4.0 Development and Detailed Analysis of Remedial Alternatives

4.1 Development of Remedial Alternatives

In this chapter, the remedial technologies and associated process options that were carried forward from the initial screening are used to form remedial alternatives for the Parcel 66(7) residuum groundwater. These alternatives are carried through the detailed analysis of alternatives included in Section 4.2. The remedial alternatives to be considered for detailed analysis include the following:

- Alternative 1 - No Action
- Alternative 2 - Land-Use Controls
- Alternative 3 - In Situ Chemical Oxidation using Potassium Permanganate and Groundwater Monitoring

4.1.1 Alternative 1 – No Action

As recommended by the NCP, the no-action alternative is intended to serve as a baseline for comparison with the other alternatives. This alternative would leave the contaminated groundwater in place with no controls to prevent human or ecological exposure. No remedial actions would be undertaken as part of this alternative to contain, remove, monitor, or treat the contaminated groundwater at Parcel 66(7).

4.1.2 Alternative 2 – Land-Use Controls

This alternative, which would not provide treatment of the contaminated groundwater, involves the implementation, documentation, and management of LUCs at Parcel 66(7). Establishment and implementation of the LUCs at the site would be based on the *Department of Defense Guidance on Land Use Controls Associated with Environmental Restoration Activities for Property Planned for Transfer Out of Federal Control* (DOD, 2001). LUCs include physical, legal, or administrative mechanisms that place restrictions on the use of, or limits access to, real property to prevent exposure to contaminants above permissible levels. The groundwater monitoring schedule would be based on the sampling required to ensure that the groundwater plume at Parcel 66(7) has not migrated beyond the boundaries of the site. The intent of the LUCs remedial alternative is to reduce the risk to human health and the environment by restricting land use and monitoring the concentrations of the COCs in the groundwater.

4.1.2.1 Land-Use Controls (Physical, Legal, and Administrative Mechanisms)

The following is a description of the DOD process for implementing, documenting, and managing LUCs for property such as Parcel 66(7) designated for transfer from DOD to nonfederal entities. Prior to property transfer, the following actions would require completion:

- ***Consideration of Land Use Controls*** – LUCs would be developed that are most effective to protect human health and the environment and to facilitate reuse of the property. For BRAC property such as Parcel 66(7), the Local Redevelopment Authority land use plan would provide the basis for the implementation of the LUCs. Parcel 66(7) has been designated for industrial reuse; therefore, the LUCs established at the site would be consistent with that land use.

- ***Finding of Suitability to Transfer (FOST)*** – After defining the LUC, the USACE would provide a description of the LUC, the rationale for the LUC, and the description and location of the affected property. The information would be included in the FOST document or in a functionally equivalent document. The FOST would include detailed information about the LUC that would be incorporated into the deed and would serve as the bridge between the environmental process and the real estate process.

- ***Implementation of Land-Use Controls*** – The implementation of LUCs would be completed in compliance with local, state, federal, and DOD-specific laws and policies. To clearly delineate the responsibilities of all parties involved in the implementation of the LUCs, a LUC implementation plan (LUCIP) would be developed. The LUCIP would explain in detail how the LUCs would be established and documented and would define who would be responsible for their maintenance and management. The LUCIP would be included in the property transfer documents and specifically include the following: a description of the site subject to the LUC, an explanation of the LUC (e.g., restrictions on groundwater use), specification of the duration of the LUC and frequency of inspections, and a reference to the location of the pertinent LUC records.

After the LUCs have been detailed in the FOST and an LUCIP has been established, the property would be ready for transfer. Concurrent with property transfer, the following actions would require completion:

- ***Deed Restrictions/Transfer Agreements*** – The LUCs will be incorporated into the deed as restrictions. The deed will also include a reference to the FOST document, appropriate environmental documents (e.g. EBS, RI, and FFS), and a copy of the LUCIP.

- ***Recordation of Land-Use Controls*** – Recordation of LUCs would be completed in accordance with Alabama real estate and environmental law governing the implementation of land-use restrictions. A copy of the deed with the LUCIP would be provided to applicable local, state, and federal agencies.

Upon completion of property transfer, the LUCIP would be implemented to ensure adherence to the LUC requirements. The DOD would work with relevant local government agencies and the transferee to ensure adherence to the LUCIP after the property has been transferred. Should the LUCs require modification or termination (i.e., change in land use, or if the RGOs are achieved), or if a deviation from the LUCIP is found, ADEM and EPA shall be issued notification. Post-transfer records management shall include establishment of a central database for tracking the LUCs and retention by USACE of the FOST, LUCIP, deed copies, and applicable environmental studies.

LUCs at Parcel 66(7) would be implemented via physical, legal, and administrative mechanisms. LUC physical mechanisms at Parcel 66(7) would include expanding the current fence around the parcel boundary and posting signs to limit access and warn of the risk associated with the groundwater contamination. Legal mechanisms would include deed and zoning restrictions at Parcel 66(7) for restriction of groundwater well installation. Deed and zoning restrictions serve to alert concerned parties of the presence of contaminants in the groundwater. Administrative mechanisms would include internal notices and site inspections to serve as a reminder of the existence of the LUCs; a site approval process to review construction projects and other land-use changes at Parcel 66(7) to ensure the LUCs are followed; training of federal, state, and local government officials regarding the existence and care of the LUCs; regular inspection and maintenance of the LUCs, and maintenance of an LUC database and reporting to the regulatory agencies, as required (annual certification and report and five-year review).

LUCs implemented at Parcel 66(7) would ensure that potential receptors (e.g., future resident) are not exposed to the groundwater (through consumption or bathing) by prohibiting the installation of potable water wells. The existing water distribution system at Anniston Water Works located southwest of FTMC would continue to supply potable water to FTMC and the surrounding communities.

An LUC database would be maintained after implementation of the LUC. The Army would track the selection and management of the LUCs in the Defense Site Environmental Restoration Tracking System. The following information shall be captured in the tracking system: title of the LUC; location/applicable restoration area (e.g., CERCLA, Resource Conservation and Recovery Act); record of the LUC (type of document where the LUC is recorded [e.g., the FOST]); LUC enforcement (e.g., five-year reviews, transferee reporting); in-place date; actual termination date; type of engineering control; type of institutional control; and description of control.

The USACE would perform annual certification and reporting of the LUCs. As part of the annual certification and reporting process, USACE personnel would conduct quarterly inspections of the LUCs, which would include visual checks to ensure that proper maintenance is taking place. The inspection would include a visual check of physical restriction mechanisms (e.g., fencing and signs) and checks to ensure that no well installations are taking place. The USACE would provide notice of the inspection to ADEM and EPA and provide a description of any deficiencies and the appropriate measures that have been taken to correct the deficiencies. An annual report would be prepared for ADEM and EPA certifying the continuation of the LUCs. As recommended by CERCLA, a five-year review would be completed and documented to review Parcel 66(7) site conditions and the effectiveness of the LUCs in place, to ensure the restrictions are being enforced, and to make a determination to continue, modify, or terminate the LUCs at the site.

4.1.2.2 Land-Use Controls (Groundwater Monitoring)

Groundwater monitoring would be conducted to ensure that the groundwater contaminant plume does not migrate horizontally beyond the Parcel 66(7) property boundary or vertically into bedrock. Existing permanent residuum and bedrock wells at Parcel 66(7) would be sampled to monitor the groundwater for VOCs. Groundwater sampling would be conducted in accordance with existing site sampling protocols.

Sampling and analysis for VOCs would be conducted at all existing residuum monitoring wells (except PPMP-66-MW04) and at bedrock wells PPMP-66-MW08 and PPMP-66-MW12. The sampling frequency would be quarterly for the first two years and annually thereafter. USACE would complete an annual review of the groundwater results to observe COC concentration trends and to ensure that groundwater contamination does not migrate beyond the Parcel 66(7) property boundary or vertically into bedrock. The results of the quarterly and annual groundwater sampling would be provided to ADEM and EPA.

4.1.3 Alternative 3 – In Situ Chemical Oxidation Using Potassium Permanganate and Groundwater Monitoring

Alternative 3 entails the use of pneumatic fracturing and in situ chemical oxidation using potassium permanganate ($KMnO_4$) to achieve the RGOs for the COCs in the residuum water-bearing zone at Parcel 66(7). Pneumatic fracturing would be conducted in the weathered shale of the residuum water-bearing zone, followed immediately by a $KMnO_4$ injection. A $KMnO_4$

slurry (1 pound [lb] of $KMnO_4$ per gallon of water) would be injected into the residuum water-bearing zone from a depth of approximately 10 to 30 feet bgs over an area of 8,200 square feet. The area of the injection comprises the contaminant plume with concentrations of total chlorinated VOCs greater than or equal to 0.001 mg/L. The $KMnO_4$ application would be enhanced with pneumatic fracturing of the weathered shale of the residuum followed by pressurized/atomized liquid injection of the chemical oxidant. The injected $KMnO_4$ would react with the COCs (except 1,2-DCA) in the residuum water-bearing zone, resulting in the formation of innocuous breakdown products. The chlorinated ethane 1,2-DCA is present in the residuum groundwater at a concentration below its MCL; therefore, active remediation for this COC is not required. The entire process of Alternative 3 is described in detail in the following paragraphs. In preparation for the $KMnO_4$ injection, an underground injection control (UIC) permit would be obtained from ADEM. In order to implement in situ chemical oxidation using $KMnO_4$, a work plan and a health and safety plan would also be completed.

$KMnO_4$ is a dark purple, odorless, nonvolatile, granular solid with a metallic luster. It has a specific gravity of 1.039 and a bulk density of 100 lbs per cubic foot. $KMnO_4$ forms a visible (purple) solution, which makes the injection influence or the degree of treatment easy to track. $KMnO_4$ is chemically stable in groundwater and stays in solution until it reacts. Pharmaceutical grade $KMnO_4$ is recommended for in situ applications because trace metal impurities (e.g., arsenic, chromium, nickel, and molybdenum) are at nondetectable levels as compared to metal concentrations typically present in technical grade $KMnO_4$.

The permanganate ion (MnO_4^-) in $KMnO_4$ oxidizes a wide range of common organic compounds relatively quickly and completely. In particular, MnO_4^- reacts rapidly with the double bonds in chlorinated ethenes, such as the chlorinated ethene COCs identified at Parcel 66(7) (i.e., TCE, DCE isomers, and VC). The products of the chemical reactions are innocuous breakdown products, including carbon dioxide, manganese dioxide, potassium ion, and chloride ion. The balanced chemical equations for $KMnO_4$ oxidation of chlorinated ethenes are as follows:

TCE: $6KMnO_4 + 3C_2HCl_3 \text{--->} 6CO_2 + 6MnO_2 + 6K^+ + 9Cl^- + 3H^+$
DCE: $8KMnO_4 + 3C_2H_2Cl_2 \text{--->} 6CO_2 + 8MnO_2 + 8K^+ + 6Cl^- + 2OH^- + 2H_2O$
VC: $10KMnO_4 + 3C_2H_3Cl \text{--->} 6CO_2 + 10MnO_2 + 10K^+ + 3Cl^- + 7OH^- + H_2O$

As can be seen from these equations, the lower the degree of chlorination, the more $KMnO_4$ is required to oxidize the chlorinated ethene. However, the lower the degree of chlorination, the faster the reaction rate between $KMnO_4$ and the chlorinated ethenes (Yan and Schwartz, 2000).

In addition to reacting with the chlorinated ethene COCs at Parcel 66(7), $KMnO_4$ will also oxidize organic matter and chemically reduced metal species in the aquifer soil matrix. The $KMnO_4$ demand required to oxidize the soil matrix (i.e., organic matter and other oxidizable species in the soil such as sulfides and reduced metal species) is called the soil oxidant demand (SOD). SOD was measured through laboratory testing of a soil sample collected from the residuum water-bearing zone at Parcel 66(7). Results of the SOD test indicate a demand of 12 grams of $KMnO_4$ per kilogram of wet soil (Appendix C). The weathered shale at Parcel 66(7) can best be described as a fractured medium, rather than a porous medium. Therefore, the porosity is attributed primarily to microfractures and not pore space. The SOD test was conducted by completely saturating the soil sample with $KMnO_4$. Since the actual field application of $KMnO_4$ would not result in the complete saturation of the weathered shale, the $KMnO_4$ demand of the microfractures was estimated to be 25 percent of the SOD calculated for soil through laboratory testing. Calculations of the chemical demand presented in Appendix C indicate a total $KMnO_4$ requirement of approximately 54,120 lbs.

