DEPARTMENT OF THE ARMY
LONGHORN ARMY AMMUNITION PLANT
POST OFFICE BOX 220
RATCLIFF, AR 72951

September 19, 2016

DAIM-ODB-LO

Mr. Rich Mayer
US Environmental Protection Agency
Federal Facilities Section R6
1445 Ross Avenue
Dallas, TX 75202-2733

Re: Final Record of Decision, LHAAP-16, Landfill,
Longhorn Army Ammunition Plant, Karnack, Texas, August 2016

Dear Mr. Mayer,

The above-referenced document is being transmitted to you for your records. The Draft Final document was previously prepared and submitted by Shaw Environmental, Inc. (Shaw) on behalf of the Army as part of Shaw's performance based contract for the facility on September 29, 2011. The Final document has been updated by Army to address the EPA Administrator's decision resolving the dispute in a letter dated October 31, 2014.

The point of contact for this action is the undersigned. I may be contacted at 479-635-0110, or by email at rose.zeiler@us.army.mil.

Sincerely,

Rose M. Zeiler

Rose M. Zeiler, Ph.D.
Longhorn AAP Site Manager

Copies furnished:
A. Palmie, TCEQ, Austin, TX
P. Bruckwicki, Caddo Lake NWR, TX
R. Smith, USACE, Tulsa District, OK
A. Williams, USACE, Tulsa District, OK
N. Smith, USAEC, San Antonio, TX
D. Richmann, AECOM – San Antonio, TX (for project files)

DEPARTMENT OF THE ARMY
LONGHORN ARMY AMMUNITION PLANT
POST OFFICE BOX 220
RATCLIFF, AR 72951

September 19, 2016

DAIM-ODB-LO

Ms. April Palmie
Texas Commission on Environmental Quality Superfund Section, MC-136
12100 Park 35 Circle, Bldg D
Austin, TX 78753

Re: Final Record of Decision, LHAAP-16, Landfill,
Longhorn Army Ammunition Plant, Karnack, Texas, August 2016

Dear Ms. Palmie,

The above-referenced document is being transmitted to you for your records. The Draft Final document was previously prepared and submitted by Shaw Environmental, Inc. (Shaw) on behalf of the Army as part of Shaw's performance based contract for the facility on September 29, 2011. The Final document has been updated by Army to address the EPA Administrator's decision resolving the dispute in a letter dated October 31, 2014.

The point of contact for this action is the undersigned. I may be contacted at 479-635-0110, or by email at rose.zeiler@us.army.mil.

Sincerely,

Rose M. Zeiler

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Longhorn AAP Site Manager

Copies furnished:
R. Mayer, USEPA Region 6, Dallas, TX
P. Bruckwicki, Caddo Lake NWR, TX
R. Smith, USACE, Tulsa District, OK
A. Williams, USACE, Tulsa District, OK
N. Smith, USAEC, San Antonio, TX
D. Richmann, AECOM, San Antonio, TX (for project files)

20774818

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Protecting Texas by Reducing and Preventing Pollution

September 6, 2016

Mr. Thomas E. Lederle
Chief, ACSIM BRAC Division
2530 Crystal Drive, Room 5000
Taylor Bldg./NC3
Arlington, Virginia 22202

Re: Record of Decision for LHAAP-16, Landfill
Longhorn Army Ammunition Plant Superfund Site TX6213820529
Karnack, Harrison County, Texas

Dear Mr. Lederle:

The Texas Commission on Environmental Quality (TCEQ) received the final Record of Decision (ROD) for the LHAAP-16, Landfill, at the Longhorn Army Ammunition Plant Federal Superfund Site in Karnack, Texas on August 16, 2016. The TCEQ has completed the review of the above referenced document and concurs that the response action described in the ROD is the most appropriate remedy for LHAAP-16.

Sincerely,

Richard A. Hyde, P.E.
Executive Director

cc: Mr. Carl Edlund, P.E., Director, Superfund Division, U.S. Environmental Protection Agency, Region 6

FINAL

RECORD OF DECISION
LHAAP-16 LANDFILL
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Prepared for

U.S. Army Corps of Engineers
Tulsa District
1645 South 101st Avenue
Tulsa, Oklahoma

Prepared by

Shaw Environmental, Inc.
1401 Enclave Parkway, Suite 250
Houston, Texas 77077

Contract Number W912QR-04-D-0027, Task Order No. DS02
Shaw Project No. 117591

August 2016

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Glossary of Terms

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Acronyms and Abbreviations

µg/L	micrograms per liter
ARAR	applicable or relevant and appropriate requirement
BERA	baseline ecological risk assessment
bgs	below ground surface
BHHRA	baseline human health risk assessment
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CFR	Code of Federal Regulations
cfm	cubic feet per minute
cm/sec	centimeters per second
COC	chemical of concern
COPEC	chemical of potential ecological concern
COPC	chemical of potential concern
CSM	conceptual site model
DCA	dichloroethane
DCE	dichloroethene
DNT	dinitrotoluene
DPT	direct-push technology
ECOP	environmental condition of property
EPC	exposure point concentration
ESD	explanation of significant differences
ESTCP	Environmental Security Technology Certification Program
FFA	Federal Facility Agreement
FS	feasibility study
gpm	gallons per minute
HEAST	health effects assessment summary tables
HI	hazard index
HQ	hazard quotient
IRA	interim remedial action
IRIS	Integrated Risk Information System
Jacobs	Jacobs Engineering Group, Inc.
LDR	land disposal restriction
LHAAP	Longhorn Army Ammunition Plant
LTM	long-term monitoring

Acronyms and Abbreviations (continued)

LUC	land use control
MCL	maximum contaminant level
mg/kg	milligrams per kilogram (parts per million [ppm] – soil analyses)
mg/kg-day	milligrams per kilogram per day
MNA	monitored natural attenuation
MOA	Memorandum of Agreement
MSC	medium-specific concentration
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
O&M	operation and maintenance
PCB	polychlorinated biphenyl
PCL	Protective Concentration Level
Plexus	Plexus Scientific Corporation
pvc	polyvinyl chloride
RAB	Restoration Advisory Board
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RFA	RCRA Facility Assessment
RfD	reference dose
RI	remedial investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SF	slope factor
Shaw	Shaw Environmental, Inc.
STEP	Solutions to Environmental Problems, Inc.
SVE	soil vapor extraction
SVOC	semivolatile organic compound
TAC	Texas Administrative Code
TCDD	tetrachlorodibenzo-p-dioxin
TCE	trichloroethene
TCLP	toxicity characterisitc leaching procedure
TCEQ	Texas Commission on Environmental Quality
TNT	Trinitrotoluene

Acronyms and Abbreviations *(continued)*

TRRP	Texas Risk Reduction Program
UCL	upper confidence limit
U.S. Army	U.S. Department of the Army
USACE	U.S. Army Corps of Engineers
USAEHA	U.S. Army Environmental Hygiene Agency
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USC	U.S. Code
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
VC	vinyl chloride
VOC	volatile organic compound

1.0 The Declaration

1.1 Site Name and Location

Longhorn Army Ammunition Plant-16 (LHAAP-16), Landfill

Longhorn Army Ammunition Plant
Karnack, Texas

Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS), U.S. Environmental Protection Agency (USEPA) Identification Number: TX6213820529.

1.2 Statement of Basis and Purpose

This decision document presents the selected remedy for LHAAP-16 Landfill, located at the Longhorn Army Ammunition Plant (LHAAP) in Karnack, Texas. The remedy was chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, and, to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), Code of Federal Regulations (CFR) Title 40 §300.

The remedy selection was based on the Administrative Record for the site, including the remedial investigation (RI) (Jacobs Engineering Group, Inc. [Jacobs], 2000), baseline human health risk assessment (BHHRA) report (Jacobs, 2001a), addendum to the BHHRA (Jacobs, 2001b), installation-wide baseline ecological risk assessment (BERA) report (Shaw Environmental, Inc. [Shaw], 2007a), feasibility study (FS) (Jacobs, 2002), addendum to the FS report (Shaw, 2010), Proposed Plan (U.S. Department of the Army [U.S. Army], 2010) and other related documents contained in the Administrative Record for LHAAP-16.

This document is issued by the U.S. Army, the lead agency for this installation. The U.S. Army, USEPA, and the Texas Water Commission (currently known as the TCEQ) entered into the FFA for remedial activities at LHAAP which became effective on December 30, 1991. The USEPA (Region 6) and the Texas Commission on Environmental Quality (TCEQ) are the regulatory agencies providing technical support, project review and comment, and oversight of the LHAAP cleanup program. The USEPA and the U.S Army jointly select the remedy and TCEQ concurs with the selected remedy in this Record of Decision (ROD).

1.3 Assessment of the Site

The response action selected in this ROD is necessary to protect the public health or welfare or the environment from actual or threatened releases of hazardous substances, pollutants, or contaminants into the environment.

1.4 Description of the Selected Remedy

The final selected remedy for LHAAP-16 includes maintenance of the existing cap, enhanced land use controls (LUCs), in situ enhanced bioremediation in a target area, biobarriers, and monitored natural attenuation (MNA). The final remedy also incorporates those LUCs already in place as a result of an early interim remedial action (IRA), a containment presumptive remedy.

The IRA was implemented from 1996 to 1998 at LHAAP-16 to address the landfill waste materials (source area). The containment remedy, a multilayer landfill cap, was necessary to mitigate potential risks posed by buried source material at the site. Placement of a multilayer cap addressed the risks associated with landfill source materials by eliminating the direct exposure pathway to source area waste material, preventing contaminant transport to surface water via surface runoff, and reducing leaching of contaminants to the groundwater. The IRA ROD (U.S. Army and USEPA, 1995) called for warning signage, use restrictions, regular inspections, maintenance and repair of the cover system and five-year reviews. The IRA ROD also noted that a final ROD would be issued when the groundwater investigations and subsequent risk assessment were completed.

The final selected remedy for LHAAP-16 protects human health and the environment by preventing human exposure to the landfill waste and contaminated groundwater, and preventing groundwater contaminated with chemicals of concern (COCs) from migrating into nearby surface water. The human health scenarios evaluated were based on the hypothetical future maintenance worker. In the groundwater, the COCs are trichloroethene [TCE], cis-1,2-dichloroethene [DCE], vinyl chloride [VC]), perchlorate, and five metals (arsenic, chromium, manganese, nickel and thallium). The components of the selected remedy are summarized below.

- Maintenance and repair of the existing landfill cap. Groundwater monitoring activities at select wells also will be conducted to evaluate the effectiveness of the existing landfill cap. The need to continue groundwater monitoring for this purpose will be evaluated at five-year reviews.
- In situ enhanced bioremediation in the most contaminated portion of the shallow and intermediate groundwater zones to reduce contaminant mass and lower the contaminant concentrations. Bioremediation will be implemented in conjunction with phased shut down of the existing groundwater extraction system.
- Installation of a biobarrier in the downgradient portion of the contaminant plume to prevent contaminated groundwater from seeping into Harrison Bayou at concentrations that would cause surface water to exceed Texas Surface Water Quality Standards, the Safe Drinking

Water Act (SDWA) maximum contaminant levels (MCLs), and in the absence of federal drinking water standards, cleanup levels based on Texas Risk Reduction Program (TRRP) Tier 1 Groundwater Residential Protective Concentration Levels (PCLs). A second biobarrier will be installed at the edge of the landfill to control potential migration of volatile organic compounds (VOCs) from the landfill. The purpose of the biobarriers in conjunction with natural attenuation will be to reduce groundwater contaminant and by-product contaminant concentrations to levels that will prevent surface water from exceeding surface water standards, to reduce groundwater contaminant and by-product contaminant concentrations to levels that attain groundwater cleanup standards, to reduce the potential migration of contaminants and by-product contaminant from the landfill, and to reduce groundwater contaminant and by-product contaminant mass.

- MNA will be implemented for areas outside the influence of the active remedies to assure protection of human health and the environment by documenting that further reductive dechlorination is occurring within the plume and that contaminant concentrations are being reduced to cleanup levels. MNA monitoring will be initiated immediately following issuance of the remedial design. Groundwater samples will be collected from wells that are determined to be outside any significant influence from the in situ enhanced bioremediation and the biobarriers. If MNA is not successful, a contingency remedy will be implemented. That contingency remedy will comprise injection of bioremediation amendments in locations that are selected based on evaluation of site data available at that time.

- MNA will also be implemented in the areas of active remediation following successful implementation of in situ bioremediation and the biobarriers. The active remedies will significantly reduce contaminant concentrations, and MNA will ultimately restore the groundwater to cleanup levels. MNA monitoring will be initiated at wells within the treatment areas when performance monitoring of the active remedies demonstrates that further amendment injections are not necessary. If MNA is not successful, the active remedies will be re-implemented, in part or in whole, based on evaluation of site data available at that time.

- Groundwater monitoring will be conducted to evaluate inorganic COCs. The need to continue groundwater monitoring for this purpose will be evaluated at five year reviews.

- Surface water monitoring will also be conducted to confirm that surface water standards for the contaminants and by-product contaminants are not exceeded in Harrison Bayou, which flows into Caddo Lake. The surface water sampling events will be conducted when groundwater sampling events are conducted for performance monitoring, MNA monitoring, and inorganics monitoring.

- The LUC's objectives include maintaining the integrity of any current or future remedial or monitoring systems, and preventing the use of groundwater contaminated above cleanup levels as a potable water source. The groundwater treatment and MNA remedial components include a groundwater monitoring system that will be used to characterize the condition of the groundwater during the period the groundwater remedy is in place until the groundwater remediation goals are achieved, and to demonstrate achievement of the groundwater remediation goals when the groundwater remedy is complete. As a part of this groundwater remedy, the Army will maintain the remedial and monitoring systems associated with the groundwater remedies until these components of the remedy are no longer needed to achieve cleanup levels, and when these levels have been achieved. During the period of operation of the groundwater remedy, if any of the elements of the remedial and groundwater monitoring systems are damaged, destroyed, or become ineffective, they will be repaired or replaced with suitable components to ensure that the remedial and groundwater monitoring systems are able to provide data of the quality necessary to determine the progress of and eventual completion of this component of the remedy. The actions to be taken to implement these LUC objectives and requirements will be provided through modifying the "Comprehensive Land Use Control (LUC) Management Plan, Former Longhorn Army Ammunition Plant, Karnack, Texas" and detailed in the LUC RD.

- The LUCs' performance objectives are to prohibit access to the contaminated groundwater except for environmental monitoring and testing only, to preserve the integrity of the landfill cap, and to restrict intrusive activities (e.g., digging) that would degrade or alter the cap, to restrict land use to nonresidential, to maintain the integrity of any current or future remedial or monitoring systems and to prevent the use of groundwater contaminated above cleanup levels as a potable water source. The landfill LUCs will remain in place as long as the landfill waste remains at the site or until the levels of Contaminants of Concern (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) allow for unlimited use and unrestricted exposure. The LUCs restricting the use of groundwater to environmental monitoring and testing only and the LUC restricting land use to nonresidential will remain in place until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater allow for unlimited use and unrestricted exposure. The LUC to maintain the integrity of any current or future remedial or monitoring systems will remain in place until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met. The LUC prohibiting groundwater use (except for environmental monitoring and testing) as a potable source will remain in place until the levels of COCs (i.e., all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in soil and groundwater allow for unlimited use and unrestricted exposure.

- CERCLA five-year reviews and inspections of physical mechanisms at LHAAP-16.

Based on a preliminary natural attenuation evaluation, groundwater cleanup levels in areas without in situ bioremediation are expected to be met through natural attenuation in approximately 280 years (Shaw, 2010). The time-frame will be reevaluated after additional sampling is conducted following shut down of the extraction system and implementation of in situ bioremediation and the biobarriers. MNA will be implemented for the entire site including areas of active remediation and areas outside the influence of active remedies where proper conditions of natural attenuation are established. Natural attenuation will be evaluated in the areas of active remedies 2 years following implementation of the remedies. In the areas outside of the active remedies, natural attenuation will be evaluated for 2 years immediately following issuance of the remedial design.

If proper conditions of natural attenuation are established, monitoring for the entire site will continue at a reduced frequency. Otherwise, re-application of bio-amendments (i.e., additional in situ bioremediation) will be implemented.

A LUC Remedial Design (RD) will be finalized as the land use component of the Remedial Design. Within 21 days of the issuance of the ROD, the Army will propose deadlines for completion of the RD Work Plan, RD, and Remedial Action Work Plan. The documents will be prepared and submitted to EPA and TCEQ pursuant to the FFA. The LUC RD will contain implementation and maintenance actions, including periodic inspections. The long-term groundwater and surface water monitoring and MNA performance monitoring plan will also be presented in the RD.

The Army will implement, maintain, monitor, report on and enforce land use controls at Army-owned property. The Army shall perform those actions related to land use control activities described in this ROD and in the Remedial Design for the ROD. For portions of the Site subject to land use controls that are not owned by the Army, the Army will monitor and report on the implementation, maintenance, and enforcement of land use controls, and coordinate with federal, state, and local governments and owners and occupants of properties subject to land use controls. The Army will provide notice of the groundwater and soil (surface and subsurface) contamination and any land use restrictions referenced in the ROD. The Army will send these notices to the federal, state and local governments involved at this site and the owners and occupants of the properties subject to those use restrictions and land use controls. The Army shall provide the initial notice within 90 days of ROD signature. The frequency of subsequent notifications will be described in the Remedial Design for the ROD. The Army remains responsible for ensuring that the remedy remains protective of human health and the environment. The Army will fulfill its responsibility and obligations under CERCLA and the NCP as it implements, maintains, and reviews the selected remedy.

Upon transfer of Army-owned property, the Army will provide written notice of the land use controls to the transferee of the groundwater and soil (surface and subsurface) contamination and any land use restrictions referenced in the ROD. Within 15 days of transfer, the Army shall provide EPA and the TCEQ with written notice of the division of implementation, maintenance, and enforcement responsibilities unless such information has already been provided in the LUC RD. The LUC RD will address the procedures to be used by the Army and the transferee to document compliance with the LUCs described in this ROD. In the event property is transferred out of Federal control, the land use controls relating to property and groundwater restrictions shall be recorded in the deed and shall be enforceable by the United States and the state of Texas.

A LUC Remedial Design (RD) will be finalized as the land use component of the Remedial Design. Within 21 days of the issuance of the ROD, the Army will propose deadlines for completion of the RD Work Plan, RD, and Remedial Action Work Plan. The documents will be prepared and

submitted to EPA and TCEQ pursuant to the FFA. The LUC RD will contain implementation and maintenance actions, including periodic inspections. The long-term groundwater and surface water monitoring and MNA performance monitoring plan will also be presented in the RD.

U.S. Army and regulators will consult to determine appropriate enforcement actions should there be a failure of a LUCs objective at these sites after they have been transferred.

The management strategy at LHAAP is to approach each site separately to address human health issues and to approach the sites by sub-area to address ecological risk. Thus, the implementation of this remedy at LHAAP-16 is independent of any other remedial action at LHAAP to address human health issues. To address ecological risk, LHAAP-16 was grouped with several other sites as part of the Waste Sub-Area. The final chemicals of potential ecological concern (COPECs) in soil that require remedial action in the Waste Sub-Area are barium, 2,4-dinitrotoluene (DNT), 2,6-DNT, 2,4,6-trinitrotoluene (TNT), and dioxins (Shaw, 2010). Based on the evaluation of soil samples collected during the RI from outside the landfill, the BERA concluded that no action is needed at LHAAP-16 for the protection of ecological receptors. The proposed remedy at LHAAP-17 will be sufficient to address ecological risks for the entire Waste Sub-Area. The proposed remedy at LHAAP-17 is identified in the Proposed Plan (Shaw 2010b) that has been reviewed and approved by the regulatory agencies. The Proposed Plan is in the Administrative Record file for LHAAP.

1.5 Statutory Determinations

The final selected remedy is protective of human health and the environment, complies with Federal and State requirements that are applicable or relevant and appropriate to the remedial action, and is cost-effective. In addition, the remedy offers long-term effectiveness through the long-term inspection and maintenance of the landfill cap (that controls infiltration, contaminant runoff, and contaminant exposure) and implementation of LUCs which will minimize the potential risk to the hypothetical future maintenance worker posed by the landfill waste material and contaminated groundwater. Furthermore, evaluation of natural attenuation (including determination of contaminant reduction rates and routine monitoring of the attenuation until cleanup levels are met) will document the effectiveness of the final selected remedy. The final selected remedy is easily and immediately implementable.

The in situ bioremediation and biobarriers components of the selected remedy satisfy the statutory preference for treatment as a principal treatment element of the remedy. The MNA component does not address the statutory preference for treatment to the maximum extent practicable; MNA is a passive remedial action using natural processes. Although none of the landfill waste will be actively treated, the potential mobility and toxicity of the landfill waste contaminants would be minimized through proper landfill cap maintenance, and the biobarrier near the landfill fence line.

Because hazardous substances, pollutants, or contaminants may remain at the site above levels that allow for unlimited use and unrestricted exposure, reviews will be conducted every 5 years as required under CERCLA §121(c), U.S. Code (USC) Title 42 §9621(c). In accordance with 30 Texas Administrative Code (TAC) §335.566, a notification will be recorded in Harrison County records stating that the site has restrictions against intrusive activities (e.g., digging) as long as landfill waste remains or until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) allow for unlimited use and unrestricted exposure. It will also be recorded that the site is suitable for nonresidential use, and that a prohibition of groundwater use (except for environmental monitoring and testing) as a potable source is in place until the levels of COCs (i.e., all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in soil and groundwater allow for unlimited use and unrestricted exposure, and that the integrity of any current or future remedial or monitoring systems will remain in place until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met. Although the U.S. Army may later pass these procedural responsibilities to the transferee by property transfer agreement, the U.S. Army shall retain ultimate responsibility for remedy integrity, per the FFA and CERCLA §121.

1.6 ROD Data Certification Checklist

The following information is included in the Decision Summary section of this ROD. Additional information can be found in the Administrative Record for this site.

- Current and reasonably anticipated future land use assumptions and current and potential future beneficial uses of groundwater as identified in the baseline risk assessment and ROD (**Section 2.6**).
- Potential land and groundwater use that will be available at the sites as a result of the selected remedy (**Section 2.6**).
- COCs and their concentrations (**Section 2.7**).
- Baseline risk represented by the COCs (**Section 2.7**).
- Cleanup levels established for COCs and the basis for these levels (**Sections 2.7.4** and **2.8**).
- How source materials constituting principal threats are addressed at this site (**Section 2.11**).
- Key factor(s) that led to selecting the remedy (**Section 2.12**).
- Estimated capital, annual operation and maintenance (O&M), and total present worth costs, discount rate, and the number of years over which the remedy cost estimates are projected (**Section 2.12**).

1.7 Authorizing Signatures

As the lead agency, the U.S. Army issues this ROD for LHAAP-16 which documents the final selected remedy. The undersigned is the appropriate approval authority for this decision.

Thomas E. Lederle 16 Aug 2016
(*Name*) (*Date*)
Thomas E. Lederle
Division Chief
Base Realignment and Closure Division
Assistant Chief of Staff for Installation Management
U.S. Army

The U.S. Environmental Protection Agency approves the final selected remedy as provided in the ROD for LHAAP-16.

09/13/16
(*Name*) (*Date*)

Carl E. Edlund, P.E.
Director
Superfund Division
U.S. Environmental Protection Agency
Region 6

2.0 Decision Summary

2.1 Site Name, Location, and Description

LHAAP-16 Landfill

Longhorn Army Ammunition Plant
Karnack, Texas

Comprehensive Environmental Response, Compensation, and Liability Information System USEPA Identification Number: TX6213820529

Lead Agency: U.S. Army, Department of Defense
Support Agencies: USEPA Region 6, TCEQ

Source of Cleanup Money: U.S. Army, Department of Defense
Site Type: Landfill

The former LHAAP is an inactive, government-owned, formerly contractor operated and maintained, Department of Defense facility located in central east Texas (see **Figure 2-1**) in the northeast corner of Harrison County. LHAAP is approximately 14 miles northeast of Marshall, Texas, and approximately 40 miles west of Shreveport, Louisiana. The former U.S. Army installation occupied 8,416 acres between State Highway 43 at Karnack, Texas, and the southwestern shore of Caddo Lake. The facility can be accessed via State Highways 43 and 134.

LHAAP was placed on the USEPA National Priorities List (NPL) on August 9, 1990. Activities to remediate contamination began in 1990. After its listing on the NPL, the U.S. Army, the USEPA, and the Texas Water Commission (currently known as the TCEQ) entered into a CERCLA §120 FFA for remedial activities at LHAAP. The FFA became effective December 30, 1991. LHAAP operated until 1997 when it was placed on inactive status and classified by the U.S. Army Armament, Munitions, and Chemical Command as excess property. The majority of LHAAP has been transferred by the U.S. Army to the U.S. Fish and Wildlife Service (USFWS) for management as the Caddo Lake National Wildlife Refuge.

LHAAP-16, a capped landfill, is located in the south-central portion of LHAAP and covers an area of approximately 20 acres (**Figure 2-2**). Harrison Bayou runs along the northeastern edge of LHAAP-16. The landfill was established in the 1940s and was used for the disposal of solid and industrial wastes until the 1980s when disposal activities were terminated.

2.2 Site History and Enforcement Activities

2.2.1 History of Site Activities

LHAAP was established in December 1941 with the primary mission of manufacturing TNT. Production of TNT began at Plant 1 in October 1942 and continued through World War II until August 1945, when the facility was placed on standby status until February 1952. LHAAP facility was reactivated with the opening of Plant 2, where pyrotechnic ammunition, such as photoflash bombs, simulators, hand signals, and tracers for 40 millimeter ammunition, were produced until 1956.

In December 1954, a third facility, Plant 3, began production of solid-fuel rocket motors for tactical missiles. Rocket motor production at Plant 3 continued to be the primary operation at LHAAP until 1965 when Plant 2 was reactivated for the production of pyrotechnic and illuminating ammunition. In the years following the Vietnam conflict, LHAAP continued to produce flares and other basic pyrotechnic or illuminating items for the U.S. Department of Defense inventory. From September 1988 to May 1991, LHAAP was also used for the static firing and elimination of Pershing I and II rocket motors in compliance with the Intermediate-Range Nuclear Force Treaty in effect between the United States and the former Union of Soviet Socialist Republics. LHAAP operated until 1997 when it was placed on inactive status and classified by the U.S. Army Armament, Munitions, and Chemical Command as excess property.

LHAAP-16 Landfill was established in the 1940s and was used for disposal of solid and industrial wastes until the 1980s when disposal activities were terminated. The U.S. Army and the USEPA signed a ROD in 1995 approving an interim remedial action for LHAAP-16 to mitigate potential risks posed by buried source material at the site. The interim remedial action included the construction of a landfill cap, considered a component of the final remedy for the site. Construction of the 13-acre multilayer cap was completed in 1998. The ROD also specified that the U.S. Army would be required to "perform long-term maintenance of the cap." The landfill cap would be inspected at regular intervals to check for erosion, settlement, and deep-rooted vegetation. Repairs would be implemented as needed. LUCs, such as future use restrictions, would also be required.

In addition, at the request of the regulatory authorities, but not pursuant to a decision document (e.g., a record of decision or consent order), a groundwater extraction system was voluntarily installed by the U.S. Army in 1996 and 1997 as a treatability study to prevent the groundwater plume from migrating to Harrison Bayou. The extraction system has now been operating for nearly 20 years (Shaw, 2010).

2.2.2 History of Investigative Activities

As part of the Installation Restoration Program, the U.S. Army began an environmental investigation in 1976 at LHAAP followed by installation wide assessments/investigations that included the following:

- In 1980, U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) conducted a record search to assess the impact of the LHAAP installation activities including usage, storage, treatment, and disposal of toxic and hazardous materials on the environment, and defined conditions that may have adversely affected human health and the environment. Groundwater monitoring wells were installed and water samples were collected from the wells at the LHAAP-16 site (USATHAMA, 1980).
- Contamination Survey – In 1982 as part of the LHAAP contamination survey, Environmental Protection Systems collected six groundwater samples for laboratory analyses. Subsequently in 1987, as part of the Resource Conservation and Recovery Act (RCRA) permit application process, and as a continuation of the contamination survey, U.S. Army Environmental Hygiene Agency (USAEHA) identified, described, and evaluated all solid waste management units at LHAAP. Soil, groundwater, surface water and sediment samples were collected from the LHAAP-16 site (USAEHA, 1987). Units requiring further sampling, investigation and corrective action were delineated.
- RCRA Facility Assessment (RFA) – In 1988, a preliminary RFA was conducted by the U.S. Army (Maley, 1988). Waste at the various sites was characterized, but no samples were collected.

Several investigations to determine the nature and extent of contamination in the soil, groundwater, surface water, and sediments at LHAAP-16 were conducted and are listed below. Samples were analyzed for VOCs, semivolatile organic compounds (SVOCs), metals, explosive compounds, perchlorate, pesticides, polychlorinated biphenyls (PCBs), and/or dioxins/furans, depending on the focus of the investigation. For some of the earlier investigations, LHAAP sites were organized into groups, and LHAAP-16 was included in Group 2. LHAAP-16 was pulled out of Group 2 to allow for expedited decision making, and early actions to control the release of site-related contaminants. The following summarizes the investigations at LHAAP-16.

- **Multi-phase investigation of LHAAP-16**: Between 1993 and 1999 numerous investigations were conducted in a phased approach by Sverdrup, U.S. Army Corps of Engineers (USACE), and Jacobs. Activities included installation of monitoring wells and analysis of groundwater, surface water, soil, and sediment samples. Various landfill investigative tools were also used, including collecting soil gas samples. The results are documented in the RI report (Jacobs, 2000).
- **Plant-wide perchlorate investigation**: The soil and groundwater investigation was conducted by Solutions to Environmental Problems, Inc. (STEP) in 2000 through 2003 (STEP, 2005).

- **Baseline Human Health Risk Assessment**: The BHHRA (Jacobs, 2001a) used data from the investigations conducted through 1999. Dioxin and furan results had been omitted from the BHHRA, therefore an addendum to the BHHRA addressing potential human health risks associated with exposure to dioxins and furan was issued (Jacobs, 2001b).

- **Environmental Site Assessment:** Media evaluated in 2003 included soil and groundwater (Plexus, 2005), although no sampling was conducted at LHAAP-16 for this assessment.

- **Groundwater Monitoring**: Additional groundwater monitoring was conducted between 2003 and 2004 after the BHHRA was finalized to provide additional information regarding LHAAP-16 groundwater contamination identified during previous sampling events. Groundwater monitoring results from sampling conducted during Spring 2003, Spring 2004, and Winter 2004 were presented in the Groundwater Monitoring Report (USACE and ALL Consulting, 2007).

- **Surface Water Monitoring**: Since 1999 to present, surface water monitoring has been conducted on a quarterly basis at LHAAP-16. Surface water samples are collected from three locations in Harrison Bayou; upgradient, downgradient and immediately adjacent to LHAAP-16. Surface water analytical results indicated that in the past there has been some discharge by seepage into Harrison Bayou (Jacobs, 2002 and Shaw, 2007c).

- **Baseline Ecological Risk Assessment**: The BERA (Shaw, 2007a) iden**tified COPECs for the Waste S**ub-Area, which includes LHAAP-16. COPECs for the sub-area are addressed in the remedial actions for LHAAP-17, another site within the sub-area. The evaluation was based on environmental investigations from 1993 to 2006.

- **Feasibility Study**: The FS (Jacobs, 2002) was based on available results from investigation conducted up to 1999. The FS presented an interim analysis of remedial alternatives for LHAAP-16. Final Ecological risks and extent of groundwater remediation were not addressed in that document. Shaw issued the FS Addendum (Shaw, 2010) providing a basis for the final evaluation of alternatives and selection of a final remedy for LHAAP-16 consistent with the intended future use of LHAAP-16 as part of the national wildlife refuge. A new alternative, Alternative 7 was added to the existing FS. The FS Addendum also included natural attenuation and geochemical evaluation conducted in 2007, installation and sampling of wells near Harrison Bayou conducted in 2007, installation and sampling of wells to address data gaps conducted in 2008, and groundwater sampling for metals, perchlorate, and volatile organic compounds performed in 2009. The findings of the BERA were also included in the FS Addendum.

Figures 2-3 and **2-4** show the sampling locations for soil and groundwater, and surface water and sediment, respectively.

2.2.3 History of CERCLA Enforcement Activities

Due to the releases of chemicals from facility operations, the USEPA placed LHAAP on the Superfund NPL on August 9, 1990. Activities to remediate contamination associated with the listing of LHAAP as a Superfund site began in 1990. After the listing on the NPL, the U.S. Army, the USEPA, and the Texas Water Commission (currently known as the TCEQ) entered into a CERCLA §120 FFA for remedial activities at LHAAP. The FFA became effective December 30, 1991.

In 1995 as part of the public participation requirements under CERCLA, the U.S. Army issued a Proposed Plan for LHAAP-16 (U.S. Army, 1995) followed by a ROD (U.S. Army and USEPA, 1995) for the site addressing an early IRA. The early IRA was necessary to mitigate potential risks posed by buried source materials. Specifically, the objectives of the IRA were to minimize long-term vertical infiltration of water through the landfill and minimize contaminant transport.

From 1996 to 1998 a landfill cover system (also referred to as a cap) was placed over the site (**Figure 2-5**) and was completed as part of an early IRA in accordance with the USEPA presumptive remedy guidance under CERCLA for municipal landfills (USEPA, 1993) and for military landfills (USEPA, 1996).

The FS (Jacobs, 2002), presenting an interim analysis of remedial alternatives for LHAAP-16, was issued in March 2002. In order to evaluate a final remedy for LHAAP-16, a FS Addendum (Shaw, 2010) was issued in March 2010, and the Proposed Plan (U.S. Army, 2010) was issued in September 2010. This ROD follows that Proposed Plan and precedes the more detailed RD.

2.3 Community Participation

The U.S. Army, USEPA, TCEQ and the LHAAP Restoration Advisory Board (RAB) have provided public outreach to the surrounding community concerning LHAAP-16 and other environmental sites at LHAAP. The outreach program has included fact sheets, media interviews, site visits, invitations to attend quarterly RAB meetings, and public meetings consistent with its public participation responsibilities under Sections 113(k)(2)(B), 117(a), and 121(f)(1)(G) of CERCLA.

The Final Proposed Plan (U.S. Army, 2010) for the selection of the remedy for LHAAP-16 was released to the Administrative Record and made available to the public for review and comment on September 23, 2010. A media release was sent to radio stations KETK, KMSS, KSLA, and KTBS on September 23, 2010. The notice of availability of the Proposed Plan and other related documents in the Administrative Record file was published in *The Shreveport Times* and the *Marshall News Messenger* on September 26, 2010. The newspaper and media notices for the meeting are provided in **Appendix A**. The public comment period for the Proposed Plan began on October 10, 2010, and ended November 9, 2010. A public meeting was held on October 19, 2010, in a formal format and with a court reporter. The transcript for the meeting is part of the Administrative Record. The significant comments (oral or written) are addressed in the Responsiveness Summary, which is included in this ROD as **Section 3.0**.

The Administrative Record may be found locally at the information repository maintained at the following location:

Location: Marshall Public Library
300 S. Alamo
Marshall, Texas, 75670

Business Hours: Monday – Thursday 10:00 a.m. – 8:00 p.m.
Friday – Saturday 10:00 a.m. – 5:00 p.m.

2.4 Scope and Role of Response Action

The scope and role of the action discussed in this ROD includes all remedial actions planned for this site. The final selected remedy at LHAAP-16 will prevent potential risks associated with exposure of the hypothetical future maintenance worker to landfill waste material and exposure to contaminated groundwater. The remedial action will include maintenance of the existing cap, groundwater use restrictions, installation of a biobarrier in the shallow groundwater zone adjacent to the landfill, in situ enhanced bioremediation in the shallow and intermediate groundwater zones, installation of a biobarrier in the shallow groundwater zone between LHAAP-16 and Harrison Bayou, and MNA of the shallow and intermediate groundwater zones.

The selected action at LHAAP-16 will prevent potential risks associated with exposure to contaminated groundwater. Although groundwater at Longhorn is not currently being used as drinking water, nor may it be used in the future based on its reasonably anticipated use as a national wildlife refuge, when establishing the remedial action objectives for this response action, the U. S. Army has considered the NCP's expectation to return usable groundwaters to their potential beneficial uses wherever practicable and has also considered the State of Texas designation of all groundwater as potential drinking water, unless otherwise classified, and consistent with 30 TAC 335.563(h)(1) [background total dissolved solids (TDS) content less than or equal to 10,000 mg/L and that occurs within a geologic zone that is sufficiently permeable to transmit water to a pumping well in usable quantities]. The U.S. Army intends to return the contaminated groundwater at LHAAP-16 to its potential beneficial uses, which for the purposes of this ROD is considered to be attainment of the Safe Drinking Water Act (SDWA) MCLs to the extent practicable, and consistent with 40 CFR § 300.430(e)(2)(i)(B&C). In the absence of federal drinking water standards, cleanup levels will be based on TRRP Tier 1 Groundwater Residential PCLs. If a return to potential beneficial uses is not practicable, the NCP expectation is to prevent further migration of the plume, prevent exposure to the contaminated groundwater, and evaluate further risk reduction.

The selected remedial action will treat the contaminated groundwater plume to prevent the migration of groundwater COCs and COC by-products into Harrison Bayou that would result in an exceedance of surface water criteria In addition, the selected remedial action will include groundwater monitoring to demonstrate that the contaminants and by-product contaminants are not migrating into Harrison Bayou at or above the SDWA MCLs, or in the absence of federal drinking water standards, TRRP Tier 1 Groundwater Residential PCLs and surface water monitoring to confirm that surface water standards for the contaminants and by-product contaminants are not exceeded. For purposes of this ROD, surface water standards include the Texas Surface Water Quality Standards found at 30 TAC 307, or if those standards are not available, the SDWA MCLs, or in the absence of federal drinking water standards, TRRP Tier 1 Groundwater Residential PCLs.

The final selected remedy will protect human health and the environment. The human receptor evaluated was the hypothetical future maintenance worker. The maintenance and repair will preserve the integrity of the existing landfill cover system. In situ bioremediation will treat/remediate and reduce contaminant mass and lower contaminant concentrations in groundwater. Installation of biobarriers will treat/remediate and thereby control potential migration of contaminants and by-product contaminants from the landfill and will reduce groundwater contaminant mass thus providing additional protection of Harrison Bayou. Natural attenuation will further reduce groundwater contaminants and by-product contaminants respective concentrations. The LUC performance objectives to be implemented include groundwater use restrictions and land use restrictions to protect and maintain the integrity of the existing landfill cover system. The LUCs to protect and maintain the integrity of the landfill cap will remain in place as long as the landfill waste remains at the site or until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in soil and groundwater allow for unlimited use and unrestricted exposure. The LUCs restricting the use of groundwater to environmental monitoring and testing only and the LUC restricting land use to nonresidential will remain in place until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in soil and groundwater allow for unlimited use and unrestricted exposure. The LUC to maintain the integrity of any current or future remedial or monitoring systems shall remain in effect until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met. The LUC to preserve any current or future remedial or monitoring systems shall remain in effect until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met. The LUC to prevent the use of groundwater contaminated above cleanup levels as a potable water source shall remain in effect until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in soil and groundwater allow for unlimited use and unrestricted exposure. Without the selected remedial action, the potential for the contaminated groundwater to seep into Harrison Bayou, at levels that equal or exceed surface water standards constitutes an unacceptable risk to human health and the environment.

2.5 Site Characteristics

This section of the ROD presents a brief comprehensive overview of LHAAP-16 site characteristics with respect to the conceptual site model (CSM), physical site features, known or suspected sources of contamination, types of contamination, and affected media. Known or potential routes of contaminant migration are also discussed. Detailed information about the site characteristics can be found in the RI (Jacobs, 2000).

