection Control (Program).
EPA = U.S. Environmental Protection Agency.
OSWER = Office of Solid Waste and Emergency Response.
RL = Remedial level.

Table 4. Corrective Action Alternatives, Implementation Time, and Costs for Benzene Remediation

Corrective Action	Description	Time to Implement	Cost	Comments
Alternative 1. Monitored Natural Attenuation	The action would require the monitoring of contaminant levels to ensure the reduction of these levels through biodegradation and dispersion.	The estimated time to reach the RL of 5 µg/L in groundwater is approximately 2 years.	Approximately $100,000 (semiannual monitoring of 8 wells during attenuation period, confirmatory sampling after 6 months).	Least expensive, yet longer time to implement.
Alternative 2. Air Sparging	Air sparging of groundwater to 5 µg/L. Treatment using 9 injection wells operated at 10 scfm each (90 scfm total).	Air sparging treatment would require approximately 12 months to reduce benzene to 5 µg/L.	Approximately $340,000 (monthly monitoring of 8 wells during treatment, treatment with nine injection wells, confirmatory sampling after 6 months).	More costly than Alternative 1.
Alternative 3. Enhanced Bioremediation	Enhanced bioremediation of groundwater to 5 µg/L. Treatment using 45 injection points operated at 0.7 scfm each (32 scfm total).	Oxygen injection treatment would require approximately 4 months to reduce benzene to 5 µg/L.	Approximately $329,000 (monthly monitoring of 8 wells during treatment, treatment with 45 injection points, confirmatory sampling after 6 months).	More costly than Alternatives 1 and 2, yet shortest time to implement.

RL = Remedial level.
scfm = Standard cubic feet per minute.

Table 5. Corrective Action Alternatives;Implementation Time and Costs for PCE Remediation

Corrective Action	Description	Time to Implement	Cost	Comments
Alternative 1. Monitored Natural Attenuation	The action would require the monitoring of contaminant levels to ensure the reduction of these levels through advection and dispersion.	The estimated time to reach the RL of 5 µg/L in groundwater is approximately 5 years.	Approximately $283,000 (installation of 3 monitoring wells, semiannual monitoring of a total of 10 wells during attenuation period, and confirmatory sampling after 6 months).	Least expensive, but longest implementation time.
Alternative 2. Air Sparging	Air sparging of groundwater to the MCL of 5 µg/L. Treatment using 8 injection wells operated at 10 scfm each (80 scfm total).	Air sparging treatment would require approximately 12 months to reduce the maximum concentration of PCE from 40 µg/L to 5 µg/L.	Approximately $503,000 (installation of 3 monitoring wells, monthly monitoring of a total of 10 wells during treatment, treatment with 8 injection wells, and confirmatory sampling after 6 months).	Moderately expensive to implement and moderately short time frame.
Alternative 3. Geo-Cleanse® with Monitored Natural Attenuation	Injection of Fenton's reagent in the plume "hot spot," followed by natural attenuation of residual contamination in groundwater. Treatment using 15 injection points and injecting 3,000 lbs of reagent in each (45,000 lbs total).	Injection of Fenton's reagent would require a few days to decrease the PCE contamination to levels below 15 µg/L. The estimated time for subsequent natural attenuation to reach the RL of 5 µg/L in groundwater is approximately 2 years.	$459,000 (installation of 3 monitoring wells, treatment with 15 injection wells, monthly monitoring of a total of 10 wells during natural attenuation period, and confirmatory sampling after 6 months).	Moderately expensive to implement and moderately short time frame.
Alternative 4. Geo-Cleanse® Full Plume Treatment	Injection of Fenton's reagent in the full plume. Tretement using 29 injection points and injecting 3,000 lbs of reagent in each (87,000 lbs total).	Injection of Fenton's reagent would require about 2 weeks to decrease PCE concentrations to below 5 µg/L over the full plume area.	$626,000 (installation of 3 monitoring wells, treatment with 29 injection wells, and confirmatory sampling after 6 months).	Most expensive alternative to implement, yet shortest time frame and less uncertainty.

MCL = Maximum contaminant level.
RL = Remedial level.
PCE = tetrachloroethene.
Scfm = Standard cubic feet per minute.