In situ oxidation is a chemical reaction. The effectiveness of the treatment is a function of three elements: the kinetics of the reactions between the $KMnO_4$ and the contaminants, the contact between the $KMnO_4$ and the contaminants, and competitive reactions of $KMnO_4$ with other oxidizable species in the soil. If the contaminants targeted for chemical oxidation are reactive (e.g., chlorinated ethenes), and if sufficient oxidant has been added to overcome the SOD, the limiting factor to the successful application of in situ oxidation is the transport of the oxidant to the areas of contamination and not the rate of reaction between the $KMnO_4$ and the contaminants. A uniform distribution of $KMnO_4$ in the subsurface is essential to achieving the RGOs. Residual $KMnO_4$ will physically stain the soil and groundwater until such time that groundwater carries sufficient chemical reductants (e.g., dissolved organic carbon) into the affected area or until soil species in the area can react to consume the $KMnO_4$. Short-term water quality changes in color, total dissolved solids, metals concentrations, and chloride concentrations are to be expected.

An undesirable side effect of the $KMnO_4$ injection is the oxidation of select metals present in the natural soil matrix, which could result in mobilization of metals. The most common metals that may potentially be oxidized and mobilized in the presence of $KMnO_4$ are chromium, selenium, and molybdenum. Under natural conditions, chromium is typically present as the chemically reduced trivalent form, which is immobile. In the presence of $KMnO_4$, chromium undergoes chemical oxidation to the mobile hexavalent form. The reaction may result in the temporary increase of chromium concentrations above its MCL. However, the elevated chromium, selenium, or molybdenum concentrations generated from the $KMnO_4$ treatment would attenuate to pre-injection levels as the oxidative conditions dissipate and the aquifer geochemistry returns to background conditions. Pre- and post-injection monitoring for metals will be conducted to ensure compliance with ARARs.

Injecting the $KMnO_4$ in solution using injection wells or direct-push rods would be difficult due to the low hydraulic conductivity of the weathered shale at Parcel 66(7). Not only would it be difficult to achieve uniform distribution of the chemical oxidant, but also the duration of the injection would be extended due to anticipated low groundwater flow rates. These factors would reduce the radius of influence of the injection points, thereby requiring a larger number of injection points, which translates into higher capital costs. Therefore, it is recommended that pneumatic fracturing be performed, immediately followed by pressurized liquid atomization injection of the $KMnO_4$ slurry into the residuum water-bearing zone. Fracturing would enable a uniform distribution of $KMnO_4$ to be accomplished in shorter duration. The atomized injection would reduce the volume of water required to deliver the $KMnO_4$ to the subsurface, because the $KMnO_4$ could be injected as a slurry.

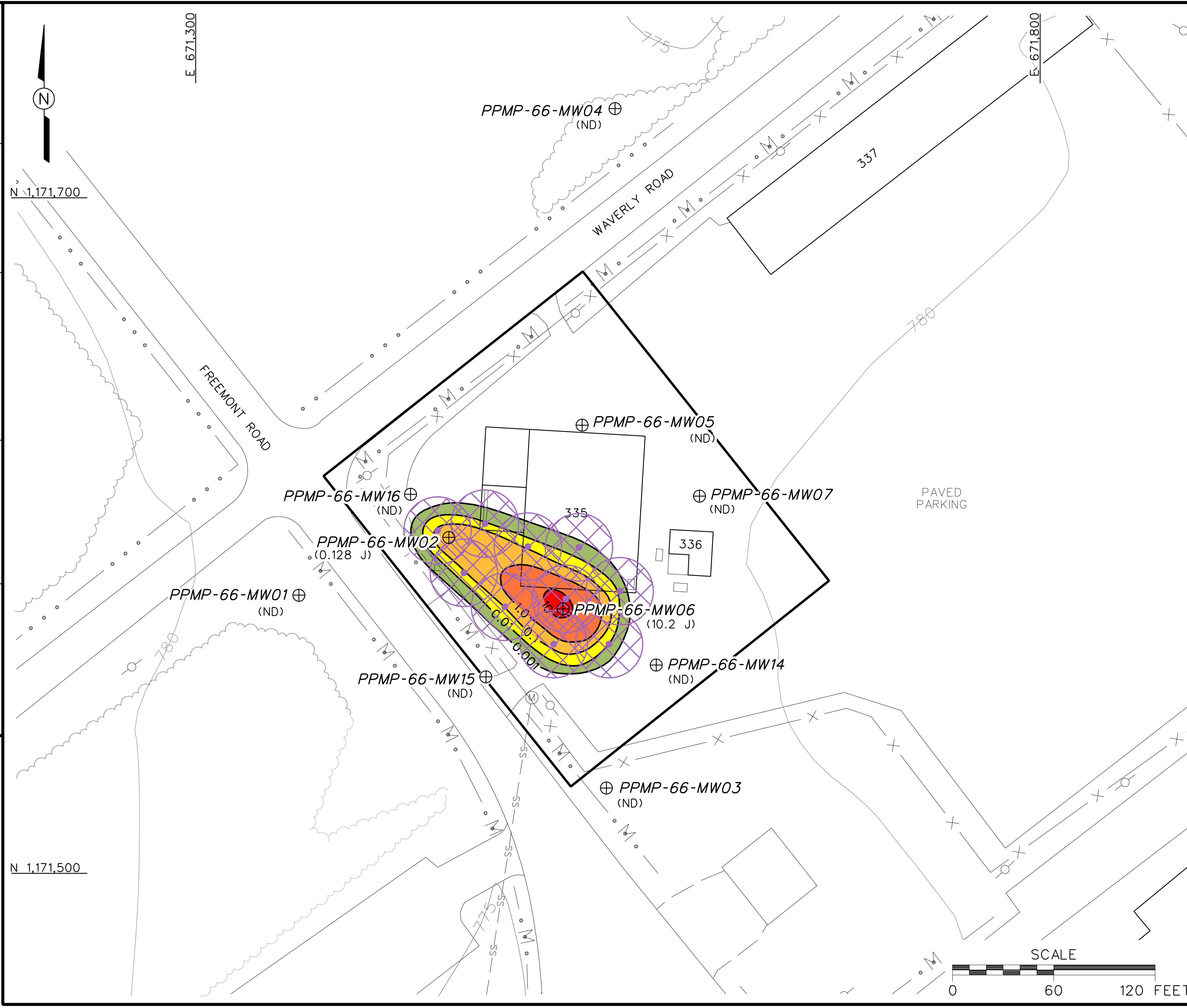
Pneumatic fracturing is a process whereby a gas is injected into the subsurface at pressures exceeding the natural pressures present in the soil interface (i.e., overburden pressure and cohesive stresses). The fracturing is conducted at flow volumes exceeding the natural permeability of the subsurface, resulting in the propagation of fractures outward from the injection point. Unconsolidated silts and clays typically exhibit fracture propagation distances of 20 to 40 feet (ARS Technologies, 2002). During fracturing, the pressure is monitored in the injection points. The pressure-time history curve is typically the best evidence that cohesive bonds within the geologic matrix are broken and fractures are created in the subsurface. Pneumatic fracturing is implemented by lowering a packer system down an open borehole and applying the injection in 2- to 3-foot intervals. Following pneumatic fracturing, the formation settles and the fracture network constricts. Since the cohesive bonds of the geologic matrix are broken, closure of the fractures due to overburden stress will not occur at shallow depths (less than 75 feet bgs) (ARS Technologies, 2002).

Once created, the fracture network is capable of transmitting significant amounts of fluid flow. The $KMnO_4$ would then be injected into the fractures in the form of an atomized slurry. If significant gas-to-slurry ratios are maintained, the slurry will change physical states and transform into a mist within the gas stream. Therefore, fracturing of the weathered shale coupled with atomized injection of the $KMnO_4$ slurry would increase the injection flow rates and the radius of influence, decrease the injection time, and improve the distribution of the $KMnO_4$.

A portion of the contaminant plume at Parcel 66(7) is located beneath the southwest corner of Building 335. Several injection points would have to be placed within Building 335 in order to conduct pneumatic fracturing and atomized injection to treat this portion of the plume. Since Building 335 is in relatively poor condition, pneumatic fracturing would probably compromise the structural integrity of Building 335 because of the resulting upward surface heave during the fracturing process. Because of the potential safety hazards to workers during fracturing activities near the building, Building 335 would be demolished and removed prior to conducting pneumatic fracturing at Parcel 66(7). The demolition of Building 335 would be conducted using conventional construction/demolition equipment. During the course of the demolition, like materials would be segregated prior to off-site disposal. Wood, concrete, and miscellaneous debris would be transported and disposed at a solid waste landfill, and metal debris would be transported to a metal recycling facility.

Ten injection points will be used to deliver the 54,120 lb of $KMnO_4$ into the subsurface. The radius of influence of each injection point is estimated to be 20 ft, and the injection rate of the atomized $KMnO_4$ slurry is estimated to be 25 gallons per minute. The time required for injection of the $KMnO_4$ slurry, assuming one injection point at a time at 3-foot depth intervals, is estimated to be 18 days. A conceptual layout of the injection points is shown on Figure 4-1. Placement of the injection points was based on treating total chlorinated VOC concentrations within the plume that are greater than or equal to 0.001 mg/L and assuming an estimated radius of influence of 20 feet.

During the injection process, monitoring wells screened in both the residuum and bedrock water-bearing zones will be monitored for $KMnO_4$ to indicate if the wells are being influenced by the injection. One week following completion of the $KMnO_4$ injection, monitoring wells screened in the residuum water-bearing zone will be sampled for VOCs to monitor the decrease in the COC concentrations. Additional sampling for VOCs in select monitoring wells will be conducted once a month for the first three months, followed by quarterly monitoring for a period of two years. This sampling schedule is required to verify treatment and monitor for a rebound in the COC concentrations. Detections of COCs above the RGOs may warrant further $KMnO_4$ injections. Four consecutive quarters with COC concentrations below cleanup levels would indicate that the RGOs have been achieved. In addition, groundwater samples from select monitoring wells collected during the sampling events will be analyzed for metals to monitor the long-term effects of the $KMnO_4$ injection on metals concentrations. As a contingency, a second injection activity would be conducted in the event that cleanup levels are not reached after one year following the initial injection. For cost estimating purposes, the second injection event is



LEGEND

- UNIMPROVED ROADS AND PARKING
- PAVED ROADS AND PARKING
- BUILDING
- TOPOGRAPHIC CONTOURS (CONTOUR INTERVAL - 5 FOOT)
- TREES / TREELINE
- PARCEL BOUNDARY
- CULVERT WITH HEADWALL
- SURFACE DRAINAGE / CREEK
- MANMADE SURFACE DRAINAGE FEATURE
- FENCE
- UTILITY POLE
- SS — SANITARY SEWER LINE
- MANHOLE
- RESIDUUM MONITORING WELL LOCATION
- 10.0 — TOTAL CHLORINATED VOC CONCENTRATION (mg/L)
- (0.20) — CONCENTRATION IN MILLIGRAMS PER LITER (mg/L)
- (ND) — NOT DETECTED
- J — ESTIMATED CONCENTRATION
- LOCATION AND AREA OF INFLUENCE OF POTASSIUM PERMANGANATE INJECTION (20-FEET RADIUS OF INFLUENCE)

NOTES:

1. TOTAL CHLORINATED VOC CONCENTRATION EXCLUDES COMMON LABORATORY CONTAMINANTS CHLOROFORM AND METHYLENE CHLORIDE.
2. POTASSIUM PERMANGANATE WOULD BE INJECTED THROUGH BOREHOLES USING PNEUMATIC FRACTURING.
3. TEN INJECTION POINTS ARE REQUIRED TO INJECT POTASSIUM PERMANGANATE THROUGHOUT THE CHLORINATED VOC PLUME.