2.5.1 Conceptual Site Model

Figure 2-6 illustrates the conceptual model for the source area at LHAAP-16. The model presents the role of the landfill cap constructed in the IRA of 1998 (**Section 1.4**) and specifies the potential exposure pathways that were cut off by the landfill cap. The construction of the cap as part of the IRA is consistent with USEPA (1993) guidance. **Figure 2-7** illustrates the conceptual model for the non-source area, which lies outside the landfill cap, and which may contain residues of waste materials that may have been transported from the landfill prior to the IRA of 1998. The model presents pathways associated with the non-source area media that are complete and are being considered for remediation, and pathways that are likely incomplete or have negligible impact and are not being considered for remediation.

The landfill contents are not thoroughly known, but disposal history indicates that TNT wastewater ash was deposited in the early 1940s. During the 1950s, a large bermed depression in the central section of the currently capped area was reportedly used for disposal of a variety of materials such as substandard TNT, barrels of chemicals, oil, paint, , scrap iron, containers, scrap metal, wood, and other items. Burn pits and waste storage were reported to be common at the site, although there is little documentation of these activities (Jacobs, 2002). Consistent with the USEPA guidance on presumptive remedies for landfills (1993), it was anticipated that the landfill would pose an unacceptable human health risk, and the landfill was capped as part of the 1998 IRA.

Before the landfill was capped, soil outside the landfill, the non-source area, could have become contaminated from spills, leaks, and runoff of contaminants from the landfill. The baseline human health risk assessment indicated that the cancer risk for the hypothetical maintenance worker was at the lower end of or below the target risk range for surface soil, surface/subsurface soil and sediment. The BERA concluded that no action is needed for LHAAP-16 for the protection of ecological receptors (Shaw, 2007a).

The groundwater is affected by contaminants from the landfill. This was probably caused by the migration of contaminants, via rainwater infiltration, from the landfill waste to groundwater prior to capping the landfill. Analytical results from groundwater samples indicate that the groundwater contamination poses a risk well above the target risk range. The primary COCs in groundwater include TCE, cis-1,2- DCE, vinyl chloride, and perchlorate. Since the groundwater at LHAAP-16 may pose a risk for the hypothetical future maintenance worker, the pathways considered for remediation include future industrial groundwater use.

The contaminants in the shallow groundwater migrate toward and discharge by seepage into Harrison Bayou. The seepage of contaminated groundwater into Harrison Bayou represents a groundwater to surface water pathway of exposure that is identified and addressed by the selected remedial action.

2.5.2 Overview of the Site

LHAAP-16 encompasses an area of approximately 20 acres, of which 13 acres are covered by a landfill cap, in the south-central portion of LHAAP. Harrison Bayou runs along the northeastern edge of LHAAP-16. Most of LHAAP-16 is relatively flat. The outer edges of the site are forested, and the land becomes steeper near Harrison Bayou. The capped landfill is vegetated. Surface drainage from LHAAP-16 flows mostly through small gullies and ditches to Harrison Bayou. Harrison Bayou flows into Caddo Lake, to the northeast of the site. The lake is a source of drinking water for several neighboring communities in Louisiana including Vivian, Oil City, Mooringsport, South Shore, Blanchard, Shreveport, and Bossier City.

The eastern and southeastern edges of LHAAP-16 are located within the 100-year floodplain of Harrison Bayou. LHAAP-16 has no known areas of archeological or historical importance.

2.5.3 Geology and Hydrogeology

The surface soil at LHAAP-16 consists of fine sandy loam. The subsurface is composed of medium plastic sandy silt, fine sands, and clay. The clay layers tend to separate the groundwater into shallow, intermediate, upper deep and deep zones.

The shallow groundwater zone varies in thickness from 9 to 18 feet and extends 33 feet below ground surface (bgs). Groundwater elevations were measured by Shaw in June 2007. The shallow zone groundwater elevation contours based on these data are shown on **Figure 2-8**. Depth to groundwater in the shallow zone is approximately 4 to 25 feet bgs. An intermediate groundwater zone containing fewer fines than the shallow zone extends from 35 to 62 feet bgs. **Figure 2-9** shows measured groundwater elevations and groundwater contours for the data collected in June 2007. The upper deep groundwater zone extends from approximately 80 to 151 feet bgs. The deep groundwater zone extends below 220 feet bgs. While flow is primarily horizontal in these zones, vertical interaction between the shallow and intermediate zones is evidenced by pumping test results as well as the presence of contamination in both zones. Such interconnection is consistent with soil layers formed in fluvial depositional environments. The groundwater flow direction is northeast toward Harrison Bayou in the shallow, intermediate and deep zones, while flow direction is southeast toward Harrison Bayou in the upper deep groundwater zone. Overall, the groundwater flow is toward Caddo Lake. The mean hydraulic conductivity value varies from

1.5×10^{-3} centimeters per second (cm/sec) in the shallow zone to 4.2×10^{-4} cm/sec in the deep zone (Jacobs, 2002).

Groundwater flow between the landfill and Harrison Bayou is also influenced by the presence of an extraction well system consisting of four wells in the shallow groundwater zone and four wells in the intermediate groundwater zone. The wells were installed in 1996 and 1997 as part of a treatability study.

2.5.4 Sampling Strategy

Several sampling events were conducted at LHAAP-16 from 1980 to 2009, as outlined in **Section 2.2.2** on site investigations. In the early investigations, groundwater monitoring wells were installed and samples were collected from throughout the site to determine the areas of contamination. Subsequent investigations focused on the areas where contamination was found, performing additional soil, groundwater, surface water and sediment sampling and installing additional monitoring wells to delineate the contamination. Samples were analyzed for various analytes including VOCs, SVOCs, metals, explosives, perchlorate, pesticides/PCBs, and dioxins/furans. In the area of the contaminant plume, groundwater samples were also analyzed for indicators of conditions that promote natural attenuation (biodegradation), such as dissolved oxygen, conductance, pH, oxidation-reduction potential, sulfide, methane, and chloride.

2.5.5 Nature and Extent of Contamination

The contaminated media at LHAAP-16 include buried source material (landfill waste under the cap) and the shallow and intermediate groundwater beneath and down-gradient of the landfill. A presumptive remedy (IRA) was implemented in 1996 through 1998 by placement of a multilayer cap at LHAAP-16 mitigating potential risks posed by buried landfill waste. The cap prevents rainfall from infiltrating and leaching contaminants from principal threat wastes within the landfill. However, contaminated groundwater still appears to be migrating from beneath the landfill presenting an unacceptable risk. A groundwater extraction system was installed as a treatability study to prevent the groundwater plume from migrating to Harrison Bayou.

The major groundwater COCs for LHAAP-16 identified in the FS (Shaw, 2010) are VOCs, including TCE, cis-1,2-DCE, and vinyl chloride and perchlorate in the shallow and intermediate groundwater. The approximate extent of VOC and perchlorate contamination in the shallow and intermediate zones is shown on **Figure 2-3**. The highest concentration of TCE detected was 173,000 micrograms per liter (µg/L) on October 1, 2003 at the extraction well 16EW02. The TCE plume’s edge is defined by the MCL of 5 µg/L. The daughter products cis-1,2-DCE had a maximum detection of 520,000 µg/L on March 21, 1995 at 16PB08 and vinyl chloride had a maximum detection of 11,000 µg/L on June 15, 1998 at 16WW16. The maximum concentration for perchlorate was detected at 5990 µg/L at 16WW12 in October 2007. Five metals (arsenic, chromium, manganese, nickel and thallium) had sporadic elevated detections and were also retained as COCs. The detected metals do not appear to be associated with widespread contamination from the landfill.

Data collected from the upper deep groundwater zone indicate that no groundwater contamination has been detected since 1997. Data also confirmed that contaminants have not migrated down to the deep zone.

2.6 Current and Potential Future Land and Resource Uses

2.6.1 Current and Future Land Uses

LHAAP is located near the unincorporated community of Karnack, Texas. Karnack is a rural community with a population of 775 people. The incorporated community of Uncertain, Texas, population 205, is located to the northeast of LHAAP on the edge of Caddo Lake and is a resort area and an access point to Caddo Lake. The industries in the surrounding area consist of agriculture, timber, oil and natural gas production, and recreation.

LHAAP has been an industrial facility since 1942. Production activities and associated waste management activities continued until the facility was determined to be in excess of the U.S. Army's needs in 1997. The plant area has been relatively dormant since that time. LHAAP is surrounded by a fence (except on the border with Caddo Lake), and current security measures at the LHAAP preclude unlimited public access to areas within the fence. The fence now represents the National Wildlife Refuge boundary. Approved access for hunters is very limited.

The reasonably anticipated future use of LHAAP-16 is as part of a national wildlife refuge. This anticipated future use is based on a Memorandum of Agreement (MOA) (U.S. Army, 2004) between the USFWS and the U.S. Army. That MOA documents the transfer process of the LHAAP acreage to USFWS to become the Caddo Lake National Wildlife Refuge and will be used to facilitate a future transfer of LHAAP-16. Presently the Caddo Lake National Wildlife Refuge occupies approximately 7,000 acres of the 8,416-acre former installation. In accordance with the National Wildlife Refuge System Administration Act of 1966 and its amendments (16 USC 668dd), the land will remain as a national wildlife refuge unless there is a change brought about by an act of Congress, or the land is part of an exchange authorized by the Secretary of the Interior.

2.6.2 Current and Future Surface Water Uses

Harrison Bayou, which is located on and adjacent to LHAAP, currently supports wildlife and aquatic life. Humans may have limited access to parts of Harrison Bayou during animal hunts, but there is no routine use of Harrison Bayou located at LHAAP. Harrison Bayou does not carry adequate numbers and size of fish to support either sport or subsistence fishing. During the summer months, Harrison Bayou ceases flowing and/or dries up. The eastern portion of the LHAAP-16 is located within Harrison Bayou's 100-year flood-plain. When flowing, Harrison Bayou discharges into Caddo Lake, a large recreational lake covering 51 square miles with a mean depth of 6 feet. The watershed of the lake encompasses approximately 2,700 square miles. Caddo Lake is used extensively for fishing and boating. The anticipated future uses of surface water are the same as the current uses.

2.6.3 Current and Future Groundwater Uses

Groundwater in the drinking water aquifer (250-430 feet bgs) under and near LHAAP is currently used as a drinking water source. The drinking water aquifer should not be confused with the deep zone groundwater, which extends only to a depth of approximately 151 feet bgs. The deep zone groundwater and the drinking water aquifers are distinct from each other and there is no connectivity between the contaminated zone and the drinking water aquifer. There are five active water supply wells near LHAAP that are completed in the drinking water aquifer. One well is located in and owned by Caddo Lake State Park. The well is completed to a depth of 315 feet bgs and has been in use since 1935. A second well owned by the Karnack Water Supply Corporation services the town of Karnack and is located approximately 2 miles southeast of town. This well is completed to approximately 430 feet bgs and has been in use since 1942. The Caddo Lake Water Supply Corporation has three wells located both north and northwest of LHAAP. These wells are identified as Caddo Lake Water Supply Corporation Wells 1, 2, and 3, and all are hydraulically upgradient of LHAAP (Jacobs, 2002). These wells are completed deeper than the deepest zone of contamination at LHAAP. Because of this and the large distance between these wells and LHAAP, water removal from these wells is not expected to affect groundwater flow at the site. In addition, there are several livestock and domestic wells located in the vicinity of LHAAP with depths averaging approximately 250 feet bgs.

Three water supply wells are located within the boundary of LHAAP itself. One well is located at the Fire Station; the second well is located approximately 0.35 miles southwest of the Fire Station. The third well is located north of the USFWS administration building for Caddo lake National Wildlife Refuge, near the main entrance to LHAAP. The distances from these water supply wells to the middle of LHAAP-16 are approximately 2.2 miles, 1.75 miles, and 1.77 miles, respectively. The three water supply wells were completed at a depth much greater than the zone of contamination described at LHAAP-16. Two additional wells previously supplied water to the installation, but these have been plugged and abandoned. None of these three wells are currently used for drinking water at LHAAP, although they may supply water for non-potable uses.

Although the anticipated future use of the facility as a national wildlife refuge does not include the use of the groundwater at LHAAP-16 as a drinking water source, the State of Texas designates all groundwater as potential drinking water, unless otherwise classified, and consistent with 30 TAC 335.563(h)(1). To be conservative, a hypothetical industrial use scenario was evaluated for risk. The future industrial scenario for LHAAP assumes limited use of groundwater as a drinking water source.

2.7 Summary of Site Risks

Quantitative risk assessment for the non-source areas anticipated to have received contaminants migrating from the source area are consistent with USEPA (1993) guidance for presumptive remedies as conducted in the 1998 IRA. This section summarizes the results of the baseline human health and ecological risk assessments conducted for LHAAP-16 (Jacobs, 2001a; 2001b; Shaw 2007a). The risk assessment consists of a BHHRA (Jacobs, 2001a), an Addendum to the BHHRA (Jacobs, 2001b) and an installation-wide BERA performed by Shaw (Shaw, 2007a) and summarized in the Addendum to the Final FS (Shaw, 2010). The assessments provide the basis for taking action and identify the contaminants and exposure pathways that need to be addressed by the remedial action.

2.7.1 Summary of Human Health Risk Assessment

This section is based on the conclusions presented in the *Final Baseline Risk Assessment: Human Health Evaluation, Site 16* (Jacobs, 2001a), in the *Addendum to Final Baseline Risk Assessment: Human Health Evaluation, Site 16* (Jacobs, 2001b), in the *Final Feasibility Study LHAAP-16* (Jacobs, 2002), and in the *Final Addendum to Final Feasibility Study, LHAAP-16* (Shaw, 2010). The risk assessment used data from the investigations conducted through 1999. Results from the later investigations through 2009 did not change the overall outcome of the risk assessment. During the risk assessment, soil and groundwater, and Harrison Bayou surface water and sediment data were used to calculate the aggregate risk, which was then compared to the USEPA target risk range of 1×10^{-4} to 1×10^{-6} for the excess lifetime carcinogenic risk and to a hazard index (HI) of 1 for non-carcinogenic hazards. If there is no unacceptable risk associated with a medium, and a cleanup level is not exceeded, then the medium is not identified in this ROD for remediation. The human health risk did not include contaminant concentrations in the waste material within the landfill because the exposure to the waste material has been eliminated. The CSM that is associated with the risk assessment was introduced in **Section 2.5.1**, and is presented as **Figure 2-7**.

2.7.1.1 Identification of Chemicals of Potential Concern

The BHHRA identified chemicals of potential concern (COPCs) for LHAAP-16 and evaluated the carcinogenic risk and non-carcinogenic hazard for each. **Table 2-1** summarizes the risk assessment data for the COPCs, including minimum and maximum detected concentrations, number of samples with detectable concentrations, and exposure point concentrations (EPCs).

2.7.1.2 Exposure Assessment

The Jacobs risk assessment (Jacobs, 2001a; 2001b) presented the human health risks and hazards to an on-site trespasser under current site conditions for surface soil, surface water, sediment, and fish ingestion and a hypothetical future maintenance worker under an industrial scenario for soil and/or groundwater.

For the trespasser, reasonable exposure pathways evaluated are: incidental ingestion of the surface soil (0 to 0.5 feet bgs), dermal contact with the surface soil, inhalation of particulates, and inhalation of VOCs from the soil (0 to 0.5 feet bgs). The trespasser scenario was also evaluated for potential contact with Harrison Bayou media including ingestion of sediment, dermal contact with sediment and surface water, and ingestion of fish.

The BHRRA found that for the current trespasser, none of the exposure pathways contributed to carcinogenic risk or non-carcinogenic hazard, thus the current trespasser data was not included in **Table 2-1**.

For the hypothetical future maintenance worker, reasonable soil exposure routes evaluated are: incidental ingestion of the surface soil (0 to 5 feet bgs), dermal contact with the surface soil, inhalation of particulates, and inhalation of VOCs from the soil (0 to 5 feet bgs).

For groundwater, reasonable exposure pathways for the hypothetical future maintenance worker are ingestion of groundwater, dermal contact while showering with contaminated groundwater, and inhalation of VOCs while showering with contaminated groundwater.

2.7.1.3 Toxicity Assessment

The carcinogenic and non-carcinogenic toxicity assessments from the BHHRA are summarized in **Tables 2-2** and **2-3**, respectively. The toxicity data assumes that exposure would be chronic to be conservative. Sources for the data include the Integrated Risk Information System (IRIS) and Health Effects Assessment Summary Tables (HEAST).

2.7.1.4 Risk Characterization

Characterization of the carcinogenic risk and non-carcinogenic hazard are summarized in **Tables 2-4** and **2-5**, respectively. For carcinogens, risks are generally expressed as the incremental probability of an individual's developing cancer over a lifetime as a result of exposure to the carcinogen. Excess lifetime carcinogenic risk is calculated from the following equation:

$$\text{Risk} = \text{CDI} \times \text{SF}$$

where:
- risk = unitless probability of an individual developing cancer
- CDI = chronic daily intake averaged over 70 years, expressed as milligrams per kilogram per day (mg/kg-day)
- SF = slope factor, expressed as $(\text{mg/kg-day})^{-1}$

These risks are probabilities that usually are expressed in scientific notation. An excess lifetime carcinogenic risk of 1×10^{-6} indicates that an individual experiencing the reasonable maximum exposure estimate has a 1 in 1,000,000 chance of developing cancer as a result of site-related exposure. This is referred to as an "excess lifetime carcinogenic risk" because it would be in addition to the risks of cancer that individuals face from other causes such as smoking or exposure to too much sunlight. The chance of an individual developing cancer from all other causes has been estimated to be as high as one in three. USEPA's generally acceptable risk range for site-related exposures is 1×10^{-4} to 1×10^{-6}.

The potential for non-carcinogenic effects is evaluated by comparing an exposure level over a specified time period (e.g., lifetime) with a reference dose (RfD) derived for a similar exposure period. An RfD represents a level that an individual may be exposed to that is not expected to cause any deleterious effect. The ratio of exposure to toxicity is called a hazard quotient (HQ). An HQ < 1 indicates that a receptor's dose of a single contaminant is less than the RfD, and that toxic non-carcinogenic effects from that chemical are unlikely. The HI is generated by adding the HQs for all COCs that affect the same target organ (e.g. liver) or that act through the same mechanism of action within a medium or across all media to which a given individual may reasonably be exposed. An HI < 1 indicates that, based on the sum of all HQ's from different contaminants and exposure routes, toxic non-carcinogenic effects from all contaminants are unlikely. An HI > 1 indicates that site-related exposures may present a risk to human health.

The HQ is calculated as follows:

Non-carcinogenic HQ = CDI/RfD

Where: CDI = chronic daily intake
RfD = reference dose

CDI and RfD are expressed in the same units and represent the same exposure period (e.g. chronic, subchronic, or short-term).

The carcinogenic risk for soil and groundwater are 8.1×10^{-6} and 1.4×10^{-1}, respectively, based on the initial human health risk evaluation (Jacobs, 2001a). The dioxins and furans results had been omitted from the initial risk assessment evaluation. When the assessment was revised to address the potential human health risks associated with exposure to dioxins and furans congeners detected in surface and subsurface soil and groundwater (Jacobs, 2001b), the risks for soil and groundwater became 1.0×10^{-5} and 1.4×10^{-1}, respectively. Risks from potential exposure to dioxin and furan congeners detected in surface soil and groundwater are within USEPA target risk range. The HI for soil and groundwater are 0.13 and 1,230, respectively. The carcinogenic risk and non-carcinogenic hazard for soil are within the acceptable range. The carcinogenic risk and non-carcinogenic hazard for groundwater are unacceptable; therefore, the remedial action focuses on the groundwater. The major contributors to the non-carcinogenic hazard in groundwater were cis-1,2-DCE, TCE and 1,2-DCE accounting for approximately 97% of the total non-carcinogenic hazard. The carcinogenic risk in groundwater was driven by maximum detection of TCE, and vinyl chloride.

The BHHRA included an uncertainty analysis which identified factors that would cause values used in the risk assessment to be over or underestimated. The analysis concluded that the risks and HIs are overestimated, making the BHHRA a conservative evaluation. The analysis listed seven factors that would lead to overestimations, three that would lead to underestimations, and five that could lead to either over or underestimations.

2.7.2 Post Risk Assessment Data Evaluation

The risk assessment (Jacobs, 2001a; 2001b) was completed using data from the samples reported in the Final Remedial Investigation Report (Jacobs, 2000). Since that time, additional samples have been collected at LHAAP-16. A plant-wide perchlorate investigation was conducted in 2002, and the results were presented in the Plant-wide Perchlorate Investigation Report (STEP, 2005). Three groundwater monitoring events were conducted at the site during winter 2003, spring 2004, and winter 2004, and the results were reported in the Groundwater Monitoring Report (USACE and ALL CONSULTING, 2007). In 2007, 2008, and 2009, Shaw collected groundwater samples and analyzed them for various analytes, including analysis of MNA parameters in 2007. In 2007 and 2008, Shaw installed additional wells to better define the groundwater contamination.

2.7.2.1 Soil

No significant concentrations of perchlorate were detected in the soil samples collected at LHAAP-16. The results obtained from these post-risk assessment soil samples do not alter the conclusions of the risk assessment for soil. The cancer risks and non-cancer hazards posed by soil are 8.1×10^{-6} and 0.13, respectively. These fall within the acceptable ranges.

2.7.2.2 Groundwater

TCE was found in well 16EW02 at an estimated concentration of 173,000 µg/L in October 2003. This is higher than the groundwater exposure point concentration of 160,000 µg/L. However, both the risk and hazard were already noted as above 1×10^{-6} and 0.1, respectively, so TCE is already addressed as a potential COC and this does not change the outcome of the risk assessment. Methylene chloride was found in well 16WW16 at an estimated concentration of 9,500 µg/L in October 2000. This is higher than the groundwater exposure point concentration of 3,500 µg/L. However, both the risk and hazard were already noted as above 1×10^{-6} and 0.1, respectively, so methylene chloride is already addressed as a potential COC and this does not change the outcome of the risk assessment.

1,2-dichloroethane (DCA) was found in well 16EW01 at a concentration of 161 µg/L in April 2004. This is comparable to the groundwater exposure point concentration of 160 µg/L. However, the risk was already noted as above 1×10^{-6}, so 1,2-DCA is already addressed as a potential COC and this does not change the outcome of the risk assessment.

1,1,2-trichloroethane was found in well 16EW02 at a concentration of 23.6 µg/L in April 2005. This is higher than the groundwater exposure point concentration of 12 µg/L. However, the risk was already noted as above 1×10^{-6}, so 1,1,2-trichloroethane is already addressed as a potential COC and this does not change the outcome of the risk assessment.

Acetone was detected in 16WW16 at an estimated concentration of 14,000 µg/L in October 2000. This is higher than the groundwater exposure point concentration of 3,920 µg/L. Both the previous maximum concentration of acetone in groundwater from 16EW01 in 1996 (3,920 µg/L), used as the EPC, and the most recent acetone result at 16WW16 from October 2000, did not exceed the TRRP Tier 1 Groundwater Residential PCL (TRRP PCL) comparison value of 22,000 µg/L. Acetone is not considered a COC for the hypothetical future maintenance worker at LHAAP-16.

Arsenic was found in well 16WW35 at an estimated concentration of 123 µg/L in March 2009. This is higher than the groundwater exposure point concentration of 34 µg/L. However, both the risk and hazard were already noted as above 1×10^{-6} and 0.1, respectively, so arsenic is already addressed as a potential COC and this does not change the outcome of the risk assessment.

Chromium was found in well 16WW34 at a concentration of 32,400 µg/L in February 2004. This is higher than the groundwater exposure point concentration of 5,220 µg/L. However, the hazard was already noted as above 0.1, so chromium is already addressed as a potential COC and this does not change the outcome of the risk assessment.

Nickel was found in well 16WW34 at a concentration of 1,780 µg/L in March 2009. This is higher than the groundwater exposure point concentration of 1,630 µg/L. However, the hazard was already noted as above 0.1, so nickel is already addressed as a potential COC and this does not change the outcome of the risk assessment.

Strontium was detected in 16WW25 at a concentration of 12,300 µg/L in December 2004. This is higher than the groundwater exposure point concentration of 10,400 µg/L. Both the previous maximum concentration of strontium in groundwater (10,400 µg/L), used as the EPC, that was from 16WW13 in October 1997 and the most recent strontium result at 16WW25 from December 2004 did not exceed the TRRP Tier 1 Groundwater Residential PCL comparison value of 15,000 µg/L. Strontium is not considered a COC for the hypothetical future maintenance worker at LHAAP-16.

The maximum concentration of perchlorate (5,990 µg/L) in the groundwater was from 16WW12 in October 2007. Perchlorate was not analyzed in the samples collected prior to the risk assessment and therefore perchlorate was not included in the risk assessment evaluation. The maximum concentration of perchlorate at 5,990 µg/L was higher than the TRRP Tier 1 Groundwater Residential PCL comparison value of 17 µg/L, therefore, perchlorate is added as a potential COC at LHAAP-16.

The other chemical concentrations found in groundwater samples collected after the risk assessment was completed, were all less than the values used for the exposure point concentrations.

The results obtained from these post-risk assessment groundwater samples do not alter the conclusions of the risk assessment for groundwater. The cancer risks and non-cancer hazards posed by groundwater are 1.4 x 10-1 and 1,230, respectively. These fall outside the acceptable ranges, and action is needed to manage and reduce those risks and hazards.

While these additional investigations did not change the overall outcome of the earlier BHHRA, they determined what COCs needed to be targeted by the remedial action. **Table 2-6** lists chemicals in the groundwater that have a carcinogenic risk greater than 1×10^{-5} and those with an HQ greater than 0.1 for the hypothetical maintenance worker. The table also summarizes the justifications for which of the COPCs should be classified as COCs. COPCs in groundwater were identified as COCs when they posed a carcinogenic risk above the acceptable range (risk greater than 1×10^{-4}), when their HQ was greater than 1.0, or when the EPC was above the MCL or the TRRP Tier 1 Groundwater Residential PCL. Perchlorate and chlorinated solvents were retained as COCs. Five inorganics (arsenic, chromium, manganese, thallium and nickel) had sporadic elevated detections and were also retained as COCs. While the occurrence of these metals does not appear to be associated with widespread contamination from the landfill, further monitoring is warranted. Recent data obtained after the BHRRA investigation was used when possible. **Table 2-7** presents the final list of COCs, along with cleanup levels.

2.7.3 Summary of Ecological Risk Assessment

The ecological risk for LHAAP-16 was addressed in the installation-wide BERA (Shaw, 2007a). The only medium of potential concern for ecological risk at LHAAP-16 is soil. LHAAP-16 is part of the Harrison Bayou watershed, and no COPECs were identified in Harrison Bayou surface water or sediment (Shaw, 2007a). The BERA provides a process that evaluates the likelihood that adverse ecological effects may occur, or are occurring, as a result of exposure to one or more stressors. A stressor is any physical, chemical, or biological entity that can induce an adverse ecological response. The BERA for LHAAP focuses only on chemical stressors.

Ecological risk does not exist unless:

- The stressor has the inherent ability to cause adverse effects

- It co-occurs with or contacts an ecological component (i.e., organism, population, community, or ecosystem) long enough and at sufficient intensity to elicit an adverse effect

For the BERA, the entire installation was divided into three large sub-areas (i.e., the Industrial Sub-Area, Waste Sub-Area, and Low Impact Sub-Area) for the terrestrial evaluation. Each of the individual sites at LHAAP was grouped into one of these sub-areas based on commonalities of historic use, habitat type, and spatial proximity to each other. Conclusions for individual sites and the potential for detected chemicals to adversely affect the environment are made in the context of the overall conclusions of the sub-area in which the site falls. LHAAP-16 lies within the Waste Sub-Area.

The BERA concluded that the final COPECs in soil that require remedial action in the waste sub-area are barium, 2,4-DNT, 2,6-DNT, 2,4,6-TNT, and dioxin (2,3,7,8-tetrachlorodibenzo-p-dioxin [TCDD] toxic equivalent) because of their potential to cause adverse impacts to one or more ecological receptors. These COPECs pose a potential risk to ecological receptors due to the direct contact with soil and indirect (i.e., dietary) exposure routes. The BERA evaluated eleven soil samples collected during the RI from outside the landfill. Results indicated that the ecological preliminary remediation goal was exceeded by barium in only one sample in surface soil but not in total soil. Removal or treatment of barium-impacted soil at LHAAP-16 would not appreciably lower the 95 percentile upper confidence limit (UCL) for the barium exposure point concentration in the Waste Sub-Area (Shaw, 2010). Therefore, it was concluded that barium within the Waste Sub-Area will be addressed at LHAAP-17, another site within the Waste Sub-Area. TNT and DNT were below detection limits; therefore, these explosive compounds do not contribute to ecological risk at LHAAP-16. Based on detected congeners, dioxins and furans in the soil at LHAAP-16 do not exceed ecological criteria (Shaw, 2007b). In summary, no action is needed at LHAAP-16 for the protection of ecological receptors.

2.7.4 Basis of Action

The remedial action selected in this ROD is necessary to protect the public health or welfare or the environment from actual or threatened releases of hazardous substances, pollutants, or contaminants into the environment. Actions for the groundwater are necessary to address the potential for human health risks in the unlikely event there is an attempt to use groundwater as a potable water source. **Table 2-7** presents the COCs and their cleanup levels for groundwater and surface water. There are no COCs for soil.

As it concerns the contaminated groundwater at LHAAP-16, a SDWA MCL has been identified for each of the COCs with the exception of perchlorate, manganese and nickel. For those COCs and by-product (i.e., daughter) contaminants that have an MCL, the MCL constitutes the groundwater cleanup level to be attained. In the absence of federal drinking water standards, TRRP Tier 1 Groundwater Residential PCLs constitute the groundwater cleanup standards to be attained. With respect to the surface waters that could be impacted by contaminated groundwater discharging into Harrison Bayou, which flows into Caddo Lake (a drinking water source), the Texas Surface Water Quality Standards found at 30 TAC 307, or if those standards are not available, the SDWA MCLs, or in the absence of federal drinking water standards, TRRP Tier 1 Groundwater Residential PCLs constitute the surface water standards to be met at the site for the COCs and by-product (i.e., daughter) contaminants to confirm that the RAO for groundwater to surface water migration is achieved.

2.8 Remedial Action Objectives

The RAOs for LHAAP-16, which address contamination associated with the media at the site and take into account the future uses of LHAAP surface waters, land, and groundwater, are:

- Protection of human health and the environment by preventing exposure to landfill contents;
- Protection of human health and the environment by reducing leaching and migration of landfill hazardous substances into the groundwater;
- Protection of human health by preventing human exposure to the contaminated groundwater;
- Protection of human health and the environment by preventing COCs and COC by-products from migrating into Harrison Bayou at levels that cause surface water in Harrison Bayou to exceed surface water criteria; and
- Return of groundwater to its potential beneficial uses as drinking water, wherever practicable.

The above RAO recognizes USEPA's policy to return all groundwater to beneficial uses, based on the non-binding programmatic expectation in the NCP and is consistent with the NCP regulations requiring the lead agency, the U.S. Army in this case, to establish RAOs specifying contaminants and media of concern, potential exposure pathways, and remediation goals.

Per the ROD's RAOs, and consistent with the NCP, groundwater will be returned to its beneficial uses as drinking water. The groundwater cleanup level for perchlorate at the Site is the TRRP PCL residential groundwater cleanup level, 17 ug/L, and is protective of human health and the environment. The TRRP PCL groundwater residential 1eve1s are protective of human and the environment for purposes of selecting a protective remedial action for LHAAP-16. Therefore, the groundwater residential cleanup levels are 490 ug/L for nickel and 1,100 ug/L for manganese at LHAAP-16, and such cleanup levels are protective of human health and the environment at LHAAP-16.

2.9 Description of Alternatives

Seven alternatives (including No Further Action) have been evaluated. This section introduces the remedy components, identifies the common elements and distinguishing features of each alternative, and describes the expected outcomes of each.

2.9.1 Description of Remedy Components

Alternative 1 – No Further Action

As required by the NCP, the no action alternative provides a comparative baseline against which the action alternatives can be evaluated. At LHAAP-16, an interim remedy (landfill cap) has already been implemented and maintenance of that remedy is a legal requirement per the 1995 ROD. Therefore, the comparative baseline is considered to be “No Further Action.” Under this alternative the existing landfill cap would be left in place and the landfill waste material, surface water, and groundwater would be left “as is,” without implementing additional containment, removal, treatment, or other mitigating actions. The existing landfill cap would be maintained to isolate wastes from direct contact and to minimize the driving force of infiltration through the landfill thereby reducing the leaching of contaminants to groundwater. Land use controls would be implemented to protect the existing remedy (landfill cap). Closure and post-closure ARARs were identified for LHAAP-16 in the IRA ROD and these included 30 TAC 335.112, 335.118, 335.119 and 335.174 and 40 CFR Sections 264.228 and 264.310 addressing landfills and surface impoundments storing hazardous waste. Although closure requirements were met during implementation of the (landfill cap) presumptive remedy of the IRA, post-closure requirements remain appropriate and relevant. The existing groundwater extraction process and media monitoring would be discontinued. No other actions, including monitoring, would be implemented to reduce existing or potential future exposure to human and ecological receptors, although natural attenuation would be ongoing.

Estimated Capital Present Worth Cost: $0
Estimated O&M Present Worth Cost: $700,000
Cost Estimate Duration: 30 years
Estimated Present Worth Cost: $700,000

Alternative 2 – Maintenance of Existing Landfill Cap, Enhanced Groundwater Extraction and Land Use Controls

The major components of this alternative include the following.

- Maintenance of the landfill cap to preserve landfill cap integrity. The cap isolates wastes from direct contact and minimizes the driving force of infiltration through the landfill thereby reducing the leaching of contaminants to groundwater

- Enhanced groundwater extraction to increase reliability of the extraction wells and related equipment to treat contaminated groundwater from the shallow and intermediate groundwater plumes. Shallow groundwater will be treated before it seeps into Harrison Bayou
    - Monitoring wells and Harrison Bayou surface water sampling; quarterly for the first year followed by annual sampling

- The LUCs' performance objectives are to protect the existing remedy (landfill cap) and prevent human exposure to landfill waste for as long as the landfill waste remains at the site or until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) allow for unlimited use and unrestricted exposure, to prohibit access to contaminated groundwater (except for monitoring and testing) and to restrict land use to nonresidential use until it is demonstrated that levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater are at levels that allow for unlimited use and unrestricted exposure and to maintain the integrity of any current or future remedial or monitoring systems until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met and to prevent the use of groundwater contaminated above cleanup levels as a potable water source until levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater are at levels that allow for unlimited use and unrestricted exposure.

Estimated Capital Present Worth Cost: $850,000
Estimated O&M Present Worth Cost: $10,160,000
Cost Estimate Duration: 30 years
Estimated Present Worth Cost: $11,010,000

Alternative 3a – Maintenance of Existing Landfill Cap, Monitored Natural Attenuation and Land Use Controls

Alternative 3b – Maintenance of Existing Landfill Cap, Hot spot Extraction, Monitored Natural Attenuation and Land Use Controls

The major components of this Alternative 3a include the following:

- Maintenance of the landfill cap to preserve landfill cap integrity. The cap isolates wastes from direct contact and minimizes the driving force of infiltration through the landfill thereby reducing the leaching of contaminants to groundwater

- Discontinued use of the existing groundwater extraction system

- MNA documenting that the contaminated shallow and intermediate groundwater zones remain localized with minimal migration and that contaminant concentrations are being reduced to groundwater cleanup levels before seeping into Harrison Bayou
  - Reactivation of the existing groundwater extraction system and installation of additional extraction wells if MNA is found to be ineffective
  - Monitoring wells and Harrison Bayou surface water sampling; quarterly for the first year followed by annual sampling
- The LUCs' performance objectives are to protect the existing remedy (landfill cap) and prevent human exposure to landfill waste for as long as the landfill waste remains at the site or until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) allow for unlimited use and unrestricted exposure, to prohibit access to contaminated groundwater (except for monitoring and testing) and to restrict land use to nonresidential use until it is demonstrated that levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater are at levels that allow for unlimited use and unrestricted exposure and to maintain the integrity of any current or future remedial or monitoring systems until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met and to prevent the use of groundwater contaminated above cleanup levels as a potable water source until levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater are at levels that allow for unlimited use and unrestricted exposure.
- Alternative 3b is identical to Alternative 3a except an extraction well network would be operated in the groundwater hot spot for approximately 5 years to reduce contaminant mass followed by MNA throughout the rest of the O & M period.

Estimated Capital Present Worth Cost:	*(a) $700,000*
	(b) $1,450,000
Estimated O&M Present Worth Cost:	*(a) $2, 360,000*
	(b) $2,400,000
Cost Estimate Duration: 30 years	
Estimated Present Worth Cost:	*(a) $3,060,000*
	(b) $3,850,000

Alternative 4 – Maintenance of Existing Landfill Cap, In Situ Permeable Reactive Barrier (Passive Groundwater Treatment) and Land Use Controls

The major components of this alternative include the following:

- Maintenance of the landfill cap to preserve landfill cap integrity. The cap isolates wastes from direct contact and minimizes the driving force of infiltration through the landfill thereby reducing the leaching of contaminants to groundwater
- Discontinued use of the existing groundwater extraction system
- Installation of an in situ permeable reactive barrier across the heart of the shallow groundwater plume that is seeping into Harrison Bayou. The contaminants to be treated by this reactive media are TCE and perchlorate. The treatment process would be anaerobic biological degradation that uses a combination of gravel and various organic media.
  - Long-term monitoring (LTM) – Monitoring wells and Harrison Bayou surface water sampling; quarterly for the first year followed by annual sampling.
  - Semiannual sampling of the trench monitoring wells and the discharge of the reactive media treatment vessel.
- The LUCs' performance objectives are to protect the existing remedy (landfill cap) and prevent human exposure to landfill waste for as long as the landfill waste remains at the site or until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) allow for unlimited use and unrestricted exposure, to prohibit access to contaminated groundwater (except for monitoring and testing) and to restrict land use to nonresidential use until it is demonstrated that levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater are at levels that allow for unlimited use and unrestricted exposure and to maintain the integrity of any current or future remedial or monitoring systems until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met and to prevent the use of groundwater contaminated above cleanup levels as a potable water source until levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater are at levels that allow for unlimited use and unrestricted exposure.

Estimated Capital Present Worth Cost: $2,850,000

Estimated O&M Present Worth Cost: $2,270,000

Estimated Duration: 30 years

Estimated Total Present Worth Cost: $5,120,000

Alternative 5a – Landfill Hot Spot Removal, In Situ Permeable Reactive Barrier (Passive Groundwater Treatment), Off-Site Disposal and Land Use Controls

Alternative 5b – Complete Landfill Removal, In Situ Permeable Reactive Barrier (Passive Groundwater Treatment), Off-Site Disposal and Land Use Controls

The major components of Alternative 5a include the following:

- Removal of landfill hot areas based on the results of previous soil gas survey. The excavated waste would be field screened: the results would be used to define the location and nature of hot spot material to focus the excavation efforts and detail the waste handling and treatment process
- Repair of the landfill cap
- Discontinued use of the existing groundwater extraction system
- Installation of an in situ permeable reactive barrier across the portion of the shallow groundwat*er plume with the highest contaminant concentrati*ons, reducing the contaminant mass seeping into Harrison Bayou
  - LTM - Monitoring wells and Harrison Bayou surface water sampling; quarterly for the first year followed by annual sampling.
  - Semiannual sampling of the trench monitoring wells and the discharge of the reactive media treatment vessel.
  - Reactive media treatment vessel.
- Maintenance of the landfill cap to preserve landfill cap integrity. The cap isolates wastes from direct contact and minimizes the driving force of infiltration through the landfill thereby reducing the leaching of contaminants to groundwater
- The LUCs' performance objectives are to protect the existing remedy (landfill cap) and prevent human exposure to landfill waste for as long as the landfill waste remains at the site or until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) allow for unlimited use and unrestricted exposure, to prohibit access to contaminated groundwater (except for monitoring and testing) and to restrict land use to nonresidential use until it is demonstrated that levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater are at levels that allow for unlimited use and unrestricted exposure and to maintain the integrity of any current or future remedial or monitoring systems until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met and to prevent the use of groundwater contaminated above cleanup levels as a potable water source until levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater are at levels that allow for unlimited use and unrestricted exposure.

- **Alternative 5b** is identical to alternative 5a in all respects except that all of the landfill wastes would be removed. Because this alternative does not leave any landfill waste in place, there are no long-term cap maintenance and landfill LUCs requirements.

Estimated Capital Present Worth Cost:	*(a)$3,460,000*
	(b) $119,160,000
Estimated O&M Present Worth Cost:	*(a)$11,220,000*
	(b) $10,660,000
Estimated Duration: 30 years	
Estimated Total Present Worth Cost:	*(a)$14,680,000*
	(b) $129,820,000

Alternative 6 – Landfill Source In Situ Treatment, Monitored Natural Attenuation and Land Use Controls

The major components of this alternative include the following:

- In situ treatment of the landfill hot spots by soil vapor extraction (SVE) to reduce contaminant concentrations in targeted areas that have the highest concentrations
  - Maintenance and monitoring of the SVE system for 5 years.
- Maintenance of the landfill cap to preserve landfill cap integrity. The cap isolates wastes from direct contact and minimizes the driving force of infiltration through the landfill thereby reducing the leaching of contaminants to groundwater
- Repair of the landfill cap following completion of vapor extraction operations
- Discontinued use of the existing groundwater extraction system
- MNA documenting that the contaminated shallow and intermediate groundwater zones remain localized with minimal migration and that contaminant concentrations are being reduced to groundwater cleanup levels before seeping into Harrison Bayou
  - Reactivation of the existing groundwater extraction system and installation of additional extraction wells if MNA is found to be ineffective
  - LTM - Monitoring wells and Harrison Bayou surface water sampling; quarterly for the first year followed by annual sampling
- The LUCs' performance objectives are to protect the existing remedy (landfill cap) and prevent human exposure to landfill waste for as long as the landfill waste remains at the site or until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) allow for unlimited use and unrestricted exposure, to prohibit access to contaminated groundwater (except for monitoring and testing) and to restrict land use to nonresidential use until it is demonstrated that levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants

found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater are at levels that allow for unlimited use and unrestricted exposure and to maintain the integrity of any current or future remedial or monitoring systems until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met and to prevent the use of groundwater contaminated above cleanup levels as a potable water source until levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater are at levels that allow for unlimited use and unrestricted exposure.

Estimated Capital Present Worth Cost: $3,090,000

Estimated O&M Present Worth Cost: $4,100,000

Estimated Duration: 30 years

Estimated Total Present Worth Cost: $7,190,000

Alternative 7 – Cap, Land Use Controls, In Situ Enhanced Bioremediation, Biobarriers, and Monitored Natural Attenuation

The major components of this alternative include the following:

- Maintenance of the landfill cap to preserve landfill cap integrity. The cap isolates wastes from direct contact and minimizes the driving force of infiltration through the landfill thereby reducing the leaching of contaminants to groundwater

- Discontinue use of current extraction system

- Installation of a biobarrier in the shallow groundwater zone adjacent to the landfill near the fence line to degrade contaminants in groundwater

- In situ enhanced bioremediation in the most contaminated portion of the shallow and intermediate groundwater zones in conjunction with phased shut down of the existing groundwater extraction system.

- Installation of a second biobarrier in the shallow groundwater zone near Harrison Bayou to further degrade contaminants

- MNA of the shallow and intermediate groundwater zones to further reduce the concentrations of contaminants and by-product contaminants in the groundwater so that the contaminated groundwater attains groundwater cleanup levels/standards, and that surface water in Harrison Bayou is not adversely impacted by groundwater such that it fails to meet surface water standards for the COCs and by-product (daughter) contaminants.

  – Performance objectives to evaluate the MNA remedy performance after 2 years

 - A reapplication of bio-amendments if MNA is found to be ineffective

 - LTM semiannually for 3 years, annually until the next five-year review, then annually thereafter until recommended otherwise by the five-year review. Monitoring will continue until five-year review demonstrate that there is no further threat of release of contaminated groundwater into the surface water and the groundwater has met cleanup levels. LTM will be initiated only after MNA performance monitoring and MNA is determined to be effective.

- The LUCs' performance objectives are to protect the existing remedy (landfill cap) and prevent human exposure to landfill waste for as long as the landfill waste remains at the site or until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) allow for unlimited use and unrestricted exposure, to prohibit access to contaminated groundwater (except for monitoring and testing) and to restrict land use to nonresidential use until it is demonstrated that levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater are at levels that allow for unlimited use and unrestricted exposure and to maintain the integrity of any current or future remedial or monitoring systems until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met and to prevent the use of groundwater contaminated above cleanup levels as a potable water source until levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater are at levels that allow for unlimited use and unrestricted exposure.

Estimated Capital Present Cost: $440,000

Estimated O&M Present Worth Cost: $1,790,000

Estimated Duration: 30 years

Estimated Total Present Worth Cost: $2,230,000

2.9.2 Common Elements and Distinguishing Features of Each Alternative

Common Elements of Alternatives 1 through 7

LUCs are common to all alternatives, MNA is common to Alternatives 3, 6, and 7, and inspection/LTM is common to Alternatives 2 through 7. These elements are described below.

LUCs – The LUCs would be implemented to support the RAOs. The LUCs would prevent human exposure to landfill contents and residual groundwater contamination that may present an unacceptable risk to human health, would preclude the withdrawal or use of groundwater beneath the site for anything other than environmental monitoring and testing and would restrict the land use to nonresidential. The landfill LUC would be maintained as long as landfill waste remained at the site or until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in groundwater and soil allow for unlimited use and unrestricted exposure. The groundwater and nonresidential use LUCs would remain in place until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in groundwater and soil allow for unlimited use and unrestricted exposure. The LUC to maintain the integrity of any current or future remedial or monitoring systems shall remain in effect until levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met. The LUC prohibiting groundwater use (except for environmental monitoring and testing) as a potable source will remain in place until the levels of COCs (i.e., all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in soil and groundwater allow for unlimited use and unrestricted exposure.

In addition, within 90 days of signature of this ROD, the U.S. Army shall request the Texas Department of Licensing and Regulation to notify well drillers of groundwater use prohibitions based on a preliminary LUC boundary. Within 21 days of the issuance of the Record of Decision, the Army will propose deadlines for completion of the RD Work Plan, RD, and Remedial Action Work Plan. The documents will be prepared and submitted to EPA and TCEQ pursuant to the FFA. The LUC RD will contain implementation and maintenance actions, including periodic inspections. Consistent with the dates presented for these documents, the U.S. Army shall: 1) request the Texas Department of Licensing and Regulation to notify well drillers of the final boundary of groundwater use prohibitions; and 2) notify the Harrison County Courthouse of the LUCs to include a map showing the areas of groundwater and nonresidential use restrictions, the monitoring system and the landfill cap at the site, in accordance with 30 TAC 335.565.

The Army will implement, maintain, monitor, report on and enforce land use controls at Army-owned property. The Army shall perform those actions related to land use control activities described in this ROD and in the Remedial Design for the ROD. For portions of the Site subject to land use controls that are not owned by the Army, the Army will monitor and report on the implementation, maintenance, and enforcement of land use controls, and coordinate with federal, state, and local governments and owners and occupants of properties subject to land use controls. The Army will provide notice of the groundwater and soil (surface and subsurface) contamination and any land use restrictions referenced in the ROD. The Army will send these notices to the federal, state and local governments involved at this site and the owners and occupants of the properties subject to those use restrictions and land use controls. The Army shall provide the initial notice within 90 days of ROD signature. The frequency of subsequent notifications will be described in the Remedial Design for the ROD. The Army remains responsible for ensuring that the remedy remains protective of human health and the environment. The Army will fulfill its responsibility and obligations under CERCLA and the NCP as it implements, maintains, and reviews the selected remedy.

Upon transfer of Army-owned property, the Army will provide written notice of the land use controls to the transferee of the groundwater and soil (surface and subsurface) contamination and any land use restrictions referenced in the ROD. Within 15 days of transfer, the Army shall provide EPA and TCEQ with written notice of the division of implementation, maintenance, and enforcement responsibilities unless such information has already been provided in the LUC RD. The LUC RD will address the procedures to be used by the Army and the transferee to document compliance with the LUCs described in this ROD. In the event property is transferred out of Federal control, the land use controls relating to property and groundwater restrictions shall be recorded in the deed and shall be enforceable by the United States and the state of Texas.

To transfer LHAAP-16, an Environmental Condition of Property (ECP) document would be prepared and the Environmental Protection Provision from the ECP would be attached to the letter of transfer. The ECP will include cap protection and maintenance, land use, groundwater use and monitoring system maintenance restrictions as part of the Environmental Protection Provisions. The property would be transferred subject to the LUCs identified in the ECP. These restrictions would prohibit or restrict property uses that may result in damage to the existing remedy (landfill cap) or monitoring system or exposure to the contaminated groundwater (e.g., drilling restrictions) or soil (e.g. residential land use prohibition).

The U.S. Army and regulators will consult to determine appropriate enforcement actions should there be a failure of a LUCs objective at the site after it has been transferred.

MNA – MNA is a passive remedial action that relies on natural biological, chemical, and physical processes to reduce the mass and concentrations of groundwater COCs under favorable conditions. A preliminary natural attenuation evaluation indicates that MNA is a feasible remedy for certain portions of LHAAP-16, but not as a sole remedy for the entire site due to migration concerns for the shallow groundwater zone (Shaw, 2010). Monitoring activities associated with MNA would confirm the protection of human health and the environment by documenting the return of groundwater to its potential beneficial use as a drinking water supply, by documenting reduction of the contaminant mass and protection of surface water through containment of the plume. In Alternative 3, contaminant reduction would occur by MNA alone in both the shallow and intermediate zones. In Alternative 6, SVE would reduce contaminant concentrations in targeted landfill source areas after which the treatment in both the shallow and intermediate zones would be MNA. In Alternative 7, contaminant reduction would occur by a biobarrier in the shallow zone adjacent to the landfill, in situ enhanced bioremediation in the most contaminated portion of the shallow and intermediate zones, and a second biobarriers in the shallow groundwater zone near Harrison Bayou. Contaminant reduction would occur by MNA alone in the areas outside the influence of the active remedies in both the shallow and intermediate zones.

MNA performance monitoring will be conducted quarterly for the first 2 years in the areas outside the influence of the active remedies. For the active remedies areas, MNA performance monitoring will be conducted quarterly for 2 years following implementation of the remedies. After eight quarterly sampling events, MNA effectiveness will be evaluated. The analytical program will consist of VOCs, including chlorinated compounds and degradation products, methane, ethene, and ethane. Initially, the following geochemical parameters will also be included in the analytical program: dissolved oxygen (field), redox potential (field), sulfate, nitrate, nitrites, alkalinity, total organic carbon, and ferrous iron (field).

Inspection/Long-Term Groundwater Monitoring – Alternatives 2 through 7 include inspection and long-term groundwater and surface water monitoring activities. The long-term reliability of the LHAAP-16 landfill cap to control infiltration, contaminant runoff, and contaminant exposure depends on adequate long-term inspection and maintenance. Further groundwater and surface water monitoring would be used to evaluate contaminant and by-product contaminant migration, confirm that the COCs and by-product contaminants in the groundwater plumes degrade in a manner to achieve attainment of groundwater cleanup standards/levels, and to verify that COCs and by-product COC contaminant levels in Harrison Bayou are less than the surface water standards. The eventual groundwater concentration goal is to reduce COC concentrations to groundwater cleanup levels. The LUCs, cap maintenance, and long-term monitoring would be continued as required to demonstrate effectiveness of the remedy, compliance with applicable or relevant and appropriate requirements (ARARs), and RAOs, and to support five-year reviews.

Distinguishing Features of the Alternatives

Alternative 2, Alternative 3a and Alternative 3b

The distinguishing feature of **Alternative 2** is the inclusion of enhanced groundwater extraction. **Alternative 3a** when compared to Alternative 2 is distinguished by the discontinued use of the extraction system relying on MNA to reduce the groundwater contamination and impacts to Harrison Bayou over long-term. **Alternative 3b** is identical to 3a except that an extraction well network will be operated in the groundwater hot spot for approximately 5 years to reduce contaminant mass, followed by MNA. These actions are described below.

Enhanced Groundwater Extraction – The current groundwater extraction system would be upgraded to increase reliability of the extraction wells and related equipment and increase its hydraulic influence on the shallow and intermediate groundwater plume. There are eight existing groundwater extraction wells that were installed at the site in 1996 as part of a groundwater treatability study and design. The extraction wells were installed as four pairs (nests) each consisting of a shallow well (wells 16EW01 through 16EW04) installed in the shallow saturated zone, and an intermediate well (wells 16EW05 through 16EW08) installed to a depth of approximately 55 feet screened in the intermediate saturated zone. Historically, the extraction wells have produced below the optimum combined flow of 8 gallons per minute (gpm). Several upgrades to the existing system would be implemented to improve performance and minimize system downtime. The existing pumps have been a maintenance problem, often clogging with soil fines. Polyvinyl chloride (pvc) check valves and filter socks would be installed to remove soil fines. A remote level control system offered by the pump manufacturer would be installed at each well to allow water level adjustments to keep the pumps submerged, reducing the iron fouling problems. To reduce the amount of time the compressor runs, the 2-hp air compressor unit would be replaced by a 7-hp compressor.

Additional Extraction Wells – Based on an evaluation of the shallow and intermediate plume locations, the hydrogeologic conditions, and the location and estimated hydraulic influence of the existing extraction well network, there is considerable uncertainty as to the effectiveness of the current system's ability to adequately capture the northernmost portions of the plume. To capture that part of the plume, a pair of nested, 4-inch ID extraction wells, one each in the shallow and intermediate zones, would be installed approximately 75 to 100 feet north of extraction wells 16EW01and 16EW05. These new extraction wells would capture the northern components of the shallow and intermediate groundwater plumes. They would be tied into the groundwater extraction system piping. It is estimated that these new wells would produce approximately 2 gpm. The extracted groundwater would be treated at the LHAAP-18/24 treatment plant.

Water Treatment – The extracted groundwater would be treated at the groundwater treatment plant at LHAAP-18/24. The plant was originally built to treat contaminated water from other LHAAP sites. Since 1996 the plant has also treated groundwater from LHAAP-16 extraction wells, which contribute less than 10 percent of the total amount of water treated at the plant. The treatment plant uses air stripping, metals precipitation, carbon adsorption, and catalytic oxidation and would not require modification for this alternative. A fluidized bed reactor was added for perchlorate treatment and has been operating since April 2001. The plant is capable of treating chlorinated solvents, perchlorate, and metals. Plant influent from all sources is blended in a 300,000-gallon equalization tank before treatment. Treated effluent is discharged into Harrison Bayou or injected at LHAAP-18/24.

Performance Monitoring – Groundwater and surface water monitoring would be required throughout the O&M period, estimated to be beyond the 30-year present worth period. O&M would include continuous pumping of the extraction wells, monitoring of environmental media, extraction well and monitoring well maintenance, and water treatment. Harrison Bayou would be sampled at three locations quarterly for one year followed by annual sampling and the samples submitted for VOC and perchlorate analyses. It is also assumed that 2 new monitoring wells would be installed on the other side of Harrison Bayou and a total of 10 wells also monitored for VOCs and perchlorate. The wells would be sampled quarterly for the first year followed by annual sampling.

Upgrading the existing extraction system and installation of the new extraction wells is estimated to take approximately 3 months. The groundwater extraction system would need to operate until contaminated groundwater at LHAAP-16 has attained the SDWA MCLs and TRRP Tier 1 Groundwater Residential PCLs. For those COCs and by-product (i.e., daughter) contaminants that have an MCL, the MCL constitutes the groundwater cleanup level to be attained. In the absence of federal drinking water standards, remedial goals will be based on TRRP Tier 1 Groundwater Residential PCLs. With respect to the surface waters that could be impacted by contaminated groundwater seeping into Harrison Bayou, the Texas Surface Water Quality Standards found at 30 TAC 307, or if those standards are not available, the SDWA MCLs, or in the absence of federal drinking water standards, TRRP Tier 1 Groundwater Residential PCLs constitute the surface water standards for the COCs and by-product (i.e., daughter) contaminants to confirm that the RAO for groundwater to surface water migration is achieved.

Groundwater Hot Spot Extraction – The groundwater contaminant mass would be significantly reduced through an aggressive pump and treat operation in the heart of the shallow and intermediate contaminant plumes. The system would use four new shallow zone extraction wells, 2 existing shallow zone extraction wells, and two existing intermediate zone extraction wells. Existing shallow zone wells 16EW01 and 16EW02 would complete the shallow zone extraction network in the heart of the shallow plume. The four new shallow zone extraction wells would be installed to 30 feet. Existing intermediate zone wells 16EW05 and 16EW06 are located in the heart of the intermediate zone plume. All new wells would be constructed the same as existing extraction wells (4-inch-diameter pvc with pneumatic pumps), and both new and existing wells would employ the upgrades identified in Alternative 2. With the exception of 16EW01, 16EW02, 16EW05, and 16EW06, the existing extraction wells would not be operated under this alternative.

The extraction wells would be tied into the existing extraction well network, and the extracted groundwater would be treated at the groundwater treatment plant at LHAAP-18/24. The well network would be operated for an estimated 5 years. It is roughly estimated that the contaminant mass in this section of the shallow and intermediate zone plumes would be reduced by up to 50 percent. Extraction well maintenance would be required for the whole duration of groundwater extraction.

Performance monitoring would be conducted as described for Alternative 2. One of the Harrison Bayou sampling locations would be adjacent to the seep.

Alternative 4, Alternative 5a and Alternative 5b

The distinguishing feature of **Alternatives 4, 5a**, and **5b** is the inclusion of groundwater treatment. Compared to Alternative 4, the distinguishing features of **Alternatives 5a** and **5b**, are the inclusion of landfill hot spot excavation and complete landfill excavation, respectively. These actions are described below.

In Situ Permeable Reactive Barrier (Passive Groundwater Treatment) – To protect Harrison Bayou from shallow contaminated groundwater infiltration from the seep at the northeastern end of the site, an in situ treatment system would be installed across the heart of the shallow groundwater contaminant plume. This barrier would consist of a gravel filled groundwater collection trench with a reactive media bed located at the downslope discharge point of the collection trench. The highly permeable gravel in the trench would channel the shallow groundwater to the reactive media contained in a buried treatment vessel. The collection trench is sized to intercept only that part of the shallow groundwater plume with highest contaminant concentrations, likely having the greatest impact on VOC levels in Harrison Bayou. Installation of the trench would create a preferential flow path. The actual size and location of the trench would need to be determined during the design.

The reactive media vessel would be located approximately 250 feet downslope from the end of the collection trench to provide adequate head to move the collected groundwater through the treatment vessel. A perforated pipe would be buried at the bottom of the collection trench to convey the collected groundwater through a non-perforated pipe connected to the reactive media treatment vessel. The treatment vessel would be filled with the reactive media and sized to provide the requisite residence time for the contaminants to be treated. The treatment vessel discharges to a buried drain field, allowing the treated groundwater to drain into the soil downslope of the treatment vessel. The placement of the reactive media in a treatment vessel instead of the entire collection trench would reduce the overall media cost and facilitate the replacement of the media when expended.

The contaminants to be treated by this reactive media are TCE and perchlorate. The treatment process would be an anaerobic biological degradation process that would use a combination of gravel and various organic media. The treatment vessel would be buried to enhance anaerobic conditions. The organic media would function as carbon sources for the anaerobic microbes. Possible sources of media are, among others, compost, vegetables, molasses, cotton seed, and citrate which can be used in combination to achieve the necessary treatment levels. The organic media mix and the size of the treatment vessel must be determined through treatability testing and design. It is assumed that the media would require replacement every 5 years. Three shallow monitoring wells (one every 100 feet) would be installed immediately downgradient of the collection trench to monitor the performance of the trench.

The excavated soil material removed from the trenching operations would be placed in a prepared staging area. The excavated soil would be sampled and analyzed for perchlorate, VOCs, SVOCs, toxicity characteristic leaching procedure (TCLP), metals, dioxins/furans, and PCBs and could likely be used as clean fill at the site. Dewatering of the trench may be required during excavation. Any groundwater removed would be assumed to be contaminated and would be treated at the groundwater treatment plant at LHAAP-18/24.

It would take at least 6 months to conduct the reactive barrier treatability study. It would take approximately 6 months to clear and grub the area, install the soil staging area, and install the permeable reactive barrier. The permeable reactive barrier would have to be operated until the upgradient groundwater contamination degraded to the point that no future impacts to Harrison Bayou are likely. Groundwater and surface water monitoring would be required throughout the O&M period, estimated to be required beyond the 30-year present worth period.

Landfill Hot Spot Excavation – The landfill hot spots would be removed with conventional excavation equipment. To verify the hot spot locations, 10 test trenches would be excavated at various locations across the landfill, biased by the results of the previous soil gas survey. These test trenches, dug to the bottom of the landfill, would provide insight into the physical makeup of the waste likely to be excavated, in addition to analytical data from samples taken from these trenches. The excavated waste would be segregated, roughly catalogued, and placed in 55-gallon drums for disposal. Debris would be taken from each of the trenches and screened in the field for VOCs and analyzed for perchlorate, VOCs, SVOCs, TCLP, metals, dioxins/furans, and PCBs. The results of this sampling effort would be used to define the location and nature of hot spot material to focus the excavation efforts and detail the waste handling and treatment processes.

Once the location of the hot spot material was confirmed, an excavation path would be cut into the landfill through the center of the assumed hot spot areas. This approach would expose the greatest volume of hot spot material while minimizing disturbances to the areas of the landfill that would not be excavated. The cap covering the hot spots would be carefully removed before excavation, facilitating the replacement of the liner and other cap material after excavation is complete.

The excavated material would be placed in piles on a staging area adjacent to the landfill. Every 200 cubic yards of waste placed in the waste staging area would be sampled and analyzed for VOCs, SVOCs, TCLP, metals, dioxins/furans, and PCBs to determine whether it meets the waste acceptance criteria of the off-site disposal facility. Approximately 60 samples would be collected and shipped to an offsite laboratory. The waste would remain in the staging area until the analytical results are received from the laboratory. The probable condition is that all of the waste is not RCRA-hazardous and could be disposed of in an industrial landfill. Once the waste was sampled and determined to meet the waste acceptance criteria of the disposal facility, it would be loaded into dump trucks and transported for disposal.

Landfill Cap Repair – The cap would be repaired following landfill hot spot excavation under Alternative 5a. The open excavations would be backfilled with clean fill, and a geocomposite clay liner and a 20-mil geomembrane would be installed and joined with their counterparts in the existing cap. Approximately 425 cubic yards of soil would then be graded into the existing soil cover.

Complete Landfill Excavation – There is a degree of uncertainty as to the total volume and locations of the hot spot material. Although the results of the soil gas survey indicate the possible location of hot spot material based on elevated soil gas readings, it is possible that the volume and locations of the hot spot material are much greater and more widespread. The results of the test trenching would add significantly to the confidence level for hot spot locations, volume, and constituents, but uncertainty remains because of the inherent variability in landfill wastes and the scarcity of disposal information. Alternative 5b addresses the distinct possibility that once full-scale excavation begins, hot spots may be found throughout the landfill. To place an upper bound on the volume of waste to be excavated under this alternative, this option assumes all of the landfill wastes would need to be excavated (approximately 327,000 cubic yards of material).

The excavation, sampling, and waste transportation methods for Alternative 5b would be identical to that described for Alternative 5a. Approximately 327,000 cubic yards of backfill would be required, and waste samples collected and analyzed for every 200 cubic yards of waste removed. The entire landfill would be excavated in sections. The cap from each section would be removed as that section is excavated. Excavation operations would take approximately 30 months. Groundwater and surface water monitoring would be required throughout the O&M period.

In Situ Permeable Reactive Barrier (Permeable Reactive Barrier) – To meet surface water standards in Harrison Bayou, an in situ treatment system would be installed across the majority of the shallow groundwater contaminant plume to intercept and treat all contaminated shallow groundwater that may seep into Harrison Bayou. This permeable reactive barrier would be installed in both Alternatives 5a and 5b and operate identically to the permeable reactive barrier used in Alternative 4. This barrier would be approximately 700 feet long in order to intercept the entire shallow groundwater plume.

The possibility of the intermediate groundwater plume impacting Harrison Bayou is remote, but because of the aggressive approach to meeting surface water standards under this alternative, the intermediate zone groundwater would also be intercepted. The proposed design of the collection trench and treatment vessel relies on hydraulic head to move the collected groundwater through the trench into the treatment vessel. The intermediate zone groundwater level is below the level of the treatment vessel and even if the collection trench were constructed to intercept the intermediate zone there would be no hydraulic head to induce the collected groundwater to flow up to the treatment vessel. Because some type of active extraction would be necessary for the intermediate zone, the existing wells were selected over a deeper trench and pumping due to ease of implementation and lower cost. This alternative would use the existing intermediate zone extraction wells (16EW05, 16EW06, 16EW07, and 16EW08) to capture the intermediate zone plume. The existing shallow zone extraction wells would not be used. An additional intermediate zone extraction well would be installed north of 16EW05. It would be placed in the same location and constructed identically to the additional intermediate zone well described in Alternative 2.

The extracted water would be piped through the existing transport system to the existing groundwater treatment plant. Seven shallow zone monitoring wells (one every 100 feet) would be installed immediately downgradient of the collection trench to monitor trench performance.

The soil excavated from the trench would be staged in the staging area used for the landfill waste. The soil would be sampled and analyzed for perchlorate, VOCs, SVOCs, TCLP, metals, dioxins/furans, and PCBs. It is assumed that this soil could be used as clean fill. Dewatering may be required during the excavation of the trench. Note however, these soils would be subject to the waste analysis and land disposal restriction requirements found in 40 CFR §§ 262.11 and 268.7. The groundwater removed would likely be contaminated and transported to the treatment plant at LHAAP-18/24.

It would take at least 6 months to conduct a reactive barrier treatability study. The clearing and grubbing of the waste staging area and its construction would take approximately 1 month. The partial removal of the cap and the excavation of the 10,000 cubic yards of hot spot material would take approximately 6 months. The off-site transportation and disposal of the excavated waste material would lag behind the waste removal by 1 month. The backfilling of the excavation area, the repair of the cap, and the closure of the landfill would take 1 month. The reactive barrier would be installed concurrently with the hot spot excavation. It would take approximately 6 months to clear and grub the reactive barrier area and install the barrier. The overall duration of this alternative is approximately 12 months. Groundwater and surface water monitoring would be required throughout the O&M period, estimated to be required beyond the 30-year present worth period.

Samples for both Alternatives 5a and 5b would be collected semi-annually from the trench monitoring wells and the discharge of the media treatment vessel. These samples would be analyzed for VOCs, perchlorate, and general chemistry parameters. It is assumed that the media in the permeable reactive barrier would be replaced and disposed of every 5 years.

The contingent action for Alternatives 5a and 5b addresses the possibility that a percentage of the excavated landfill waste is RCRA-characteristic hazardous waste; it is assumed that 5 percent would be RCRA characteristic hazardous waste and require treatment to meet land disposal restrictions (LDRs) before disposal.

Alternative 6

The distinguishing feature of **Alternative 6** is the inclusion of a SVE system that would be installed in the hot spots to remove the bulk of the volatile organics (e.g., TCE, cis-l,2-dichloroethene, vinyl chloride, etc.) that likely permeate the hot spot waste. The vapor extraction operations would consist of a temporary extraction system for a short-term pilot test and a more permanent, skid- or trailer-mounted system for long-term operations. These actions are described below.

Pilot Test – The pilot test would be conducted to collect the necessary information to design and install the long-term skid- or trailer-mounted system. The pilot test would consist of a soil gas survey in 10 locations to verify the location and relative concentrations of VOCs in the landfill waste. Based on this information a pilot-scale vapor extraction system would be installed and operated as a proof of principle. Four soil-vapor extraction wells would be installed to 15 feet bgs and would feed an estimated 250 cubic feet per minute (cfm) of vapor and water to a vacuum extraction truck and an internal combustion engine. The collected VOCs would be destroyed in the internal combustion engine. Water collected from the extraction effort would be discharged to the contaminated groundwater collection tank currently used for the LHAAP-16 groundwater extraction system. This extracted water would ultimately be treated at the LHAAP treatment plant. The components of the pilot test would include the following:

- Engineering phase – develop work plans; procure subcontractors
- Field phase – install extraction wells; conduct extraction for 2 months
- Reporting – evaluate data and report results.

Soil Vapor Extraction – Based on the results of the pilot test, a full-scale extraction system would be designed and installed. Approximately eight additional wells would be installed in the areas with elevated soil gas readings found during the pilot test soil gas survey. Each extraction well is assumed to have a radius of influence of 50-75 feet. A header would be run above ground to each well, and each well would be equipped with a valve to allow adjustment of air flow. The vapor extraction system would consist of a blower, knockout tank, and a catalytic oxidation unit. The catalytic oxidation unit would be propane-fueled and have a throughput of approximately 500 cfm (assumes 300 cfm/acre × 1.5 acres). VOC concentrations in the extracted air would be automatically monitored. The components of the long-term vapor extraction would include:

- Reporting – prepare an annual report on system performance
- Engineering phase – design and procure system and subcontractors
- Installation – install additional extraction wells and install piping, treatment unit, and utilities
- Operation – start up, operate, and maintain unit
- Reporting – prepare an annual report on system performance

Water discharged from the extraction system would be sent to the existing groundwater storage tank at LHAAP 16 before being pumped to the groundwater treatment plant at LHAAP-18/24. It is assumed that the vapor extraction system would operate for 5 years.

The installation, operation, documentation, and reporting of the pilot-scale vapor extraction test results would take approximately 4 months. The installation of the full-scale extraction system would take 6 months, and the unit would operate for approximately 5 years. It is estimated that all of the VOCs that can be practicably removed by this system would have been removed in this time period. Following completion of vapor extraction operations, the extraction wells would be plugged and abandoned and the cap repaired in those areas.

The vapor extraction system would require maintenance and monitoring over the 5 years that it would be in operation. It is likely that all of the equipment would operate for the full 5 years without the need for replacement if maintenance is routinely performed. Water and water vapor would be collected, transported, and treated at the treatment plant at LHAAP-18/24 for the entire 5 years.

Alternative 7

The distinguishing features of **Alternative 7** are the inclusion of an in situ enhanced bioremediation and biobarriers. These actions of Alternative 7 are described below.

In Situ Bioremediation – To treat the highest levels of chlorinated ethenes, located in the vicinity of the shallow extraction wells and upgradient of those wells, in situ bioremediation would be performed. This technology uses a carbon source and a bioaugmentation culture to create conditions favorable for reductive dechlorination. Preliminary MNA evaluation results indicates that reductive dechlorination is taking place in the shallow groundwater zone at LHAAP-16, but carbon levels appear to decrease with distance from the landfill itself. Therefore, the addition of a carbon source would further encourage the growth of microorganisms in the subsurface. As the microorganisms multiply, they would consume available respiratory substrates including iron and sulfate. As those respiratory substrates are consumed, conditions would be created which are favorable to destruction of chlorinated ethenes via reductive pathways. A bioaugmentation culture (e.g., SDC-9) would also be added to provide a microbial species specifically able to completely degrade TCE to harmless ethene.

It is proposed to inject the carbon source and bioaugmentation culture into the shallow zone using direct push technology (DPT), and into the intermediate zone by injection through existing wells. It has been assumed that approximately 40 injection points would be required within the treatment area. The details of implementation would be established during remedial design. The number of DPT injection points and the injection volumes would be finalized at that time. The design effort would consider optional injection patterns. Once the carbon source and the bioaugmentation culture were injected into the subsurface, reducing conditions would be created, followed by a significant reduction in chlorinated ethene concentrations.

Biobarriers – A biobarrier would be installed in the downgradient portion of the groundwater plume to prevent contaminated groundwater from seeping into Harrison Bayou at concentrations that cause the surface water in Harrison Bayou to exceed the surface water standards for the COCs and by-product COCs. A second biobarrier would be installed at the edge of the landfill between 16WW38 and 16WW13 to control potential migration of VOCs from the landfill. Specifically, a row of injection points perpendicular to groundwater flow direction would be installed down-gradient of the shallow monitoring well close to Harrison Bayou (16WW12). The biobarrier would consist of emulsified oil that will enable ambient microorganisms to create favorable conditions and a bioaugmentation culture (e.g., SDC-9) to provide a microbial species that is able to completely degrade TCE to ethene. The emulsified oil is a slow-release carbon source with an enhanced subsurface longevity; it would be injected to provide a long-lasting source of fermentable carbon to stimulate the biological reduction of perchlorate and TCE and its daughter products.

Once reducing conditions were achieved in the biobarrier, bioaugmentation culture (e.g., SDC-9) would be added to provide microorganisms to completely degrade chlorinated ethenes. The emulsified oil would be injected across the path of shallow groundwater to form two biobarriers – one close to Harrison Bayou and another at the eastern edge of the landfill. Sufficient emulsified oil would be added to each injection point to provide a sustained carbon source for an estimated 3 to 5 years. Follow-up injections would be conducted if deemed necessary from the performance groundwater monitoring results. Concentrations of COCs downgradient of the biobarriers will be monitored to evaluate the continuing effectiveness of the biobarriers.

2.9.3 Expected Outcomes of Each Alternative

Alternative 1 would allow the site to remain a hazard to human receptors due to the potential ingestion of contaminated groundwater; and to the environment, because no remedial activities would be conducted and there would be no LUCs except for cap maintenance. Note however, the landfill cap maintenance would comply with RCRA landfill closure and post-closure care regulations. Alternatives 2 through 7 all provide engineering controls, treatment, containment, or removal and disposal of the waste material to levels protective of human receptors and the environment, including the groundwater at the site, and Harrison Bayou. The six action alternatives have very similar outcomes of preventing exposure to landfill wastes and contaminated groundwater utilizing the landfill cap and LUCs. Alternatives 2, 3, 4, 6, and 7 would maintain the surface water standards of Harrison Bayou through a variety of treatment processes. Alternative 2 takes advantage of the existing groundwater treatment plant. Alternative 3b, 4, 5a, 6 and 7 would achieve groundwater cleanup standards/levels in less time through utilization of active treatment. The similar outcomes include restoration of the contaminated groundwater by attainment of the SDWA MCLs for those COCs and by-product (i.e., daughter) contaminants that have an MCL, to the extent practicable, and consistent with 40 CFR §300.430(e)(2)(i)(B&C). In the absence of federal drinking water standards, cleanup levels for some COCs, including perchlorate, manganese, and nickel, will be based on TRRP Tier 1 Groundwater Residential PCLs. Similar outcomes also include the protection of surface water standards in surface waters that may be impacted by the contaminated groundwater discharges at LHAAP. As such, the Texas Surface Water Quality Standards found at 30 TAC 307, or if those standards are not available, the SDWA MCLs, or in the absence of federal drinking water standards, TRRP Tier 1 Groundwater

Residential PCLs constitute the surface water standards that will be monitored to confirm protection of Harrison Bayou surface waters. In addition, the groundwater and surface water monitoring activities associated with Alternatives 2 through 7 would confirm the protection of human health and the environment by documenting the return of groundwater to its potential beneficial use as a drinking water supply, by documenting reduction of the contaminant mass, and protection of surface water through containment of the plume. A LUC requiring maintenance of the integrity of any current or future remedial or monitoring systems shall remain in place until levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met.

LUCs prohibiting the use of the site's groundwater except for environmental monitoring and sampling and restricting land use to nonresidential will remain in place until it is demonstrated that levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in groundwater and soil allow for unlimited use and unrestricted exposure. LUCs to prevent human exposure to landfill waste will remain in place as long as the landfill waste remains at the site or until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in groundwater and soil allow for unlimited use and unrestricted exposure. The LUC prohibiting groundwater use (except for environmental monitoring and testing) as a potable source will remain in place until the levels of COCs (i.e., all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in soil and groundwater allow for unlimited use and unrestricted exposure.

2.10 Summary of Comparative Analysis of Alternatives

Nine criteria identified in the NCP §300.430(e)(9)(iii) are used to evaluate the different remediation alternatives individually and against each other in order to select a remedy. This section profiles the relative performance of each alternative against the nine criteria, noting how it compares to the other options under consideration. The nine evaluation criteria are discussed below. **Table 2-8** summarizes the comparative analysis of the alternatives.

2.10.1 Overall Protection of Human Health and the Environment

Overall protection of human health and the environment addresses whether each alternative provides adequate protection of human health and the environment and describes how risks posed through each exposure pathway are eliminated, reduced, or controlled, through treatment, engineering controls, and/or institutional controls.

Alternative 1, the no further action alternative, does not protect human health or the environment because no remedial activities would be conducted and no LUCs (except for cap maintenance) would be maintained. Therefore, LHAAP-16 contamination would present unacceptable risks to human health and the environment through ingestion of groundwater. The other six alternatives, collectively referred to as the action alternatives, would provide engineering controls, treatment, containment, or removal and disposal of the waste material to levels protective of human health and the environment.

The six action alternatives would provide access and use restrictions, capping of buried wastes (except for the entire landfill excavation option of Alternative 5), and long-term media monitoring. The landfill cap and LUCs would prevent exposure to landfill wastes and contaminated groundwater.

Alternatives 2, 3, 4, 6, and 7 would maintain Harrison Bayou water quality through a variety of means. Alternative 2 maintains the current actions of capping and groundwater extraction to contain the contaminated groundwater plume and prevent it from further impacting Harrison Bayou. Alternatives 3, 4, and 7 are similar to Alternative 2 in that they all maintain the cap, but they all discontinue the groundwater extraction system (Alternative 3b after an estimated 5 years). Alternative 4 uses an in situ permeable reactive barrier installed parallel to Harrison Bayou, and Alternatives 3, 6, and 7 use MNA to assure protection of Harrison Bayou. Alternative 6 couples vapor extraction of the landfill hot spots with groundwater natural attenuation. Alternative 7 utilizes in situ bioremediation of target areas and biobarriers in conjunction with groundwater natural attenuation.

Alternative 5a is the second most aggressive of all the alternatives in that it removes the landfill hot spots (conventional excavation, off-site disposal) and installs a permeable reactive barrier to treat groundwater before it seeps into Harrison Bayou. Alternative 5b, the most aggressive alternative, removes all of the landfill waste and uses the same reactive barrier as in Alternative 5a. All alternatives are protective, though Alternative 5b is most reliable in the long term because it has less reliance on long-term LUCs.

All action alternatives satisfy the RAOs for LHAAP-16. Action alternatives provide confirmation that human health and the environment will be protected because the monitoring will be conducted to confirm that active remedies and/or MNA is returning the contaminated shallow and intermediate groundwater zones at LHAAP-16 to their potential beneficial uses as a drinking water, wherever practicable, and to document that the plumes are contained and prevented from impacting surface water at levels that could present a risk to human health and the environment. Furthermore, the LUCs would protect human health by preventing exposure to landfill waste, protecting the landfill cover system and preventing access to the contaminated groundwater until the levels of COCs and COC by-products (daughter contaminants including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in groundwater and soil allow for unlimited use and unrestricted exposure. The LUC to maintain the integrity of any current or future remedial or monitoring systems shall remain in effect until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met. The LUC prohibiting groundwater use (except for environmental monitoring and testing) as a potable source will remain in place until the levels of COCs (i.e., all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in soil and groundwater allow for unlimited use and unrestricted exposure.

2.10.2 Compliance with ARARs

Section 121(d) of CERCLA and 40 CFR §300.430(f)(1)(ii)(B) require that remedial actions at CERCLA sites attain legally applicable or relevant and appropriate Federal and State requirements, standards, criteria, and limitations, which are collectively referred to as "ARARs" unless such ARARs are waived under CERCLA Section 121(d)(4). The ARARs that pertain to this ROD are discussed in **Section 2.13.2**.