FIGURE 4-1
POTASSIUM PERMANGANATE INJECTION POINTS LAYOUT IN THE RESIDUUM WATER-BEARING ZONE SMALL WEAPONS REPAIR SHOP PARCEL 66(7)

U. S. ARMY CORPS OF ENGINEERS
MOBILE DISTRICT
FORT McCLELLAN
CALHOUN COUNTY, ALABAMA
Contract No. DACA21-96-D-0018

IT CORPORATION
A Member of The IT Group

DWG. NO.: ...\774645es.952
PROJ. NO.: 774645
INITIATOR: J. MALINO
PROJ. MGR.: J. YACOUB
DRAFT. CHCK. BY:
ENGR. CHCK. BY: S. MORAN
DATE LAST REV.:
DRAWN BY:
STARTING DATE: 10/01/02
DRAWN BY: D. BOMAR
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scoped at 25 percent of the initial injection. A closeout report summarizing the results of the in situ chemical oxidation implementation will be submitted once the RGOs are achieved to demonstrate compliance with regulatory criteria.

4.2 Detailed Analysis of Alternatives

A detailed analysis of alternatives provides a basis for making an informed decision as to which remedial alternative is most appropriate for the site. CERCLA recommends the evaluation of alternatives against nine criteria; however, the "state acceptance" and "community acceptance" criteria will be evaluated in the decision document after comments from the regulatory agencies and the public, as required, have been received on this report. The nine CERCLA evaluation criteria are summarized as follows:

- ***Overall Protection of Human Health and the Environment.*** This criterion assesses the degree of protection to human health and the environment provided by an alternative. The evaluation should determine if the alternative achieves the RAO and explain how the alternative reduces, eliminates, and/or controls risks posed by each of the potential exposure pathways identified for the site.

- ***Compliance with ARARs.*** This evaluation criterion is used to determine if an alternative complies with federal and state ARARs and TBC requirements. If an alternative does not comply with ARARs, justification for a waiver should be provided. Under CERCLA, an ARAR may be waived if one of the following conditions is met: (1) the action is a interim action and the ARAR will be met upon project completion, (2) compliance with the ARAR would pose a greater risk to human health and the environment, (3) it is technically impractical to meet the ARAR, (4) the standard performance of an ARAR can be met by an equivalent method, (5) a state ARAR has not been consistently applied, or (6) ARAR compliance would not provide a balance between the protection achieved at one site and the demands on Superfund for other sites.

- ***Long-Term Effectiveness and Permanence.*** This evaluation criterion evaluates the long-term ability of an alternative to protect human health and the environment after remedial response levels have been achieved. The primary consideration under this criterion is the effectiveness of controls that are necessary to manage the risks posed by treatment residuals or untreated wastes.

- ***Reduction of Toxicity, Mobility, and Volume.*** This evaluation criterion addresses EPA's statutory preference for remedial alternatives that (1) permanently reduce the toxicity, mobility, and volume of the compounds of concern and (2) utilize treatment as a principal element. This criterion focuses on the following factors:

- The amount of hazardous materials treated or destroyed

- The degree of reduction in toxicity, mobility, and volume of contaminated material

- The degree to which the treatment method will be irreversible

- The characteristics and quantity of residual material that will remain.

- ***Short-Term Effectiveness.*** This evaluation criterion assesses the potential effects the construction and implementation of the alternative may have on human health and the environment (e.g., what are the risks to worker health and safety). Factors to be evaluated include protection of the workers and the community during the implementation of remedial actions, environmental impacts resulting from the implementation of the remedial actions, and the time required for achieving protection.

- ***Implementability.*** This evaluation criterion assesses the technical and administrative feasibility of implementing an alternative. Technical feasibility addresses the difficulties and unknowns associated with a technology, the reliability of a technology, the ease of undertaking future remedial actions, and the ability to monitor the effectiveness of the system. Administrative feasibility refers to the activities required to coordinate with regulatory agencies and the availability of equipment and services.

- ***Cost.*** This criterion evaluates the capital and O&M costs associated with an alternative. Cost estimates typically provide an accuracy of +50 percent to –30 percent. Present worth analysis is used to evaluate expenditures that occur over multiple years (maximum 30 years).

- ***State Acceptance.*** This evaluation criterion addresses the state's (or lead agency's) concurrence with or potential concerns with the alternative. State acceptance will be addressed once comments have been received from the lead agencies.

- ***Community Acceptance.*** This evaluation criterion addresses the community's concurrence with or potential concerns with the alternative. Community input regarding the selection of remedial alternatives will be solicited during the public comment period on the proposed plan.

CERCLA recommends that, to the maximum extent practical, the remedial action alternatives must (1) be protective of human health and the environment, (2) attain ARARs, (3) be cost effective, (4) utilize permanent solutions and alternative treatment technologies, and (5) reduce toxicity, mobility, or volume. The Parcel 66(7) remedial action alternatives are individually evaluated against seven criteria in the following sections.

4.2.1 Alternative 1 – No Action

The evaluation of the no-action alternative with respect to the seven evaluation criteria is presented in the following sections.

4.2.1.1 Overall Protection of Human Health and the Environment

Alternative 1, no action, provides no control of exposure to the contaminated medium and no reduction in the risk to human health and the environment posed by groundwater at Parcel 66(7). The no-action alternative does not actively reduce the COC concentrations in groundwater to the RGOs or eliminate the pathway for exposure to human receptors and, therefore, it does not achieve the RAO for Parcel 66(7). A decrease in the COC concentrations may occur over time through natural processes. However, the reduction of contaminant concentrations in groundwater is anticipated to be minimal based on the results of a natural attenuation evaluation completed for Parcel 66(7).

This alternative does not rely on an active treatment method to reduce COC concentrations to the RGOs or prevent exposure to groundwater. The results of the SRA indicated that, under current conditions, the risk to human health posed by the groundwater would not be realized if the groundwater is not developed as a potable water source. The no-action alternative would not ensure the long-term prevention of groundwater development as a potable water source. Therefore, the no-action alternative would not be effective in protecting human health.

4.2.1.2 Compliance with ARARs

Since no remedial activities are associated with this alternative, compliance with the chemical-specific ARARs for groundwater would not be met. Since no remedial activities would be conducted under this alternative, action-specific and location-specific ARARs would not apply.

4.2.1.3 Long-Term Effectiveness and Permanence

The no-action alternative does not provide for any controls to reduce the potential for human exposure to the COCs or long-term risk management measures for the untreated contaminants. All current and potential future risks would remain the same under this alternative.

4.2.1.4 Reduction of Toxicity, Mobility, and Volume

The implementation of this alternative does not employ any treatment that would reduce the toxicity, mobility, or volume of the COCs in groundwater; therefore, this alternative does not satisfy the statutory preference for treatment. A decrease in the COC concentrations may occur over time through natural processes. However, the reduction of contaminant concentrations in groundwater is anticipated to be minimal based on the results of a natural attenuation evaluation completed for Parcel 66(7).

4.2.1.5 Short-Term Effectiveness

Because the no-action alternative does not involve any active remedial measures, no short-term risks to the community, workers or the environment would exist.

4.2.1.6 Implementability

This criterion does not apply because no remedial action would be taken as part of this alternative.

4.2.1.7 Cost

No capital or O&M costs would be associated with this alternative because no remedial activities would be conducted.

4.2.2 Alternative 2 – Land-Use Controls

The evaluation of the LUC alternative with respect to the seven evaluation criteria is presented in the following sections.

4.2.2.1 Overall Protection of Human Health and the Environment

The implementation of LUCs as part of this alternative would prevent human exposure to the COCs through physical, legal, and administrative mechanisms and, therefore, would be protective of human health. Physical mechanisms would include fencing and warning signs to warn of groundwater contamination. Legal mechanisms would protect potential current and future human receptors through deed and zoning restrictions on potable water well installation at Parcel 66(7). Groundwater contamination at Parcel 66(7) does not present an unacceptable risk to human health provided that groundwater at the site is not developed as a source of potable water.

This alternative does not actively reduce the COC concentrations in groundwater to the RGOs. This alternative would, however, eliminate potential contaminant exposure pathways to human receptors through the implementation of the LUCs. Therefore, this alternative would achieve the RAO for Parcel 66(7). Furthermore, none of the COCs in groundwater presents a risk to terrestrial ecosystems at FTMC.

4.2.2.2 Compliance with ARARs

Chemical-Specific ARARs. This alternative would not achieve the chemical-specific ARARs (Table 2-2) for the COCs that exceed their respective MCLs in groundwater (i.e., 1,1-DCE, cis-1,2-DCE, TCE, and VC).

Location-Specific ARARs. Location-specific ARARs are listed in Table 2-3. Since no remedial action would be associated with this alternative, no location-specific ARARs have been identified.

Action-Specific ARARs. Action-specific ARARs are listed in Table 2-4. Since no remedial action would be associated with this alternative, no action-specific ARARs have been identified.

4.2.2.3 Long-Term Effectiveness and Permanence

This alternative does not provide for active treatment to reduce or eliminate groundwater contamination. However, it does provide long-term controls for eliminating potential human exposure to groundwater contaminants through the implementation of LUCs. The maintenance of the LUCs and groundwater monitoring would be required indefinitely, since no significant decrease in groundwater contaminant concentrations is expected over the long term.

Adequate long-term control would be established as long as the LUCs are maintained as defined in the LUCIP. The long-term effectiveness of the LUCs would depend on the annual and five-year reviews and inspections of the physical mechanisms in place at Parcel 66(7). The effectiveness of the LUCs would also depend on the proper implementation and coordination of activities defined in the LUCIP by the appropriate personnel from USACE, ADEM, EPA, and the property transferee.

4.2.2.4 Reduction of Toxicity, Mobility, and Volume

This alternative would not reduce the toxicity, mobility, or volume of contaminants in the groundwater through an active remedial process. A reduction in groundwater contaminant concentrations may occur over time through natural processes; however, this reduction is anticipated to be minimal. Although the migration of the groundwater contaminant plume would be monitored for the duration of the LUCs, no active reduction of contaminant mobility in the groundwater would be accomplished through this alternative.

4.2.2.5 Short-Term Effectiveness

No significant short-term risks to human health or the environment would exist during the implementation of this alternative. However, worker exposure to contaminated groundwater is possible during sampling activities associated with the groundwater monitoring events. The short-term risks associated with groundwater monitoring activities may be minimized through the implementation of an effective health and safety program.

The implementation of the LUCs would prevent exposure to contaminated groundwater by prohibiting the installation of potable water wells at Parcel 66(7). This alternative could provide almost immediate protection because LUCs can be implemented relatively quickly (e.g., within six months).

4.2.2.6 Implementability

All components of this alternative are readily implementable. Minimal technical concerns exist that would hinder the implementation of this alternative because no remedial activities would be performed under this alternative. However, routine inspection and maintenance of the LUCs would be required. All services and materials are readily available to conduct the inspection and maintenance of LUCs for this alternative.

Although administratively implementable, LUCs would require the following: development of the LUCIP; a site approval process to approve land-use changes to ensure the integrity of the LUCs; the installation of markers to identify areas of restricted use; training of appropriate personnel (i.e., property transferee) on the location and care of the LUC property; an internal notice to relevant offices (i.e., ADEM and EPA) of the existence of the LUCs; and maintenance of a LUC database by applicable local, state, and/or federal agencies.

4.2.2.7 Cost

The detailed costs associated with implementation of LUCs at Parcel 66(7) are presented in Table 4-1. The capital cost for this alternative is estimated to be $109,847. The capital cost includes the development of the LUCIP and FOST documents, the site-specific health and safety plan, the field sampling plan, and the quality assurance project plan. Capital costs also include installation of fencing and warning signs. For the purpose of this FFS, O&M costs were based on a 30-year time period. However, in actuality, LUCs would require maintenance as long as groundwater contamination exists above the RGOs, which is expected to exceed the 30-year time period. O&M costs include groundwater monitoring, reporting, meetings, and reviews. The total net present worth cost (capital cost plus O&M present worth cost plus contingency) for this alternative is $529,100, based on a LUC maintenance period of 30 years.

Table 4-1

Cost Estimate for Alternative 2 - Land Use Controls
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

Parcel 66(7)
Ft. McClellan

Alternative 2
Land Use Controls (LUCs)

Scope:
1. Generation of the Land Use Control Implementation Plan (LUCIP) and Finding of Suitability to Transfer (FOST) Document.
2. Completion of the Health and Safety Plan, Field Sampling Plan, and the Quality Assurance Project Plan.
3. Fencing and Warning Sign Installation.
4. Groundwater Monitoring.
5. LUC Meetings, Inspections, Annual Certification, Database Management, Maintenance and 5-Year Reviews.
6. Cost Summary (all present worth calculations assume a discount rate of 7%).