Because contaminated groundwater has seeped into Harrison Bayou, chemical-specific ARARs for surface water consumption are applicable, relevant and appropriate. Specifically, Texas surface water quality standards are set forth in 30 TAC 307.6(d)(1) for TCE (5 µg/L), 1,2-DCA (5 µg/L), 1,1-DCE (7 µg/L), 1,1,2-TCA (5 µg/L), vinyl chloride (2 µg/L), arsenic (10 µg/L), and thallium (2 µg/L) will be met for surface water at LHAAP-16. The SDWA MCL constitute the cleanup standards/levels to be met per 30 TAC 335.559(b). The MCL for cis-1,2-DCE (70 µg/L), methylene chloride (5 µg/L), chromium (100 µg/L), will be met at the site. In the absence of federal drinking water standards, cleanup levels will be based on the TRRP Groundwater Residential PCLs.

Alternative 1 does not comply with chemical-specific ARARs because no additional remedial action would be implemented. All of the action alternatives comply with chemical-specific ARARs for groundwater because they will return the contaminated shallow and intermediate groundwater zones at LHAAP-16 to their potential beneficial use as a drinking water, wherever practicable, which for the purposes of this ROD is considered to be attainment of the relevant and appropriate cleanup levels (SDWA MCLs) to the extent practicable, and consistent with 40 CFR 300.430(e)(2)(i)(B&C). If a return to potential beneficial uses is not practicable, these alternatives would still meet the NCP expectation to prevent further migration of the plume, prevent exposure to the contaminated groundwater, and evaluate further risk reduction. All of the action alternatives comply with surface water chemical specific ARARs because active remedial processes will reduce the contaminant concentrations in groundwater to the cleanup levels prior to seeping into surface water.

Location-specific and action-specific MCLs would not apply to Alternative 1 since no remedial activities would be conducted. All of the action alternatives comply with all location-specific and action-specific ARARs.

2.10.3 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, once clean-up levels have been met. This criterion includes the consideration of residual risk that will remain onsite following remediation and the adequacy and reliability of controls.

The no further action alternative would not be effective in the long term, because the baseline risk assessment indicates that the current groundwater conditions are not protective of human health and the environment, and no remedial activities would be conducted to address groundwater under this alternative.

All alternatives except Alternative 5b rely on LUCs and source isolation (i.e., capping) to isolate the residual waste from potential receptors. With the exception of the complete landfill excavation option for Alternative 5b, all action alternatives would leave waste on site. Because Alternative 5b removes the entire landfill source term, it is the most reliable in long-term protection of future human receptors. Alternatives 5a and 6 are the next most reliable in the long term because of their removal and in situ treatment, respectively, of the hot spot wastes. The long-term cap maintenance and LUCs offered by Alternatives 2, 3, 4, 5a, 6, and 7 restricting access to the contaminated media would adequately maintain residual risks below acceptable levels. If cap maintenance and monitoring programs are maintained and the owner of LHAAP-16 maintains the LUCs, the cap and LUCs programs can reliably maintain residual risks at acceptable levels.

The permeable reactive barriers used in Alternatives 5a and 5b to avoid the potential risk that the contaminated groundwater seeping into surface water could cause Harrison Bayou to exceed surface water standards, may be effective and relatively reliable with long-term maintenance and monitoring. To control seepage into Harrison Bayou, Alternatives 2 and 3b extract and treat contaminants in groundwater. Alternative 2 requires long-term groundwater extraction, which has proven to be moderately effective. The extraction system has had reliability problems as with any mechanical system that must operate over the long term. Alternative 3b extracts groundwater for a shorter amount of time.

The other action alternatives rely on treatment options (i.e., in situ permeable reactive barrier, in situ bioremediation, biobarriers) along with MNA to protect Harrison Bayou. The in situ permeable reactive barriers used in Alternatives 4, 5a, and 5b and in situ bioremediation and biobarriers used in Alternative 7, would require regular monitoring and replacement of the reactive media to maintain long-term effectiveness. Long-term maintenance of these barriers could prove to be problematic because of potential fouling of the treatment media and changing geochemistry that could reduce their effectiveness. Collection trenches at LHAAP-16 would be difficult to design to effectively intercept the contaminated groundwater and drain by use of gravity. Permeable barriers and biobarriers were selected to be the representative process option because of their flexibility in being used to address VOC and perchlorate removal.

If operating effectively, the in situ groundwater treatment process of Alternatives 4 and 5 and in situ enhanced bioremediation and biobarriers of Alternative 7, more reliably meet the surface water objective of preventing seepage of contaminants into Harrison Bayou than the natural attenuation option in Alternatives 3 and 6. Results of the MNA evaluation for LHAAP-16 indicated that natural attenuation is a feasible remedy for certain portions of the site but not as a sole remedy due to migration concerns for the shallow groundwater zone. Alternatives 3 and 6 have a planned contingent action of using the enhanced extraction and treatment system of Alternative 2 if natural attenuation is not occurring at a sufficient level to control future seepage into Harrison Bayou.

Alternative 7 utilizes in situ bioremediation and biobarriers to further degrade the contaminants in groundwater in conjunction with MNA. Based on the results of the ESTCP semi-passive biobarrier technology demonstration (ESTCP, 2005; ESTCP, 2007) and the preliminary MNA evaluation, the groundwater contaminants at LHAAP-16 have been shown to be amenable to degradation by biological processes prior to seepage into Harrison Bayou. In summary, all of the action alternatives, including their contingent actions, would effectively meet the RAOs. The reliability of the permeable treatment barrier of Alternatives 4 and 5 is less certain than that of the extraction system of Alternative 2 and 3b, but it may be more effective than the natural attenuation component of Alternatives 3a, 6, and 7. The biological processes utilized in Alternative 7 have been shown to be effective and reliable at LHAAP-16. The current source action, a cap, is limiting releases from the landfill material to the groundwater. However, the removal of the hot spots in Alternative 5a (to the extent these can be found without completely removing the composite synthetic/ bentonite clay liner), or treatment of those same hot spots as in Alternative 6, could enhance the reliability of the cap. LUCs to prevent access to the landfill material are considered effective. There is no information to suggest that the hot spots identified as the probable source of migration of contaminants to groundwater would also have the greatest risk if accessed, so these alternatives are not considered more reliable. However, full removal of the waste, Alternative 5b, would be the most reliable.

Monitoring activities associated with all action alternatives would confirm the protection of human health and the environment by documenting the return of the groundwater to its potential beneficial use as a drinking water supply, by documenting reduction of the contaminant mass and protection of surface water through containment of the plume.

2.10.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Reduction of toxicity, mobility, or volume through treatment refers to the anticipated performance of the treatment technologies that may be included as part of a remedy.

The no further action alternative does not include treatment and would not result in a reduction of toxicity, mobility, or volume of contaminants.

Alternatives 2, 3, 4, and 7 would not address the landfill source other than providing containment through capping. Alternative 3a, through its complete reliance on groundwater natural attenuation, provides the least reduction in contaminant volume and toxicity. The natural biological and chemical processes, over time, would gradually reduce the toxicity of VOCs in groundwater and the overall volume of contaminated groundwater. Alternative 4, with its permeable reactive barrier, would reduce the toxicity and volume of the shallow groundwater that passes through it. Although the groundwater upgradient of the reactive barrier is unaffected by the reactive media (until it passes through it), the reactive barrier provides a greater reduction in toxicity and volume than Alternative 3a. Alternatives 2 and 3b actively remove contaminated groundwater from the heart of the plume and treat it ex situ in the LHAAP treatment plant. The processes in the treatment plant would reduce the toxicity and volume of the extracted groundwater. Much of the contamination in the groundwater plume would be reduced over time, offering greater reductions in toxicity and volume than that in Alternative 3a.

Alternative 7 includes in situ bioremediation in the vicinity of shallow wells and upgradient of the wells with the highest levels of chlorinated ethenes. The process would reduce the toxicity and volume. The biobarriers provide further reduction of toxicity, mobility, and volume of the groundwater that passes through them. MNA in conjunction with in situ bioremediation would enhance reduction of toxicity and volume. Alternative 7 includes treatment of groundwater within the plume itself. Alternatives 3a, 3b, 6, and 7 include a natural attenuation component together with dilution, dispersion, and other natural processes that have the capability of ultimately reducing the contaminants to satisfy the chemical-specific ARARs.

Alternative 6 includes the in situ treatment of the landfill. The extracted VOCs, the majority of the source at LHAAP-16, would be destroyed in a thermal oxidation unit. Although the contaminants in groundwater would be treated only through natural degradation processes, the overall reduction in toxicity and volume is greater than other alternatives.

Alternative 5 removes source material from the site, but the base action does not include treatment of that material. The permeable barrier does provide some reduction of toxicity of contaminants through treatment. If the excavated material is RCRA-characteristic, treatment of such materials to meet LDRs would satisfy the CERCLA Section 121(b) statutory preference for treatment.

2.10.5 Short-Term Effectiveness

Short-term effectiveness addresses the period of time needed to implement the remedy and any adverse impacts that may be posed to workers, the community, and the environment during construction and operation of the remedy until cleanup levels are achieved.

The no further action alternative would not involve any action; therefore, there would be no increase in short-term risks and no short-term environmental effects.

Through LUCs and engineered controls (e.g., physical barriers, administrative controls, and dust suppression), the six action alternatives would be protective of the community during implementation. Alternative 3a would be the most protective in the short term because there is no construction or off-site transportation. Alternative 5b and, to a lesser extent, Alternative 5a would pose the greatest potential exposure and transportation risks to the public due to the extensive waste excavation and transportation activities. Local and site traffic would be similar for all other alternatives.

The cap maintenance activities at the landfill would require the same health and safety measures for all alternatives except for Alternative 5b. Alternative 5b and to a lesser extent Alternative 5a require extensive handling of the landfill waste and thus pose the greatest risk to remediation workers. Alternative 5a would also be inherently dangerous for workers and machinery because a landfill is an unstable area for trench excavation. Alternative 6 presents lower risks to remediation workers than Alternative 5a because of the less intrusive waste operations of the vapor extraction operations. Appropriate mitigative measures would be applied during construction and transportation to attain appropriate worker and public health exposure requirements in all action alternatives. By planning the construction, excavation, and transportation activities in accordance with industry and OSHA codes and requirements, risks from contaminant exposure and construction operations would be controlled to acceptable levels. All of the remaining alternatives pose similar risks to the remediation worker with Alternative 3a being the safest alternative to implement.

The short-term disturbance of on-property vegetation and wildlife habitat would be greatest under Alternatives 5a and 5b, primarily because of the waste excavation activities and the installation of the long groundwater collection trench. There would be short-term impacts on the vegetation and wildlife habitats in the vicinity of the permeable reactive barrier under alternative 4 and in situ bioremediation injection points and biobarriers under alternative 7, though less than that for the longer barriers in Alternatives 5a and 5b. The vapor extraction operations in Alternative 6 would lightly impact vegetation on the landfill. The remaining alternatives would have little to no short-term impacts above those related to minor maintenance activities. For earthwork and construction activities, sediment deposition into Harrison Bayou would be controlled. Erosion control measures would include surface grading; placement of rip rap and silt fences; covering surfaces with straw, mulch, riprap, or geotextile fabrics; and/or using riprap in areas with high water velocity. Following completion of all construction and excavation, disturbed areas would be regraded with clean backfill and revegetated with native grasses.

The approximate construction time for the action alternatives ranges from 6 months in Alternative 2 to 36 months in Alternative 7. Because the source term is effectively controlled in all of the alternatives (with appropriate cap maintenance), the length of time required before groundwater containment systems are no longer needed are comparable, outside the 30-year present worth period. Additional source actions (Alternatives 5 and 6) are likely to lessen the time required to control the groundwater.

The MNA evaluation for LHAAP-16 demonstrated that natural attenuation is occurring in some areas at the site. The attenuation of contaminants was observed at the source and side-downgradient of the plume. However, the shallow groundwater zone plume is still migrating along the groundwater flow direction toward Harrison Bayou. The intermediate groundwater zone plume is more stable with less migration along the flow direction toward Harrison Bayou. Thus, natural attenuation is a feasible remedy for certain portions of the site but not as a sole remedy due to migration concerns for the shallow zone. MNA is proposed for Alternative 7 in conjunction with in situ bioremediation to enhance reductive dechlorination within the plume and a biobarrier to prevent the seepage of contaminants into surface water. Natural attenuation would be evaluated after 2 years of quarterly monitoring and a re-application of bio-amendments (i.e., additional in situ bioremediation) would be implemented if deemed necessary.

Detailed evaluation of natural attenuation processes would be required to determine whether the Harrison Bayou remediation levels can be met in the near future or whether a contingent action is needed under Alternatives 3 and 6.

2.10.6 Implementability

Implementability addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility, and coordination with other governmental entities are also considered.

Under the no further action alternative, no new remedial action would be taken. Therefore, there would be no difficulties or uncertainties with implementation.

Overall, all of the action alternatives are technically feasible to implement. Although Alternatives 5a, 5b, and 6 would require more time, equipment, and activity than the other alternatives, the components of most alternatives use technologies that have been straightforward to implement at other sites with contaminants and conditions similar to those found at LHAAP-16. These technologies would be implemented using conventional equipment and construction methods. The excavation of the landfill wastes under Alternatives 5a and 5b would be moderately difficult because of the inherent difficulties associated with excavating debris from a landfill with an uncertain disposal history. Given the uncertain nature of the wastes in the landfill, the potential for delays in excavation exist should anomalous items or debris be encountered. Likewise, coordination issues between excavation, waste characterization sampling, and disposal could slow the process. Alternative 5a has additional implementation difficulties due to the need to penetrate and rebuild the capping system and the impracticability of verifying that all potential sources of groundwater contamination are removed. Although the media in the reactive barrier in Alternatives 4, 5a, and 5b is expected to treat VOCs and perchlorate, the specific conditions at LHAAP-16 (low gradient, high VOCs, low perchlorate levels) have not been tested. There are negative interactions with other site contaminants that could reduce the media's performance. Based on the ESTCP semi-passive biobarriers technology demonstrations, groundwater contaminants at LHAAP-16 are amenable to degradation by biological processes under Alternative 7. All components of Alternative 7 are readily implementable. Alternative 5b, and to a lesser extent Alternative 5a, would be the most technically difficult to implement.

Alternative 6 would be more technically implementable than Alternatives 5a and 5b, though there may be some challenges associated with the installation of the vapor extraction system in the landfill wastes. Also, the uncertainties associated with the flow of soil gas through the variable and heterogeneous buried waste would also contribute to difficulties in implementability and performance. However, the process is robust and would remove adequate volumes of soil vapor. Alternative 6 also has uncertainty associated with the implementation and operation of a permeable barrier.

There are few technical challenges to the implementation of Alternative 4 other than those associated with the installation of the permeable reactive barrier. Although Alternative 3a does not require the installation of any engineered components, the uncertainty in the long-term effectiveness of natural attenuation with the source term still in place may cause future delays should a contingent action need to be implemented. The groundwater extraction system and water treatment plant used in Alternatives 2 and 3b are currently operating and proven in their operation and effectiveness and make these alternatives the most technically implementable.

Administratively, all alternatives are implementable. Virtually all services and materials required for the implementation of the action alternatives would be standard for the construction industry and would be readily available. However, considerable testing and development may be needed to produce an effective design for in situ treatment of VOCs and perchlorate in groundwater. Alternative 5 is the least administratively implementable because of the off-site waste transportation and disposal activities. Various Department of Transportation regulations (e.g., 49 CFR 172, 173, and 177) apply to the transportation of wastes such as those expected from the landfill, and the waste acceptance criteria of the off-site disposal facility must be complied with. In the event that a portion of the wastes must be treated before disposal (Alternative 5 contingent action), the waste acceptance criteria of the treatment facility must also be met. Alternatives 4 and 5 would also require personnel with specialized experience in reactive barrier treatability testing, installation, and operation. The vapor extraction activities in Alternative 6 would require personnel with specialized experience in vapor extraction installation and operation. Alternative 7 would require expertise in engineering design and implementation of the in situ bioremediation and the biobarrier component of the alternative. Alternative 2 and Alternative 3 are the most administratively implementable.

2.10.7 Cost

Cost estimates are used in the CERCLA process to eliminate those remedial alternatives that are significantly more expensive than competing alternatives without offering commensurate increases in performance or overall protection of human health or the environment. The cost estimates developed are preliminary estimates with an intended accuracy range of –30 to +50 percent. Final costs will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final scope, final schedule, final engineering design, and other variables.

The cost estimates include capital costs (including fixed-price remedial construction) and long-term O&M costs (post-remediation). Present worth costs were developed for each alternative assuming a discount rate of 2.7 percent. The estimates for all alternatives utilize a 30-year project life for costing purposes, although the timeframe to achieve RAOs is expected to be longer. The costs of Alternatives 1 through 6 have been updated from the costs presented in the Final FS (Jacobs, 2002) to January 2008 using the Engineering News Record construction cost index, and the costs of five-year reviews have been added to all alternatives. Also, the cost of Alternative 1 has been updated to reflect the ongoing cap maintenance/inspection activities and the implementation of LUCs under the Interim ROD for LHAAP-16.

The progression of present worth costs from the least expensive alternative to the most expensive alternative is as follows: Alternative 1, Alternative 7, Alternative 3a, Alternative 3b, Alternative 4, Alternative 6, Alternative 2, Alternative 5a, and Alternative 5b. Lowest costs are associated with Alternative 1 because no further remedial activities would be conducted. Alternative 7 has the lowest present worth and capital costs of the action alternatives. Alternatives 3a, 3b, and 4 are next in costs (all $5,200,000 or below). While Alternatives 3a and 3b rely heavily on a passive remedial action component (MNA), Alternative 7 utilizes active technologies (in situ bioremediation and biobarriers) prior to MNA; those active technologies lead to much lower monitoring costs in the future, thus giving Alternative 7 a lower total present value cost. The large O&M cost for groundwater treatment (Alternative 2) and the higher capital and O&M cost of in situ vapor extraction (Alternative 6) make these alternatives roughly twice as expensive as Alternatives 3a, 3b, and 4. However, if other sites require use of the LHAAP groundwater treatment plant, the cost of Alternative 2 will be comparable to Alternative 3.

Alternatives 5a (present worth of $15 million) and 5b (present worth of $130 million) are considerably more expensive because of the combination of high capital costs and high O&M costs. The contingent action costs do not change the order of costs.

2.10.8 State/Support Agency Acceptance

The USEPA and TCEQ have reviewed the Proposed Plan, which presented Alternative 7 as the preferred alternative. Comments received from the USEPA and TCEQ during the Proposed Plan development have been incorporated. Both agencies concur with the selected remedial action.

2.10.9 Community Acceptance

Community acceptance is an important consideration in the final evaluation of the selected remedy. Three sets of written public comments were received during the 30-day public comment period; there were no verbal comments from the October 19, 2010 public meeting. The topics of the comments included: time the landfill will continue to be a source of contamination, time required to achieve cleanup levels, effectiveness of MNA, defining the extent of groundwater contamination, adequacy of the monitoring wells and Harrison Bayou sampling locations, perchlorate cleanup levels, and additional contaminants (antimony, thallium, dioxins and furans) to be added to the list of COCs. Comment responses were provided and incorporated into the ROD, including reiteration of the evaluation criteria for the selected remedy, explanation that the landfill cover system implemented in 1998 as part of the IRA was intended to be consistent with the final remedy and is considered a component of the final selected remedy, explanation that the existing monitoring wells and surface water sampling locations are adequate to monitor contamination at the site and within Harrison Bayou. In addition, explanation as to why thallium will be added to the COC list while antimony and dioxins/furans were not selected as COCs is given. The written comments received and their responses are presented in the Responsiveness Summary (**Section 3.0**).

2.11 Principal Threat Wastes

LHAAP-16 was used primarily as a solid and industrial waste landfill. Placement of the landfill cap prevents rainfall from further infiltrating and leaching contaminants from principal threat wastes in the landfill. However, contaminated groundwater beneath the landfill area continues to migrate. A groundwater extraction and treatment system was voluntarily installed in 1996 to prevent the groundwater plume from migrating to Harrison Bayou.

Capping the landfill as opposed to waste treatment or removal is a presumptive remedy at landfills as it has been shown to be more effective in comparison to other remedies. Landfill removal and landfill source treatment alternatives were included in the comparative analysis of alternatives performed during the feasibility study (Jacobs, 2002) for LHAAP-16. These remedial alternatives did not demonstrate increases in effectiveness that was balanced by their increased costs and short-term impacts.

2.12 The Selected Remedy

2.12.1 Summary of Rationale for the Selected Remedy

Alternative 7, capping, LUCs, in situ enhanced bioremediation in a target area, biobarriers, and MNA, is the selected alternative for LHAAP-16 and is consistent with the intended future use of the site as a national wildlife refuge. This alternative would satisfy the RAOs for the site through the following:

- Maintenance and repair of the existing landfill cap will preserve the integrity of the cap, thus preventing exposure to landfill contents and protecting human health and the environment by reducing leaching and migration of landfill hazardous substances into groundwater. Closure and post-closure ARARs were identified for LHAAP-16 in the IRA ROD and these included 30 TAC 335.112, 335.118, 335.119 and 335.174 and 40 CFR Sections 264.228 and 264.310 addressing landfills and surface impoundments storing hazardous waste. Although closure requirements were met during implementation of the (cap) presumptive remedy of the IRA, post-closure requirements remain appropriate and relevant.

- Treatment of groundwater by in situ enhanced bioremediation in the more contaminated areas and installation of biobarriers will reduce contaminant mass and control contaminated groundwater from migrating into Harrison Bayou. The above selected remedial actions employing treatment along with MNA, will ultimately restore the groundwater to attain groundwater cleanup standards/levels.

- MNA was selected as one component of the remedy based on available groundwater evidence as presented in the Addendum to the FS (Shaw, 2010). A tiered approach using three lines of evidence was used to examine the occurrence of natural attenuation. The first line of evidence evaluated reductions in COC concentrations over time and with distance, the second line of evidence evaluated geochemical indicators, while the third line of evidence entailed estimation of natural attenuation rates. Historical decreases in concentrations of chlorinated solvents and perchlorate in individual wells were observed in both shallow and intermediate groundwater, including the detection of daughter by-products that suggest the occurrence of complete reductive dechlorination. These results indicated the shallow and intermediate contaminant plumes are stable in certain areas (at the source area and side-downgradient in the plumes); however, there were increases in other well locations in the shallow groundwater that suggest a portion of the plume is migrating toward Harrison Bayou. The intermediate groundwater zone plume was relatively more stable than the shallow groundwater with less migration. Geochemical conditions were adequate for perchlorate degradation (as evidenced by non-detect nitrate/nitrite levels), but methanogenic conditions (needed for chlorinated ethene degradation) were not detected consistently throughout the site. Thus, natural attenuation was considered feasible for much of the site, but not as a sole remedy for the entire site. Additional evaluation, including the installation of additional monitoring wells, will be implemented as part of the MNA component. MNA, together with the in situ bioremediation and biobarriers, will ultimately restore the groundwater to attain groundwater cleanup standards/levels; this is anticipated to be completed in approximately

280 years. This approximate timeframe to achieve cleanup levels is considered reasonable based on the anticipated future land use of the site as a national wildlife refuge and the fact that there is no current or anticipated future use of groundwater as a drinking water supply. Thus, MNA is an appropriate component of the remedy for those regions outside the influence of the active remedies because it will protect human health and the environment and will document that further reductive dechlorination is occurring within the groundwater plume and that contaminant concentrations are being reduced to attain groundwater standards/levels.

- Landfill LUCs will remain in place as long as the landfill waste remains at the site or until the levels of COCs and COC by-products (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) allow for unlimited use and unrestricted exposure. The LUC restricting the use of groundwater to environmental monitoring and testing only and the LUC restricting land use to nonresidential will remain in place until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater allow for unlimited use and unrestricted exposure. The LUC to maintain the integrity of any current or future remedial or monitoring systems will remain in place until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met. The LUC to preserve any current or future remedial or monitoring systems will remain in place until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met. The LUC prohibiting groundwater use (except for environmental monitoring and testing) as a potable source will remain in place until the levels of COCs (i.e., all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in soil and groundwater allow for unlimited use and unrestricted exposure.

Groundwater monitoring will be conducted to confirm that COC and by-product contaminant concentrations in the groundwater plume are declining through treatment and natural processes and that Harrison Bayou is protected from groundwater seeps that fail to attain groundwater cleanup standards/levels. In situ bioremediation and biobarriers constitute treatment measures designed to reduce the COCs and by-products contaminant mass, and protect Harrison Bayou from contaminant and by-product contaminant seeps that would cause Harrison Bayou surface water to exceed Texas Surface Water Quality Standards. Monitoring will continue until it is demonstrated that groundwater has achieved the cleanup standards.

The selected remedies employing treatment will significantly reduce contaminant concentrations. The remedies employing treatment along with MNA will ultimately restore the groundwater to attain groundwater cleanup standards/levels. The performance of natural attenuation will be evaluated by 2 years of monitoring using data acquired from quarterly results. If MNA is not successful, the active remedies will be re-implemented, in part or in whole, based on evaluation of site data available at that time.

Five-year reviews will be performed to document that the remedy remains protective of human health and the environment.

Alternative 7 is readily implementable and no significant short-term risks to worker health and safety or to the community would be expected. The present worth cost of Alternative 7 is lower than the other remedial alternatives except for Alternative 1, the no further action alternative.

Based on the information currently available, the U.S. Army believes that the selected alternative meets the threshold criteria and provides the best balance of tradeoffs among the other alternatives with respect to the CERCLA §121(b) criteria used to evaluate remedial alternatives. The selected alternative will 1) be protective of human health and the environment; 2) comply with ARARs; 3) be cost-effective; 4) utilize permanent solution; and 5) utilizes treatment as a principal element.

The U.S Army will present details of the in situ bioremediation and biobarrier implementation, groundwater and surface water monitoring plan, LUCs implementation plan, and the MNA remedy implementation in a remedial design for LHAAP-16.

2.12.2 Description of the Selected Remedy

The selected remedy, Alternative 7, was outlined in **Section 2.9**; that description is expanded in the following discussion. The remedy may undergo modifications as a result of the RD and construction processes. Modifications of the remedy described in the ROD will be documented using a technical memorandum in the Administrative Record, an Explanation of Significant Differences (ESD), or a ROD amendment.

The major components of the remedy and the contingency remedies include:

- *Cap Maintenance*. The existing cap was designed as a standard RCRA-style multilayer cap. The current cap meets USEPA performance standards established for hazardous waste landfill closure and post-closure care. Therefore, the current cap will not be modified as part of this alternative. Further, consistent with the requirements described in the 1995 ROD for LHAAP-16 establishing an interim remedial action for the site to mitigate potential risks posed by buried landfill waste, the existing cap will continue to be monitored, maintained, and repaired, as necessary, to preserve its long-term effectiveness. This includes inspections of the landfill to check for erosion, settlement, and deep-rooted vegetation and implementation of necessary repairs. Routine maintenance and repair of the cap will include actions needed to preserve the integrity of the cap (e.g., mowing, seeding, and settlement/erosion repair). Post-closure requirements identified as ARARs in the IRA ROD are considered appropriate and relevant and include 40 CFR 264.228 (b)(1), (3), and (4), 264.310 (b)(1), (4) and (5)and 30 TAC 335.174. Although there is no permanent benchmark inside the Site 16 area, one is located adjacent to the site. Therefore 40 CFR 264.310(b)(6) is considered appropriate and relevant for a benchmark located near the landfill. In addition, those substantive requirements of 40 CFR 264.117 through 120 related to post-closure for the remedy-in-place are considered appropriate and relevant.

- *Land Use Control*. The LUC's objectives include maintaining the integrity of any current or future remedial or monitoring systems, and preventing the use of groundwater contaminated above cleanup levels as a potable water source. The groundwater treatment and MNA remedial components include a groundwater monitoring system that will be used to characterize the condition of the groundwater during the period the groundwater remedy is in place until the groundwater remediation goals are achieved, and to demonstrate achievement of the groundwater remediation goals when the groundwater remedy is complete. As a part of this groundwater remedy, the Army will maintain the remedial and monitoring systems associated with the groundwater remedies until these components of the remedy are no longer needed to achieve cleanup levels, and when these levels have been achieved. During the period of operation of the groundwater remedy, if any of the elements of the remedial and groundwater monitoring systems are damaged, destroyed, or become ineffective, they will be repaired or replaced with suitable components to ensure that the remedial and groundwater monitoring systems are able to provide data of the quality necessary to determine the progress of and eventual completion of this component of the remedy. The actions to be taken to implement these LUC objectives and requirements will be provided through modifying the "Comprehensive Land Use Control (LUC) Management Plan, Former Longhorn Army Ammunition Plant, Karnack, Texas" and detailed in the LUC RD.

- The LUCs' performance objectives are to prohibit access to the contaminated groundwater except for environmental monitoring and testing only, to preserve the integrity of the landfill cap, and to restrict intrusive activities (e.g., digging) that would degrade or alter the cap, to restrict land use to nonresidential, to maintain the integrity of any current or future remedial or monitoring systems and to prevent the use of groundwater contaminated above cleanup levels as a potable water source. The landfill LUCs will remain in place as long as the landfill waste remains at the site or until the levels of Contaminants of Concern (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) allow for unlimited use and unrestricted exposure. The LUCs restricting the use of groundwater to environmental monitoring and testing only and the LUC restricting land use to nonresidential will remain in place until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in surface and subsurface soil and groundwater allow for unlimited use and unrestricted exposure. The LUC to maintain the integrity of any current or future remedial or monitoring systems will remain in place until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-7) are met. The LUC prohibiting groundwater use (except for environmental monitoring and testing) as a potable source will remain in place until the levels of COCs (i.e., all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in soil and groundwater allow for unlimited use and unrestricted exposure. A LUC RD will be finalized as the land use component of the Remedial Design. Within 21 days of the issuance of the ROD, the Army will propose deadlines for completion of the RD Work Plan, RD, and Remedial Action Work Plan. The documents will be prepared and submitted to EPA and TCEQ pursuant to the FFA. The LUC RD will contain implementation and maintenance actions, including periodic inspections. The long-term groundwater and surface water monitoring and MNA performance monitoring plan will also be presented in the RD. The recordation notification for the site which will be filed with Harrison County will include a description of the LUCs. The boundary of the LUCs would enclose the site boundaries and the plume boundaries shown on **Figure 2-3**.

The Army will implement, maintain, monitor, report on and enforce land use controls at Army-owned property. The Army shall perform those actions related to land use control activities described in this ROD and in the Remedial Design for the ROD. For portions of the Site subject to land use controls that are not owned by the Army, the Army will monitor and report on the implementation, maintenance, and enforcement of land use controls, and coordinate with federal, state, and local governments and owners and occupants of properties subject to land use controls. The Army will provide notice of the groundwater and soil (surface and subsurface) contamination and any land use restrictions referenced in the ROD. The Army will send these notices to the federal, state and local governments involved at this site and the owners and occupants of the properties subject to those use restrictions and land use controls. The Army shall provide the initial notice within 90 days of ROD signature. The frequency of subsequent notifications will be described in the Remedial Design for the ROD. The Army remains responsible for ensuring that the remedy remains protective of human health and the environment. The Army will fulfill its responsibility and obligations under CERCLA and the NCP as it implements, maintains, and reviews the selected remedy.

Upon transfer of Army-owned property, the Army will provide written notice of the land use controls to the transferee of the groundwater and soil (surface and subsurface) contamination and any land use restrictions referenced in the ROD. Within 15 days of transfer, the Army shall provide EPA and TCEQ with written notice of the division of implementation, maintenance, and enforcement responsibilities unless such information has already been provided in the LUC RD. The LUC RD will address the procedures to be used by the Army and the transferee to document compliance with the LUCs described in this ROD. In the event property is transferred out of Federal control, the land use controls relating to property and groundwater restrictions shall be recorded in the deed and shall be enforceable by the United States and the state of Texas.

LUCs implementation and maintenance actions would be described in the RD for LHAAP-16. The LUCs would be included in the property transfer documents and a recordation of them would be filed in the Harrison County Courthouse. The LUCs will prevent human exposure to groundwater contaminated with chlorinated solvents, metals, and perchlorate through the prohibition of groundwater use (except for environmental monitoring and testing), require cap protection and maintenance, restrict land use to nonresidential, require maintenance of the integrity of any current or future remedial or monitoring systems and prevent the use of groundwater contaminated above cleanup levels as a potable water source. In addition, within 90 days of signature of this ROD, the U.S. Army shall request the Texas Department of Licensing and Regulation to notify well drillers of groundwater use prohibitions based on a preliminary LUC boundary. Within 21 days of the issuance of the Record of Decision, the Army will propose deadlines for completion of the RD Work Plan, RD, and Remedial Action Work Plan. The documents will be prepared and submitted to EPA and TCEQ pursuant to the FFA. The LUC RD will contain implementation and maintenance actions, including periodic inspections. Consistent with the dates presented for these documents, the U.S. Army shall: 1) request the Texas Department of Licensing and Regulation to notify well drillers of the final boundary of groundwater use prohibitions; and 2) notify the Harrison County Courthouse of the LUCs to include a map showing the area of groundwater use prohibition at the site, in accordance with 30 TAC 335.565.

Monitoring activities associated with the LUCs would be undertaken to confirm that groundwater is not being used and the cap is protected and maintained. Long-term operational requirements under this alternative would include maintenance of the LUCs. Groundwater monitoring will demonstrate no migration of the plume and the eventual reduction of contaminates to levels below cleanup levels. The need for continued groundwater and surface water monitoring will be evaluated every 5 years during the reviews. Monitoring for metals will be evaluated at the first five year review to determine if any further monitoring for metals is warranted. Sampling frequency and analytical requirements will be presented as an appendix to the RD for LHAAP-16.

- *In Situ Bioremediation*. The desired outcome will be to reduce contaminant mass and lower the contaminant concentrations that reach the biobarrier in the future. Elevated levels of chlorinated ethenes (TCE 1,2-DCE, and VC) have been observed in the shallow groundwater zone downgradient of the landfill cap at LHAAP-16, and will be treated by an addition of a carbon source. Evidence indicates that reductive dechlorination is taking place in the shallow groundwater zone at LHAAP-16, but carbon levels appear to decrease with distance from the landfill itself. Therefore, the addition of a carbon source will further encourage the growth of microorganisms in the subsurface. As the microorganisms multiply, they will consume available respiratory substrates including iron and sulfate. As those respiratory substrates are consumed, conditions are created which are favorable to destruction of chlorinated ethenes via reductive pathways. A bioaugmentation culture (e.g., SDC-9) will also be added to provide a microbial species specifically able to completely degrade TCE to harmless ethene. Injection of the carbon source and bioaugmentation culture into the shallow zone will be accomplished utilizing DPT, and into the intermediate zone by injection through the existing wells. The number of DPT injection points and the injection volumes will be finalized at that time. The design effort will consider optional injection patterns. Once the carbon source and the bioaugmentation culture have been injected into the subsurface, reducing conditions will be created, followed by a significant reduction in chlorinated ethene concentrations.

  The natural attenuation rates measured for TCE showed half-lives ranging from less than 2 years to more than 25 years. Half-lives measured for TCE daughter by-products (cis-1,2-DCE and VC) and perchlorate were much faster, so the attenuation rate of TCE determines the time to reach cleanup goals. The application of in situ bioremediation is expected to reduce the half-life for TCE to between 2 and 5 years, thus accelerating remediation in the treatment area.

- *Biobarriers.* The purpose of the biobarriers (in conjunction with natural attenuation) is to reduce groundwater concentrations to levels that will not cause surface water to exceed surface water standards, to control potential migration of contaminants from the landfill, and to reduce groundwater contaminant mass. A biobarrier will be installed in the downgradient portion of the contaminant plume to prevent contaminated groundwater from seeping into Harrison Bayou at concentrations that would cause surface water to exceed Texas Surface Water Quality Standards, SDWA MCL standards and TRRP Tier 1 Groundwater Residential PCLs. A second biobarrier will be installed at the edge of the landfill between 16WW38 and 16WW13 to control potential migration of VOCs from the landfill. Specifically, a row of injection points perpendicular to groundwater flow direction will be installed down-gradient of the shallow monitoring well close to Harrison Bayou (16WW12). The biobarrier will consist of emulsified oil that will enable ambient microorganisms to create favorable conditions and a bioaugmentation culture (e.g., SDC-9) to provide microbial species able to completely degrade TCE to ethene. The emulsified oil is a slow-release carbon source with an enhanced subsurface longevity; it will be injected to provide a long-lasting source of fermentable carbon to stimulate the biological reduction of perchlorate and TCE and its daughter products. Sufficient emulsified oil will be added to each injection point to provide a sustained carbon source for an estimated 3 to 5 years. Follow-up injections will be conducted if deemed necessary from the performance groundwater monitoring results. COC and by-product concentrations will be reduced as contaminated groundwater flows through the biobarrier. Concentrations of COCs and by-product downgradient of the biobarriers will be monitored to evaluate the continuing effectiveness of the biobarriers.

- *MNA to return groundwater to its potential beneficial use, wherever practicable*. A preliminary MNA evaluation demonstrated that natural attenuation is occurring in some areas at LHAAP-16. The attenuation of perchlorate, TCE, 1,2-DCE, VC, and 1,1-DCE have been observed at the source and side-downgradient of the plume. However, the shallow groundwater zone plume is still migrating along the groundwater flow direction toward Harrison Bayou. The intermediate groundwater zone plume is more stable with less migration along the flow direction. Thus, natural attenuation is a feasible remedy for certain portions of the site but not as a sole remedy for the entire plume due to migration concerns for the shallow zone. Therefore, MNA is proposed for LHAAP-16 in conjunction with in situ bioremediation to enhance reductive dechlorination within the groundwater plume. Biobarriers will prevent the seepage of contaminants and by-product contaminants into surface water (i.e. Harrison Bayou). Monitoring wells will be sampled for eight consecutive quarters to evaluate and confirm the occurrence of natural attenuation in conjunction with historical data. Data from the eight quarterly events will be combined with historic data to evaluate the effectiveness of various natural physical, chemical, and biological processes in reducing contaminant concentrations.

  - *Performance objectives to evaluate the MNA remedy performance after 2 years.* Each of the general performance objectives must be met as indicated below. If the criteria are not met to illustrate that MNA is an effective remedy, the contingency action would be initiated. If MNA is effective, a baseline will be established from the data to this point in time. Specific evaluation criteria will be developed in the RD. The MNA evaluation will be based on consideration of plume stability, the USEPA lines of evidence (USEPA, 1999) and the anaerobic screening (USEPA, 1998) as follows:

  - Plume stability (i.e., the plume concentrations are decreasing in the majority of performance wells, and the plume is not expanding in area as demonstrated with compliance wells).

  - MNA potential based on evaluation biodegradation screening scores using USEPA guidance

  - MNA Process Evaluation demonstrated based on an attenuation rate calculated with empirical performance monitoring data, and MNA Process Demonstration based on the presence of daughter products and bacterial culture counts.

- *A contingency remedy involving in situ bioremediation to reach the RAOs if MNA is found to be ineffective.* The contingency remedy will use reapplication of bio-amendments (i.e. additional in situ bioremediation) to address the ineffective aspects of MNA. The area and the elements of the contingency remedy would be selected based on the entire data set available. If the contingency remedy is implemented, it will be documented in an ESD.

- *Initiate LTM.* If MNA is determined to be effective, monitoring will be conducted to evaluate the remedy performance and determine if the plume conditions remain constant, improve or worsen after the baseline is established. LTM will be implemented at a frequency of semiannual for 3 years, then annually until the next five-year review. The performance monitoring plan will be developed in the RD and will be based on USEPA guidance (USEPA, 2004).