1.0 Generation of the Land Use Control Implementation Plan (LUCIP) and Finding of Suitability to Transfer (FOST) Document

Includes:
1. Completion of the site-specific LUCIP and the FOST document.

Service/Materials	No. Units	Unit Cost	Unit	Cost
Contractor Labor:				
Paralegal	60	$100.00	/hr.	$6,000.00
Attorney	60	$150.00	/hr.	$9,000.00

Capital Cost Subtotal **$15,000**

2.0 Plan Writing

Includes:
1. Completion of the Health and Safety Plan, Field Sampling Plan, and the Quality Assurance Project Plan.

Service/Materials	No. Units	Unit Cost	Unit	Cost
Health and Safety Plan	1	$7,500.00	ls	$7,500.00
Field Sampling Plan	1	$7,500.00	ls	$7,500.00
Quality Assurance Project Plan	1	$5,000.00	ls	$5,000.00

Capital Cost Subtotal **$20,000**

3.0 Fencing and Warning Sign Installation

Includes:
1. Expansion of existing fenceline to border the property boundary and signs (costs include labor).
2. Unit Cost of Fenceline from *RSMeans, Environmental Remediation Cost Data - Unit Price* 6th Annual Edition, 2000 adjusted to present day (2002) with a 3% inflation rate.
3. Unit Cost of Warning Signs from *www.McMaster-Carr.com.*

Service/Materials	No. Units	Unit Cost	Unit	Cost
6' high fenceline expansion	400	$21.59	/ft.	$8,635.73
Aluminum custom warning signs	10	$33.90	/ea.	$339.00

Capital Cost Subtotal **$8,975**

Table 4-1

Cost Estimate for Alternative 2 - Land Use Controls
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

4.0 Groundwater Monitoring

Includes:
1. Sampling and analysis for VOCs in 9 residuum monitoring wells and 2 bedrock monitoring wells quarterly for first two years and annually thereafter up to 30 years.
2. Contractor field crew consists of two field technicians; 2 wells/day (48 hours/tech/event).
3. Office labor for data validation, management, and results evaluation.

Service/Materials	No. Units	Unit Cost	Unit	Cost
Contractor Labor:				
Project Manager (E-12)	12	$100.00	/hr.	$1,200.00
Field Technician (H-4)	48	$35.00	/hr.	$1,680.00
Field Technician (H-4)	48	$35.00	/hr.	$1,680.00
Project Chemist (E-6)	24	$50.00	/hr.	$1,200.00
Geologist (E-8)	12	$58.00	/hr.	$696.00
Equipment and Materials:				
PID	6	$50.00	/day	$300.00
DO, ORP, pH, and turbidity meter	6	$70.00	/day	$420.00
PPE	6	$24.00	/day	$144.00
Water level indicator	6	$14.00	/day	$84.00
Submersible pump and control box	6	$90.00	/day	$540.00
Generator (120 V)	6	$30.00	/day	$180.00
Consumable Supplies	1	$750.00	ls	$750.00
Analytical:				
VOCs - EPA 8260B	15	$150.00	/ea.	$2,250.00
Shipping	1	$50.00	/ea.	$50.00
Contractor Travel:				
Vehicle (4WD)	6	$33.00	/day	$198.00
Per Diem	12	$30.00	/day	$360.00
Lodging	12	$55.00	/day	$660.00
Total Cost Per Sampling Event:				**$12,392.00**
1st Year Sampling Events (4 events):				**$49,568.00**
Present Worth of 2nd Year Sampling Events (4 events):				**$46,326.25**
Present Worth of 3rd to 30th Year Sampling Events (1 annual event):				**$129,740.52**

Capital Cost Subtotal	**$49,568**
Present Worth O&M Subtotal	**$176,067**

Table 4-1

Cost Estimate for Alternative 2 - Land Use Controls
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

5.0 LUC Meetings, Inspections, Annual Certification, Database Management, Maintenance and 5-Year Reviews

Includes:
1. Quarterly meeting for the first two years and annual for the 3rd to 30th year to ensure the Land Use is consistent with the LUCs.
2. Quarterly LUC inspection.
3. 5 -year review, notice to EPA and ADEM, meeting, and review documentation.

Service/Materials	No. Units	Unit Cost	Unit	Cost
Contractor Labor (Land Use Meeting):				
Project Manager (E-12)	4	$100.00	/hr	$400.00
Project Engineer (E-8)	8	$62.00	/hr	$496.00
Total Cost Per Land Use Meeting:				**$896.00**
1st Year Quarterly Land Use Meetings:				**$3,584.00**
Present Worth of 2nd Year Quarterly Land Use Meetings:				**$3,349.61**
Present Worth of 3rd to 30th Year Annual Land Use Meetings:				**$9,380.85**
Contractor Labor (Quarterly inspection):				
Project Manager (E-12)	4	$100.00	/hr	$400.00
Field Technician (H-4)	8	$35.00	/hr.	$280.00
Total Cost Per Quarterly Inspection:				**$680.00**
1st Year of Quarterly LUC Inspection:				**$2,720.00**
Present Worth of Year 2 to Year 30 of Quarterly LUC Inspections:				**$33,395.34**
Annual Certification, DSERTS database management and LUC Maintenance:				
Annual Certification and DSERTS Database Management:	1	$5,000.00	ls	$5,000.00
LUC Maintenance	1	$5,000.00	ls	$5,000.00
1st Year of Annual Certification, DSERTS database management and LUC Maintenance:				**$10,000.00**
Present Worth of Year 2 to Year 30 of Annual Certification, DSERTS database management and LUC Maintenance:				**$122,777.00**
Contractor Labor (5-year review):				
Project Manager (E-12)	8	$100.00	/hr	$800.00
Project Engineer (E-8)	24	$62.00	/hr	$1,488.00
Total Cost Per 5-Year Review:				**$2,288.00**
Present Worth of 30 Years of 5-Year Reviews:				**$5,282.53**

Capital Cost Subtotal	**$16,304**
Present Worth O&M Subtotal	**$174,185**

6.0 Cost Summary

Base Capital Cost	**$109,847**
Present Worth O&M Costs	**$350,252**
Total Contingency (15%)	**$69,015**
Total Present Worth Cost	**$529,100**

4.2.3 Alternative 3 – In Situ Chemical Oxidation Using Potassium Permanganate and Groundwater Monitoring

The evaluation of this alternative with respect to the seven evaluation criteria is presented in the following sections.

4.2.3.1 Overall Protection of Human Health and the Environment

This alternative would reduce the COC concentrations in groundwater to their respective RGOs through in situ chemical oxidation using $KMnO_4$ and, therefore, would be protective of human health and the environment. In situ chemical oxidation using $KMnO_4$ has been demonstrated through many pilot-scale and full-scale applications to achieve complete destruction of chlorinated ethenes in groundwater. Since this alternative would actively reduce the COC concentrations in groundwater to the RGOs through treatment, the groundwater remaining after treatment would no longer pose an unacceptable potential risk to human health. Therefore, this alternative would achieve the RAO for Parcel 66(7).

4.2.3.2 Compliance with ARARs

This alternative will comply with the chemical-, location-, and action-specific ARARs. The $KMnO_4$ will react with the COCs at Parcel 66(7), resulting in the formation of innocuous breakdown products and the reduction of COC concentrations to the RGOs. Post-injection monitoring for VOCs will be conducted to verify long-term treatment effectiveness. A UIC permit will be obtained prior to the $KMnO_4$ injection in order to comply with ADEM regulations.

Injection of $KMnO_4$ may mobilize some metals due to the creation of a highly oxidized environment. The mobilization of metals may result in the temporary increase of metal concentrations above MCLs. Elevated metals concentrations generated from the $KMnO_4$ treatment typically attenuate to pre-injection levels as the oxidative conditions dissipate and the aquifer geochemistry returns to background conditions. Pre-injection and post-injection monitoring for metals will be conducted to ensure compliance with chemical-specific ARARs.

4.2.3.3 Long-Term Effectiveness and Permanence

The application of pneumatic fracturing followed by in situ chemical oxidation using $KMnO_4$ will significantly and permanently decrease the concentrations of the chlorinated ethenes at Parcel 66(7) to the RGOs. Numerous pilot-scale and full-scale $KMnO_4$ applications have been proven successful at treating chlorinated ethenes such as the COCs (except 1,2-DCA) detected in the residuum water-bearing zone at Parcel 66(7). Implementation of this alternative will result in the immediate decrease in the concentrations of chlorinated ethenes. Post-injection monitoring for VOCs will be conducted to verify treatment. As a contingency, a second injection activity may be conducted in the event that cleanup levels are not reached by one year after the initial injection. Reduction of the chlorinated ethene concentrations to the RGOs would allow the Army to release Parcel 66(7) to the public domain for unrestricted reuse (i.e., LUCs would not be required).

4.2.3.4 Reduction of Toxicity, Mobility, and Volume

Implementation of pneumatic fracturing followed by in situ chemical oxidation using $KMnO_4$ will permanently reduce the toxicity, mobility, and volume of the chlorinated ethene COCs through the irreversible oxidation of these chemicals to innocuous breakdown products. Therefore, this alternative satisfies EPA's statutory preference for remedial actions that permanently reduce the toxicity, mobility, and volume of the COCs and utilize treatment as a principal element.

4.2.3.5 Short-Term Effectiveness

This alternative would involve potential short-term risks to workers associated with general construction activities and potential exposure to the $KMnO_4$. Subsurface pneumatic fracturing and building demolition activities would require operation of heavy equipment that would increase the risk to remediation workers. Other risks to workers include those generally associated with construction activities (e.g., slips, trips, and falls). $KMnO_4$ also poses a risk to remediation personnel because it is a strong oxidant and may cause damage to the eyes, skin, and the respiratory tract.

The implementation of proper engineering controls and safety equipment would minimize the potential short-term risks to the community or to remediation personnel conducting building demolition, pneumatic fracturing, and $KMnO_4$ injection activities. Measures would be taken to prevent the inhalation of $KMnO_4$ particulates during the mixing and injection processes. The injection of $KMnO_4$ would be limited to contaminated areas, and measures would be taken to ensure that the $KMnO_4$ slurry does not reach the surface. Remediation workers would be equipped with the necessary personal protective equipment and would conform to the site health and safety program. A site-specific health and safety plan, including hazard analyses for pneumatic fracturing and in situ chemical oxidation using $KMnO_4$, would be prepared prior to implementing this alternative.

The estimated time to achieve groundwater RGOs is 12 to 24 months. This alternative includes preparation of a final design work plan and site-specific safety and health plan, obtaining a UIC permit, procurement, mobilization, building demolition, equipment rentals, borehole drilling, pneumatic fracturing, $KMnO_4$ injection, groundwater monitoring for a total of three years after the initial injection, data evaluation, and generation of a closeout report.

4.2.3.6 Implementability

This alternative is technically and administratively implementable. The chemicals and equipment required for this remedial alternative are readily available. The injection approach has been repeatedly field tested in similar lithologies and is not expected to pose any difficulties. In situ chemical oxidation using $KMnO_4$ has been demonstrated in many field-scale applications to be capable of achieving complete destruction of chlorinated ethenes.

The efficiency of treatment is limited only by the success of the delivery system in bringing the oxidant into contact with the chlorinated ethenes. Pneumatic fracturing and atomized liquid injection will enhance the distribution of the $KMnO_4$ slurry at Parcel 66(7). Post-injection monitoring for VOCs will be conducted to verify treatment. As a contingency, a second injection activity may be conducted in the event that cleanup levels are not reached after one year following the initial injection.

4.2.3.7 Cost

The detailed cost estimate associated with implementing this alternative at Parcel 66(7) is presented in Table 4-2. Additional backup cost information associated with $KMnO_4$ material, $KMnO_4$ injection (including pneumatic fracturing), and Building 335 demolition is included in Appendix C. The capital cost of this alternative is estimated to be $805,675. The capital cost includes preparing the final design work plan, developing the site-specific safety and health plan, Building 335 demolition, obtaining a UIC permit, procurement, mobilization, chemical costs, equipment rentals, borehole drilling, pneumatic fracturing, $KMnO_4$ injection, and post-injection monitoring for one year. O&M costs include groundwater monitoring for two years, reporting, and a second permanganate injection. The total net present worth cost (capital cost plus O&M present worth cost plus contingency) is $1,200,700.