- *Continue LTM to evaluate remedy performance and determine if plume conditions remain constant, improve, or worsen.* The results from monitoring will be reviewed during the five-year review. Unless otherwise indicated by the data, the wells will then be sampled annually.

- *Groundwater and Surface Water Monitoring.* Groundwater monitoring will continue at LHAAP-16 to evaluate the effectiveness of the cap, confirm the decrease in COC concentrations within the groundwater plume, and to protect surface water in Harrison Bayou from the seepage of contaminated groundwater that would prevent Harrison Bayou from attaining the surface water standards for those contaminants. Following completion of the MNA evaluation, groundwater and surface water monitoring will continue at a number of locations. The monitoring program will be established during remedial design. Following the MNA evaluation, sampling will be conducted semi-annually for 3 years. Surface water and wells will then be sampled annually until the next five-year review and annually thereafter until recommended otherwise by the five-year review.

- *Long-Term Operations.* Long-term operations will include maintenance of the landfill cap, maintenance of LUCs, and groundwater and surface water monitoring. Additional injections (approximately every 5 years) of vegetable oil may be required at the biobarriers to provide continued treatment effectiveness. LUCs include activities to protect the integrity of the landfill cap, restrict groundwater and land use at the site and maintain the integrity of any monitoring system. Groundwater use restrictions will remain in place until groundwater COC and by-product contaminant concentrations (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) allow for unlimited use and unrestricted exposure. Groundwater and surface water monitoring will be implemented at least every 5 years. Monitoring will continue until the sampling data demonstrate that there are no releases or threat of releases of contaminated groundwater into Harrison Bayou at levels that would cause surface water to exceed the Texas Surface Water Quality Standards, the SDWA MCLs, and TRRP Tier 1 Groundwater Residential PCLs for the COCs and by-product COCs that are present.

2.12.3 Cost Estimate for the Selected Remedy

Table 2-9 presents the present worth analysis of the cost for the selected remedy, Alternative 7. The information in the table is based on the best available information regarding the anticipated scope of the remedial alternative. The quantities used in the estimate are for estimating purposes only. Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternative. Modifications may be documented in the form of a memorandum in the Administrative Record, an ESD, or a ROD amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within -30 to +50 percent of the actual project cost.

The total project present worth cost of this alternative is approximately $2,230,000, using a discount rate of 2.7%. The capital cost is estimated at $440,000. The total O&M present value cost is estimated at approximately $1,790,000. The O&M cost includes evaluation of MNA, maintenance of the cap, maintenance of LUCs, two additional emulsified vegetable oil injections subsequent to the initial implementation of the barrier, and LTM through Year 30. The LTM will support the required CERCLA five-year reviews.

2.12.4 Expected Outcomes of Selected Remedy

The purpose of this response action is to attain the RAOs stated in Section 2.8 of this ROD. The groundwater will be restored to attain groundwater cleanup standards/levels, to the extent practicable. With respect to the COCs and by-product contaminants found in the groundwater at the site, the groundwater cleanup standards/levels include attainment of the SDWA MCL for those COCs and by-product (i.e., daughter) contaminants that have a MCL, to the extent practicable, consistent with 40 CFR § 300.430(e)(2)(i)(B & C). In the absence of federal drinking water standards, cleanup levels will be based on TRRP Tier 1 Groundwater Residential PCLs (Table 2-7). Surface water standards in surface waters impacted by the contaminated groundwater seeps at LHAAP will be protected as well. The Texas Surface Water Quality Standards found at 30 TAC

307, or if those standards are not available, the SDWA MCLs, or in the absence of federal drinking water standards, TRRP Tier 1 Groundwater Residential PCLs constitute the surface water standards in Harrison Bayou.

The expected outcome of the selected remedy is that the contaminants and by-product contaminants in the groundwater will be reduced to attain the SDWA MCLs and TRRP Tier 1 Groundwater Residential PCLs, and that any groundwater seeping into Harrison Bayou will be at concentrations that do not result in exceedances of the Texas Surface Water Quality Standards for the COCs and by-product COCs. Achievement of the groundwater cleanup standards/levels is anticipated to be completed in approximately 280 years. The actual time frame depends on the success of the active remediation, but, for cost estimating purposes, it is assumed that five-year reviews will continue until Year 30. When the groundwater cleanup levels are achieved, the LUC for the maintenance of the monitoring system will be removed. The groundwater and soil LUC restrictions will be maintained until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) in soil and groundwater allow for unlimited use and unrestricted exposure. The LUCs to protect the landfill remedy will remain in place as long as the landfill waste remains at the site or until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) allow unlimited use and unrestricted exposure. In the short-term (prior to the groundwater achieving cleanup levels), the site will be made part of a national wildlife refuge operated by USFWS, and will continue as such in the long-term (after the groundwater achieves cleanup levels).

In addition, the monitoring activities associated with MNA will confirm the protection of human health and the environment by documenting the return of the groundwater to its potential beneficial use as a drinking water supply, by documenting reduction of the contaminant mass and protection of surface water through containment of the plume. The groundwater LUC will prohibit the use of the site's groundwater except for environmental monitoring and testing.

As part of the evaluation of MNA, attenuation rates are computed and evaluated in accordance with the USEPA guidance material (USEPA, 1998). Time-dependent attenuation rate constants and estimated in-well cleanup times are determined based on COC concentration data over time from individual wells assuming first order degradation kinetics. Attenuation rates are calculated for the monitoring wells with the highest concentrations for which the available data allow such a calculation. Attenuation rates are based on the following formula from the USEPA guidance (USEPA, 1998):

$$C = C_o e^{-kt}$$

where: C = concentration at time t

C_o = initial concentration
k = attenuation rate constant (first order reaction).

2.13 Statutory Determinations

Under CERCLA §121 and the NCP, the U.S. Army must select remedies that are protective of human health and the environment, comply with ARARs (unless a statutory waiver is justified), are cost effective, and utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. In addition, CERCLA includes a preference for remedies that employ treatment that permanently and significantly reduces the volume, toxicity, or mobility of hazardous wastes as a principal element and a bias against off-site disposal of untreated wastes. The following sections discuss how the selected remedy meets the statutory requirements.

2.13.1 Protection of Human Health and the Environment

The selected remedy, Alternative 7 will achieve the RAOs for LHAAP-16 by protecting human health from exposure to landfill waste and contaminated groundwater, reducing the COC and by-product contaminant concentrations within the groundwater plume to attain groundwater cleanup standards/levels, and reducing surface water quality impacts to Harrison Bayou such that surface water standards/levels for COCs and by-products are not exceeded. LUCs and continued maintenance of the existing cap would ascertain that receptors are not exposed to landfill contents or contaminated groundwater. The LUCs associated with the contaminated groundwater would be required until the COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) and by-product contaminants attained levels in soil and groundwater that allow for unlimited use and unrestricted exposure.

The cap is considered an effective means of source control to reduce contamination entering the groundwater via prevention of surface water infiltration. In situ bioremediation would reduce the mass of contamination in the heart of the shallow groundwater plume and in specific target areas within the intermediate groundwater zone. The biobarriers would prevent the eastward migration of COCs in the shallow groundwater. Natural attenuation would also reduce the COC concentrations in both the shallow and intermediate groundwater plumes over time, thereby reducing the potential risk of human exposure. A MNA program would be implemented to verify the effectiveness of monitored natural attenuation following shutdown of the extraction wells and completion of the in situ bioremediation. Further monitoring would be used to evaluate contaminant and by-product contaminant migration, confirm that the COCs and by-product (daughter) contaminants in the groundwater plumes continue to degrade, and verify that contaminant and by-product contaminant concentration levels in Harrison Bayou do not exceed the in-stream standards/levels of the Texas Surface Water Quality Standards, SDWA MCLs and TRRP Tier 1 Groundwater Residential PCLs. The eventual groundwater concentration remedial action objective is the return of groundwater to its potential beneficial uses as drinking water, wherever practicable. Achievement of this RAO will be measured by attainment of the SDWA MCLs and TRRP Tier 1 Groundwater Residential PCLs for all COCs.

A site-wide ecological baseline risk assessment has been performed for LHAAP. As noted in **Section 2.7.3**, no action is required to address soil concentrations outside the landfill to protect ecological receptors at LHAAP-16. Therefore, ecological risks can be controlled by preventing contact with contents of the landfill. Maintenance of the existing cap and enforcement of LUCs will achieve that objective.

There are no short-term threats associated with the selected remedy that cannot be readily controlled. In addition, no adverse cross-media impacts are expected from the selected remedy.

2.13.2 Compliance with ARARs

The selected remedy complies with all ARARs. The ARARs are presented below and in **Table 2-10**.

Chemical-Specific ARARs

The chemical-specific ARAR is the attainment of the SDWA MCL for all groundwater COCs and by-product contaminants. In the absence of federal drinking water standards, cleanup levels will be based on TRRP Tier 1 Groundwater Residential PCLs. The selected remedial action employs treatment including in situ bioremediation and biobarriers, and passive remedial action (i.e., MNA) to return the contaminated shallow and intermediate groundwater zone at LHAAP-16 to its potential beneficial use as drinking water, wherever practicable. For the purposes of this ROD attainment of the SDWA MCLs or in the absence of federal drinking water standards, cleanup levels based on TRRP Tier 1 Groundwater Residential PCLs constitutes a return of the contaminated groundwater to it potential beneficial use as a drinking water. If a return to potential beneficial uses is not practicable based upon 40 CFR§ 300.430(f)(1)(ii)(C), this alternative would still meet the NCP remedy selection requirements by reducing or controlling exposure to the contaminated groundwater consistent with 40 CFR§ 300.430(e)(9). With respect to the surface waters impacted by the contaminated groundwater seeping into Harrison Bayou, the Texas Surface Water Quality Standards (in-stream) found at 30 TAC 307, or if those standards are not available, the SDWA MCLs, or in the absence of federal drinking water standards, cleanup levels based on TRRP Tier 1 Groundwater Residential PCLs constitute the surface water standards confirming protectiveness of the remedy.

Location-Specific ARARs

The activities that will be conducted under this alternative will comply with location-specific ARARs.

Action-Specific ARARs

The selected remedy has potential action-specific ARARs related to the following activities: site preparation, construction, and excavation activities; waste management activities, well construction and post closure care.

- **Site preparation, construction, and excavation activities**: Certain on-site preparation, construction, and/or excavation activities will be necessary under all remediation actions to prepare the site for remediation, including the soil-moving or site-grading activities. Storm water discharges from construction activities that disturb equal to or greater than one acre of land must comply with the substantive requirements of a USEPA National Pollutant Discharge Elimination System (NPDES) general permit (40 CFR 122.26; 30 TAC 205, Subchapter A; and 30 TAC 308.121), depending on the amount of acreage disturbed. Substantive requirements include implementation of good construction management techniques; phasing of large construction projects; minimal clearing; and sediment, erosion, structural, and vegetative controls to mitigate runoff and satisfy discharge requirements.

- **Waste Management**: The processes of monitoring, intercepting, or treating contaminated groundwater may generate a variety of primary and secondary waste streams (e.g., soil, personal protective equipment, and dewatering and decontamination fluids). These waste streams are expected to be non-hazardous waste. All wastes must be managed in accordance with the ARARs for waste management listed in **Table 2-10** for the particular type of waste stream or contaminants in the waste.

- **Well construction**: The remedial action may involve the placement, use, or eventual plugging and abandonment of some type of groundwater monitoring, injection, and/or extraction wells, either for in situ treatment or extraction of the contaminated groundwater or for LTM of the groundwater. Available standards for well construction and plugging/abandonment would provide ARARs for such actions and include 30 TAC 331, Subchapters A, C, and H. Texas has promulgated technical requirements in Chapter 76 of Title 16 of the TAC applicable to construction, operation, and plugging/abandonment of water wells. In particular, 16 TAC 76.1000 (*Locations and Standards of Completion for Wells*), 16 TAC 76.1002 (*Standards for Wells Producing Undesirable Water or Constituents*) (LHAAP-16 contaminated groundwater could be considered "undesirable water" defined pursuant to Section 76.10[36] as "water that is injurious to human health and the environment or water that can cause pollution to land or other waters"), 16 TAC 76.1004 (*Standards for Capping and Plugging of Wells and Plugging Wells that Penetrate Undesirable Water or Constituent Zones*), and 16 TAC 76.1008 (*Pump Installation*) may provide ARARs for the placement, construction, and eventual plugging/abandonment of groundwater injection or extraction wells or the placement and long-term operation of groundwater monitoring wells for proposed groundwater remedial strategies.

- **Post-closure Care**: Closure and post-closure ARARs were identified for LHAAP-16 in the IRA ROD and included 30 TAC 335.112, 335.118, 335.119 and 335.174 and 40 CFR

Sections 264.228 and 264.310 addressing landfills and surface impoundments storing hazardous waste. Closure requirements were met during implementation of the (cap) presumptive remedy of the IRA. Post-closure requirements are relevant and appropriate, and include 40 CFR 264.228(b)(1), (3) and (4); 264.310(b)(1), (4), (5), and (6); and 30 TAC 335.174. Although there is no permanent benchmark inside the LHAAP-16 area, one is located adjacent to the Site. Therefore, 40 CFR 264.310(b)(6) is relevant and appropriate for a benchmark located near a landfill. In addition, those substantive requirements of 40 CFR 264.117 through 120 related to post-closure for the remedy in place are relevant and appropriate.

2.13.3 Cost-Effectiveness

Alternative 7 has the lowest present worth and capital costs of the action alternatives that were evaluated in the FS (Jacobs, 2002) and FS Addendum (Shaw, 2010). Alternative 7 utilizes active technologies (in situ bioremediation and biobarriers) prior to MNA; those active technologies lead to much lower monitoring costs in the future, thus giving Alternative 7 a relatively low total present value cost. **Table 2-9** is the cost estimate summary table for the selected remedy.

2.13.4 Utilization of Permanent Solutions and Alternative Treatment (or Resource Recovery) Technologies to the Maximum Extent Practicable

The U.S. Army has determined that the selected final remedy represents the maximum extent to which permanent solutions and treatment technologies can be utilized in a practicable manner at the site. In situ bioremediation will lower groundwater COC concentrations in the most contaminated portion of the groundwater plume. Biobarriers between the landfill and Harrison Bayou will provide additional reduction of COC concentrations in the groundwater through degradation by biological processes prior to seeping into Harrison Bayou. The active biodegradation that occurs as part of the natural attenuation, together with dilution, dispersion, and other natural processes has the capability to ultimately reduce the groundwater contaminants to cleanup levels. Although none of the landfill waste will be actively treated, the long-term reliability of the landfill cap to control infiltration, contaminant runoff, and contaminant exposure depends on adequate long-term inspection and maintenance. If a portion of the cap is breached and contaminants subsequently leach into the groundwater, the biobarrier would capture the additional contamination. However, the breach would need to be corrected in a reasonable time frame, and the increased groundwater contaminant loading would increase the frequency of bioremediation amendment injections at the biobarrier.

Alternative 7 would provide almost immediate protection because the LUCs would be implemented relatively quickly. Maintenance of this control would be required until COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-7) and by-product (daughter) contaminant concentrations in soil and groundwater allow for unlimited use and unrestricted exposure.

2.13.5 Preference for Treatment as a Principal Element

The selected remedy satisfies the statutory preference for treatment as a principal element of the remedy. The selected final remedy will reduce the toxicity, mobility, or volume of COCs in groundwater through the implementation of in situ bioremediation and biobarriers. The in situ bioremediation will lower COC concentrations in the most contaminated portion of the shallow groundwater plume to levels that can be effectively treated by the biobarrier near Harrison bayou. The biological activity in the biobarriers and the bioremediation treatment area will significantly reduce the overall mass of COCs in the groundwater. In conjunction with natural attenuation, these treatments will convert the COCs to innocuous byproducts, thereby reducing the toxicity of the contaminants. In addition, natural attenuation will provide a reduction in the volume of contaminated groundwater. Although none of the landfill waste will be actively treated, the potential mobility and toxicity of the landfill waste contaminants will be minimized through proper landfill cap maintenance, and the biobarrier near the landfill fence line.

2.13.6 Five-Year Review Requirements

Section 121(c) of CERCLA and NCP §300.430(f)(5)(iii)(C) provide the statutory and legal bases for conducting five-year reviews. Because this remedy will result in contaminants that remain onsite above levels that allow unlimited use and unrestricted exposure, a review will be conducted at least every 5 years to ascertain that the remedy continues to provide adequate protection of human health and the environment.

2.14 Significant Changes from the Proposed Plan

The Proposed Plan for LHAAP-16 was released for public comments on October 10, 2010. The Proposed Plan identified Alternative 7 as the Preferred Alternative for groundwater remediation. The U.S. Army reviewed all written comments during the public comment period (there were no verbal comments). After careful consideration of the comments, it was determined that no significant changes to the remedy, as originally identified in the Proposed Plan, were necessary or appropriate.

Table 2-1
Summary of Chemicals of Potential Concern and Medium-Specific Exposure Point Concentrations

Scenario Timeframe: Future
Medium: Soil
Exposure Medium: Soil (0 to 5.0 feet below ground surface)

Exposure Point	Chemical	Concentration Detected[1] (mg/kg)		Number of Samples with Detectable Conc.	Exposure Point Concentration (mg/kg)	Statistical Measure
		Minimum	Maximum			
Incidental ingestion, inhalation of particulates, inhalation of volatiles, dermal contact	**Metals**					
	Aluminum	4.52E+03	2.15E+04	20	2.15E+04	maximum
	Antimony	4.8E-01	4.8E-01	1	1.64E+00	95% UCL
	Arsenic	1.43E+00	1.44E+01	36	7.44E+00	95% UCL
	Barium	4.67E+01	3.84E+02	34	1.72E+02	95% UCL
	Beryllium	3.80E-01	1.4E+00	9	1.4E+00	maximum
	Cadmium	5.10E-01	8.60E-01	4	5.70E-01	95% UCL
	Chromium	7.80E+00	4.09E+01	40	2.27E+01	95% UCL
	Cobalt	2.80E+00	1.98E+01	19	1.98E+01	maximum
	Copper	3.40E+00	1.05E+01	14	9.17E+00	95% UCL
	Lead	3.02E+00	4.93E+01	41	1.81+01	95% UCL
	Manganese	2.92E+01	1.27E+03	20	1.27E+03	maximum
	Mercury	2.00E-02	6.20E-02	7	7.00E-02	95% UCL
	Nickel	4.10E+00	1.73E+01	29	1.18E+01	95% UCL
	Selenium	6.10E-01	1.40E+00	6	7.40E-01	95% UCL
	Silver	5.50E-01	5.50E-01	1	6.9E-01	95% UCL
	Strontium	2.4E+00	6.27E+01	14	6.27E+01	maximum
	Thallium	1.80E-01	5.96E+00	8	1.18+00	95% UCL
	Vanadium	1.43E+01	4.33E+01	9	4.33E+01	maximum
	Zinc	1.19E+01	1.68E+02	20	7.92E+01	95% UCL
	Semivolatile Organics					
	Butyl Benzyl Phthalate	9.60E-01	9.60E-01	1	3.32E-01	95% UCL
	Di-N-Butyl Phthalate	1.60E+00	1.90E+00	8	6.75E-01	95% UCL
	Volatile Organics					
	Acetone	2.20E-02	1.03E-01	4	1.60E-02	95% UCL
	Methylene Chloride	5.00E-03	1.00E-02	3	6.40E-03	95% UCL
	Styrene	2.00E-03	9.30E-02	2	8.10E-03	95% UCL
	Trichloroethene	6.50E-02	2.20E-01	4	1.10E-02	95% UCL

Table 2-1 *(continued)*
Summary of Chemicals of Potential Concern and Medium-Specific Exposure Point Concentrations

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	Chemical	Concentration Detected[1] (µg/L) Minimum	Concentration Detected[1] (µg/L) Maximum	Number of Samples with Detectable Conc.	Exposure Point Concentration (µg/L)	Statistical Measure
Incidental ingestion, inhalation of volatiles, dermal contact	**Explosive**					
	1,3-Dinitrobenzene	3.29E-01	1.56E+00	18	1.56E+00	maximum
	2,4,6-Trinitrotoluene	9.00E-01	1.56E+00	3	2.40E+02	maximum[a]
	4-Amino-2,6-Dinitrotoluene	5.90E-02	1.00E+00	18	1.00E+00	maximum
	2,6-Dinitrotoluene	4.50E-02	2.63E-01	10	2.63E-01	maximum
	HMX	1.20E-01	2.90E+00	2	2.90E+00	maximum
	Nitrobenzene	6.20E-02	1.50E+00	8	2.00E+01	maximum[a]
	3-Nitrotoluene	2.00E-01	1.00E+00	3	1.10E+01	maximum[a]
	Tetryl	3.49E-01	4.40E+00	3	3.60E+01	maximum[a]
	RDX	2.70E-01	4.75E+00	15	2.00E+02	maximum[a]
	1,3,5-Trinitrobenzene	3.02E-01	7.40E-01	3	2.20E+00	maximum[a]
	Metals					
	Aluminum	1.10E+02	6.70E+04	34	6.70E+04	maximum
	Arsenic	7.00E+00	3.40E+01	24	3.40E+01	maximum
	Barium	1.70E+01	9.90E+03	78	9.90E+03	maximum
	Beryllium	6.00E-01	7.40E+00	6	7.40E+00	maximum
	Cadmium	1.10E+00	5.45E+00	7	8.00E+00	maximum[a]
	Chromium	1.00E+01	5.22E+03	52	5.22E+03	maximum
	Cobalt	5.30E+01	1.10E+03	4	1.10E+03	maximum
	Copper	2.10E+01	4.84E+02	19	4.84E+02	maximum
	Lead	3.00E+00	5.70E+01	14	2.00E+02	maximum[a]
	Manganese	1.50E+01	2.98E+04	50	2.98E+04	maximum
	Mercury	2.00E-01	8.60E-01	12	1.60E+00	maximum[a]
	Nickel	1.50E+01	1.63E+03	45	1.63E+03	maximum
	Selenium	7.00E+00	1.56E+01	8	1.56E+01	maximum
	Silver	1.40E+01	1.14E+02	4	1.14E+02	maximum
	Strontium	5.80E+01	1.04E+04	51	1.04E+04	maximum
	Thallium	1.20E+01	1.20E+01	1	1.20E+01	maximum
	Vanadium	9.70E+01	1.46E+02	3	1.46E+02	maximum
	Zinc	2.10E+01	3.70E+04	26	3.70E+04	maximum
	Pesticides					
	Aldrin	4.00E-02	4.00E-02	1	4.00E-02	maximum
	Semivolatile Organics					
	Bis(2-ethylhexyl)phthalate	1.10E+01	2.60E+01	5	2.60E+01	maximum
	Butyl Benzyl Phthalate	5.00E+00	7.00E+00	3	7.00E+00	maximum

Scenario Timeframe: Future
Medium: Groundwater

Table 2-1 *(continued)*
Summary of Chemicals of Potential Concern and Medium-Specific Exposure Point Concentrations

Exposure Medium: Groundwater

Exposure Point	Chemical	Concentration Detected[1] (µg/L)		Number of Samples with Detectable Conc.	Exposure Point Concentration (µg/L)	Statistical Measure
		Minimum	Maximum			
Incidental ingestion, inhalation of volatiles, dermal contact	***Volatile Organics***					
	Acetone	1.00E+01	3.92E+03	4	3.92E+03	maximum
	Benzene	8.30E-01	5.00E+00	4	5.00E+00	maximum
	Bromodichloromethane	1.10E+00	8.40E+00	3	8.40E+00	maximum
	2-Butanone	6.50E+00	6.50E+00	1	3.40E+01	maximum[a]
	Chloroform	5.20E-01	3.60E+01	21	1.20E+02	maximum
	1,1-Dichloroethane	6.00E-01	3.60E+01	4	3.60E+01	maximum
	1,1-Dichloroethene	9.90E-01	7.40E+02	16	7.40E+02	maximum
	1,2-Dichloroethane	2.20E+01	1.60E+02*	6	1.60E+02	maximum
	1,2-Dichloroethene	1.60E+01	2.75E+05	11	2.75E+05	maximum
	cis-1,2-Dichloroethene	5.20E-01	2.70E+05	53	5.20E+05	maximum[a]
	1,1,2-Trichloroethane	1.20E+01	1.20E+01	1	1.20E+01	maximum
	Ethylbenzene	5.00E+00	5.00E+00	1	5.00E+00	maximum
	Methylene chloride	5.6E-01*	3.50E+03	16	3.50E+03	maximum
	Toluene	2.90E+01	2.90E+01	1	2.90E+01	maximum
	Trichloroethene	8.40E-01	5.8E+04*	104	1.60E+05	maximum[a]
	Trichlorofluoromethane	8.00E-01	8.92E+02	2	8.92E+02	maximum
	1,2,4-Trimethylbenzene	6.80E-01	2.40E+01	2	2.40E+01	maximum
	1,3,5-Trimethylbenzene	1.60E+01	1.60E+01	1	1.60E+01	maximum
	Vinyl Chloride	4.80E+00	1.10E+04	17	1.10E+04	maximum
	Xylene	8.00E-01	1.20E+01	2	1.20E+01	maximum

Notes

[1] **Minimum/maximum detected concentration above the reporting limit**

* Maximum concentration was from a duplicate sample collected during the sampling event

[a] Maximum detected concentration from a grab sample

µg/L micrograms per liter
HMX high melting explosives
RDX 1,3,5-Trinitroperhydro-1,3,5-triazine

References

Jacobs Engineering Group, Inc. (Jacobs), 2001, *Final Baseline Risk Assessment Human Health Evaluation, Site 16 Landfill remedial Investigation/Feasibility Study, Longhorn Army Ammunition Plant, Karnack, Texas*, Final, June.

Summary of Chemicals of Potential Concern and Medium-Specific Exposure Point Concentrations

The table presents the chemicals of potential concern (COPCs) and exposure point concentration (EPC) for each (i.e. the concentration used to estimate the exposure and risk from each COPC). The table includes the range of concentrations detected for each COPC, the frequency of detection (i.e. the number of times the chemical was detected in the samples collected at the site), the EPC, and the statistical measure upon which the EPC was based. The COPCs listed are the ones that were quantitatively evaluated for carcinogenic risk and non-carcinogenic hazard in the Baseline Human Health Risk Assessment (Jacobs, 2001a).

Table 2-2
Carcinogenic Toxicity Data Summary

Pathway: Ingestion, Dermal Contact				
Chemical of Concern	**Oral Cancer Slope Factor (mg/kg-day)**	**Dermal Cancer Slope Factor (mg/kg-day)**	**Weight of Evidence/ Carcinogen Guideline Description**	**Source/Date**
Explosive				
1,3-Dinitrobenzene	---	---	---	---
2,4,6-Trinitrotoluene	3.00E-02	3.00E-02	--	USEPA-IRIS, 1999
4-Amino-2,6-Dinitrotoluene	1.00E-02	1.00E-02	---	TNRCC, 2000
2,6-Dinitrotoluene	6.80E-01	6.80E-01	---	USEPA-IRIS, 1999
HMX	---	---	---	---
Nitrobenzene	---	---	---	---
3-Nitrotoluene	---	---	---	---
Tetryl	---	---	---	---
RDX	1.10E-01	1.10E-01	---	USEPA-IRIS, 1999
1,3,5-Trinitrobenzene	---	---	---	---
Metals				
Aluminum	---	---	---	---
Antimony	---	---	---	---
Arsenic	1.50E+00	5.00E+00	---	USEPA-IRIS, 1999
Barium	---	---	---	---
Beryllium	---	---	---	---
Cadmium	---	---	---	---
Chromium	---	---	---	---
Cobalt	---	---	---	---
Copper	---	---	---	---
Lead	---	---	---	---
Manganese	---	---	---	---
Mercury	---	---	---	---
Nickel	---	---	---	---
Selenium	---	---	---	---
Silver	---	---	---	---
Strontium	---	---	---	---
Thallium	---	---	---	---
Vanadium	---	---	---	---
Zinc	---	---	---	---
Pesticides				
Aldrin	1.70E+01	1.70E+01	--	USEPA-IRIS, 1999
Semivolatile Organics				
Bis(2-ethylhexyl)phthalate	1.40E-02	1.40E-02	--	USEPA-IRIS, 1999
Butyl Benzyl Phthalate	---	---	---	---
Di-N-Butyl Phthalate	---	---	---	---
Volatile Organics				
Acetone	---	---	---	---
Benzene	2.90E-02	2.90E-02	--	USEPA-IRIS, 1999
Bromodichloromethane	6.20E-02	6.20E-02		USEPA-IRIS, 1999
2-Butanone (MEK)	---	---	---	---
Chloroform	6.10E-03	6.10E-03	--	USEPA-IRIS, 1999

Table 2-2 *(continued)*
Carcinogenic Toxicity Data Summary

Chemical of Concern	Oral Cancer Slope Factor (mg/kg-day)	Dermal Cancer Slope Factor (mg/kg-day)	Weight of Evidence/ Carcinogen Guideline Description	Source/Date
1,1-Dichloroethane	---	---	---	---
1,1-Dichloroethene	6.00E-01	6.00E-01	--	USEPA-IRIS, 1999
1,2-Dichloroethane	9.10E-02	9.10E-02	--	USEPA-IRIS, 1999
1,2-Dichloroethene	---	---	---	---
cis-1,2-Dichloroethene	---	---	---	---
1,1,2-Trichloroethane	5.70E-02	5.70E-02	--	USEPA-IRIS, 1999
Ethylbenzene	---	---	---	---
Methylene chloride	7.50E-03	7.50E-03	--	USEPA-IRIS, 1999
Styrene	---	---	---	---
Toluene	---	---	---	---
Trichloroethene	1.10E-02	1.10E-02	--	USEPA-NCEA, 1999
Trichlorofluoromethane	---	---	---	---
1,2,4-Trimethylbenzene	---	---	---	---
1,3,5-Trimethylbenzene	---	---	---	---
Vinyl Chloride	1.90E+00	1.90E+00	--	USEPA-HEAST, 1997
Xylene	---	---	---	---

Pathway: Inhalation

Chemical of Concern	Unit Risk Factor (µg/m3)	Inhalation Cancer Slope Factor (mg/kg-day)	Weight of Evidence/ Carcinogen Guideline Description	Source/Date
Explosive				
1,3-Dinitrobenzene	---	---	---	---
2,4,6-Trinitrotoluene	---	---	---	---
4-Amino-2,6-Dinitrotoluene	---	---	---	---
2,6-Dinitrotoluene	---	---	---	---
HMX	---	---	---	---
Nitrobenzene	---	---	---	---
3-Nitrotoluene	---	---	---	---
Tetryl	---	---	---	---
RDX	---	---	---	---
1,3,5-Trinitrobenzene	---	---	---	---
Metals				
Aluminum	---	---	---	---
Antimony	---	---	---	---
Arsenic	4.30E-03	1.50E+01	---	USEPA-IRIS, 1999
Barium	---	---	---	---
Beryllium	2.40E-03	8.40E+00	--	USEPA-IRIS, 1999
Cadmium	1.80E-03	6.30E+00	--	USEPA-IRIS, 1999
Chromium	1.20-E02	4.20+01	---	USEPA-IRIS, 1999
Cobalt	---	---	---	---
Copper	---	---	---	---
Lead	---	---	---	---

Table 2-2 *(continued)*
Carcinogenic Toxicity Data Summary

Chemical of Concern	Oral Cancer Slope Factor (mg/kg-day)	Dermal Cancer Slope Factor (mg/kg-day)	Weight of Evidence/ Carcinogen Guideline Description	Source/Date
Manganese	---	---	---	---
Mercury	---	---	---	---
Nickel	---	---	---	---
Selenium	---	---	---	---
Silver	---	---	---	---
Strontium	---	---	---	---
Thallium	---	---	---	---
Vanadium	---	---	---	---
Zinc	---	---	---	---
Pesticides				
Aldrin	4.90E-03	1.72E+01	--	USEPA-IRIS, 1999
Semivolatile Organics				
Bis(2-ethylhexyl)phthalate	---	---	---	---
Butyl Benzyl Phthalate	---	---	---	---
Di-N-Butyl Phthalate	---	---	---	---
Volatile Organics				
Acetone	---	---	---	---
Benzene	7.80E-06	2.70E-02	--	USEPA-IRIS, 1999
Bromodichloromethane	---	---	---	---
2-Butanone (MEK)	---	---	---	---
Chloroform	2.30E-05	8.10E-02	--	USEPA-IRIS, 1999
1,1-Dichloroethane	---	---	---	---
1,1-Dichloroethene	5.00E-05	1.80E-01	--	USEPA-IRIS, 1999
1,2-Dichloroethane	2.60E-05	9.10E-02	--	USEPA-IRIS, 1999
1,2-Dichloroethene	---	---	---	---
cis-1,2-Dichloroethene	---	---	---	---
1,1,2-Trichloroethane	1.60E-05	5.60E-02	--	USEPA-IRIS, 1999
Ethylbenzene	---	---	---	---
Methylene chloride	4.70E-07	1.65E-03	--	USEPA-IRIS, 1999
Styrene	---	---	---	---
Toluene	---	---	---	---
Trichloroethene	1.70E-06	5.95E-03	--	---
Trichlorofluoromethane	---	---	---	---
1,2,4-Trimethylbenzene	---	---	---	---
1,3,5-Trimethylbenzene	---	---	---	---
Vinyl Chloride	---	3.00E-01	--	USEPA-HEAST, 1997
Xylene	---	---	---	---

Notes
--- : No information available
μg/m³: micrograms per cubic meter
HMX: High melting explosives
mg/kg-day: milligrams per kilogram per day
RDX: 1,3,5-Trinitroperhydro-1,3,5-triazine

Weight of Evidence/Carcinogen Guideline Description Information:
Not provided in the Final Baseline Risk Assessment Human Health Evaluation(Jacobs, 2001a)

References

Table 2-2 (*continued*)
Carcinogenic Toxicity Data Summary

Jacobs Engineering Group, Inc. (Jacobs), 2001a, *Final Baseline Risk Assessment Human Health Evaluation for the Site 16 Landfill Remedial Investigation/Feasibility Study, Longhorn Army Ammunition Plant, Karnack, Texas*, Final, June.

Texas Natural Resources Conservation Commission (TNRCC), 2000. Toxicity Factors Table, October 2000.

USEPA-HEAST, 1997, *Health Effects Assessment Summary Tables (HEAST), FY-1997, Update*. Office of Emergency and Remedial Response, USEPA, Washington, D.C. EPA/540/R-97-036, July.

USEPA-IRIS, 1999. Integrated Risk Information System (IRIS). United States Environmental Protection Agency Online Database for Toxicity Information on Hazardous Chemicals, 1999.

USEPA-NCEA, USEPA Region 3 Risk-Based Concentration Tables Referenced values from National Center for Environmental Assessment (NCEA).

Summary of Toxicity Assessment

The table provides carcinogenic risk information which is relevant to the contaminants of potential concern in soil and groundwater. The list of chemicals of concern presented here are the ones that were quantitatively evaluated for carcinogenic risk and non-carcinogenic hazard in the Baseline Human Health Risk Assessment (Jacobs, 2001a).