Table 4-2

Cost Estimate for Alternative 3 - In Situ Chemical Oxidation using Potassium Permanganate
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

Parcel 66(7)
Ft. McClellan

Alternative 3
In Situ Chemical Oxidation using Potassium Permanganate and Groundwater Monitoring

Scope:

1. Generate pneumatic fracturing and in situ chemical oxidation work plan, H&S plan, and materials list.
2. Conduct baseline sampling and analysis.
3. Procure drilling subcontractor, fracturing subcontractor, and $KMnO_4$.
4. Generate plans and permits, mobilization and demobilization of equipment and personnel, and perform Bldg. 335 demolition.
5. Mobilize and setup equipment, personnel, $KMnO_4$, and subcontractors for in situ chemical oxidation activities.
6. Drill ten (10) 5-inch diameter injection boreholes.
7. Initiate fracturing and injection activities.
8. Post-injection sampling and analysis.
9. Demobilize equipment and personnel for permanganate injection.
10. Second permanganate injection.
11. Reporting.
12. Cost Summary (all present worth calculations assume a discount rate of 7%).

1.0 Work Plan, Health and Safety Plan, and Materials List for Fracturing/Permanganate Injection

Includes:
1. Labor to generate work plan, eng. specifications, and Health and Safety Plan as needed.
2. Generate materials list.

Service/Materials	No. Units	Unit Cost	Unit	Cost
Contractor Labor:				
Project Manager (E-12)	16	$100.00	/hr.	$1,600.00
Senior Engineer (E-12)	40	$97.00	/hr.	$3,880.00
Task Manager (E-8)	40	$62.00	/hr.	$2,480.00
Project Engineer (E-8)	120	$62.00	/hr.	$7,440.00
Geologist (E-8)	60	$58.00	/hr.	$3,480.00
Health and Safety Specialist (E-5)	40	$33.00	/hr.	$1,320.00
Drafting (E-6)	30	$40.00	/hr.	$1,200.00
Document Reproduction (Draft and Final)	2	$1,000.00	/ea.	$2,000.00
Fracturing and Injection Subcontractor:				
Fracturing Work Plan and Assessment	1	$12,500.00	ls	$12,500.00

Capital Cost Subtotal **$35,900**

Table 4-2

Cost Estimate for Alternative 3 - In Situ Chemical Oxidation using Potassium Permanganate Small Weapons Repair Shop, Parcel 66(7) Fort McClellan, Calhoun County, Alabama

2.0 Baseline Sampling and Analysis

Includes:
1. Monitoring of groundwater quality parameters in the field (ORP, pH, turbidity).
2. Sampling and analysis for VOCs using EPA Method 8260B in 14 monitoring wells.
3. Sampling and analysis for Metals using EPA Method 6010B in 14 monitoring wells.
4. Sampling and analysis for Chloride using EPA Method 300 in 14 monitoring wells.
5. Contractor field crew consists of two field technicians; 2 wells/day, total of 7 days.
6. Office labor for data validation and management.

Service/Materials	No. Units	Unit Cost	Unit	Cost
Contractor Labor:				
Project Manager (E-12)	16	$100.00	/hr.	$1,600.00
Field Technician (H-4)	56	$35.00	/hr.	$1,960.00
Field Technician (H-4)	56	$35.00	/hr.	$1,960.00
Project Chemist (E-6)	30	$50.00	/hr.	$1,500.00
Geologist (E-8)	15	$58.00	/hr.	$870.00
Equipment and Materials:				
PID	7	$50.00	/day	$350.00
DO, ORP, pH, and turbidity meter	7	$70.00	/day	$490.00
PPE	7	$24.00	/day	$168.00
Water level indicator	7	$14.00	/day	$98.00
Submersible pump and control box	7	$90.00	/day	$630.00
Generator (120 V)	7	$30.00	/day	$210.00
Consumable Supplies	1	$750.00	ls	$750.00
Analytical:				
VOCs - EPA 8260B	18	$150.00	/ea.	$2,700.00
Metals - EPA 6010B	18	$250.00	/ea.	$4,500.00
Chloride - EPA 300	18	$50.00	/ea.	$900.00
Shipping	2	$50.00	/ea.	$100.00
Contractor Travel:				
Vehicle (4WD)	7	$33.00	/day	$231.00
Per Diem	14	$30.00	/day	$420.00
Lodging	14	$55.00	/day	$770.00

Capital Cost Subtotal **$20,207**

Table 4-2

Cost Estimate for Alternative 3 - In Situ Chemical Oxidation using Potassium Permanganate Small Weapons Repair Shop, Parcel 66(7) Fort McClellan, Calhoun County, Alabama

3.0 Procurement

Includes:
1. Procure Drilling Subcontractor.
2. Procure Fracturing and Injection Subcontractor.
3. Procure 54,120 lbs of $KMnO_4$.

Service/Materials	No. Units	Unit Cost	Unit	Cost	
Contractor Labor:					
Project Manager (E-12)	8	$100.00	/hr.	$800.00	
Project Engineer (E-8)	30	$62.00	/hr.	$1,860.00	
Procurement	40	$32.00	/hr.	$1,280.00	
				Capital Cost Subtotal	**$3,940**

4.0 Building Demolition

Includes:
1. Completion of building demolition work plan, H&S plan, and associated permits.
2. Mobilization of demolition equipment and personnel.
3. Demolition of the building and transportation and disposal of waste as non-hazardous.
4. Demobilization of demolition equipment and personnel.
5. Site support equipment and personnel.

Service/Materials	No. Units	Unit Cost	Unit	Cost	
Contractor Labor:					
Work Plan Completion	1	$8,651.00	ls	$8,651.00	
Health & Safety Plan Completion	1	$6,658.00	ls	$6,658.00	
Permit Completion	1	$5,542.00	ls	$5,542.00	
Mobilization of Equipment	1	$2,331.00	ls	$2,331.00	
Setup Prior to Demolition	1	$2,300.00	ls	$2,300.00	
Mobilization of Personnel	1	$2,546.00	ls	$2,546.00	
Removal of Interior Piping & Equipment	1	$24,304.00	ls	$24,304.00	
Demolition of Top 20ft. Of Building	1	$54,254.00	ls	$54,254.00	
Demolition of Block Wall to Grade	1	$78,213.00	ls	$78,213.00	
Demobilization of Equipment	1	$2,331.00	ls	$2,331.00	
Demobilization of Personnel	1	$2,546.00	ls	$2,546.00	
Site Support	1	$29,276.00	ls	$29,276.00	
Oversight Support	1	$30,723.00	ls	$30,723.00	
				Capital Cost Subtotal	**$249,675**

Table 4-2

Cost Estimate for Alternative 3 - In Situ Chemical Oxidation using Potassium Permanganate Small Weapons Repair Shop, Parcel 66(7) Fort McClellan, Calhoun County, Alabama

5.0 Fracturing/Injection Mobilization and Setup

Includes:
1. Mobilization of contractor personnel.
2. Mobilization of drilling subcontractor.
3. Mobilization of fracturing and injection subcontractor.
4. Mobilization of materials and equipment.
5. Mobilization and setup time is estimated at 3 days.

Service/Materials	No. Units	Unit Cost	Unit	Cost
Contractor Labor:				
Project Manager (E-12)	8	$100.00	/hr.	$800.00
Project Engineer (E-8)	30	$62.00	/hr.	$1,860.00
Geologist (E-8)	30	$58.00	/hr.	$1,740.00
Field Technician (H-4)	30	$35.00	/hr.	$1,050.00
Drilling Subcontractor:				
Mobilization and Setup	1	$2,500.00	ls	$2,500.00
Fracturing and Injection Subcontractor:				
Mobilization and Setup	1	$10,500.00	ls	$10,500.00
Materials and Equipment:				
USP $KMnO_4$ chemical cost	54,120	$1.59	/lb	$86,050.80
Water	54	$10.00	00 gallons	$541.20
Secondary containment and pump	1	$1,000.00	/ea.	$1,000.00
50kw Electric generator	3	$300	/wk	$900.00
Generator fuel (Diesel)	100	$1.50	/gal	$150.00
Forklift	3	$500	/wk	$1,500.00
Safety Gear (baricades)	10	$25.00	/ea.	$250.00
PPE	16	$24.00	/day	$384.00
Water level indicator	3	$60.00	/wk	$180.00
PID	3	$200.00	/wk	$600.00
DO, ORP, pH, and turbidity meter	3	$275.00	/wk	$825.00
Colorimetric Analyzer	3	$100.00	/wk	$300.00
Quenching supplies (peroxide and vinega	100	$5.00	/gal	$500.00
Miscellaneous supplies	1	$1,000.00	ls	$1,000.00
IDW Rolloff Box (mobe/demobe, rental)	1	$1,500.00	ls	$1,500.00
Contractor Travel:				
Vehicle (4WD)	3	$33.00	/day	$99.00
Roundtrip Airfare (3 personnel)	3	$800.00	/ea	$2,400.00
Per Diem (3 personnel)	9	$30.00	/day	$270.00
Lodging (3 personnel)	9	$55.00	/day	$495.00

Capital Cost Subtotal **$117,395**

Table 4-2

Cost Estimate for Alternative 3 - In Situ Chemical Oxidation using Potassium Permanganate Small Weapons Repair Shop, Parcel 66(7) Fort McClellan, Calhoun County, Alabama

6.0 Injection Points Drilling

Includes:
1. Drilling of ten (10) 5-inch boreholes to a depth of 32-ft bgs (total of 320 feet).
2. Assume drilling of three boreholes per day.
3. Total field time is 4 days.
4. Contractor geologist will be onsite for oversight.

Service/Materials	No. Units	Unit Cost	Unit	Cost
Contractor Labor:				
Project Manager (E-12)	4	$100.00	/hr.	$400.00
Geologist (E-8)	40	$58.00	/hr	$2,320.00
Drilling Subcontractor:				
Borehole Drilling	320	$50.00	/ft	$16,000.00
Contractor Travel:				
Vehicle (4WD)	4	$33.00	/day	$132.00
Per Diem	4	$30.00	/day	$120.00
Lodging	4	$55.00	/day	$220.00

Capital Cost Subtotal **$19,192**

7.0 Fracturing and Injection Activities

Includes:
1. Daily monitoring of $KMnO_4$ mixing system (system runtime, changing drums).
2. Daily monitoring of $KMnO_4$ delivery system (manifold, hoses, injection points).
3. Monitoring of subsurface parameters in select monitoring wells (ORP, water levels, $KMnO_4$).
4. Maintenance of test activity log and tracking amount injected.
5. Injection of $KMnO_4$ slurry according to designed injection sequence.
6. The $KMnO_4$ slurry will be injected into one injection point at a time, at 3-foot intervals, starting at 10-ft and extending to a maximum depth of 30-ft bgs (depending on refusal). The estimated injection rate is 25 gallons per minute. The estimated field time is 18 days.
7. Contractor Personnel On-Site: Field engineer (100%), geologist, technician (100%), and site superintendent (25% of time).
8. Off-Site Support: Task Manager and Senior Engineer at 10% and Project Manager at 5%.
9. Assume 12-hour field days to allow for setup, maintenance, and shut-down.
10. Total hours in the field: 18 days x 12 hours/day = ------> 216 hrs.
12. All equipment, rentals, and materials included under system set-up.
13. Airfare included under mobilization.

Service/Materials	No. Units	Unit Cost	Unit	Cost
Contractor Labor:				
Project Manager (E-12)	16	$100.00	/hr.	$1,600.00
Task Manager (E-8)	24	$62.00	/hr.	$1,488.00
Senior Engineer (E-12)	24	$97.00	/hr.	$2,328.00
Project Engineer (E-8)	216	$62.00	/hr.	$13,392.00
Geologist (E-8)	216	$58.00	/hr.	$12,528.00
Field Technician (H-4)	216	$35.00	/hr.	$7,560.00
Site Superintendent (E-8)	54	$60.00	/hr.	$3,240.00
Fracturing and Injection Subcontractor:				
Field Injection Implementation	1	$199,000.00	ls	$199,000.00

Table 4-2

Cost Estimate for Alternative 3 - In Situ Chemical Oxidation using Potassium Permanganate
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

7.0 Fracturing and Injection Activities (continued)

Contractor Travel:					
Vehicle (4WD)	18	$33.00	/day	$594.00	
Per Diem (3 personnel)	54	$30.00	/ea.	$1,620.00	
Lodging (3 personnel)	54	$55.00	/ea.	$2,970.00	
				Capital Cost Subtotal	**$246,320**

8.0 Post-Injection Sampling and Analysis

Includes:

1. Sampling and analysis for VOCs, Chloride, and Metals in 14 monitoring wells one week post-injection, monthly for 3 months, followed by quarterly sampling for two years.
2. Total number of sampling events is 12.
3. Monitoring of groundwater quality parameters (ORP, pH, turbidity, conductivity, temperature).
4. Contractor field crew consists of two field technicians; 2 wells/day (56 hours/tech/event).
5. Office labor for data validation, management, and results evaluation.
6. Assume the first four sampling events will occur during the first year, and the quarterly sampling the 2nd and 3rd years.

Service/Materials	No. Units	Unit Cost	Unit	Cost	
Contractor Labor:					
Project Manager (E-12)	16	$100.00	/hr.	$1,600.00	
Field Technician (H-4)	56	$35.00	/hr.	$1,960.00	
Field Technician (H-4)	56	$35.00	/hr.	$1,960.00	
Project Chemist (E-6)	30	$50.00	/hr.	$1,500.00	
Geologist (E-8)	16	$58.00	/hr.	$928.00	
Equipment and Materials:					
PID	7	$50.00	/day	$350.00	
DO, ORP, pH, and turbidity meter	7	$70.00	/day	$490.00	
PPE	7	$24.00	/day	$168.00	
Water level indicator	7	$14.00	/day	$98.00	
Submersible pump and control box	7	$90.00	/day	$630.00	
Generator (120 V)	7	$30.00	/day	$210.00	
Consumable Supplies	1	$750.00	ls	$750.00	
Analytical:					
VOCs - EPA 8260B	18	$150.00	/ea.	$2,700.00	
Metals - EPA 6010B	18	$250.00	/ea.	$4,500.00	
Chloride	18	$50.00	/ea.	$900.00	
Shipping	2	$50.00	/ea.	$100.00	
Contractor Travel:					
Vehicle (4WD)	7	$33.00	/day	$231.00	
Per Diem	14	$30.00	/day	$420.00	
Lodging	14	$55.00	/day	$770.00	
			Total Cost Per Sampling Event:	**$20,265.00**	
			Total Cost Per Year (4 Sampling Events):	**$81,060.00**	
			1st Year Sampling Events:	**$81,060.00**	
			Present Worth of 2nd Year Sampling Events:	**$75,758.68**	
			Present Worth of 3rd Year Sampling Events:	**$70,797.80**	
				Capital Cost Subtotal	**$81,060**
				Present Worth O&M Subtotal	**$146,556**

Table 4-2

Cost Estimate for Alternative 3 - In Situ Chemical Oxidation using Potassium Permanganate
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

9.0 Demobilization of Equipment and Personnel

Includes:
1. Decontamination and washdown of injection equipment (1/2 day).
2. Demobilization of Contractor Labor (1 day).
3. Demobilization of drilling subcontractor (cost included under mobilization).
4. Demobilization of fracturing and injection subcontractor (cost included under mobilization).
5. Demobilization of contractor sampling equipment, forklift, and generator.
6. Disposal of IDW.

Service/Materials	No. Units	Unit Cost	Unit	Cost
Contractor Labor:				
Project Manager (E-12)	4	$100.00	/hr.	$400.00
Project Engineer (E-8)	12	$62.00	/hr	$744.00
Geologist (E-8)	12	$58.00	/hr	$696.00
Field Technician (H-4)	12	$35.00	/hr	$420.00
Equipment and Materials:				
50 kW Generator	1	$100.00	/ea.	$100.00
Forklift	1	$250.00	/ea.	$250.00
Field sampling and analysis equipment	1	$100.00	/ea.	$100.00
IDW Waste Characterization	1	$2,000.00	ls	$2,000.00
IDW Disposal	1	$1,000.00	ls	$1,000.00
Contractor Travel:				
Vehicle (4WD)	2	$33.00	/day	$66.00
Per Diem (3 personnel)	6	$30.00	/ea.	$180.00
Lodging (3 personnel)	6	$55.00	/ea.	$330.00

Capital Cost Subtotal **$6,286**

10.0 Second Permanganate Injection

Includes:
1. If required, a second permanganate injection is proposed should cleanup levels not be reached within one year of the intial injection.
2. For cost estimating purposes, the second injection is scoped at 25% of the initial injection.

Service/Materials	No. Units	Unit Cost	Unit	Cost
Second Permanganate Injection	0.25	$393,133.00	ls	**$98,283.25**
	Present Worth of Second Injection:			**$91,855.53**

Capital Cost Subtotal **$0**
Present Worth O&M Subtotal **$91,856**

Table 4-2

Cost Estimate for Alternative 3 - In Situ Chemical Oxidation using Potassium Permanganate Small Weapons Repair Shop, Parcel 66(7) Fort McClellan, Calhoun County, Alabama

11.0 Reporting

Includes:
1. Fracturing and injection subcontractor summary letter report.
2. Contractor reporting on treatment events and summary of quarterly sampling results.

Service/Materials	No. Units	Unit Cost	Unit	Cost
Contractor Labor:				
Project Manager (E-12)	16	$100.00	/hr	$1,600.00
Senior Engineer (E-12)	20	$97.00	/hr	$1,940.00
Task Manager (E-8)	40	$62.00	/hr	$2,480.00
Project Engineer (E-8)	120	$62.00	/hr	$7,440.00
Geologist (E-8)	80	$58.00	/hr	$4,640.00
Drafting (E-6)	40	$40.00	/hr	$1,600.00
Document Reproduction (Draft and Final)	2	$1,000.00	/ea.	$2,000.00
Fracturing and Injection Subcontractor:				
Field Summary Letter Report	1	$4,000.00	ls	$4,000.00

Capital Cost Subtotal	**$25,700**

12.0 Cost Summary

Base Capital Cost	**$805,675**
Present Worth O&M Costs	**$238,412**
Total Contingency (15%)	**$156,613**
Total Net Present Worth Cost	**$1,200,700**

5.0 Comparative Analysis of Alternatives

This chapter presents a comparative analysis of alternatives to evaluate the relative performance of each alternative with respect to the seven evaluation criteria presented in Chapter 4.0. The purpose of this analysis is to determine the advantages and disadvantages of each alternative, which will ultimately provide the rationale for recommending a preferred alternative.

5.1 Overall Protection of Human Health and the Environment

The three alternatives provide varying levels of human health protection. Alternative 1 (no action) does not achieve the RAO; it provides no reduction in human health risk because measures would not be implemented to eliminate the pathway for human exposure to groundwater. Furthermore, Alternative 1 does not actively reduce the COC concentrations in the groundwater to the RGOs.

Alternative 2 (LUCs) would be protective of human health because LUCs would prohibit the development of groundwater as a potable water source, thereby eliminating the potential contaminant exposure pathway for human receptors. Alternative 2 satisfies the RAO for Parcel 66(7), although no active reduction of COC concentrations in groundwater would be achieved under this alternative.

Alternative 3, which involves in situ chemical oxidation using $KMnO_4$ and groundwater monitoring, would provide the highest level of human health protection as compared to the other remedial alternatives selected for detailed analysis. Alternative 3 achieves the RAO by reducing the above-MCL COC concentrations in groundwater to the RGOs; therefore, the ILCR and HI estimates would be reduced to acceptable risk management levels. Per the RI, no site media at Parcel 66(7) do not present a risk to the terrestrial ecosystems at FTMC.

5.2 Compliance with ARARs

5.2.1 Chemical-Specific ARARs

Alternatives 1 and 2 do not comply with the chemical-specific ARARs for the above-MCL levels of COCs in groundwater because no remedial activities are associated with either alternative. Alternative 3 complies with the chemical-specific ARARs because the $KMnO_4$ would react with the COCs in the groundwater resulting in the formation of innocuous breakdown products and the reduction of COC concentrations to the RGOs.

5.2.2 Location-Specific ARARs

Location-specific ARARs do not pertain to Alternatives 1 and 2 because no active remedial actions would be conducted under these alternatives. Alternative 3 complies with all location-specific ARARs.

5.2.3 Action-Specific ARARs

Action-specific ARARs do not pertain to Alternatives 1 and 2 because no remedial activities would be conducted under these alternatives. Alternative 3 complies with all action-specific ARARs.

5.3 Long-Term Effectiveness and Permanence

Alternative 1 (no action) does not reduce the COC concentrations in groundwater or provide any controls to reduce the potential for human exposure and would therefore be the least effective alternative over the long term. Alternative 1 would not provide a permanent remedy for the exposure risk posed by the elevated COC concentrations in the groundwater.

Alternative 2 (LUCs) offers a moderate degree of long-term effectiveness through the implementation of LUCs, which would eliminate the potential for human exposure to the elevated COC concentrations in the groundwater. The long-term effectiveness of the LUCs would depend on the proper implementation and coordination of activities defined in the LUCIP. Alternative 2, however, does not actively reduce the COC concentrations in the groundwater to the RGOs; therefore, maintenance of the LUCs would be required indefinitely.

Alternative 3 (in situ $KMnO_4$ oxidation) would significantly and permanently decrease the chlorinated ethene concentrations in groundwater at Parcel 66(7) to the RGOs. Although in situ chemical oxidation using $KMnO_4$ will not treat the chlorinated ethane 1,2-DCA, this COC is present in the residuum groundwater at a concentration below its MCL. Therefore, active remediation for this COC is not required. This alternative offers the highest degree of long-term effectiveness compared to the other remedial alternatives. Reduction of the above-MCL levels of COCs to the RGOs would allow the Army to release Parcel 66(7) to the public domain for unrestricted reuse (i.e., LUCs would not be required).

5.4 Reduction of Toxicity, Mobility, and Volume

Alternatives 1 and 2 would not reduce the toxicity, mobility, or volume of contaminants in the groundwater at the site because no active remedial process would be conducted under these alternatives. Alternative 3 will permanently reduce the toxicity, mobility, and volume of the chlorinated ethenes through the irreversible oxidation of these chemicals to innocuous breakdown products.

5.5 Short-Term Effectiveness

Because Alternatives 1 and 2 do not involve any active remedial measures, no short-term risks to worker health and safety or the community are expected. Alternative 2 would provide almost immediate protection from the risk associated with elevated COC concentrations in the groundwater through the installation of fencing and warning signs and the prohibition of potable well installation. However, for Alternative 2, worker exposure to contaminated groundwater is possible during groundwater monitoring activities. Since Alternative 2 does not actively reduce the COC concentrations in the groundwater to the RGOs, maintenance of the LUCs would be required indefinitely.

Alternative 3 would involve potential short-term risks to workers associated with general construction activities and potential exposure to $KMnO_4$. The demolition of Building 335 and subsurface fracturing activities would require operation of heavy equipment that would increase the risk to remediation workers. Other risks to workers include those generally associated with construction activities, (e.g., slips, trips, and falls). The use of $KMnO_4$ during the injection activities would also increase the risk to the remediation workers because $KMnO_4$ is a strong oxidant and may cause damage to the eyes, skin, and the respiratory tract. The implementation of proper engineering controls and safety equipment would minimize any short-term risks to the community or remediation workers. The estimated time to achieve the groundwater RGOs under this alternative is 12 to 24 months.

5.6 Implementability

This criterion does not apply to Alternative 1 because no remedial action would be taken as part of this alternative. Alternative 2 is easily implemented because no remedial activities would be performed, although routine inspections and maintenance of the LUCs would be required. Alternative 3 is also easily implementable, although less so than Alternatives 1 and 2. The chemicals and equipment required for Alternative 3 are readily available, and the injection approach has been repeatedly field tested in similar lithologies.

5.7 Cost

The progression of present worth costs from the least expensive alternative to the most expensive alternative is as follows: Alternative 1, Alternative 2, and Alternative 3.