Table 2-3
Non-Carcinogenic Toxicity Data Summary

Pathway: Ingestion, Dermal Contact						
Chemical of Concern	**Chronic/ Subchronic**	**Oral RfD Value (mg/kg-day)**	**Dermal RfD (mg/kg-day)**	**Primary Target Organ**	**Combined Uncertainty/ Modifying Factors**	**Source/Date**
Explosive						
1,3-Dinitrobenzene	Chronic	1.00E-04	1.00E-04	Splenic weight	---	USEPA-IRIS, 1999
2,4,6-Trinitrotoluene	Chronic	5.00E-04	5.00E-04	Liver effects	---	USEPA-IRIS, 1999
4-Amino-2,6-Dinitrotoluene	Chronic	1.67E-04	1.67E-04	---	---	TNRCC, 2000
2,6-Dinitrotoluene	Chronic	1.00E-03	1.00E-03	Whole body	---	USEPA-HEAST, 1997
HMX	Chronic	5.00E-02	5.00E-02	Hepatic lesions	---	USEPA-IRIS, 1999
Nitrobenzene	Chronic	5.00E-04	5.00E-04	Hematological effects, adrenal, renal, hepatitis lesions	---	USEPA-IRIS, 1999
3-Nitrotoluene	Chronic	1.00E-02	1.00E-02	Spleen lesions	---	USEPA-HEAST, 1997
Tetryl	Chronic	---	---		---	---
RDX	Chronic	3.00E-03	3.00E-03	Prostate	---	USEPA-IRIS, 1999
1,3,5-Trinitrobenzene	Chronic	3.00E-02	3.00E-02	Increased splenic weight	---	USEPA-IRIS, 1999
Metals						
Aluminum	Chronic	---	---	---	---	---
Antimony	Chronic	4.00E-04	1.20E-04	Whole body	---	USEPA-IRIS, 1999
Arsenic	Chronic	3.00E-04	9.00E-05	Skin, blood vessels	---	USEPA-IRIS, 1999
Barium	Chronic	7.00E-02	2.10E-02	Increased blood pressure	---	USEPA-IRIS, 1999
Beryllium	Chronic	2.00E-03	6.00E-04	Small intestine	---	USEPA-IRIS, 1999
Copper	Chronic	---	---	---	---	---
Cadmium	Chronic	5.00E-04	1.50E-04	Proteinuria	---	USEPA-IRIS, 1999
Chromium	Chronic	1.50E+00	4.50E-01	---	---	USEPA-IRIS, 1999
Manganese	Chronic	1.40E-01	4.20E-02	CNS effects	---	USEPA-IRIS, 1999
Mercury	Chronic	---	---	---	---	---
Nickel	Chronic	2.00E-02	6.00E-03	Body weight	---	USEPA-IRIS, 1999
Selenium	Chronic	---	---	---	---	---
Silver	Chronic	5.00E-03	1.50E-03	Argyria	---	USEPA-IRIS, 1999
Strontium	Chronic	6.00E-01	1.80E-01	Rachitic bone	---	USEPA-IRIS, 1999
Thallium	Chronic	---	---	---	---	---
Vanadium	Chronic	7.00E-03	2.10E-03	---	---	USEPA-HEAST, 1997
Zinc	Chronic	3.00E-01	9.00E-02	---	---	USEPA-IRIS, 1999
Pesticides						
Aldrin	Chronic	3.00E-05	3.00E-05	Liver toxicity	---	USEPA-IRIS, 1999
Semivolatile Organics						
Bis(2-ethylhexyl)phthalate	Chronic	2.00E-02	2.00E-02	Liver	---	USEPA-IRIS, 1999

Table 2-3 *(continued)*
Non-Carcinogenic Toxicity Data Summary

Butyl Benzyl Phthalate	Chronic	2.00E-01	2.00E-01	Liver	---	USEPA-IRIS, 1999
Di-N-Butyl Phthalate	Chronic	1.00E-01	1.00E-01	Increased mortality		USEPA-IRIS, 1999
Chemical of Concern	**Chronic/ Subchronic**	**Oral RfD Value (mg/kg-day)**	**Dermal RfD (mg/kg-day)**	**Primary Target Organ**	**Combined Uncertainty/ Modifying Factors**	**Source/Date**
Volatile Organics						
Acetone	Chronic	1.00E-01	1.00E-01	Liver, kidney		USEPA-IRIS, 1999
Benzene	Chronic	---	---	---	---	---
Bromodichloromethane	Chronic	2.00E-02	2.00E-02	Renal cytomegaly	---	USEPA-IRIS, 1999
2-Butanone (MEK)	Chronic	6.00E-01	6.00E-01	Fetal birth weight	---	USEPA-IRIS, 1999
Chloroform	Chronic	1.00E-02	1.00E-02	Liver	---	USEPA-IRIS, 1999
1,1-Dichloroethane	Chronic	1.00E-01	1.00E-01	---	---	USEPA-HEAST, 1997
1,1-Dichloroethene	Chronic	9.00-E03	9.00E-03	Hepatic lesions	---	USEPA-IRIS, 1999
1,2-Dichloroethane	Chronic	---	---	---	---	---
1,2-Dichloroethene	Chronic	2.00E-02	2.00E-02	Blood	---	USEPA-IRIS, 1999
cis-1,2-Dichloroethene	Chronic	1.00E-02	1.00E-02	Blood	---	USEPA-HEAST, 1997
1,1,2-Trichloroethane	Chronic	4.00E-03	4.00E-03	Clinical serum chemistry	---	USEPA-IRIS, 1999
Ethylbenzene	Chronic	1.00E-01	1.00E-01	Liver, kidney	---	USEPA-IRIS, 1999
Methylene chloride	Chronic	6.00E-02	6.00E-02	Liver	---	USEPA-IRIS, 1999
Styrene	Chronic	2.00E-01	2.00E-01	Red blood cells, Liver effects	---	USEPA-IRIS, 1999
Toluene	Chronic	2.00E-01	2.00E-01	Liver, kidney	---	USEPA-IRIS, 1999
Trichloroethene	Chronic	6.00E-03	6.00E-03	NA	---	USEPA-NCEA, 1999
Trichlorofluoromethane	Chronic	3.00E-01	3.00E-01	Whole body (increased mortality)	---	USEPA-IRIS, 1999
1,2,4-Trimethylbenzene	Chronic	5.00E-02	5.00E-02	---	---	TNRCC, 2000
1,3,5-Trimethylbenzene	Chronic	5.00E-02	5.00E-02	---	---	TNRCC, 2000
Vinyl Chloride	Chronic	---	---	---	---	---
Xylene	Chronic	2.00E+00	2.00E+00	Hyperactivity, body weight	---	USEPA-IRIS, 1999

Pathway: Inhalation

Chemical of Concern	**Chronic/ Subchronic**	**Inhalation RfC (mg/m^3)**	**Primary Target Organ**	**Combined Uncertainty/ Modifying Factors**	**Source/Date**
Explosive					
1,3-Dinitrobenzene	Chronic	---	---	---	---
2,4,6-Trinitrotoluene	Chronic	---	---	---	---
4-Amino-2,6-Dinitrotoluene	Chronic	0.0001	---	---	TNRCC, 2000
2,6-Dinitrotoluene	Chronic	---	---	---	---

Table 2-3 *(continued)*
Non-Carcinogenic Toxicity Data Summary

HMX	Chronic	---	---	---	---
Nitrobenzene	Chronic	0.002	Blood effects	----	USEPA-HEAST, 1997
3-Nitrotoluene	Chronic	---	---	---	---
Tetryl	Chronic	---	---	---	---
RDX	Chronic	---	---	---	---
1,3,5-Trinitrobenzene	Chronic	---	---	---	---
Metals					
Aluminum	Chronic	---	---	---	---
Chemical of Concern	**Chronic/ Subchronic**	**Inhalation RfC (mg/m^3)**	**Primary Target Organ**	**Combined Uncertainty/ Modifying Factors**	**Source/Date**
Antimony	Chronic	---	---	---	---
Arsenic	Chronic	---	---	---	---
Barium	Chronic	0.0005	Fetal toxicity	---	USEPA-HEAST, 1997
Beryllium	Chronic	0.00002	Lungs	---	USEPA-IRIS, 1999
Cadmium	Chronic	---	---	---	---
Chromium	Chronic	0.0001	---	---	USEPA-IRIS, 1999
Cobalt	Chronic	---	---	---	---
Copper	Chronic	---	---	---	---
Lead	Chronic	---	---	---	---
Manganese	Chronic	0.00005	Impairment of neurobehavioral function	---	USEPA-IRIS, 1999
Mercury	Chronic	0.0003	Nervous system/neurotoxicity	---	USEPA-IRIS, 1999
Nickel	Chronic	---	---	---	---
Selenium	Chronic	---	---	---	---
Silver	Chronic	---	---	---	---
Strontium	Chronic	---	---	---	---
Thallium	Chronic	---	---	---	---
Vanadium	Chronic	---	---	---	---
Zinc	Chronic	---	---	---	---
Pesticides					
Aldrin	Chronic	---	---	---	---
Semivolatile Organics					
Bis(2-ethylhexyl)phthalate	Chronic	---	---	---	---
Butyl Benzyl Phthalate	Chronic	---	---	---	---
Di-N-Butyl Phthalate	Chronic	---	---	---	---
Volatile Organics					
Acetone	Chronic	---	---	---	---
Benzene	Chronic	---	---	---	---
Bromodichloromethane	Chronic	---	---	---	---
2-Butanone (MEK)	Chronic	1	Decreased fetal birth weight	---	USEPA-IRIS, 1999
Chloroform	Chronic	---	---	---	---
1,1-Dichloroethane	Chronic	0.5	Kidney		USEPA-HEAST, 1997

Table 2-3 *(continued)*
Non-Carcinogenic Toxicity Data Summary

Chemical of Concern	Chronic/ Subchronic	Inhalation RfC (mg/m^3)	Primary Target Organ	Combined Uncertainty/ Modifying Factors	Source/Date
1,1-Dichloroethene	Chronic	---	---	---	---
1,2-Dichloroethane	Chronic	---	---	---	---
1,2-Dichloroethene	Chronic	0.79	---	---	TNRCC, 2000
cis-1,2-Dichloroethene	Chronic	---	---	---	---
1,1,2-Trichloroethane	Chronic	---	---	---	---
Ethylbenzene	Chronic	1	Developmental toxicity	---	USEPA-IRIS, 1999
Methylene chloride	Chronic	3	Liver	---	USEPA-HEAST, 1997
Styrene	Chronic	1	CNS effects	---	USEPA-IRIS, 1999
Toluene	Chronic	0.4	Neurological effects	---	USEPA-IRIS, 1999
Trichloroethene	Chronic	---	---	---	---
Trichlorofluoromethane	Chronic	0.7	Kidney	---	USEPA-HEAST, 1997
1,2,4-Trimethylbenzene	Chronic	0.125	---	---	TNRCC, 2000
1,3,5-Trimethylbenzene	Chronic	0.125	---	---	TNRCC, 2000
Vinyl Chloride	Chronic	---	---	---	---
Xylene	Chronic	---	---	---	---

Notes

---: No information for a compound with no toxicity value (NTV)
CNS central nervous system
HMX high melting explosives
IRIS Integrated Risk Information System, USEPA
mg/kg-day milligrams per kilogram per day
mg/m^3 milligrams per cubic meter
NA Information not available
RDX 1,3,5-Trinitroperhydro-1,3,5-triazine
RfC reference concentration
RfD reference dose

References

Agency for Toxic Substances and Disease Registry (ATSDR), 1997, Minimal Risk Levels (MRLs) for Hazardous Substances.

Jacobs Engineering Group, Inc. (Jacobs), 2001a, *Final Baseline Risk Assessment Human Health Evaluation for the Site 16 Landfill Remedial Investigation and Feasibility Study, Longhorn Army Ammunition Plant, Karnack, Texas*, Final, June.

Texas Natural Resources Conservation Commission (TNRCC), 2000. Toxicity Factors Table, October 2000.

USEPA-HEAST, 1997, *Health Effects Assessment Summary Tables (HEAST), FY-1997, Update*. Office of Emergency and Remedial Response, USEPA, Washington, D.C. EPA/540/R-97-036, July.

USEPA-IRIS, 1999. Integrated Risk Information System. United States Environmental Protection Agency Online Database for Toxicity Information on Hazardous Chemicals, 1999.

Summary of Toxicity Assessment

This table provides non-carcinogenic risk information relevant to the contaminants of concern in both soil and groundwater. The list of chemicals of potential concern presented here are the ones that were quantitatively evaluated for carcinogenic risk and non-carcinogenic hazard in the Baseline Human Health Risk Assessment (Jacobs, 2001a). The uncertainty factor and modifying factor used in the development of a references dose were not available in the risk assessment evaluation report (Jacobs, 2001a).

Table 2-4
Risk Characterization Summary – Carcinogens

Scenario Timeframe: Future
Receptor Population: Maintenance Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Concern	Carcinogen Risk				
				Ingestion	Inhalation (particulates)	Inhalation (volatiles)	Dermal	Exposure Routes Total
Soil (0 to 5.0 ft)	Soil and particulates	Incidental ingestion, dermal contact, inhalation of particulates, inhalation of volatiles	***Metals***					
			Arsenic	3.9E-06	5.9E-09		4.2E-06	8.1E-06
			Beryllium		6.2E-10			6.2E-10
			Cadmium		1.9E-10			1.9E-10
			Chromium		5.0E-08			5.0E-08
			Volatile Organics					
			Methylene Chloride	1.7E-11	5.6E-16	3.3E-10	5.4E-11	4.0E-10
			Trichloroethene	4.2E-11	3.5E-15	4.7E-09	1.3E-10	4.87E-09
							Soil risk total	8.1E-06

Scenario Timeframe: Future
Receptor Population: Maintenance Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Concern	Carcinogen Risk			
				Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Incidental ingestion, inhalation of volatiles, dermal contact	***Explosives***				
			2,4,6-Trinitrotoluene	2.5E-05	NE		2.5E-05
			4-Amino-2,6-Dinitrotoluene	3.5E-08	NE		3.5E-08
			2,6-Dinitrotoluene	6.3E-07	NE		6.3E-07
			RDX	7.7E-05	NE	NE(Kp<=0.01)	7.7E-05
			Metals				
			Arsenic	1.8E-04	NE	NE(Kp<=0.01)	1.8E-04
			Pesticides				
			Aldrin	2.4E-06	NE	NE(Kp<=0.01)	2.4E-06
			Semivolatile Organics				
			Bis(2-ethylhexyl)phthalate	1.3E-06	NE		1.3E-06
			Volatile Organics				
			Benzene	4.9E-07	1.8E-06	2.3E-07	2.52E-06
			Bromodichloromethane	1.8E-06			1.8E-06

Table 2-4 *(continued)*
Risk Characterization Summary – Carcinogens

Scenario Timeframe: Future
Receptor Population: Maintenance Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Concern	Carcinogen Risk			
				Ingestion	Inhalation	Dermal	Exposure Routes Total
			Chloroform	2.6E-06	1.3E-04	1.2E-06	1.3E-04
			1,1-Dichloroethene	1.6E-03	1.7E-03	1.1E-04	3.41E-03
			1,2-Dichloroethane	5.1E-05	1.9E-04		2.41E-04
			1,1,2-Trichloroethane	2.4E-06	9.0E-06		1.14E-05
			Methylene Chloride	9.0E-05	7.4E-05	NE(Kp<=0.01)	1.64E-04
			Trichloroethene	6.2E-03	1.2E-02	5.6E-03	2.38E-02
			Vinyl Chloride	7.0E-02	4.1E-02	NE(Kp<=0.01)	1.11E-01
						Groundwater risk total =	1.4E-01
						Total risk =	1.4E-01

Notes
Kp Dermal permeability coefficient
NE Not evaluated through this exposure pathway. Chemical is not identified as volatile.
NE(Kp<=0.01) Based on USEPA Region 6 guidance, COPCs with a Kp<=0.01 were not evaluated for dermal contact while showering (USEPA, 1995)
RDX 1,3,5-Trinitroperhydro-1,3,5-triazine

References

U.S. Environmental Protection Agency (USEPA), *National Oil and Hazardous Substances Pollution Contingency Plan, Final Rule, 40 CFR Part 300*, March 8, 1990.

USEPA, *Supplemental Region VI Risk Assessment Guidance, May 5, 1995*.

Summary of Risk Characterization

The table provides risk estimates for the significant routes of exposure at LHAAP-16. These risk estimates are based on a reasonable maximum exposure and were developed by taking into account various conservative assumptions about the frequency and duration of a hypothetical future maintenance worker's exposure to groundwater, as well as the toxicity of the chemicals of concern. The total risk from exposure to contaminated soil and groundwater at this site is estimated to be 1.4E-01. A risk below 10^{-4} is generally considered to be acceptable (USEPA, 1990). The soil risk is acceptable, while the groundwater risk is not. The COCs contributing the most to the groundwater risk are TCE, VC, cis-1,2-DCE and perchlorate. This risk level indicates that if no clean-up action is taken, an individual would have an increased probability of 1 in 10 of developing cancer as a result of site-related exposure to the COCs.

Table 2-5
Risk Characterization Summary – Non-Carcinogens

Scenario Timeframe: Future
Receptor Population: Maintenance Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Concern	Primary Target Organ	Non-Carcinogenic Hazard Quotient			
					Ingestion	Inhalation	Dermal	Exposure Routes Total
Ground-water	Ground-water	Ingestion or exposure through showering	***Explosives***					
			1,3-Dinitrobenzene	--	1.5E-01			1.5E-01
			2,4,6-Trinitrotoluene	--	4.6E+00			4.6E+00
			4-Amino-2,6-Dinitrotoluene	--	5.9E-02	1.28E+00		1.3E+00
			2,6-Dinitrotoluene	--	2.6E-03			2.6E-03
			HMX	--	5.6E-04			5.6E-04
			Nitrobenzene	--	4.0E-01	1.28E+00		1.68E+00
			3-Nitrotoluene	--	1.1E-02		7.4E-04	1.17E-02
			RDX	--	6.7E-01			6.7E-01
			1,3,5-Trinitrobenzene	--	7.3E-04			7.3E-04
			Metals					
			Arsenic	--	1.1E+00	NE	NE (Kp<=0.01)	1.1E+00
			Barium	--	1.39E+00	NE	NE (Kp<=0.01)	1.39E+00
			Beryllium	--	3.6E-02	NE	NE (Kp<=0.01)	3.6E-02
			Cadmium	--	1.6E-01	NE	NE (Kp<=0.01)	1.6E-01
			Chromium	--	1.7E+01	NE	NE (Kp<=0.01)	1.7E+01
			Manganese	--	2.07E+00	NE	NE (Kp<=0.01)	2.07E+00
			Nickel	--	8.0E-01	NE	NE (Kp<=0.01)	8.0E-01
			Selenium	--	3.0E-02			3.0E-02
			Silver	--	2.2E-01	NE	NE (Kp<=0.01)	2.2E-01
			Strontium	--	1.7E-01	NE	NE (Kp<=0.01)	1.7E-01
			Vanadium	--	2.0E-01	NE	NE (Kp<=0.01)	2.0E-01
			Zinc	--	1.2E+00	NE	NE (Kp<=0.01)	1.2E+00
			Pesticides					
			Aldrin	--	1.3E-02	NE	NE (Kp<=0.01)	1.3E-02
			Semivolatile Organics					
			Bis(2-ethylhexyl)phthalate		1.3E-02	NE	NE (Kp<=0.01)	1.3E-02
			Butyl Benzyl Phthalate	--	3.4E-04	NE	2.90E-05	3.69E-04
			Acetone	--	3.8E-01			3.8E-01
			Bromodichloromethane	--	4.1E-03			4.1E-03
			2-Butanone (MEK)	--	5.5E-04	4.2E-03		4.75E-03
			Chloroform	--	1.2E-01		5.4E-02	1.74E-01
			1,1-Dichloroethane	--	3.5E-03	9.1E-03		1.26E-02
			1,1-Dichloroethene	--	8.0E-01		5.9E-02	8.59E-01
			1,2-Dichloroethene	--	1.4E+02	4.54E+01		1.85E+02
			cis-1,2-Dichloroethene	--	5.1E+02			5.1E+02
			1,1,2-Trichloroethane	--	3.0E-02			3.0E-02
			Ethylbenzene	--	4.9E-04	6.0E-04	2.3E-03	3.39E-03

Table 2-5 *(continued)*
Risk Characterization Summary – Non-Carcinogens

Scenario Timeframe: Future
Receptor Population: Maintenance Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Concern	Primary Target Organ	Non-Carcinogenic Hazard Quotient			
					Ingestion	Inhalation	Dermal	Exposure Routes Total
			Methylene chloride	--	5.7E-01	1.5E-01	NE (Kp<=0.01)	7.2E-01

Scenario Timeframe: Future
Receptor Population: Maintenance Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Concern	Primary Target Organ	Non-Carcinogenic Hazard Quotient			
					Ingestion	Inhalation	Dermal	Exposure Routes Total
			Toluene	--	1.4E-03	9.6E-03	6.5E-03	1.75E-02
			Tetrachloroethene	--	1.4E-03		2.5E-03	3.9E-03
			Trichloroethene	--	2.7E+02		2.3E+02	5.0E+02
			Trichlorofluoromethane	--	2.9E-02	1.65E-01	2.3E-03	1.96E-01
			1,2,4-Trimethylbenzene	--	4.6E-03	2.51E-02	3.0E-03	3.27E-02
			1,3,5-Trimethylbenzene	--	3.2E-03	1.69E-02	1.3E-03	2.14E-02
			Xylene		6.0E-05		2.2E-05	8.2E-05
Groundwater Hazard Index Total =								1.23E+03
Receptor Hazard Total (soil and groundwater) =								1.23E+03

Notes

---	No information available
Kp	Dermal permeability coefficient
HMX	High melting explosives
NE	Not evaluated through this exposure pathway
NE (Kp<=0.01)	Based on USEPA Region 6 guidance, chemicals of potential concern with a Kp<=0.01 were not evaluated for dermal contact while showering (USEPA, 1995)
RDX	1,3,5-Trinitroperhydro-1,3,5-triazine

References

U.S. Environmental Protection Agency (USEPA), 1989, *Risk Assessment Guidance for Superfund, Vol. I: Human Health Evaluation Manual, (Part A)*, EPA/540/1-89/002, December.

USEPA, *Supplemental Region 6 Risk Assessment Guidance*, May 5, 1995.

Summary of Risk Characterization

The table provides hazard quotients (HQs) for each route of exposure and the hazard index (sum of hazard quotients) for all routes of exposure for LHAAP-16. The Risk Assessment Guidance for Superfund (USEPA, 1989) states that, generally, a hazard index (HI) greater than 1 indicates the potential for adverse non-carcinogenic effects. The estimated HI of 31 for groundwater indicates that the potential for adverse non-carcinogenic effects could occur from exposure to contaminants in that medium; the components having HQs greater than 1 are thallium, antimony, and manganese. The non-carcinogenic risk from exposure to trichloroethene in groundwater could not be evaluated due to the lack of non-carcinogenic toxicity criteria for trichloroethene. The estimated HI of 0.12 for soil is acceptable.

Table 2-6
Chemicals of Potential Concern in Groundwater

Chemical	Baseline Risk Assessment Results			Comparison Value		Maximum Result (µg/L)	Maximum Result from Post Risk Assessment Data	Retained as Chemical of Concern?
	EPC (µg/L)	Risk	HI	Value (µg/L)	Basis			
Perchlorate	none	-	-	17	TRRP PCL	5,990	Yes	YES, 3
1,3-Dinitrobenzene	1.56	-	0.15	2.4	TRRP PCL	1.56	No	NO, 6
2,4,6-Trinitrotoluene	240	2.50E-05	4.6	12	TRRP PCL	240	No	NO, 5
4-Amino-2,6-dinitrotoluene	1	3.50E-08	1.34	4.1	TRRP PCL	1	No	NO, 6
Nitrobenzene	20	-	1.68	49	TRRP PCL	20	No	NO, 5
RDX	200	7.70E-05	0.67	8.3	TRRP PCL	200	No	NO, 5
Arsenic	34	1.80E-04	1.1	10	MCL	123	Yes	YES, 1
Barium	9,900	-	1.39	2,000	MCL	9,900	No	NO, 2
Cadmium	8	-	0.16	5	MCL	29	No	NO, 2
Chromium	5,220	-	17	100	MCL	32,400	Yes	YES, 3
Manganese	29,800	-	2.07	1,100*	TRRP PCL	29,800	No	YES, 1
Nickel	1,630	-	0.8	490	TRRP PCL	1,803.5	No	YES, 1
Silver	114	-	0.22	120	TRRP PCL	114	No	NO, 6
Strontium	10,400	-	0.17	15,000	TRRP PCL	12,300	Yes	NO, 6
Thallium	12	-	-	2	MCL	90.5	Yes	YES, 1
Zinc	37,000	-	1.2	7300	TRRP PCL	37,000	No	NO, 5
Trichloroethene	160,000	2.38E-02	500	5	MCL	173,000	Yes	YES, 3
1,1-Dichloroethene	740	3.41E-04	0.859	7	MCL	740	No	YES, 3
1,2-Dichloroethane	160	2.41E-04	-	5	MCL	161	Yes	YES, 3
1,2-Dichloroethene	275,000	-	185.4	70	MCL for cis-1,2-DCE	275,000	No	NO, 4
cis-1,2-Dichloroethene	520,000	-	510	70	MCL	520,000	No	YES, 3
Vinyl chloride	11,000	1.11E-01	-	2	MCL	11,000	No	YES, 3
1,1,2-Trichloroethane	12	1.14E-05	0.03	5	MCL	23.6	Yes	YES, 1
Acetone	3,920	-	0.38	22,000	TRRP PCL	14,000	Yes	NO, 6
Chloroform	120	1.34E-04	0.17	80	MCL for trihalomethanes	36	No	NO, 6
Methylene chloride	3,500	1.64E-04	0.72	5	MCL	9,500	Yes	YES, 3
Trichlorofluoromethane	892	-	0.196	80	MCL for trihalomethanes	892	No	NO, 5

Table 2-6 *(continued)*
Chemicals of Potential Concern in Groundwater

<u>Notes</u>:

List of Chemicals is from Table 4-9 of the Final Baseline Human Health Risk Assessment for Site 16 Landfill (plus perchlorate).
Constituents/Parameters with Hazard Index (HI) > 0.1 or Cancer Risk (Risk) > 1.00E-5 are selected.

(1) Retained as a COC to be monitored for 5 years, then evaluated again.
(2) Excluded as a COC because earlier exceedances of MCL were not confirmed by subsequent sampling.
(3) Retained as a COC because a significant number of results exceed the MCL or PCL.
(4) Excluded as a COC because the parameter will be superseded by cis-1,2-DCE.
(5) Excluded as a COC because only one or 2 anomalous sample results in early sampling were above the Comparison Value.
(6) Excluded as a COC because no detected result ever exceeded the comparison value.

* 95% UTL value from Final Evaluation of Perimeter Well Data for Use as Groundwater Background (Shaw, 2007) for Manganese is 7,820 µg/L, which is above the TRRP Tier 1 Groundwater Residential PCL thus the background value will be considered the Cleanup Level for Manganese

µg/L microgram per liter
HI Hazard Index
MCL maximum contaminant level
TRRP PCL Texas Risk Reduction Program Protective Concentration Level (Tier 1 Groundwater Residential)

Table 2-7
Groundwater and Surface Water Cleanup Levels

Chemical of Concern	Cleanup Level (µg/L)
	MCL
Trichloroethene	5
cis-1,2-Dichloroethene	70
1,1-Dichloroethene	7
1,2-Dichloroethane	5
Vinyl Chloride	2
1,1,2-Trichloroethane	5
Methylene Chloride	5
Chromium	100
Arsenic	10
Thallium	2
	TRRP Tier 1 Groundwater Residential PCLs
Nickel	490
Perchlorate	17
Manganese	1,100*

Notes and Abbreviations:

All values are in micrograms per liter (µg/L).
MCL maximum contaminant level
PCL Protective Concentration Level
* 95% UTL value from Final Evaluation of Perimeter Well Data for Use as Groundwater Background (Shaw, 2007) for Manganese is 7,820 µg/L, which is above the TRRP Tier 1 Groundwater Residential PCL thus the background value will be considered the Cleanup Level for Manganese

Table 2-8
Comparative Analysis of Alternatives

Criteria	Alternative 1 No Further Action (Maintenance of Existing Landfill Cap, Land Use Controls [Cap Only])	Alternative 2 Cap, Enhanced Groundwater Extraction, Land Use Controls	Alternative 3a/3b Cap, Monitored Natural Attenuation, Land Use Controls[1]	Alternative 4 Cap, In Situ Permeable Reactive Barrier, Land Use Controls	Alternative 5a/5b Landfill Removal, In Situ Permeable Reactive Barrier, Land Use Controls[2]	Alternative 6 Landfill Source Treatment, Monitored Natural Attenuation, Land Use Controls	Alternative 7 Cap, Monitored Natural Attenuation, Land Use Controls, In Situ Enhanced Bioremediation, Biobarriers
Overall protection of human health and the environment	Protection of human health provided by cap and associated LUCs. No additional protection from exposure to groundwater. Does not demonstrate protection of Harrison Bayou from potential groundwater impacts.	Protection of human health provided by cap and land use controls. Protection of Harrison Bayou provided by groundwater extraction.	Protection of human health provided by cap and land use controls. Protection of Harrison Bayou provided by natural attenuation.	Protection of human health provided by cap and land use controls. Protection of Harrison Bayou provided by permeable reactive barrier.	Protection of human health provided by cap (5a), source removal (5b) and land use controls. Protection of Harrison Bayou provide by groundwater treatment.	Protection of human health provided by removal and treatment of some source material and by cap and land use controls. Protection of Harrison Bayou provided by natural attenuation.	Protection of human health provided by cap and land use controls. Protection of Harrison Bayou provided by biobarriers, in situ bioremediation, and natural attenuation.
Compliance with ARARs	No compliance with chemical-specific ARARs in groundwater. Complies with location- and action-specific ARARs.	Does not comply with ARARs that apply drinking water requirements to groundwater. Complies with location-and action-specific ARARs.	Meets all ARARs.	Does not comply with ARARs that apply drinking water requirements to groundwater. Complies with location-and action-specific ARARs.	Does not comply with ARARs that apply drinking water requirements to groundwater. Complies with location-and action-specific ARARs.	Meets all ARARs.	Meets all ARARs.
Long-term effectiveness and permanence	Landfill cap and associated LUCs would be effective and reliable so long as they are maintained indefinitely. Not effective for groundwater.	Effective reliability depends on long-term maintenance and controls and ability to locate extraction wells in complex geology.	Alternative 3b enhances effectiveness of MNA by reducing the mass of contamination. If MNA is not proven effective in the long term, a contingent action of groundwater extraction would be implemented (see Alternative 2)	Effectiveness of permeable reactive barrier is uncertain and relies on adequate long-term maintenance.	Similar to Alternative 4, but reliability enhanced with source removal. More aggressive remedial approach.	Similar to Alternative 3a but reliability is enhanced by source treatment.	Should be effective and permanent as indicated by the results of the technology demonstration and the preliminary MNA evaluation. In situ bioremediation will permanently reduce contaminant mass in its treatment area.
Reduction of toxicity, mobility, or volume through treatment	No active reduction.	Some reduction in groundwater toxicity and volume through active treatment. No source treatment.	Alternative 3a includes no active reduction in toxicity, mobility, or volume. Alternative 3b includes a small	Moderate reduction in groundwater toxicity. No source treatment.	Longer trench results in larger reduction in groundwater toxicity than Alternative 4. Source treatment only	Significant source reduction in toxicity and volume. Groundwater COC	No source treatment. Provides permanent and irreversible reduction in groundwater toxicity and volume via in situ

Table 2-8 *(continued)*
Comparative Analysis of Alternatives

Criteria	Alternative 1 No Further Action (Maintenance of Existing Landfill Cap, Land Use Controls [Cap Only])	Alternative 2 Cap, Enhanced Groundwater Extraction, Land Use Controls	Alternative 3a/3b Cap, Monitored Natural Attenuation, Land Use Controls[1]	Alternative 4 Cap, In Situ Permeable Reactive Barrier, Land Use Controls	Alternative 5a/5b Landfill Removal, In Situ Permeable Reactive Barrier, Land Use Controls[2]	Alternative 6 Landfill Source Treatment, Monitored Natural Attenuation, Land Use Controls	Alternative 7 Cap, Monitored Natural Attenuation, Land Use Controls, In Situ Enhanced Bioremediation, Biobarriers
			reduction in toxicity and volume. No source treatment.		if RCRA waste is identified.	reduction is identical to Alternative 3.	bioremediation, biobarriers, and MNA.
Short-term effectiveness	Minimal impact to the community, workers, or the environment from short-term activities.	Minimal impact to the community, workers, or the environment from short-term activities. Provides almost immediate protection.	Minimal impact to the community, workers, or the environment from short-term activities. Provides almost immediate protection.	Minor disruption due to installation of the permeable reactive barrier.	Significant short-term impacts to the community from transportation and for worker risk from excavation activities. Risks can be controlled.	Potential for worker risk during source treatment. Risks can be controlled.	Minimal disruption due to implementation of in situ bioremediation and biobarrier. Provides almost immediate protection with the implementation of land use controls.
Implementability	Readily implemented.	Readily implemented. Most of the components of this alternative are already in place.	If natural attenuation does not occur, Alternative 2 would be implemented.	Need to design an effective system considering hydraulics and biological process in situ.	Most difficult to implement. Coordination of excavation, waste sampling, transportation, and disposal would be difficult. Also, need to minimize releases of contaminated material during excavation activities.	Source action not typically applied to landfills. Therefore, initial testing will be required.	Readily implemented because equipment and personnel required for implementation of this alternative (including the design of the biobarrier) are readily available.

Table 2-8 *(continued)*
Comparative Analysis of Alternatives

Criteria	Alternative 1 No Further Action (Maintenance of Existing Landfill Cap, Land Use Controls [Cap Only])	Alternative 2 Cap, Enhanced Groundwater Extraction, Land Use Controls	Alternative 3a/3b Cap, Monitored Natural Attenuation, Land Use Controls[1]	Alternative 4 Cap, In Situ Permeable Reactive Barrier, Land Use Controls	Alternative 5a/5b Landfill Removal, In Situ Permeable Reactive Barrier, Land Use Controls[2]	Alternative 6 Landfill Source Treatment, Monitored Natural Attenuation, Land Use Controls	Alternative 7 Cap, Monitored Natural Attenuation, Land Use Controls, In Situ Enhanced Bioremediation, Biobarriers
Cost[3]							
• Capital Expenditures	$0	$873,000	$696,000 (a) $1,468,000 (b)	$2,915,000	$3,524,000 (a) $125,577,000 (b)	$3,123,000	$441,,000
• O&M Expenditures	$1,026,000	$15,607,000	$3,305,000 (a) $3,381,000 (b)	$3,244,000	$17,169,000 (a) $16,378,000 (b)	$5,251,000	$2,250,000
• Total Present Worth	$710,000	$11,023,000	$3,047,000 (a) $3,847,000 (b)	$5,124,000	$14,677,000 (a) $129,822,000 (b)	$7,186,000	$2,223,000

Notes and Abbreviations:

1 Alternative 3b is identical to Alternative 3a except an extraction well network will be operated in the groundwater hot spot for approximately 5 years to reduce contaminant mass, followed by MNA throughout the rest of the O&M period.

2 Alternative 5b is identical to Alternative 5a except all of the landfill waste will be removed (compared with hot spot removal under Alternative 5a).

3 Costs have been rounded to the nearest $1,000. The capital and O&M expenditures are the sums of each year's costs without regard to discount rates or escalation rates. Each year's expenditures were converted to present worth using a 2.7% discount rate and were summed to yield the total present worth. The costs of Alternatives 1 through 6 have been updated to January 2008 using the Engineering News Record construction cost index, and the costs of five-year reviews have been added to all alternatives. Per the Army's request, the costs for all alternatives have been modified by removing the standard escalation rate (average 3 percent per year) from the present worth calculation. Also, the cost of Alternative 1 has been updated to reflect the ongoing cap maintenance/inspection activities and the implementation of LUCs under the ROD for LHAAP-16.

4 Costs have been escalated to bring FY08 dollars to FY13 dollars using escalation rate of 1.0776 and escalated to bring FY13 dollars to FY16 dollars using escalation rate of 1.0421

ARAR applicable or relevant and appropriate requirement
COC chemical of concern
LUCs land use controls
MNA monitored natural attenuation
O&M operation and maintenance
RCRA Resource Conservation and Recovery Act

Table 2-9
Remediation Cost Table, Selected Remedy (Alternative 7)
Present Worth Analysis

PROJECT LOCATION:	Karnack, Texas								DATE: June 2016		
			O & M Costs						Present Value (NPV)		
FY	Capital Costs	Capital Costs							Discount Rate	Capital	O & M
	ISEB	Other	Cap Maintenance	Biobarrier	Performance Monitoring	MNA	LTM	Total	2.7%		
									NPV	440,872	1,782,213
2016	226,517	214.354	34,327	92,492	190,729		0	317,548			
2017	0	0	25,479		152,980		0	178,459			
2018	0	0	25,479			157,982	0	183,461			
2019	0	0	25,479			167,768	0	193,247			
2020	0	0	25,479				80,919	106,398			
2021	0	0	34,327	92,492			0	126,819			
2022	0	0	25,479				0	25,479			
2023	0	0	25,479				0	25,479			
2024	0	0	25,479				0	25,479			
2025	0	0	25,479				80,919	106,398			
2026	0	0	34,327	92,492			0	126,819			
2027	0	0	25,479				0	25,479			
2028	0	0	25,479				0	25,479			
2029	0	0	25,479				0	25,479			
2030	0	0	25,479				80,919	106,398			
2031	0	0	34,327				0	34,327			
2032	0	0	25,479				0	25,479			
2033	0	0	25,479				0	25,479			
2034	0	0	25,479				0	25,479			
2035	0	0	25,479				80,919	106,398			
2036	0	0	34,327				0	34,327			
2037	0	0	25,479				0	25,479			

Table 2-9 *(continued)*
Remediation Cost Table, Selected Remedy (Alternative 7)
Present Worth Analysis

PROJECT LOCATION:	Karnack, Texas								DATE:	June 2016	
			O & M Costs						Present Value (NPV)		
FY	Capital Costs	Capital Costs							Discount Rate	Capital	O & M
	ISEB	Other	Cap Maintenance	Biobarrier	Performance Monitoring	MNA	LTM	Total	2.7%		
									NPV	440,872	1,782,213
2038	0	0	25,479				0	25,479			
2039	0	0	25,479				0	25,479			
2040	0	0	25,479				80,919	106,398			
2041	0	0	34,327				0	34,327			
2042	0	0	25,479				0	25,479			
2043	0	0	25,479				0	25,479			
2044	0	0	25,479				0	25,479			
2045	0	0	25,479				80,919	106,398			
Total Expenditures	226,517	214,354	817,446	277,475	343,709	325,952	485,510	2,250,092			$2,223,085

Notes and Abbreviations:

Major assumptions are as described below. Quantities and assumptions are for cost estimating purposes only. For further details, refer to the Final Addendum to Final Feasibility Study, LHAAP-16 (Shaw, 2010).

Capital costs include: in situ bioremediation, the first injection for the biobarriers, and establishment of LUCs.

O&M costs for the MNA evaluation, maintenance of the cap, maintenance of the LUCs, long-term monitoring, and two additional emulsified vegetable oil injections subsequent to the initial implementation of the biobarriers. LTM would support the required CERCLA five-year reviews.

Monitoring costs are based on the assumption that sampling is conducted at 7 shallow zone wells and 5 intermediate zone wells, with one quality control sample in each zone and one surface water location in Harrison Bayou. The sampling frequency is quarterly for 2 years (Years 1 and 2), then semiannual for 3 years (Years 3 through 5), then annual for Years 6 through 10, and finally every5 years (Years 15, 20, 25, and 30). Analysis of the initial groundwater sampling event is for VOCs and perchlorate and MNA parameters. Samples collected in subsequent monitoring events will be analyzed for VOCs, metals, perchlorate and MNA parameters. Five year reviews are conducted in Years 5, 10, 15, 20, 25, and 30.

The discount rate of 2.7% is based on the 30-year Real Interest Rate from Office of Management and Budget Circular A-94, Appendix B, Revised December 2009.

Costs have been escalated to bring FY08 dollars to FY13 dollars using escalation rate of 1.0776 and escalated to bring FY13 dollars to FY16 dollars using escalation rate of 1.0421

ISEB in situ enhanced bioaugmentation
LTM long-term monitoring
LUC land use control
MNA monitored natural attenuation
NPV net present value
O&M operation & maintenance

Table 2-10
Description of ARARs for Final Selected Remedy

Citation	Activity or Prerequisite/Status	Requirement
		Groundwater
Federal Safe Drinking Water Act Maximum Contaminant Levels (MCLs) **40 CFR 141**	Applicable to drinking water for a public water system—**relevant and appropriate** for water that could potentially be used for human consumption	Must not exceed MCLs/non-zero MCLGs for water designated as a current or potential source of drinking water. See **Table 2-7** for specific numeric criteria
		Surface Water
State of Texas Surface Water Quality Standards: General Criteria and Toxic Materials Criteria 30 TAC 307.4 30 TAC 307.6	Applicable to surface waters of the state - **applicable** if water is discharged to a surface water body or surface waters are remediated as part of the remedial action.	**Discharges to waters of the state must not cause in-stream exceedance of numeric and narrative water quality standards. Remediation of contaminated surface waters must ensure that numeric and narrative water quality standards are achieved, as determined by 307.8 (Application of the Standards) and Section 307.9 (Determination of Standards Attainment). See** Table 2-7 **for specific numeric criteria.**
State of Texas Surface Water Quality Standards: Antidegradation 30TAC 307.5	Applicable to surface waters of the state – **applicable** if water is discharged directly to a surface water body or surface waters are remediated as part of the remedial action.	**No activity subject to regulatory action that would cause degradation of waters that exceed fishable/swimmable quality will be allowed. Degradation is defined as a lowering of water quality by more than a de minimis extent but not to the extent than an existing use is impaired. Water quality sufficient to protect existing uses will be maintained. The highest water quality sustained since November 28, 1975, defines baseline conditions for determination of degradation.**
		General Site Preparation, Construction, and Excavation Activities
Air Contaminants – General Nuisance Rules 30 TAC 101.4	Emissions of air contaminants—**applicable**.	No person shall discharge from any source whatsoever one or more air contaminants or combinations thereof, to exceed an opacity of 30 percent for any 6-minute period as are or may tend to be injurious to or to adversely affect human health or welfare, animal life, vegetation, or property, or as to interfere with the normal use and enjoyment of animal life, vegetation, or property.
Storm Water Runoff Controls 40 CFR 122.26; 30 TAC 205, Subchapter A; 30 TAC 308.121	Storm water discharges associated with construction activities—**applicable** to disturbances of equal to or greater than 1 acre of land.	Good construction management techniques, phasing of construction projects, minimal clearing, and sediment, erosion, structural, and vegetative controls shall be implemented to mitigate storm water run-on/runoff in areas of active remediation.
		Waste Management
Characterization of Solid Waste 40 CFR 262.11 30 TAC 335.62 30 TAC 335.504 30 TAC 335.503(a)(4)	Generation of solid waste, as defined in 30 TAC 335.1—**applicable**.	Must determine whether the generated solid waste is RCRA hazardous waste by using prescribed testing methods or applying generator knowledge based on information regarding material or process used. If the waste is determined to be hazardous, it must be managed in accordance with 40 CFR 262–268. After making the hazardous waste determination as required, if the waste is determined to be nonhazardous, the generator shall then classify the waste as Class 1, Class 2, or Class 3 (as defined in Section 335.505 through Section 335.507) using one or more of the methods listed in Section 335.503(a)(4) and Section 335.508 and manage the waste in accordance with the requirements of Chapter 335 of the TAC for industrial solid waste.