No cost is associated with Alternative 1 because no remedial activities would be conducted to address groundwater contamination at the site. Although no remedial activities would be conducted for Alternative 2, cost is associated with maintenance of the LUCs, annual and five-year reviews, meetings, and groundwater monitoring. The cost associated with Alternative 3 is the highest because remedial activities would be conducted under this alternative. A cost comparison of the alternatives is included in Table 5-1.

Table 5-1

Detailed Cost Analysis Summary
Small Weapons Repair Shop, Parcel 66(7)
Fort McClellan, Calhoun County, Alabama

ALTERNATIVE	DESCRIPTION	BASE CAPITAL COST	PRESENT WORTH O&M COST	TOTAL PRESENT WORTH COST (INCLUDES 15% CONTINGENCY)
1	No Action	$0	$0	$0
2	Land-Use Controls	$109,847	$350,252	$529,100
3	In Situ $KMnO_4$ Oxidation	$805,675	$238,412	$1,200,700

6.0 Recommended Remedial Alternative

Based on the detailed analysis of remedial alternatives presented in Chapter 5.0, Alternative 2 – Land-Use Controls, most appropriately addresses the groundwater contamination at Parcel 66(7) in a manner that is cost-effective and consistent with the Army's intent to transfer the parcel to the public domain for future industrial reuse. The SRA conducted as part of the RI concluded that the groundwater contamination would not present an unacceptable risk to human health provided that groundwater at the site is not developed as a source of potable water. Alternative 2 would be protective of human health because the LUCs would prohibit development of groundwater as a potable water source, thereby eliminating the potential contaminant exposure pathway for human receptors. Alternative 2 also satisfies the RAO for Parcel 66(7), although no active reduction of COC concentrations in groundwater to the RGOs would be achieved under this alternative. Furthermore, because Alternative 2 does not involve any active remedial measures, it is easily implemented and no significant short-term risks to worker health and safety or the community would be expected. Therefore, the recommended remedial alternative for Parcel 66(7) is Alternative 2 - Land-Use Controls.

7.0 References

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ATTACHMENT 1

LIST OF ABBREVIATIONS AND ACRONYMS

List of Abbreviations and Acronyms

2,4-D	2,4-dichlorophenoxyacetic acid
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
2,4,5-TP	silvex
3D	3D International Environmental Group
AB	ambient blank
AbB3	Anniston gravelly clay loam, 2 to 6 percent slopes, severely eroded
AbC3	Anniston gravelly clay loam, 6 to 10 percent slopes, severely eroded
AbD3	Anniston and Allen gravelly clay loams, 10 to 15 percent slopes, eroded
Abs	skin absorption
ABS	dermal absorption factor
AC	hydrogen cyanide
ACAD	AutoCadd
AcB2	Anniston and Allen gravelly loams, 2 to 6 percent slopes, eroded
AcC2	Anniston and Allen gravelly loams, 6 to 10 percent slopes, eroded
AcD2	Anniston and Allen gravelly loams, 10 to 15 percent slopes, eroded
AcE2	Anniston and Allen gravelly loams, 15 to 25 percent slopes, eroded
ACGIH	American Conference of Governmental Industrial Hygienists
AdE	Anniston and Allen stony loam, 10 to 25 percent slope
ADEM	Alabama Department of Environmental Management
ADPH	Alabama Department of Public Health
AEC	U.S. Army Environmental Center
AEL	airborne exposure limit
AET	adverse effect threshold
AF	soil-to-skin adherence factor
AHA	ammunition holding area
AL	Alabama
ALAD	-aminolevulinic acid dehydratase
amb.	amber
amsl	above mean sea level
ANAD	Anniston Army Depot
AOC	area of concern
APEC	areas of potential ecological concern
APT	armor-piercing tracer
AR	analysis request
ARAR	applicable or relevant and appropriate requirement
AREE	area requiring environmental evaluation
AS/SVE	air sparging/soil vapor extraction
ASP	Ammunition Supply Point
ASR	Archives Search Report
AST	aboveground storage tank
ASTM	American Society for Testing and Materials
AT	averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
ATV	all-terrain vehicle
AUF	area use factor
AWARE	Associated Water and Air Resources Engineers, Inc.
AWQC	ambient water quality criteria
AWWSB	Anniston Water Works and Sewer Board
'B'	Analyte detected in laboratory or field blank at concentration greater than the reporting limit (and greater than zero)
BCF	blank correction factor; bioconcentration factor
BCT	BRAC Cleanup Team
BERA	baseline ecological risk assessment
BEHP	bis(2-ethylhexyl)phthalate
BFB	bromofluorobenzene
BFE	base flood elevation
BG	Bacillus globigii
BGR	Bains Gap Road
bgs	below ground surface
BHC	betahexachlorocyclohexane
BHHRA	baseline human health risk assessment
BIRTC	Branch Immaterial Replacement Training Center
bkg	background
bls	below land surface
BOD	biological oxygen demand
Bp	soil-to-plant biotransfer factors
BRAC	Base Realignment and Closure
Braun	Braun Intertec Corporation
BSAF	biota-to-sediment accumulation factors
BSC	background screening criterion
BTAG	Biological Technical Assistance Group
BTEX	benzene, toluene, ethyl benzene, and xylenes
BTOC	below top of casing
BTV	background threshold value
BW	biological warfare; body weight
BZ	breathing zone; 3-quinuclidinyl benzilate
C	ceiling limit value
Ca	carcinogen
$CaCO_3$	calcium carbonate
CAA	Clean Air Act
CAB	chemical warfare agent breakdown products
CAMU	corrective action management unit
CBR	chemical, biological, and radiological
CCAL	continuing calibration
CCB	continuing calibration blank
CCV	continuing calibration verification
CD	compact disc
CDTF	Chemical Defense Training Facility
CEHNC	U.S. Army Engineering and Support Center, Huntsville
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERFA	Community Environmental Response Facilitation Act
CESAS	Corps of Engineers South Atlantic Savannah
CF	conversion factor
CFC	chlorofluorocarbon
CFDP	Center for Domestic Preparedness
CFR	Code of Federal Regulations
CG	carbonyl chloride (phosgene)
CGI	combustible gas indicator
ch	inorganic clays of high plasticity
CHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
CK	cyanogen chloride
cl	inorganic clays of low to medium plasticity
Cl	chlorinated
CLP	Contract Laboratory Program
cm	centimeter
CN	chloroacetophenone
CNB	chloroacetophenone, benzene, and carbon tetrachloride
CNS	chloroacetophenone, chloropicrin, and chloroform
CO	carbon monoxide
CO_2	carbon dioxide
Co-60	cobalt-60
CoA	Code of Alabama
COC	chain of custody; chemical of concern
COE	Corps of Engineers
Con	skin or eye contact
COPC	chemical(s) of potential concern
COPEC	chemical(s)/constituent(s) of potential ecological concern
CPSS	chemicals present in site samples
CQCSM	Contract Quality Control System Manager
CRDL	contract-required detection limit
CRL	certified reporting limit
CRQL	contract-required quantitation limit
CRZ	contamination reduction zone
Cs-137	cesium-137
CS	ortho-chlorobenzylidene-malononitrile
CSEM	conceptual site exposure model
CSM	conceptual site model
CT	central tendency
ctr.	container
CWA	chemical warfare agent; Clean Water Act
CWM	chemical warfare material; clear, wide mouth
CX	dichloroformoxime
'D'	duplicate; dilution
D&I	detection and identification
DAAMS	depot area air monitoring system
DAF	dilution-attenuation factor
DANC	decontamination agent, non-corrosive
°C	degrees Celsius
°F	degrees Fahrenheit
DCA	dichloroethane
DCE	dichloroethene
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethene
DDT	dichlorodiphenyltrichloroethane

DEH	Directorate of Engineering and Housing
DEP	depositional soil
DFTPP	decafluorotriphenylphosphine
DI	deionized
DID	data item description
DIMP	di-isopropylmethylphosphonate
DM	dry matter; adamsite
DMBA	dimethylbenz(a)anthracene
DMMP	dimethylmethylphosphonate
DOD	U.S. Department of Defense
DOJ	U.S. Department of Justice
DOT	U.S. Department of Transportation
DP	direct-push
DPDO	Defense Property Disposal Office
DPT	direct-push technology
DQO	data quality objective
DRMO	Defense Reutilization and Marketing Office
DRO	diesel range organics
DS	deep (subsurface) soil
DS2	Decontamination Solution Number 2
DSERTS	Defense Site Environmental Restoration Tracking System
DWEL	drinking water equivalent level
E&E	Ecology and Environment, Inc.
EB	equipment blank
EBS	environmental baseline survey
EC_{50}	effects concentration for 50 percent of a population
ECBC	Edgewood Chemical/Biological Command
ED	exposure duration
EDD	electronic data deliverable
EF	exposure frequency
EDQL	ecological data quality level
EE/CA	engineering evaluation and cost analysis
Elev.	elevation
EM	electromagnetic
EMI	Environmental Management Inc.
EM31	Geonics Limited EM31 Terrain Conductivity Meter
EM61	Geonics Limited EM61 High-Resolution Metal Detector
EOD	explosive ordnance disposal
EODT	explosive ordnance disposal team
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
EPIC	Environmental Photographic Interpretation Center
EPRI	Electrical Power Research Institute
ER	equipment rinsate
ERA	ecological risk assessment
ER-L	effects range-low
ER-M	effects range-medium
ESE	Environmental Science and Engineering, Inc.
ESMP	Endangered Species Management Plan
ESN	Environmental Services Network, Inc.
ESV	ecological screening value
ET	exposure time
EU	exposure unit
Exp.	explosives
E-W	east to west
EZ	exclusion zone
FAR	Federal Acquisition Regulations
FB	field blank
FD	field duplicate
FDA	U.S. Food and Drug Administration
Fe^{+3}	ferric iron
Fe^{+2}	ferrous iron
FedEx	Federal Express, Inc.
FEMA	Federal Emergency Management Agency
FFCA	Federal Facilities Compliance Act
FFE	field flame expedient
FFS	focused feasibility study
FI	fraction of exposure
Fil	filtered
Flt	filtered
FMDC	Fort McClellan Development Commission
FML	flexible membrane liner
FMP 1300	Former Motor Pool 1300
f_{oc}	fraction organic carbon
FOMRA	Former Ordnance Motor Repair Area
FOST	Finding of Suitability to Transfer
Foster Wheeler	Foster Wheeler Environmental Corporation
FR	Federal Register
Frtn	fraction
FS	field split; feasibility study
FSP	field sampling plan
ft	feet
ft/day	feet per day
ft/ft	feet per foot
ft/yr	feet per year
FTA	Fire Training Area
FTMC	Fort McClellan
FTRRA	FTMC Reuse & Redevelopment Authority
g	gram
g/m^3	gram per cubic meter
G-856	Geometrics, Inc. G-856 magnetometer
G-858G	Geometrics, Inc. G-858G magnetic gradiometer
GAF	gastrointestinal absorption factor
gal	gallon
gal/min	gallons per minute
GB	sarin
gc	clay gravels; gravel-sand-clay mixtures
GC	gas chromatograph
GCL	geosynthetic clay liner
GC/MS	gas chromatograph/mass spectrometer
GCR	geosynthetic clay liner
GFAA	graphite furnace atomic absorption
GIS	Geographic Information System
gm	silty gravels; gravel-sand-silt mixtures
gp	poorly graded gravels; gravel-sand mixtures
gpm	gallons per minute
GPR	ground-penetrating radar
GPS	global positioning system
GRA	general response action
GS	ground scar
GSA	General Services Administration; Geologic Survey of Alabama
GSBP	Ground Scar Boiler Plant
GSSI	Geophysical Survey Systems, Inc.
GST	ground stain
GW	groundwater
gw	well-graded gravels; gravel-sand mixtures
H&S	health and safety
HA	hand auger
HCl	hydrochloric acid
HD	distilled mustard
HDPE	high-density polyethylene
HEAST	Health Effects Assessment Summary Tables
Herb.	herbicides
HHRA	human health risk assessment
HI	hazard index
H_2O_2	hydrogen peroxide
HPLC	high performance liquid chromatography
HNO_3	nitric acid
HQ	hazard quotient
HQ_{screen}	screening-level hazard quotient
hr	hour
HRC	hydrogen releasing compound
HSA	hollow-stem auger
HTRW	hazardous, toxic, and radioactive waste
'I'	out of control, data rejected due to low recovery
IATA	International Air Transport Authority
ICAL	initial calibration
ICB	initial calibration blank
ICP	inductively-coupled plasma
ICRP	International Commission on Radiological Protection
ICS	interference check sample
ID	inside diameter
IDL	instrument detection limit
IDLH	immediately dangerous to life or health