Table 2-10 *(continued)*
Description of ARARs for Final Selected Remedy

Citation	Activity or Prerequisite/Status	Requirement
Characterization of Hazardous Waste 40 CFR 268.7 30 TAC 335.504(3) 30 TAC 335.509 30 TAC 335.511	Generation of a RCRA hazardous waste for treatment, storage, or disposal—**applicable** if hazardous waste is generated (e.g., personal protective equipment [PPE]).	Must obtain a detailed chemical and physical analysis of a representative sample of the waste(s) that at a minimum contains all the information that must be known to treat, store, or dispose of the waste in accordance with 40 CFR 264 and 268. Must also determine whether the waste is restricted from land disposal under 40 CFR 268 et seq. by testing in accordance with prescribed methods or use of generator knowledge of waste.
Requirements for Temporary Storage of Hazardous Waste in Accumulation Areas 40 CFR 262.34(a) and (c)(1) 30 TAC 335.69(a) and (d)	On-site accumulation of 55 gallons or less of RCRA hazardous waste for 90 days or less at or near the point of generation—**applicable** if hazardous waste is generated (e.g., PPE) and stored in an accumulation area.	Remedial activities derived waste (from monitoring, intercepting and treating contaminated groundwater) is expected for this facility. A generator may accumulate hazardous waste at the facility provided that • Waste is placed in containers that comply with 40 CFR 264.171 to 264.173 (Subpart I); and • Container is marked with the words "hazardous waste"; or • Container may be marked with other words that identify the contents.
	Well Construction	
Well Construction Standards—Monitoring or Injection Wells 16 TAC 76.1000	Construction of water wells—**applicable** to construction of new monitoring or injection wells, if needed.	Injection wells shall be completed in accordance with the technical requirements of Section 76.1000, as appropriate. Substantive requirements applicable to the injection wells will be adhered to.
Class V Injection Wells 30 TAC 331, Subchapters A,C and H	Installation, operation, and closure of injection wells fall in the category of Class V Injection Wells – **relevant and appropriate**.	Injection wells shall be constructed to the required specifications for isolation casing, surface completion, prevention of commingling, and confinement of undesirable groundwater to its zone of origin. Closure shall be accomplished by removing all of the removable casing and the entire well shall be pressure filled via a tremie pipe with cement from bottom to the land surface, or closure shall be performed by the alternative method for Class V Wells completed in zones of undesirable groundwater. Groundwater concentrations at time of well closure will determine the appropriate method of abandonment. Substantive requirements applicable to the injection wells will be adhered to.
	Treatment/Disposal	
Disposal of Wastewater (e.g., contaminated groundwater, dewatering fluids, decontamination liquids) 40 CFR 268.1(c)(4)(i) 30 TAC 335.431(c)	RCRA-restricted characteristically hazardous waste intended for disposal—**applicable** if extracted groundwater or rinsate from incinerator is determined to be RCRA characteristically hazardous.	Disposal is not prohibited if such wastes are managed in a treatment system subject to regulation under Section 402 of the CWA that subsequently discharges to waters of the United States.
	Closure	
Standards for Plugging Wells that Penetrate Undesirable Water or Constituent Zones 16 TAC 76.1004(a) through (c)	Plugging and abandonment of wells—**applicable** to plugging and closure of monitoring and/or extraction wells.	If a well is abandoned, all removable casing shall be removed and the entire well pressure filled via a tremie pipe with cement from bottom up to the land surface. In lieu of this procedure, the well shall be pressure-filled via a tremie tube with bentonite grout of a minimum 9.1 lb/gal weight followed by a cement plug extending from land surface to a depth of not less than 2 feet. Undesirable water or constituents or the freshwater zone(s) shall be isolated with cement plugs.

Table 2-10 *(continued)*
Description of ARARs for Final Selected Remedy

Citation	Activity or Prerequisite/Status	Requirement
Post Closure Care		
Post Closure Care Requirements for Hazardous Waste Landfills 40 CFR 264.310(b)(1)(4)(5)(6) 40 CFR 264.228(b)(1)(3)(4) 30 TAC 335.174(b) 40 CFR 264.117 - 264.120	Closure of a RCRA landfill **– relevant and appropriate** to closure or post closure under CERCLA of landfills containing RCRA hazardous waste	Owner or operator must • Maintain the effectiveness and integrity of the final cover including making repairs to the cap as necessary to correct effects of settling, erosion, etc.; • Prevent run-on and runoff from eroding or otherwise damaging final cover; and • Maintain and monitor a groundwater monitoring system.

Abbreviations:

CFR Code of Federal Regulations
PPE personal protective equipment
RCRA Resource Conservation and Recovery Act of 1976
TAC Texas Administrative Code

Figure 2-1
LHAAP Location Map

Figure 2-2
Site Location Map

Figure 2-3
Soil and Groundwater Sample Locations and Extent of Groundwater Contamination Map

Figure 2-4
Surface Water / Sediment Sample Locations Map

Figure 2-5
Site Map

Figure 2-6
Conceptual Site Model – LHAAP-16 Source Area

Figure 2-7
Conceptual Site Model – LHAAP-16 Non-Source Area

Figure 2-8
Shallow Zone Groundwater Elevation Map June 2007 Data

Figure 2-9
Intermediate Zone Groundwater Elevation Map June 2007 Data

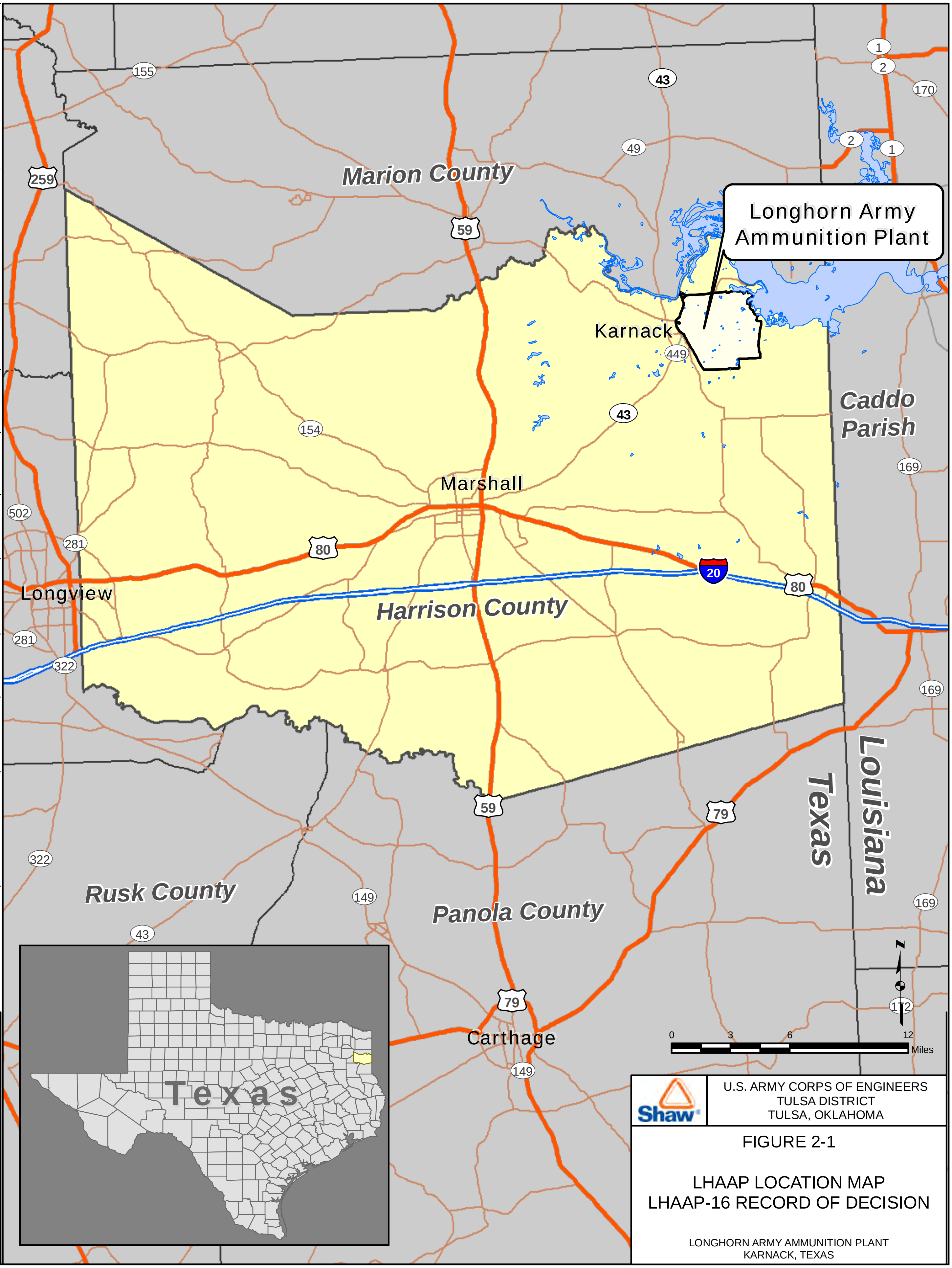

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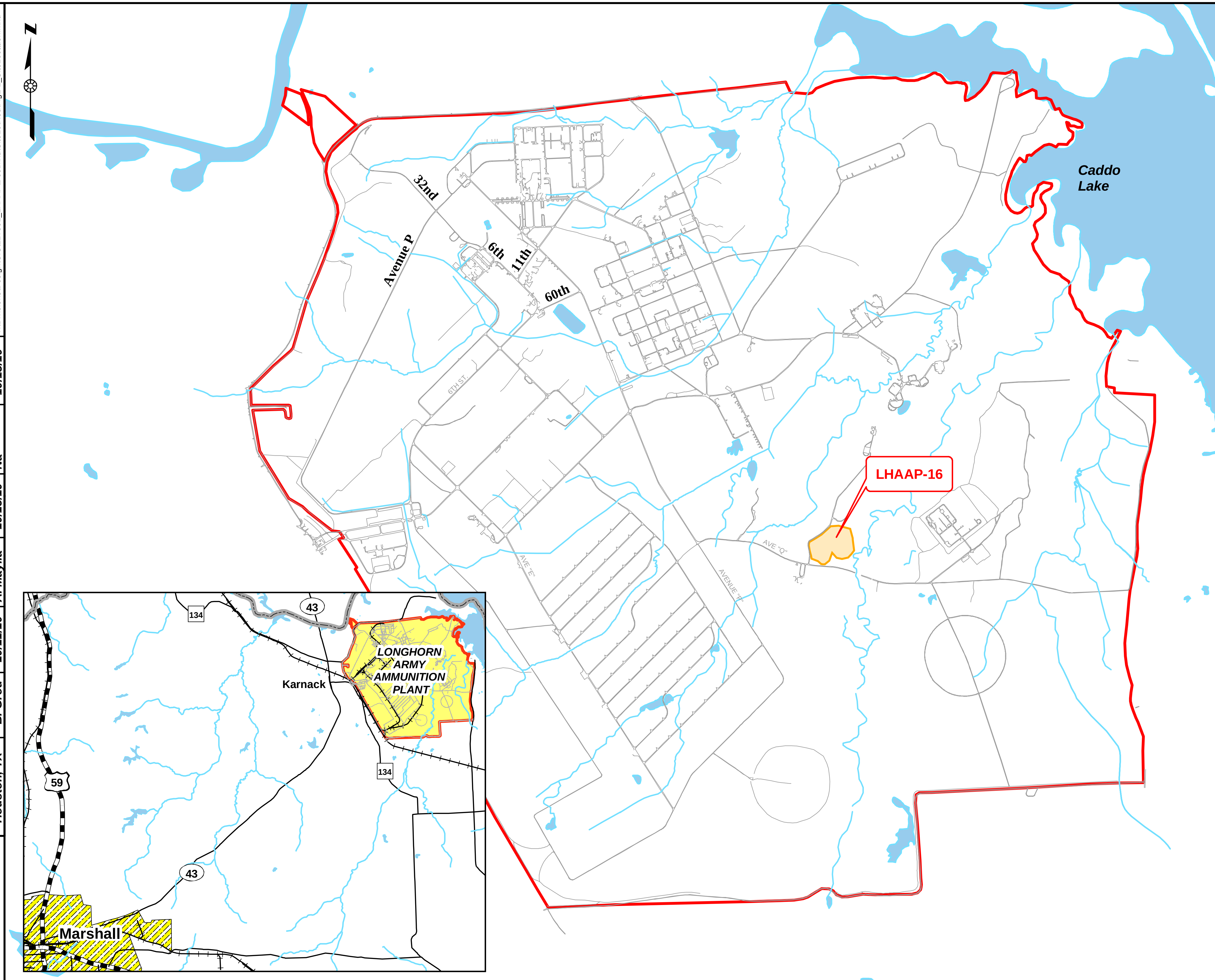
FIGURE 2-1

LHAAP LOCATION MAP
LHAAP-16 RECORD OF DECISION

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

OFFICE	DRAWN BY	CHECKED BY	APPROVED BY	FILE NAME
Houston, TX	B. Grod 10/11/2010	R. Duffield 10/28/09	A. Maylia 10/15/2010	T:\117591_LHAAP\Doc\Mxd\Site16\Rod\Fig2-1_LhaapLocation.mxd



LEGEND

Stream

Road

LHAAP Boundary

Site

Lake

0 1,250 2,500 5,000 Feet

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FIGURE 2-2

SITE LOCATION MAP
LHAAP-16 RECORD OF DECISION

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

OFFICE	DRAWN BY	CHECKED BY	APPROVED BY	FILE PATH
Houston, TX	B. Grod 10/11/10	A. Mayila 10/15/10	Na 10/15/10	T:\Divisions\Design\GIS\117591_LHAAP\Doc\Mxd\Site16\Rod\Fig2-2_SiteLocation.mxd

OFFICE Houston, TX
DRAWN BY B. Grod 03/01/11
CHECKED BY A. Mayila 10/15/10
APPROVED BY Na 10/15/10
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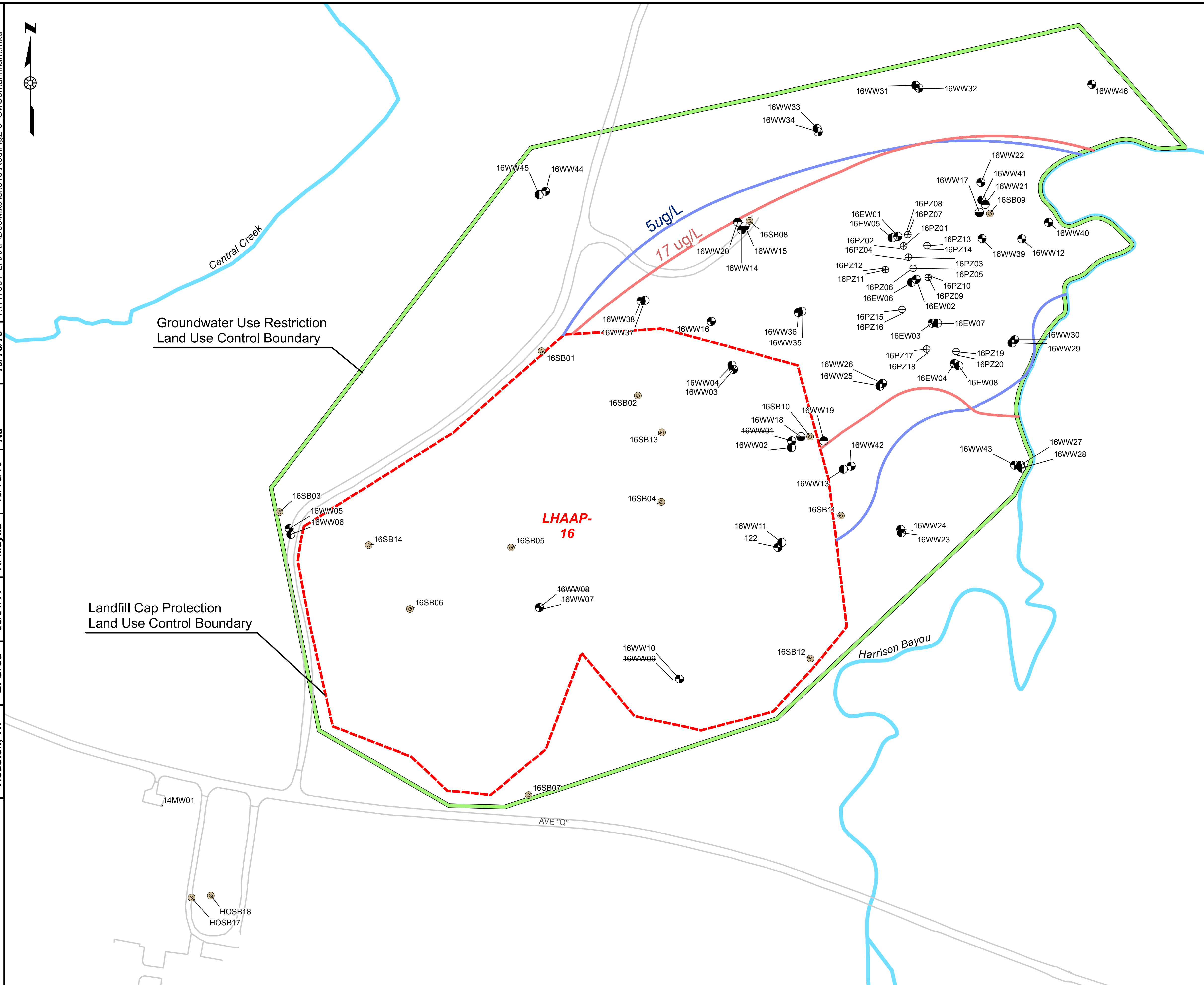

LEGEND

- Shallow Monitoring Well
- Intermediate Monitoring Well
- Upper Deep Monitoring Well
- Deep Monitoring Well
- Piezometer
- Soil Boring
- Extent of Perchlorate Contamination > 17 ug/L in Intermediate and Shallow Zones
- Extent of TCE Contamination > 5 ug/L in Intermediate and Shallow Zones
- Road
- Stream
- Groundwater Use Restriction Land Use Control Boundary
- LHAAP-16 Landfill Fence

Notes:
1. Abandoned or Plugged Wells (Ex. ~~Well ID~~)

0 50 100 200 300 400 Feet

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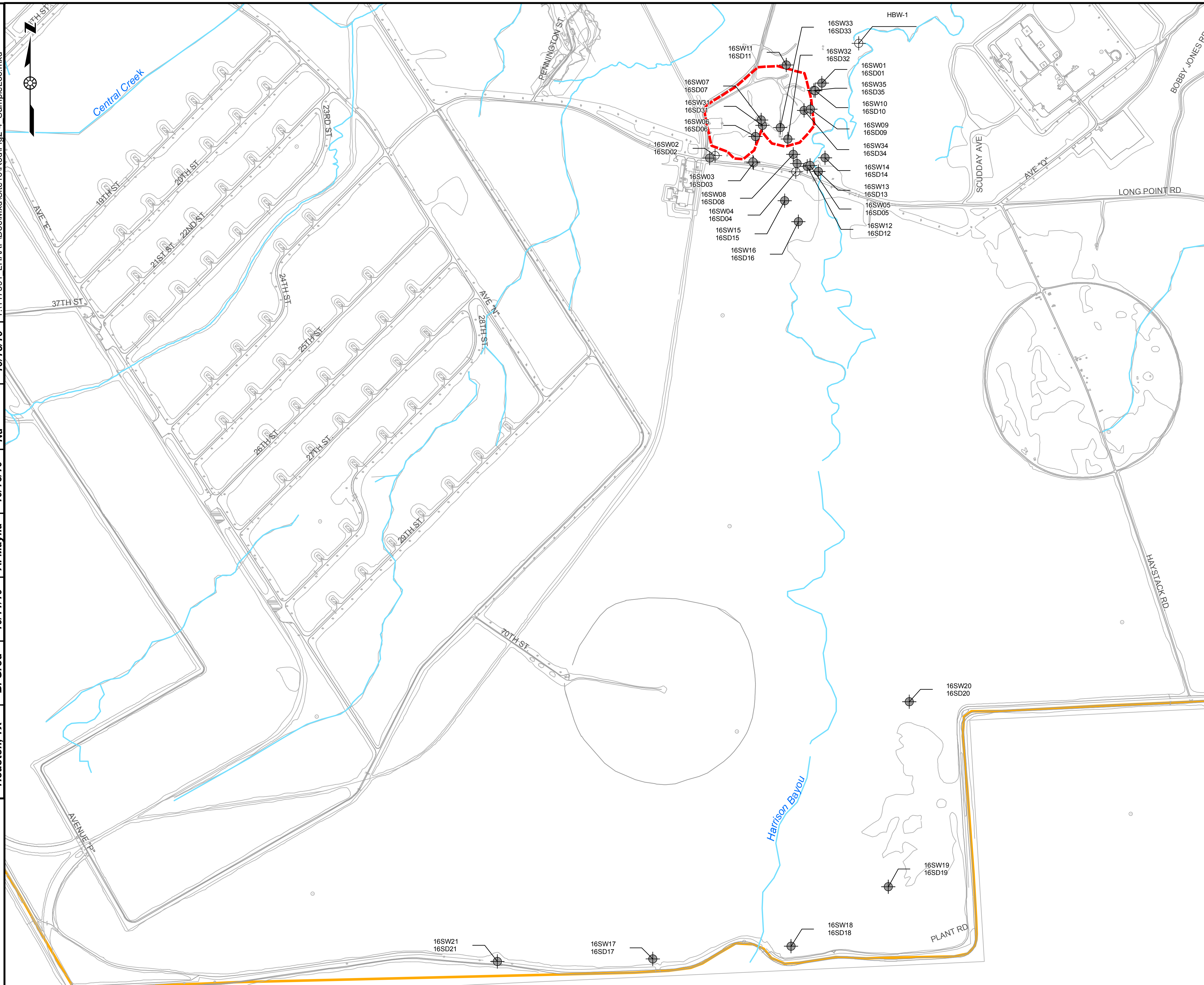
FIGURE 2-3
SOIL AND GROUNDWATER SAMPLE LOCATIONS, EXTENT OF GROUNDWATER CONTAMINATION, AND LAND USE CONTROL BOUNDARIES
LHAAP-16 RECORD OF DECISION
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS



LEGEND

- Sediment Sample
- Surface Water Sample
- LHAAP-16 Landfill Fence
- Stream
- Road
- LHAAP Boundary

0 500 1,000 2,000 Feet

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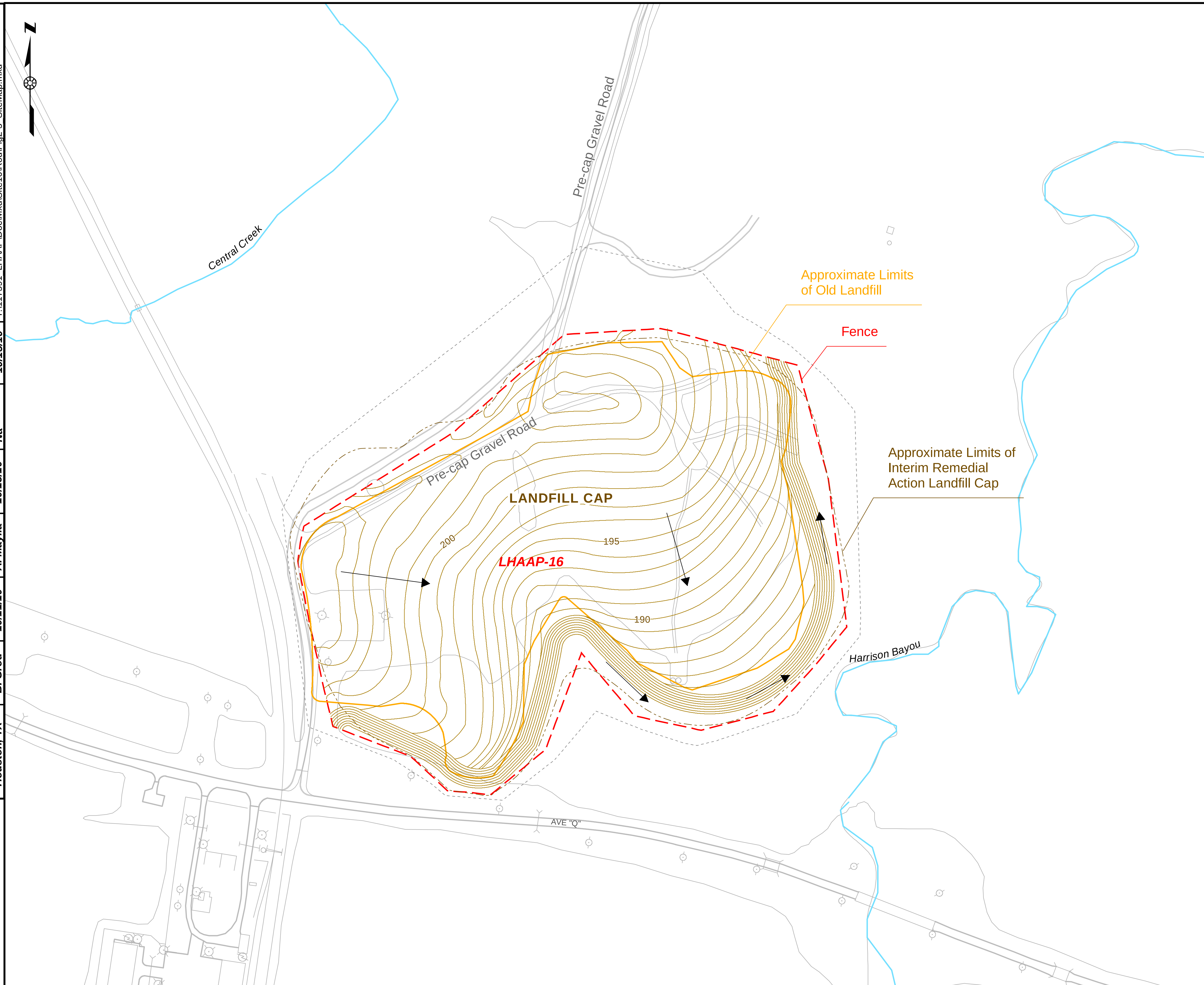
FIGURE 2-4
SURFACE WATER/SEDIMENT
SAMPLE LOCATIONS MAP
LHAAP-16 RECORD OF DECISION
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

OFFICE	DRAWN BY	CHECKED BY	APPROVED BY	FILE PATH
Houston, TX	B. Grod 10/11/10	A. Mayila 10/15/10	Na 10/15/10	T:\117591 LHAAP\Doc\Mxd\Site16\Rod\Fig2-4 SampleLoc.mxd



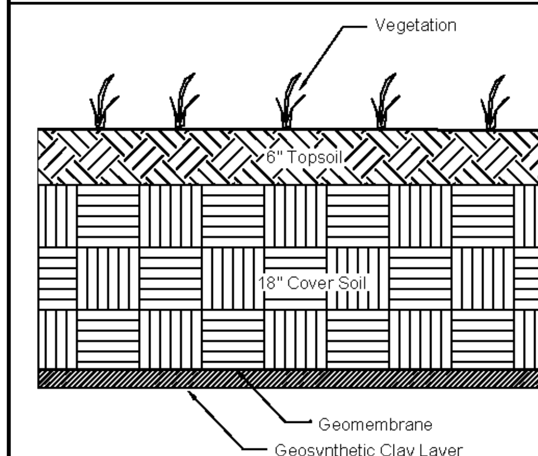
LEGEND

LHAAP-16 Landfill Fence

Landfill Cap Contours

Stream

Road



Cap Cross Section

0 115 230 460 Feet

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FIGURE 2-5

SITE MAP
LHAAP-16 RECORD OF DECISION

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		FILE PATH
Houston, TX	B. Grod	10/11/10	A. Mayila	10/15/10	Na	10/15/10	T:\117591_LHAAP\Doc\Mxd\Site16\Rod\Fig2-5_SiteMap.mxd

OFFICE	DRAWN BY		APPROVED BY		FILE PATH
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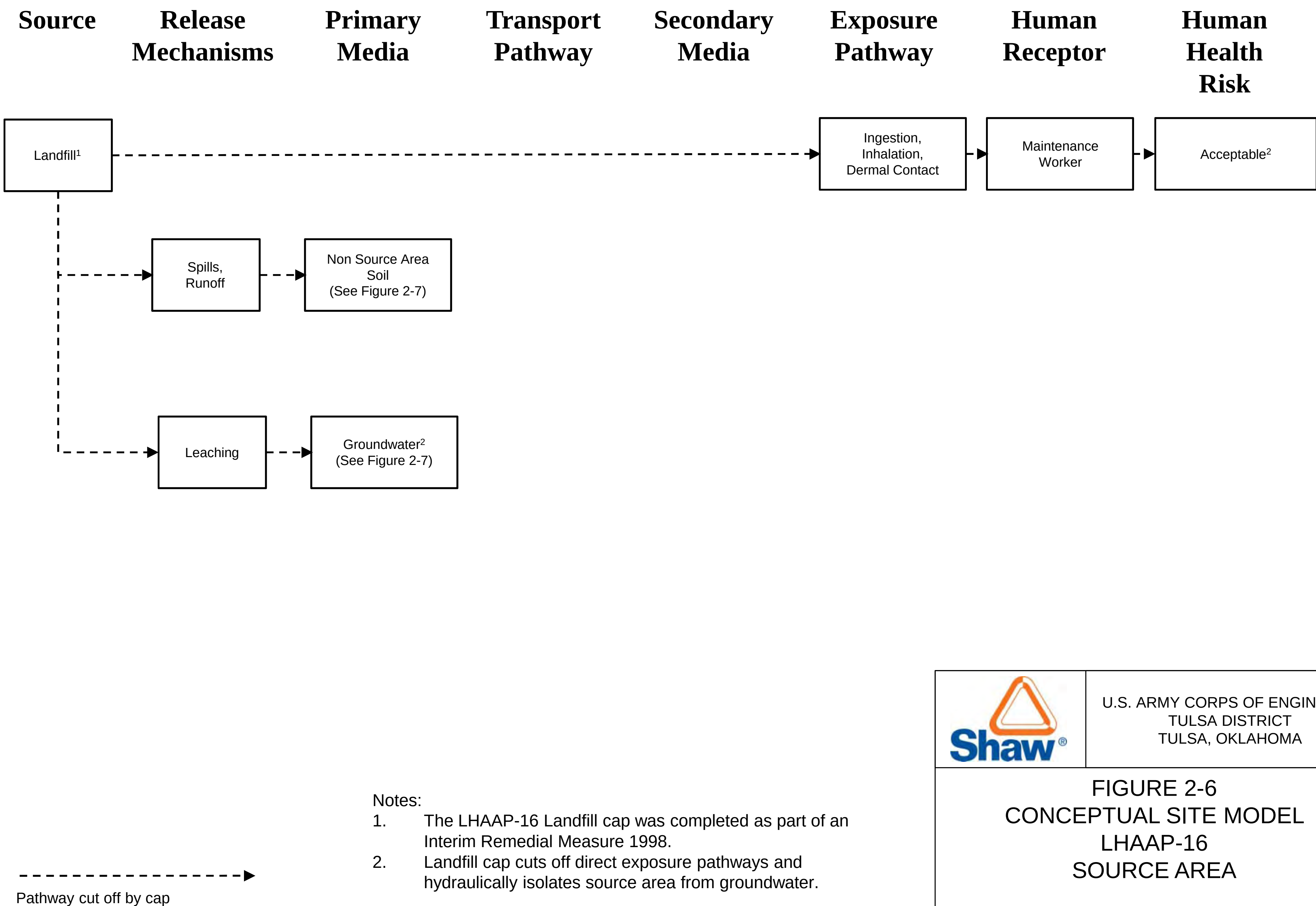

Notes:

1. The LHAAP-16 Landfill cap was completed as part of an Interim Remedial Measure 1998.
2. Landfill cap cuts off direct exposure pathways and hydraulically isolates source area from groundwater.

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FIGURE 2-6
CONCEPTUAL SITE MODEL
LHAAP-16
SOURCE AREA

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

OFFICE	DRAWN BY		APPROVED BY		FILE PATH
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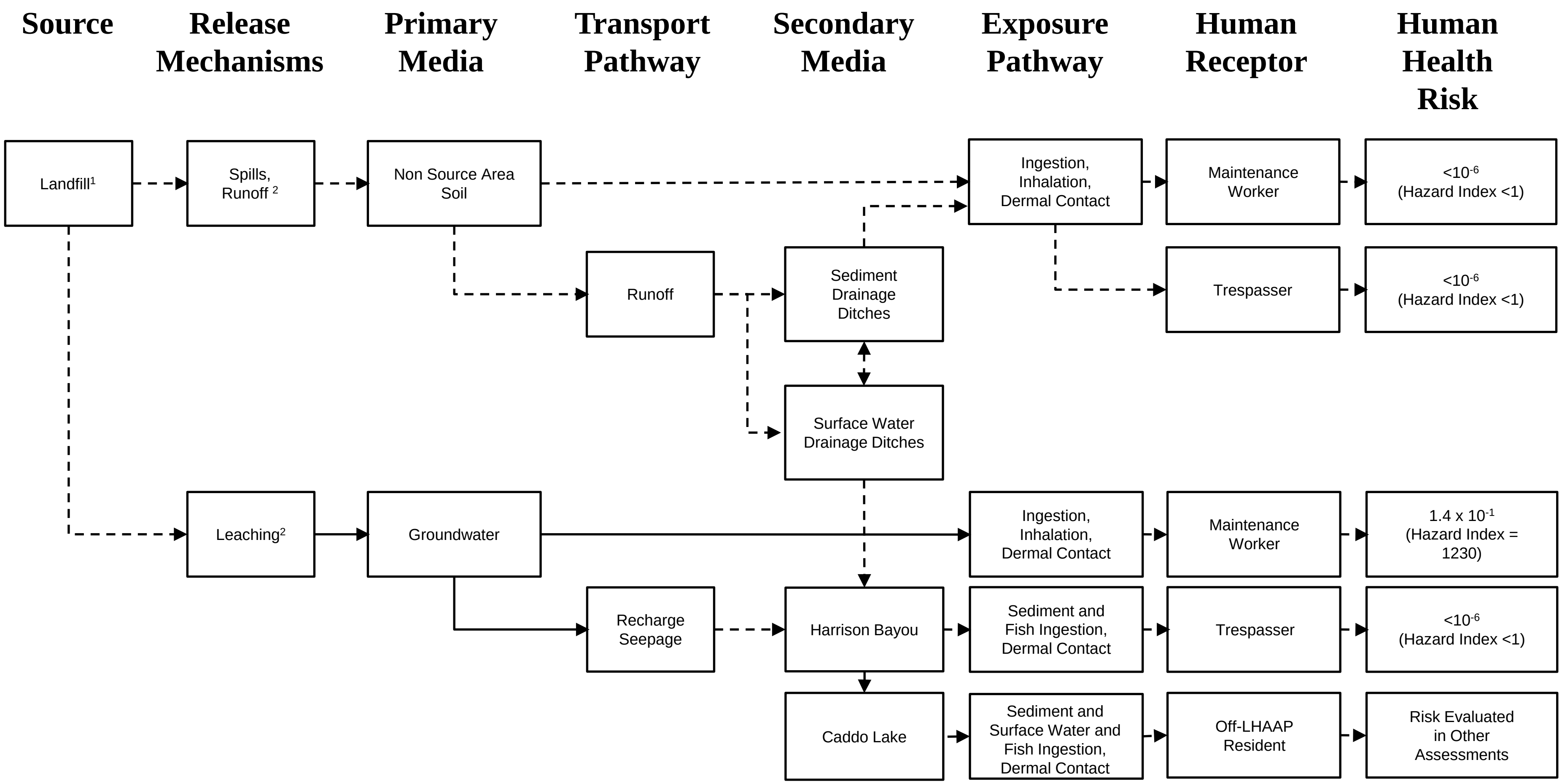

Pathway considered for remediation

Pathway not considered for remediation[3]

Notes:
1. The LHAAP-16 Landfill cap was completed as part of an Interim Remedial Measure 1998.
2. Prior to Interim Remedial Measure in 1998.
3. Risks are within acceptable range or are evaluated in separate assessments of Harrison Bayou or Caddo Lake.

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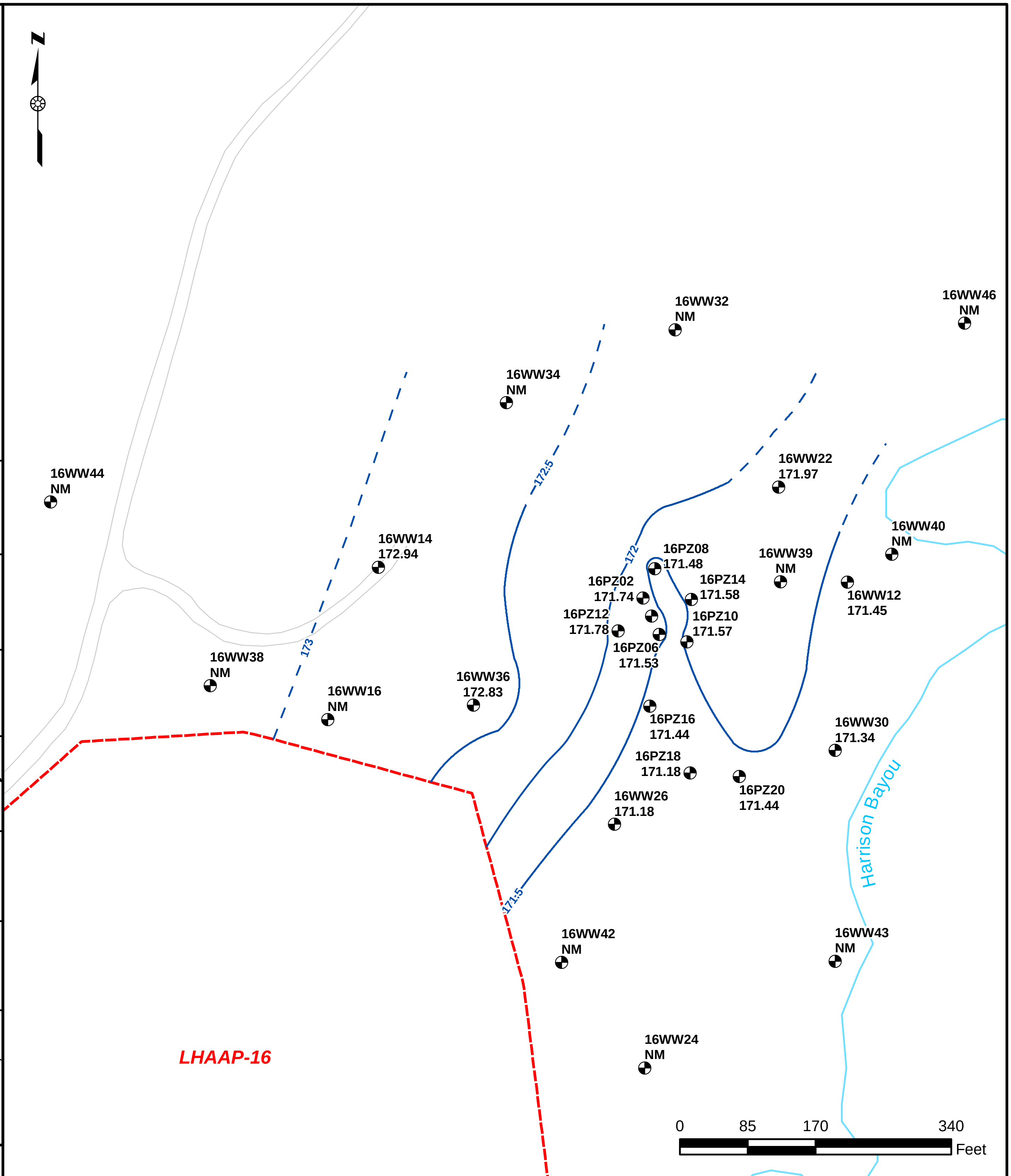
FIGURE 2-7
CONCEPTUAL SITE MODEL
LHAAP-16
NON-SOURCE AREA

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS



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Legend

- Shallow Monitoring Well
- Groundwater Elevation Countour
- Inferred Groundwater Elevation Countour
- Road
- Harrison Bayou
- LHAAP-16 Landfill Fence

NM - Not Measured

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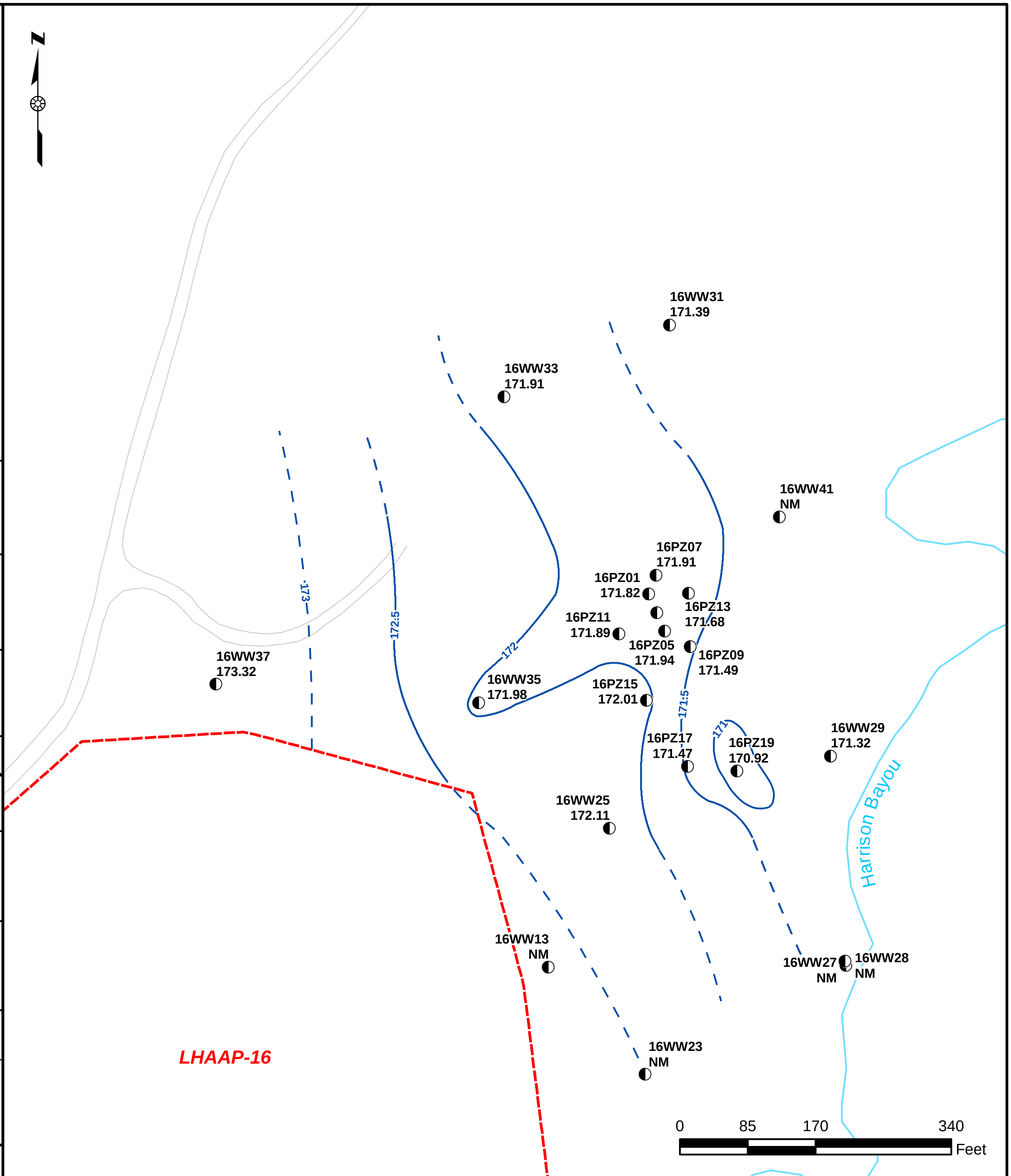
FIGURE 2-8

SHALLOW ZONE
GROUNDWATER ELEVATION MAP
JUNE 2007 DATA
LHAAP-16 RECORD OF DECISION

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS



OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		FILE PATH
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Legend

- Intermediate Monitoring Well
- LHAAP-16 Landfill Fence
- Groundwater Elevation Countour
- Inferred Groundwater Elevation Countour
- Road
- Harrison Bayou

NM - Not Measured

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FIGURE 2-9

INTERMEDIATE ZONE
GROUNDWATER ELEVATION MAP
JUNE 2007 DATA
LHAAP-16 RECORD OF DECISION

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

3.0 Responsiveness Summary

The Responsiveness Summary serves three purposes. First, it provides the U. S. Army, USEPA, and TCEQ with information about community concerns with the preferred alternative at LHAAP-16 as presented in the Proposed Plan. Second, it shows how the public's comments were considered in the decision-making process for selection of the remedy. Third, it provides a formal mechanism for the U.S. Army to respond to public comments.