IDM	investigative-derived media
IDW	investigation-derived waste
IEUBK	Integrated Exposure Uptake Biokinetic
IF	ingestion factor; inhalation factor
ILCR	incremental lifetime cancer risk
IMPA	isopropylmethyl phosphonic acid
IMR	Iron Mountain Road
in.	inch
Ing	ingestion
Inh	inhalation
IP	ionization potential
IPS	International Pipe Standard
IR	ingestion rate
IRDMIS	Installation Restoration Data Management Information System
IRIS	Integrated Risk Information Service
IRP	Installation Restoration Program
IS	internal standard
ISCP	Installation Spill Contingency Plan
IT	IT Corporation
ITEMS	IT Environmental Management System™
'J'	estimated concentration
JeB2	Jefferson gravelly fine sandy loam, 2 to 6 percent slopes, eroded
JeC2	Jefferson gravelly fine sandy loam, 6 to 10 percent slopes, eroded
JfB	Jefferson stony fine sandy loam, 0 to 10 percent slopes have strong slopes
JPA	Joint Powers Authority
K	conductivity
K_d	soil-water distribution coefficient
kg	kilogram
KeV	kilo electron volt
K_{oc}	organic carbon partioning coefficient
K_{ow}	octonal-water partition coefficient
$KMnO_4$	potassium permanganate
L	lewisite; liter
L/kg/day	liters per kilogram per day
l	liter
lb	pound
LBP	lead-based paint
LC	liquid chromatography
LCS	laboratory control sample
LC_{50}	lethal concentration for 50 percent population tested
LD_{50}	lethal dose for 50 percent population tested
LEL	lower explosive limit
LOAEL	lowest-observed-advserse-effects-level
LRA	land redevelopment authority
LT	less than the certified reporting limit
LUC	land-use control
LUCAP	land-use control assurance plan
LUCIP	land-use control implementation plan
max	maximum
MB	method blank
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MCPA	4-chloro-2-methylphenoxyacetic acid
MCS	media cleanup standard
MD	matrix duplicate
MDC	maximum detected concentration
MDCC	maximum detected constituent concentration
MDL	method detection limit
mg	milligrams
mg/kg	milligrams per kilogram
mg/kg/day	milligram per kilogram per day
mg/kgbw/day	milligrams per kilogram of body weight per day
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
mh	inorganic silts, micaceous or diatomaceous fine, sandy or silt soils
MHz	megahertz
µg/g	micrograms per gram
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µmhos/cm	micromhos per centimeter
MeV	mega electron volt
min	minimum
MINICAMS	miniature continuous air monitoring system
ml	inorganic silts and very fine sands
mL	milliliter
mm	millimeter
MM	mounded material
MMBtu/hr	million Btu per hour
MNA	monitored natural attenuation
MnO_4-	permanganate ion
MOGAS	motor vehicle gasoline
MOUT	Military Operations in Urban Terrain
MP	Military Police
MPA	methyl phosphonic acid
MPM	most probable munition
MQL	method quantitation limit
MR	molasses residue
MRL	method reporting limit
MS	matrix spike
mS/cm	millisiemens per centimeter
mS/m	millisiemens per meter
MSD	matrix spike duplicate
MTBE	methyl tertiary butyl ether
msl	mean sea level
MtD3	Montevallo shaly, silty clay loam, 10 to 40 percent slopes , severely eroded
mV	millivolts
MW	monitoring well
MWI&P	Monitoring Well Installation and Management Plan
Na	sodium
NA	not applicable; not available
NAD	North American Datum
NAD83	North American Datum of 1983
$NaMnO_4$	sodium permanganate
NAVD88	North American Vertical Datum of 1988
NAS	National Academy of Sciences
NCEA	National Center for Environmental Assessment
NCP	National Contingency Plan
NCRP	National Council on Radiation Protection and Measurements
ND	not detected
NE	no evidence; northeast
ne	not evaluated
NEW	net explosive weight
NFA	No Further Action
NG	National Guard
NGP	National Guardsperson
ng/L	nanograms per liter
NGVD	National Geodetic Vertical Datum
Ni	nickel
NIC	notice of intended change
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NLM	National Library of Medicine
NO_3^-	nitrate
NPDES	National Pollutant Discharge Elimination System
NPW	net present worth
No.	number
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no-observed-adverse-effects-level
NR	not requested; not recorded; no risk
NRC	National Research Council
NRCC	National Research Council of Canada
NRHP	National Register of Historic Places
ns	nanosecond
N-S	north to south
NS	not surveyed
NSA	New South Associates, Inc.
nT	nanotesla
nT/m	nanoteslas per meter
NTU	nephelometric turbidity unit
nv	not validated
O_2	oxygen
O_3	ozone
O&G	oil and grease
O&M	operation and maintenance

OB/OD	open burning/open detonation
OD	outside diameter
OE	ordnance and explosives
oh	organic clays of medium to high plasticity
OH•	hydroxyl radical
ol	organic silts and organic silty clays of low plasticity
OP	organophosphorus
ORC	Oxygen Releasing Compound
ORP	oxidation-reduction potential
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OVM-PID/FID	organic vapor meter-photoionization detector/flame ionization detector
OWS	oil/water separator
oz	ounce
PA	preliminary assessment
PAH	polynuclear aromatic hydrocarbon
PARCCS	precision, accuracy, representativeness, comparability, completeness, and sensitivity
Parsons	Parsons Engineering Science, Inc.
Pb	lead
PBMS	performance-based measurement system
PC	permeability coefficient
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-p-dioxins
PCDF	polychlorinated dibenzofurans
PCE	perchloroethene
PCP	pentachlorophenol
PDS	Personnel Decontamination Station
PEF	particulate emission factor
PEL	permissible exposure limit
PERA	preliminary ecological risk assessment
PES	potential explosive site
Pest.	pesticides
PETN	pentarey thritol tetranitrate
PFT	portable flamethrower
PG	professional geologist
PID	photoionization detector
PkA	Philo and Stendal soils local alluvium, 0 to 2 percent slopes
PM	project manager
POC	point of contact
POL	petroleum, oils, and lubricants
POTW	publicly owned treatment works
POW	prisoner of war
PP	peristaltic pump; Proposed Plan
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
PPMP	Print Plant Motor Pool
ppt	parts per thousand
PR	potential risk
PRA	preliminary risk assessment
PRG	preliminary remediation goal
PS	chloropicrin
PSSC	potential site-specific chemical
pt	peat or other highly organic silts
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	quality assurance/quality control
QAM	quality assurance manual
QAO	quality assurance officer
QAP	installation-wide quality assurance plan
QC	quality control
QST	QST Environmental, Inc.
qty	quantity
Qual	qualifier
R	rejected data; resample; retardation factor
R&A	relevant and appropriate
RA	remedial action
RAO	remedial action objective
RBC	risk-based concentration; red blood cell
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RDX	cyclonite
ReB3	Rarden silty clay loams
REG	regular field sample
REL	recommended exposure limit
RFA	request for analysis
RfC	reference concentration
RfD	reference dose
RGO	remedial goal option
RI	remedial investigation
RL	reporting limit
RME	reasonable maximum exposure
ROD	Record of Decision
RPD	relative percent difference
RRF	relative response factor
RSD	relative standard deviation
RTC	Recruiting Training Center
RTECS	Registry of Toxic Effects of Chemical Substances
RTK	real-time kinematic
SA	exposed skin surface area
SAD	South Atlantic Division
SAE	Society of Automotive Engineers
SAIC	Science Applications International Corporation
SAP	installation-wide sampling and analysis plan
SARA	Superfund Amendments and Reauthorization Act
sc	clayey sands; sand-clay mixtures
Sch.	Schedule
SCM	site conceptual model
SD	sediment
SDG	sample delivery group
SDWA	Safe Drinking Water Act
SDZ	safe distance zone; surface danger zone
SEMS	Southern Environmental Management & Specialties, Inc.
SF	cancer slope factor
SFSP	site-specific field sampling plan
SGF	standard grade fuels
SHP	installation-wide safety and health plan
SI	site investigation
SINA	Special Interest Natural Area
SL	standing liquid
SLERA	screening-level ecological risk assessment
sm	silty sands; sand-silt mixtures
SM	Serratia marcescens
SMDP	Scientific Management Decision Point
s/n	signal-to-noise ratio
SO_4^{-2}	sulfate
SOD	soil oxidant demand
SOP	standard operating procedure
SOPQAM	U.S. EPA's *Standard Operating Procedure/Quality Assurance Manual*
sp	poorly graded sands; gravelly sands
SP	submersible pump
SPCC	system performance calibration compound
SPCS	State Plane Coordinate System
SPM	sample planning module
SQRT	screening quick reference tables
Sr-90	strontium-90
SRA	streamlined human health risk assessment
SRM	standard reference material
Ss	stony rough land, sandstone series
SS	surface soil
SSC	site-specific chemical
SSHO	site safety and health officer
SSHP	site-specific safety and health plan
SSL	soil screening level
SSSL	site-specific screening level
SSSSL	site-specific soil screening level
STB	supertropical bleach
STC	source-term concentration
STD	standard deviation
STEL	short-term exposure limit
STL	Severn-Trent Laboratories
STOLS	Surface Towed Ordnance Locator System®
Std. units	standard units

SU	standard unit
SUXOS	senior UXO supervisor
SVOC	semivolatile organic compound
SW	surface water
SW-846	U.S. EPA's *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*
SWMU	solid waste management unit
SWPP	storm water pollution prevention plan
SZ	support zone
TAL	target analyte list
TAT	turn around time
TB	trip blank
TBC	to be considered
TCA	trichloroethane
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TCDF	tetrachlorodibenzofurans
TCE	trichloroethene
TCL	target compound list
TCLP	toxicity characteristic leaching procedure
TDEC	Tennessee Department of Environment and Conservation
TDGCL	thiodiglycol
TDGCLA	thiodiglycol chloroacetic acid
TERC	Total Environmental Restoration Contract
THI	target hazard index
TIC	tentatively identified compound
TLV	threshold limit value
TN	Tennessee
TNT	trinitrotoluene
TOC	top of casing; total organic carbon
TPH	total petroleum hydrocarbons
TR	target cancer risk
TRADOC	U.S. Army Training and Doctrine Command
TRPH	total recoverable petroleum hydrocarbons
TSCA	Toxic Substances Control Act
TSDF	treatment, storage, and disposal facility
TWA	time-weighted average
UBR	upper background range
UCL	upper confidence limit
UCR	upper certified range
'U'	not detected above reporting limit
UIC	underground injection control
UF	uncertainty factor
USACE	U.S. Army Corps of Engineers
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
USAEC	U.S. Army Environmental Center
USAEHA	U.S. Army Environmental Hygiene Agency
USACMLS	U.S. Army Chemical School
USAMPS	U.S. Army Military Police School
USATCES	U.S. Army Technical Center for Explosive Safety
USATEU	U.S. Army Technical Escort Unit
USATHAMA	U.S. Army Toxic and Hazardous Material Agency
USC	United States Code
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	underground storage tank
UTL	upper tolerance level; upper tolerance limit
UXO	unexploded ordnance
UXOQCS	UXO Quality Control Supervisor
UXOSO	UXO safety officer
V	vanadium
VC	vinyl chloride
VOA	volatile organic analyte
VOC	volatile organic compound
VOH	volatile organic hydrocarbon
VQlfr	validation qualifier
VQual	validation qualifier
VX	nerve agent (O-ethyl-S-[diisopropylaminoethyl]-methylphosphonothiolate)
WAC	Women's Army Corps
Weston	Roy F. Weston, Inc.
WP	installation-wide work plan
WRS	Wilcoxon rank sum
WS	watershed
WSA	Watershed Screening Assessment
WWI	World War I
WWII	World War II
XRF	x-ray fluorescence
yd^3	cubic yards