The U.S. Army, USEPA, and TCEQ provide information regarding LHAAP-16 through public meetings, the Administrative Record for the facility, and announcements published in the Shreveport Times and Marshall News Messenger newspapers. **Section 2.3** discusses community participation on LHAAP-16, including the dates for the public comment period, the date, location, and time of the public meetings, and the location of the Administrative Record. The following documents related to community involvement were added to the Administrative Record:

- Transcript of the public meeting on October 19, 2010
- Presentation slides from the October 19, 2010 public meeting
- Written questions and comments from the public during the public comment period, and the U.S. Army response to those comments dated March 14, 2011.

3.1 Stakeholder Issues and Lead Agency Responses

This section responds to significant issues raised by stakeholders including the public and community groups that were received in written or verbal form.

Question/comment: The Army states that it could take 280 years to reduce groundwater contaminant concentrations to acceptable levels. It is not reasonable to propose plans that could require water quality monitoring, maintenance of the landfill cap, maintenance of the biobarriers, and maintenance of LUCs for such a length of time.

The Army should take steps to reduce the length of time that will be required to achieve acceptable contaminant concentrations. These steps could include: installation of an effective pump and treat system, modification of the proposed in-situ bioremediation system to cover a greater portion of the site and to operate until acceptable concentrations are achieved, thermal treatment (e.g., steam stripping), and elimination or reduction of the contaminant source by removing the landfill or reducing the mass of contaminants that it contains.

Response: Given the nature of the residual contaminants that are present at LHAAP-16, the length of time that will be required to achieve cleanup levels would be long for any of the remedial alternatives, whether treatment, migration control, or source control by removal.

It is believed that TCE was present within the landfill as DNAPL has dissolved into the groundwater at very high concentrations and migrated to the east (down-gradient of the landfill). This high concentration region acts as a secondary source of groundwater contamination. Although TCE may remain in the landfill, the landfill cover system has significantly reduced the driving force of recharge and added a degree of isolation to the remaining waste. Removal of the landfill would not affect the secondary source of groundwater contamination outside the landfill and would be a very large cost without corresponding benefit.

The LUCs restricting the use of groundwater will be highly effective as will be long term maintenance of the LUCs, given that the reasonably anticipated future use of the site is as a national wildlife refuge (i.e., Caddo Lake National Wildlife Refuge) and the owner a federal agency. Once the property is transferred into the refuge system, the property must be kept as a National Wildlife Refuge unless there is an act of Congress which removes the parcel or the land is exchanged in accordance with the National Wildlife Refuge System Administration Act of 1966 and the National Wildlife Refuge System Act Amendments of 1974. A national wildlife refuge by its very nature includes physical access and use restrictions, and is subject to control and continual inspection by Refuge personnel. The LUCs will restrict access to the groundwater for purposes other than environmental testing until cleanup levels are met. Additionally, access of groundwater through well installations requires a permit from the Texas Department of Licensing and Regulation or Texas Water District authority. The department will be provided a copy of the county recordation that indicates the location of contaminated groundwater at the site and associated restriction.

Since LHAAP-16 is enclosed within a national wildlife refuge with no current or planned use of groundwater for human consumption, plume stability and protection of Harrison Bayou are key measures for evaluation of a remedial strategy. A detailed analysis of alternatives, including those with aggressive treatments, was conducted according to the evaluation criteria identified in the NCP (40CFR 300.430). Advantages, disadvantages, and trade-offs were considered as part of the evaluation process during the feasibility study (Jacobs, 2002). The suggested alternatives were considered in the FS and were not seen as sufficiently advantageous over the preferred alternative (Shaw, 2010).

Question/Comment: Groundwater contamination at LHAAP-16 is caused by contaminants being leached from wastes in the landfill. The landfill could continue to generate large amounts of contaminants for decades or centuries. The Army's preferred alternative does not attempt to reduce the length of time that the landfill will generate contaminants.

The Army should attempt to reduce the length of time the landfill will generate large amounts of contaminants. This could be done by 1) removing the landfill or 2) treating the landfill to reduce the mass of contaminants it contains (e.g., hot-spot removal, flushing with surfactants or solvents, bioremediation, vapor extraction).

Response: It is believed that TCE was present within the landfill as DNAPL has dissolved into the groundwater at very high concentrations and migrated to the east (down-gradient of the landfill). This high concentration region acts as a secondary source of groundwater contamination. Although TCE may remain in the landfill, the landfill cover system has significantly reduced the driving force of recharge and added a degree of isolation to the remaining waste. The biobarrier will be installed at the edge of the landfill to treat/remediate and thereby control potential migration of contaminants from the landfill. Removal of the landfill would not affect the secondary source of groundwater contamination outside the landfill and would be a very large cost without corresponding benefit. Since LHAAP-16 is enclosed within a national wildlife refuge with no current or planned use of groundwater for human consumption, plume stability and protection of Harrison Bayou are more important measures for evaluation of remedial alternatives than the time factor.

In 1998 a landfill system was placed over the site and was completed as part of an early Interim Remedial Action (IRA) in accordance with the USEPA presumptive remedy guidance under CERCLA for municipal landfills (EPA 540-F-93-035) and for military landfills (EPA 540-F-96-020). Capping as opposed to waste treatment or removal, is a presumptive remedy at landfills as it has been shown to be more appropriate in comparison to other remedies. The IRA was intended to be consistent with the final remedy and is considered a component of the final remedy being proposed for LHAAP-16.

Landfill removal and landfill source treatment alternatives were included in the comparative analysis of alternatives performed during the feasibility study (Jacobs, 2002) and during the generation of the proposed plan (Shaw 2010) for LHAAP-16. These remedial alternatives did not demonstrate increases in effectiveness that were balanced by their increased costs and short-term impacts.

Question/Comment: The Army's 280 year estimate of cleanup time due to natural attenuation is not based on solid evidence. It appears that the Army chose this number because it was the cleanup time calculated for natural attenuation of TCE at well 16WW16. However, a longer TCE cleanup time (492 years) was calculated for well 16WW12. In addition, contaminant concentrations in some wells are stable or increasing rather than decreasing (e.g., perchlorate in well 16WW12, and TCE in well 16WW36). The calculated cleanup time due to natural attenuation for these wells would be infinity.

The Army does not address the question of whether the remedial actions it has conducted at the site have affected the cleanup time calculations. That is, are the contaminant reductions seen at the site due to natural attenuation, the remedial actions, or both?

Response: The duration of 280 years was considered as a reasonable estimate based on the prior history of TCE concentrations at 16WW16. The wells with stable or increasing concentrations are in areas where treatment will be applied, or where biobarriers will cut off renewal of contaminants from upgradient areas. Implementing the remedy is expected to expedite attenuation rates, making them faster, so the worst case scenario at 16WW12 was not chosen as a representative case. Instead the second slowest measurable attenuation was used as an initial estimate for duration.

Contaminant reductions thus far are due to a combination of past actions and natural attenuation. Past actions have removed contaminant mass in some areas of the site and can thus be assumed to have reduced cleanup time in those specific areas, though there is insufficient historical data to quantify the extent of that reduction. The areas most affected in this way would be the capture zone of the extraction wells and a small area immediately down-gradient of the semi-passive biobarrier. The cleanup times at locations that are outside the immediate down-gradient vicinity of the semi-passive biobarrier and far from the extraction wells can be assumed to be outside any significant influence from either of those past actions. Most of the wells at the site (e.g., 16WW16, 16WW12, 16WW43, etc.) are outside those influences.

Question/Comment: The Army intends to evaluate the effectiveness of natural attenuation in a 28 month period following the installation of the biobarriers and the in-situ bioremediation system, and after groundwater extraction has been discontinued. This does not appear to make sense. The effects of the remedial actions will persist for some unknown period of time. How will the Army distinguish between the effects of the remedial actions, and the effects of natural attenuation?

Response: The application of biobarriers and bioremediation will be in discrete areas. The effectiveness of remedial actions will be evaluated for wells in those areas. MNA will be evaluated for wells that are outside the remedial action areas.

Question/Comment: The Army should clearly explain how it will determine whether natural attenuation is reducing contaminants concentrations at an acceptable rate.

Response: The Army intends to present details of the MNA remedy implementation in a remedial design for LHAAP-16. The regulatory guidance established by USEPA (1998) for MNA will be followed to demonstrate that natural attenuation is occurring.

Question/Comment: The passive biobarriers will intercept groundwater only in the shallow zone. However, the intermediate zone also contains high concentrations of contaminants. The Army should explain why it chose not to extend the passive barriers into the intermediate zone.

Response: Biobarriers were not extended into the intermediate zone because the intermediate zone does not intersect surface water in Harrison Bayou. The intermediate zone is deeper than the flowline elevation of the bayou. The highest recent COC concentrations in the intermediate zone are more than 10 times lower than recent COC concentrations in the shallow zone. Nonetheless, the intermediate zone will be addressed via bioremediation injections in the most contaminated locations that have been detected within that zone. MNA will be implemented for areas outside the influence of the active remedies. Monitoring will verify protection of human health and the environment by documenting that further reductive dechlorination is occurring within the plume, that the plume is not migrating, and that contaminant concentrations are being reduced to cleanup levels.

Question/Comment: The pumping of the extraction wells may be limiting the lateral expansion of the contaminant plume. After the extraction wells are shut down, the plume may expand such that it will flow around the ends of the down gradient biobarrier. The Army should consider this possibility in its final remedial design.

Response: There are no plans to remove the extraction system, just to turn it off. The extraction wells will be shut down after application of in situ bioremediation. In situ bioremediation is expected to greatly reduce contaminant concentrations in the application area, minimizing the migration of contaminants toward the biobarrier that will be installed near the bayou. The biobarrier at the landfill is expected to treat contaminated groundwater thereby controlling renewal of the plume at the landfill boundary. The biobarrier is a treatment remedy for contaminated groundwater and not a physical barrier to preventing flow of groundwater. The remnants of the plume are expected to attenuate over time, and groundwater monitoring will continue to check for future potential migration.

Question/Comment: Groundwater up-gradient of Harrison Bayou is highly contaminated, and the contaminant plume emanating from the landfill is discharging to Harrison Bayou. However, there is no reason to believe that Harrison Bayou acts as a complete barrier to groundwater flow. A portion of the contaminant plume may extend beyond the bayou. The Army should install monitor wells to the east of Harrison Bayou to determine the full extent of groundwater contamination.

Response: Since 1999, the Army has collected quarterly surface water samples from three locations in Harrison Bayou. During August 2003 and August 2007, perchlorate was detected in the surface water samples collected from one sampling location in Harrison Bayou (HBW-1) indicating there is some discharge by seepage into Harrison Bayou. Except for the 2 quarters, perchlorate was not detected in any other samples during any other sampling events.

Many wells exist on the east side of Harrison Bayou. The pair of wells closest to the east is 18WW10 (shallow) and 18WW11 (intermediate), which show no COC contamination.

Question/Comment: The proposed monitor well network will not detect contaminants that flow to the southeast of the down gradient barrier. The Army should install at least one shallow and one intermediate monitor well between the southeast end of the barrier and Harrison Bayou.

The proposed monitor well network does not include an intermediate monitor well between the down gradient barrier and Harrison Bayou. The Army should install an intermediate monitor well next to well 16WW40.

The proposed monitor well network will not detect contaminants that flow thorough the northern portion of the down gradient barrier. The Army should install at least one shallow and one intermediate monitor well between the northern portion of the barrier and Harrison Bayou.

The extent of the contaminant plume in the shallow aquifer north of well 16WW22, and in the intermediate aquifer north of well 16WW41, is unknown. The Army should install at least one shallow well and one intermediate monitor well to the north of these wells.

Response: The need for installation of additional monitoring wells will be evaluated during the remedial design.

Question/Comment: The Army Corps of Engineers determined that the eastern portion of the site is within the floodplain of Harrison Bayou. It is not clear, however, whether any portion of the landfill itself is in the floodplain. The Army should determine whether any portion of the landfill is within the floodplain. If it is, steps should be taken to protect the landfill from the effects of flooding.

Response: The southeastern edge of the landfill is within the floodplain (U.S. Department of Housing and Urban Development, Flood Hazard Boundary Map, Harrison County, Texas, Unincorporated Area, Community Panel Number 480847 0004 A, Effective date: September 6, 1977, Converted by Letter Effective 11/1/89). This was known at the time the record of decision was signed for design and construction of the landfill. The southeastern portion of the landfill was designed with a compacted soil berm to protect the cap from flood waters. Additionally, the landfill cap is inspected periodically and maintenance is performed as necessary. The design and the follow-up inspection/maintenance activities are expected to be sufficient to protect the landfill from the effects of flooding.

Question/Comment: The Army is proposing only one sampling point on Harrison Bayou near site 16. Thus, if contaminants are detected, the Army will not be able to determine whether they are coming from site 16 or from an upstream source. In addition, this single sampling point will not detect any site 16 contaminants that enter Harrison Bayou downstream of the point. That is, it will not detect contaminants that may flow around the northern end of the biobarrier, or through the barrier if it fails to function as intended.

Response: Based on groundwater flow and the proximity of Harrison Bayou, sampling location HBW-1 is considered the location most likely to reveal contamination resulting from LHAAP-16. Continued sampling of HBW-1 or a nearby location will be required by the ROD for LHAAP-16. In accordance with a 1999 agreement between Army, TCEQ, and EPA, the Army currently collects quarterly surface water samples from HBW-1 plus two other locations in Harrison Bayou - HBW-10, which is upstream, and HBW-7, which is downstream. While the Army, TCEQ, and EPA might agree to alter the locations of HBW-7 and HBW-10 at some later date, perchlorate results over the last 10 years have indicated that HBW-1 is the location of greatest concern.

In addition, the selected remedy also includes a network of monitoring wells down gradient of the biobarrier in addition to the surface water sampling. Therefore, concentrations of groundwater that has the potential to enter into Harrison Bayou would be known.

Question/Comment: Although Harrison Bayou was not flowing on October 19, 2010, there was a pool of standing water in the streambed. This pool was about 30 feet upstream of well 16WW40, and in the same area as the seep that was sampled in 1995. The pool was approximately 20 feet long, three feet wide, and a few inches deep. This pooled water may be groundwater that has discharged to the streambed. During periods when Harrison Bayou was not flowing, the Army should monitor the streambed for pools of water. If they are present, they should be sampled. The Army should also monitor the banks of Harrison Bayou for seeps and should attempt to sample any that are discovered.

Response: Previous sampling of the standing water in Harrison Bayou indicated that in the past contaminated groundwater discharged by seepage into Harrison Bayou. Because the basis for sampling is protection of human health by protecting the surface water that flows through Harrison Bayou to Caddo Lake, continued sampling of standing water in pools will serve no purpose. Periodic sampling of surface water is already conducted on a quarterly basis at three locations in Harrison Bayou. The banks of Harrison Bayou will be inspected for locations of possible seeps.

Question/Comment: The Army performed a 'streamlined' Human Health Risk Assessment for Harrison Bayou at site 16. This risk assessment found that the excess lifetime cancer risk for dermal contact with Harrison Bayou surface water was 1.62×10^{-5}. This is higher than the lower bound (1.0×10^{-6}) of the EPA target risk range. The streamlined assessment did not estimate the human health risk from drinking the water, nor did it estimate the effects that the water could have on Caddo Lake. The Army stated that a full risk assessment of Harrison Bayou would be conducted as part of the Group 2 risk assessment. However, site 16 does not appear to have been included in the Group 2 risk assessment. The Army should perform a full Human Health Risk Assessment for Harrison Bayou at site 16.

Response: The calculated risk from surface water (1.62×10^{-5}) was within the range of acceptable risk levels for excess lifetime cancer risk (1×10^{-4} to 1×10^{-6}). The Group 2 Risk Assessment included a risk assessment for Harrison Bayou and sampling location HBW-1, which is associated with LHAAP-16 was included as part of that assessment. Additionally the risk assessment report states "because the depth of this surface water body ranges from a few inches to a few feet, it is unlikely that it would be used to any significant extent for swimming; therefore, the incidental ingestion of surface water is not evaluated".

Question/Comment: Concentrations of antimony and thallium that exceed the EPA MCL are commonly detected in groundwater at site 16. However, the Army has not included antimony or thallium as contaminants of concern (COC). The Army should either include antimony and thallium as a COCs for groundwater at site 16, or explain why they are omitted.

Response: Antimony and thallium are commonly found in groundwater and were detected in groundwater at LHAAP-16. However, they were not found to be significant contributors to cancer risk or non-cancer hazard in groundwater at LHAAP-16 during the human health risk assessment conducted for the site (Jacobs, 2001). The detections of antimony and thallium were erratic and did not appear to represent a plume of contamination. Additionally, they were not detected above background levels in soil at the landfill. These factors indicated that their occurrence was unlikely to be associated with contamination from the landfill. The detections of antimony in groundwater were also within the range of groundwater background values at Longhorn AAP (Shaw, 2007) indicating antimony is naturally occurring at the site. Therefore, antimony has not been included in the list of contaminants of concern at the site. Since thallium does not have a background value and has had historically high detection limits (2003 and 2004 analytical results), additional groundwater sampling for thallium will be integrated into the RD phase for LHAAP-16.

Question/Comment: The Army is using reporting limits for thallium in groundwater that are higher than the EPA MCL. Thus, concentrations of thallium that exceed the MCL may be undetected or unreported. The Army should use a thallium reporting limit that is less than the MCL.

Response: Given the results from 1997 (which had appropriate detection limits) and the lack of significant soil results, the U.S. Army considered thallium in the LHAAP-16 groundwater samples to be naturally occurring sporadic detections that were unrelated to site contamination. However, the Army concurs that analytical results in 2003 and 2004 samples had high detection limits and drive the need for further evaluation of thallium. Thus, thallium will be added to the COC list and will be the subject of additional groundwater monitoring. Monitoring results will be evaluated at the first five-year review to determine if any further monitoring for thallium is warranted.

Question/Comment: High concentrations of dioxins and/or furans have been detected in surface water and groundwater at site 16. However, neither dioxins nor furans are included as COCs for surface water or groundwater. The Army should either include dioxins and furans as COCs, or explain why they are omitted.

Response: The concentrations of dioxins/furans were evaluated as a composited value for total dioxins/furans based on relative toxicities of the individual chemicals. That composited value is the toxicity equivalent (TEQ), and it can be directly compared with the MCL for dioxin. The highest TEQ dioxin concentration was lower than the MCL, so dioxins/furans were not selected as a COC.

Question/Comment: The Army's compliance level for perchlorate in Harrison Bayou is 26 µg/L, which is TCEQ's groundwater medium specific concentration for residential use (GW-Res). However, the EPA's Health Advisory (HA) level for perchlorate is 15 µg/L. Although the HA is not an enforceable MCL, it is reasonable to assume that when it is finally established, the perchlorate MCL will be similar to the HA. The Army should explain why it did not use the HA level as the cleanup level.

Response: The cleanup level and surface water compliance level for perchlorate is 17 µg/L, which is the TRRP Tier 1 Groundwater Residential PCL. The cleanup level for perchlorate was revised as a result of dispute resolution between the Army and the EPA. If enforceable limits change in the future, or are newly introduced, the difference between the cleanup level and any such new limits will be subject for discussion during the five year reviews.

Question/Comment: The final details of the remedial action will be presented in a Remedial Design (RD). The Army should make the RD available for public review and comment as soon as it is developed. The Army's Proposed Plan does not mention the development of a contingency plan to be invoked if the remedial actions are not performing satisfactorily. A contingency plan should be included in the RD.

Response: The public will be provided with updates on remedial design and remedial action status through the RAB meeting and any concerns can be addressed through this forum. The RD will include performance objectives, schedule and other design criteria and will follow established regulatory guidance for MNA.

The concept of a contingency plan for what to do if the remedy is unsuccessful as implemented is inherent in the process of remediation. The remedy must be determined to be operating properly and successfully. Other opportunities for implementing contingency plans will occur with each five-year review.

Question/Comment: The Army reported an average groundwater speed in the shallow zone of 36.7 ft/yr. However, groundwater speeds in the shallow zone range from 0.44 ft/yr - 990 ft/yr.

The higher values may be associated with paleochannels, while the lower values may be associated with ancient overbank deposits that border the paleochannels. When evaluating the transport of contaminants in groundwater, we are usually more concerned with the contaminants that flow most rapidly, rather than those that flow at average or lower speeds.

Response: Noted. The groundwater velocity is not directly measured, but is estimated from groundwater gradients and the average of hydraulic conductivities measured in individual wells. There can be considerable variability of hydraulic conductivity from well to well, so using the average hydraulic conductivity is reasonable for calculating the overall groundwater velocity for the entire site.

Question/Comment: Alternative 7 seems to be the path of least resistance rather than a proactive approach. It appears the Army is trying to do as little as possible for a very contaminated site and not fix the problems for LHAAP-16. The relative low cost was based on the Army's 30 year payout and the possible length of time to remediate the landfill is projected to be 280 years. More investigation should be conducted before finalizing the plans for Site 16 Landfill.

Response: More investigation is not considered necessary to understand the contamination and hydrogeology at LHAAP-16. Additional investigations are unlikely to alter the conclusions that have led to the development of remedial alternatives for the site. Delaying implementation of a remedy to perform more investigations would be less protective of human health than proceeding with the preferred remedy. Besides actively treating the more contaminated portions of the groundwater, the preferred remedy will require monitoring, control of groundwater use, and periodic review of the conditions of the site. The components of the remedy that apply to the more contaminated portions of the groundwater would be implemented within a few years – well within the 30 year period of the cost estimate. Due to the future land use, it is reasonable to utilize monitored natural attenuation to address the remaining contamination over a much longer time period. The preferred remedy has been deemed to be protective of the human health and the environment.

Question/Comment: The Army's proposal for dealing with this highly contaminated landfill consist mostly of future monitoring, periodic groundwater water treatment, and implementing some small barrier walls to hopefully slow down the migration of contaminated groundwater into nearby Caddo Lake. Unfortunately, this is already happening, although the Army claims to not know to what extent. Site 16 landfill remedy has a projected cost of a little less than 2 million dollars for its proposed 30 year clean-up plan. The Army says it will possibly take 280 years to complete the site 16 landfill clean-up; this must indicate that the site is highly contaminated.

Response: A landfill cap and cover system was placed over the site and was completed as part of an early IRA. Landfill cap is a presumptive remedy for municipal landfills (USEPA, 1993) and for military landfills (USEPA, 1996). A landfill cap and cover system eliminated the direct exposure pathway to source area waste material, preventing contaminant transport to surface water via surface runoff, and reducing leaching of contaminants to the groundwater The IRA was intended to be consistent with the final remedy and is considered a component of the final remedy being proposed for LHAAP-16.

Rather than slowing the migration of the contamination, the proposed biobarriers and bioremediation injections are intended to destroy much of the identified contamination. The active remedies that apply to the more contaminated portions of the groundwater would be implemented first and followed by monitored natural attenuation. Due to the future land use, it is reasonable for the preferred alternative to utilize monitored natural attenuation to address the areas outside of the active remedies over a much longer time period.

Question/Comment: Does the Army have a plan for what it intends to do after the first 30 year segment of the clean-up project has been completed? Could it possibly be the same remedy continued, or a new plan at a much greater cost? Or, could it be that nothing will be done because the sands of time have by then washed away all the records and memory of site 16, leaving it for future generations to unknowingly suffer from and possibly have to deal with?

Response: The expectation at this time is that the remedy would continue. At the five-year reviews, the remedy is evaluated and adjusted or changed if necessary.

Question/Comment: The remediation cost is $183.00 per day for LHAAP-16 for 'no' removal of many "known" and "unknown" toxic chemicals buried at the site. Site 16 landfill has been determined by the EPA to be so contaminated it is listed as a Federally Funded Military Superfund Clean-up site. There are most likely metal containers of toxic chemicals buried at the site that will eventually rust through and cause additional soil and groundwater contamination beyond what is currently known or detected.

Response: A detailed analysis of several alternatives including landfill removal was conducted in accordance with the evaluation criteria identified in the NCP (40CFR 300.430). Advantages, disadvantages, and trade-offs were considered as part of the evaluation process during the feasibility study (Jacobs, 2002). The selected remedy for LHAAP-16 was preferred over other alternatives because it provides the best combination of major trade-offs, is protective of human health and the environment and is compliant with regulatory requirements.

Question/Comment: Nearby Caddo Lake may eventually be home to this toxic waste since it is migrating through the soil and groundwater in that direction.

Response: The history of LHAAP-16 indicates the contamination migrates via groundwater flow, not through transport of soil. Contaminated groundwater does exist at LHAAP-16, but is not flowing into Caddo Lake. While sample results for Harrison Bayou surface water indicate that it is within the allowable water quality limits for the contaminants of concern, the groundwater near the bayou has elevated concentrations of those contaminants. The concern for preventing seepage of contaminants to the bayou was a significant factor in proposing a remedial action that includes a biobarrier to intercept that contamination.

3.2 Technical and Legal Issues

This section is used to expand on technical and legal issues. However, there are no issues of that nature beyond the technical issues already discussed in **Section 3.1**.

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Glossary of Terms

Glossary of Terms

Administrative Record File – The body of reports, official correspondence, and other documents that establishes the official record of the analysis, clean up, and final closure of a site.

ARARs – Applicable or relevant and appropriate requirements. Refers to the federal and state requirements that a selected remedy will attain.

Attenuation – The process by which a compound is reduced in concentration over time, through absorption, adsorption, degradation, dilution, and/or transformation.

Background Levels – Naturally-occurring concentrations of inorganic elements (metals) that are present in the environment and have not been altered by human activity.

Baseline Ecological Risk Assessment (BERA) – A study conducted as part of a remedial investigation to determine the risk posed to environmental receptors by site-related chemicals.

Baseline Human Health Risk Assessment (BHHRA) – A study conducted as part of a remedial investigation to determine the risk posed to human health by site-related chemicals.

Characterization – The compilation of available data about the waste site to determine the rate and extent of contaminant migration resulting from the site, and the concentration of any contaminants that may be present.

Chemicals of Concern (COCs) – Those chemicals that significantly contribute to a pathway in an exposure model of a hypothetical receptor (e.g., a child that resides on a site). They exceed either the calculated numerical limit for cumulative site carcinogenic risk (1 in 10,000 exposed individuals) or the calculated numerical limit of 1 for non-carcinogenic effects, a value proposed by the USEPA.

Chemical of Potential Concern (COPCs) – Those chemicals that are identified as a potential threat to human health or the environment and are evaluated further in the baseline risk assessment. COCs are a subset of the COPCs that are identified in the Remedial Investigation/Feasibility Study as needing to be addressed by the response action proposed in the Record of Decision.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) – CERCLA was enacted by Congress in 1980 and was amended by the Superfund Amendments and Reauthorization Act in 1986. CERCLA provides federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment. CERCLA established prohibitions and requirements concerning closed and abandoned hazardous waste sites and established the Superfund Trust Fund.

Glossary of Terms (continued)

Contaminant Plume – A column of contamination with measurable horizontal and vertical dimensions that is suspended and moves with groundwater.

Exposure – Contact of an organism with a chemical or physical agent. Exposure is quantified as the amount of the agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut) and available for absorption.

Federal Facility Agreement – A binding legal agreement among USEPA, TCEQ, and U.S. Army that sets the standards and schedules for the comprehensive remediation of Longhorn Army Ammunition Plant.

Groundwater – Underground water that fills pores in soil or openings in rocks to the point of saturation.

Human Health Risk Assessment – A study conducted as part of a remedial investigation to determine the risk posed to human health by site-related chemicals.

Maximum Contaminant Level (MCL) – The maximum contaminant level is the maximum permissible level of a contaminant in a public water system. MCLs are defined in the Code of Federal Regulation (40 CFR 141, National Primary Drinking Water Regulations, which implement portions of the Safe Drinking Water Act). The TCEQ has adopted MCLs as the regulatory cleanup levels for both industrial and residential uses. Any detected compound in the groundwater samples with a MCL was evaluated by comparing it to its associated MCL.

National Priorities List (NPL) – The USEPA's list of the most serious uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial action under Superfund. USEPA is required to update the NPL at least once a year. A site must be on the NPL to receive money from the Trust Fund for remedial action.

Organic Compounds – Carbon compounds such as solvents, oils, and pesticides. Most are not readily dissolved in water.

Perchlorate – Ammonium perchlorate is a strong oxidizing compound that was used in various industries (solid rocket and jet propellant, medical field, and other processes).

Record of Decision – A legal document presenting the remedial action selected for a site or operable unit. It is based on information and technical analyses generated during the remedial investigation/feasibility study process and consideration of public comments on the proposed plan and community concerns.

Glossary of Terms (continued)

Remedial Investigation – A study designed to gather data needed to determine the nature and extent of contamination at a Superfund site.

Resource Conservation and Recovery Act (RCRA) – Gives USEPA the authority to control the generation, transport, treatment, storage, and disposal of hazardous waste. RCRA focuses only on active and future facilities and does not address abandoned or historical sites.

Responsiveness Summary – A summary of oral and/or written comments received during the proposed plan comment period, including responses to these comments. The responsiveness summary is a key part of a ROD highlighting community concerns.

Proposed Plan – A plan for a site cleanup that proposes a recommended or preferred remedial alternative. The Proposed Plan is available to the public for review and comment. The preferred alternative may change based on public and other stakeholder input.

Superfund Amendments and Reauthorization Act (SARA) – Amended CERCLA in 1986. SARA resulted in more emphasis on permanent remedies for cleaning up hazardous waste sites, increased the focus on human health problems posed by hazardous waste sites, and encouraged greater citizen participation in making decisions on how sites should be cleaned up.

Surface Media – The soil (surface or subsurface), surface water, and sediment present at a site as applicable.

Superfund – The common name used for CERCLA; also referred to as the Trust Fund. The Superfund Program was established to help fund cleanup of hazardous waste sites. It also allows legal action to force those responsible for sites to clean them up.

Trichloroethene (TCE) – TCE is a colorless or blue liquid with an odor similar to ether. It is man-made and does not occur naturally in the environment. TCE was once commonly used to remove oils and grease from metal parts and is used in the dry cleaning industry.

Appendix A

Public Meeting Newspaper and Media Notices

PUBLIC NOTICE
THE UNITED STATES ARMY INVITES PUBLIC COMMENT ON THE PROPOSED PLAN FOR ENVIRONMENTAL SITE LHAAP-16
LONGHORN ARMY AMMUNITION PLANT, TEXAS
PUBLIC MEETING ON OCTOBER 19, 2010,
AT THE CADDO LAKE STATE PARK RECREATIONAL FACILITY

The U.S. Army is the lead agency for environmental response actions at Longhorn Army Ammunition Plant (LHAAP). In partnership with Texas Commission on Environmental Quality and the U.S. Environmental Protection Agency Region 6 (USEPA), the U.S. Army has developed the Proposed Plan for NPL site LHAAP-16. Although the Proposed Plan for LHAAP-16 identifies the preferred remedy for the site, the U.S. Army welcomes the public's review and comments. Beginning on October 10, 2010 copies of the Proposed Plan and supporting documentation will be available for public review at the Marshall Public Library, 300 S. Alamo, Marshall, Texas, 75670. The public comment period is October 10, 2010, through November 9, 2010. **The public meeting will be held on Tuesday, October 19, 2010 at the Caddo Lake State Park Group Recreation Hall from 7:00 PM to 9:00 PM.** Caddo Lake State Park is located at 245 Park Road 2 near Karnack, Texas off of FM 2198 between SH 43 and Old Farm to Market Road 134, approximately 1 mile north from the Karnack Post Office (and front gate of the former Longhorn Army Ammunition Plant). The park entrance fee will be waived for the attendees of this meeting. Questions, comments, and responses on the Proposed Plan will be recorded by a court reporter during the public meeting. Written comments will be accepted throughout the public comment period.

Longhorn Army Ammunition Plant (LHAAP) is an inactive, government-owned, formerly contractor-operated and -maintained industrial facility located in central-east Texas in the northeastern corner of Harrison County. The installation occupies nearly 8,416 acres between State Highway 43 at Karnack, Texas, and the western shore of Caddo Lake. LHAAP was established in December 1941 near the beginning of World War II for the manufacture of trinitrotoluene. Other past industrial operations at the installation included the use of secondary explosives, rocket motor propellants, and various pyrotechnics, such as illuminating and signal flares and ammunition. LHAAP was found to have actual and potential releases of hazardous substances or pollutants or contaminants associated with past operations, and it was added to the National Priorities List (NPL) in 1990.

LHAAP-16 encompasses an area of approximately 20 acres in the south-central portion of LHAAP. Harrison Bayou runs along the northeastern edge of LHAAP-16. The landfill was established in the 1940s and was used for disposal of solid and industrial wastes until the 1980s when disposal activities were terminated. The Army and USEPA signed a Record of Decision in 1995 approving an interim remedial action for LHAAP-16 to mitigate potential risks posed by buried source material at the landfill. The interim remedial action included the construction of a multilayer landfill cap, which was completed in 1998.

The current Proposed Plan for LHAAP-16 addresses groundwater contamination as well as material buried in the landfill at the site. Continued maintenance of the existing landfill cap has been retained as a component of most of the remedial alternatives considered for the site. In addition, most alternatives include specific measures for groundwater remediation, and all alternatives utilize some degree of land use controls (LUCs). The full list of alternatives is: I) No action; 2) Cap, enhanced groundwater extraction; 3a) Cap, monitored natural attenuation; 3b) Cap, hot spot extraction, monitored natural attenuation; 4) Cap, passive groundwater treatment; 5a) Landfill hotspot removal, passive groundwater treatment; 5b) Complete landfill removal, passive groundwater treatment; 6) Landfill Source Treatment (in situ), monitored natural attenuation; and 7) Cap, monitored natural attenuation, in situ enhanced bioremediation, passive bio barriers. Based on available information, the preferred remedy is Alternative 7, which addresses the groundwater contamination at LHAAP-16 in a manner that is cost-effective and consistent with the Army's intent to transfer the site to the USFWS for use as a wildlife refuge. Alternative 7 would be protective of human health due to the implementation of LUCs prohibiting unauthorized use of the cap and groundwater, thereby eliminating the potential contaminant exposure pathways for human receptors. The bioremediation and bio barriers would reduce contaminant concentrations in groundwater and prevent discharge of contamination to Harrison Bayou.

For further information or to submit written comments, contact: Dr. Rose M. Zeiler, Longhorn Army Ammunition Plant, P.O. Box 220, Ratcliff, Arkansas, 72951; phone number 479-635-0110 or e-mail rose.zeiler@us.army.mil.

MEDIA RELEASE

The United States Army has prepared a Proposed Plan for the environmental site LHAAP-16 Landfill, at the Longhorn Army Ammunition Plant. The Proposed Plan is the document that describes LHAAP-16 and its proposed remedies. The Proposed Plan was developed to facilitate public involvement in the remedy selection process.

Copies of the Proposed Plan and other supporting documentation for LHAAP-16 are available for public review at the Marshall Public Library, 300 S. Alamo, Marshall, Texas, 75670. The public comment period is October 10, 2010 through November 9, 2010.

A public meeting will be held on October 19, 2010, from 7:00 to 9:00 p.m. at the Caddo Lake State Park Group Recreation Hall located at 245 Park Road 2 off FM 2198, between SH 43 and Old Farm to Market Road 134 near Karnack, Karnack, Texas approximately 1 mile north from the front gate of the former Longhorn Army Ammunition Plant. The park entrance fee will be waived for attendees of this meeting.

All written public comments on the Proposed Plan must be postmarked on or before November 9, 2010. Written comments may be provided to Dr. Rose M. Zeiler, Longhorn Army Ammunition Plant, P.O. Box 220, Ratcliff, Arkansas, 72951 or e-mailed to rose.zeiler@us.army.mil. E-mailed comments must be submitted by close of business on November 9, 2010.