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

September 26, 2019

DAIM-ODB-LO

Ms. April Palmie
Texas Commission on Environmental Quality
Remediation Division
12100 Park 35 Circle, Bldg D
Austin, TX 78753

Re: LHAAP-29 Record of Decision, August 2019
Longhorn Army Ammunition Plant, Karnack, Texas

Dear Ms. Palmie,

Enclosed please find the replacement pages for the August 2019 LHAAP-29 Record of Decision (ROD) for your records. This is the final ROD and includes the completed signature page with Army and EPA signatures, and the TCEQ concurrence.

The Final document transmitted for signature and concurrence on 16 August 2019 was revised in response to EPA's 4 September 2019 request to remove "Major" from the fourth sentence in Section 2.12.3 Cost Estimate of the Selected Remedy. The sentence "Major changes may be documented in the form of a memorandum in the Administrative Record, an Explanation of Significant Difference (ESD), or a ROD amendment" was revised to "Changes will be documented in accordance with 40 CFR 300.435(c)(2) in the form of a memorandum in the Administrative Record, an Explanation of Significant Difference (ESD), or a ROD amendment, as necessary." The revision also required changes to the notes for Tables 2-12 and 2-13. Other than these changes, the document remains the same as the 16 August 2019 Final ROD.

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

Sincerely,

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

One Enclosure
Copies furnished:

R. Mayer, USEPA, Dallas, TX
R. Smith, USACE, Tulsa District, OK
A. Williams, USACE, Tulsa District, OK
A. Sherman, USAEC, San Antonio, TX
K.Nemmers, Bhate
P. Werner, HDR

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

September 26, 2019

DAIM-ODB-LO

Mr. Rich Mayer
U.S. Environmental Protection Agency
Federal Facilities Section R6
1201 Elm Street, Suite 500
Dallas, TX 75202-2102

Re: LHAAP-29 Record of Decision, August 2019
Longhorn Army Ammunition Plant, Karnack, Texas

Dear Mr. Mayer,

Enclosed please find the August 2019 LHAAP-29 Record of Decision (ROD) for your records. This is the final ROD and includes the completed signature page with Army and EPA signatures, and the TCEQ concurrence.

The Final document transmitted for signature and concurrence on 16 August 2019 was revised in response to EPA's 4 September 2019 request to remove "Major" from the fourth sentence in Section 2.12.3 Cost Estimate of the Selected Remedy. The sentence "Major changes may be documented in the form of a memorandum in the Administrative Record, an Explanation of Significant Difference (ESD), or a ROD amendment" was revised to "Changes will be documented in accordance with 40 CFR 300.435(c)(2) in the form of a memorandum in the Administrative Record, an Explanation of Significant Difference (ESD), or a ROD amendment, as necessary." The revision also required changes to the notes for Tables 2-12 and 2-13. Other than these changes, the document remains the same as the 16 August 2019 Final ROD.

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Sincerely,

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

One Enclosure
Copies furnished:

A. Palmie, TCEQ, Austin, TX
R. Smith, USACE, Tulsa District, OK
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A. Sherman, USAEC, San Antonio, TX
K.Nemmers, Bhate
P. Werner, HDR

Jon Niermann, *Chairman*
Emily Lindley, *Commissioner*
Toby Baker, *Executive Director*

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Protecting Texas by Reducing and Preventing Pollution

September 13, 2019

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

Subject: Record of Decision for LHAAP-29, Former TNT Production Area, Longhorn Army Ammunition Plant Federal 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 LHAAP-29, Former TNT Production Area, Longhorn Army Ammunition Plant Federal Superfund Site in Karnack, Texas on August 16, 2019. The TCEQ has completed the review of the above referenced document and concurs that the described action is appropriate.

Sincerely,

Toby Baker
Executive Director

Cc: Ms. Wren Stenger, Director, Superfund Division, US Environmental Protection Agency, Region 6

HDR

Final

Record of Decision

for LHAAP-29,
Former TNT Production Area, Group 2
Longhorn Army Ammunition Plant
Karnack, Texas

August 2019

Prepared For:

U.S. Army Corps of Engineers – Tulsa District

Prepared By:

HDR
9871 S. Meridian Blvd, Suite 400
Englewood, CO 80112

Contract No. W912BV-15-D-0014
Task Order No. W912BV18F0023

Final

RECORD OF DECISION

FOR

LHAAP-29, FORMER TNT PRODUCTION AREA, GROUP 2

LONGHORN ARMY AMMUNITION PLANT

KARNACK, TEXAS

Prepared For:

U.S. Army Corp of Engineers Tulsa District

Prepared By:

HDR, Inc.
9871 S. Meridian Blvd, Suite 400
Englewood, CO 80112

Contract No. W912BV-15-D-0014
Task Order No. W912BV18F0023

August 2019

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Acronyms and Abbreviations

ARAR	applicable or relevant and appropriate requirement
BERA	baseline ecological risk assessment
bgs	below ground surface
BHHRA	baseline human health risk assessment
°C	degrees Celsius
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
C. F. R.	Code of Federal Regulations
COC	chemical of concern
COPEC	chemical of potential ecological concern
COPC	chemical of potential concern
CSM	conceptual site model
CWA	Clean Water Act of 1972
DCA	dichloroethane
DCE	dichloroethene
DNAPL	dense non-aqueous phase liquid
DNT	dinitrotoluene
ECP	environmental condition of property
EcoPRG	ecological preliminary remediation goal
EEQ	ecological effects quotient
EISB	Enhanced in-situ bioremediation
EPC	exposure point concentration
ERH	Electrical resistance heating
ESD	Explanation of Significant Differences
FFA	Federal Facility Agreement
FR	Federal Register
FS	feasibility study
g/L	grams per liter
GWP-Ind	medium-specific concentration for industrial use based on groundwater protection
GWTP	Groundwater treatment plant
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HQ	hazard quotient
IRIS	Integrated Risk Information System
ISTD	In-situ thermal desorption
Jacobs	Jacobs Engineering Group
LHAAP	Longhorn Army Ammunition Plant
LTM	long-term monitoring
LUC	land use control
MC	methylene chloride
MCL	maximum contaminant level
µg/L	Micrograms per liter
mg/kg	milligrams per kilogram
mg/L	Milligrams per liter
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

NOAEL	no-observed adverse effect level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NT	nitrotoluene
O&M	operation and maintenance
PCB	polychlorinated biphenyl
PCL	Protective concentration level
PP	Proposed Plan
RA	remedial action
RAB	Restoration Advisory Board
RAO	remedial action objective
RAWP	Remedial Action Work Plan
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RFA	RCRA Facility Assessment
RfD	reference dose
RI	remedial investigation
ROD	record of decision
SAI-Ind	soil MSC for industrial use based on inhalation, ingestion, and dermal contact
SARA	Superfund Amendments and Reauthorization Act
scfm	standard cubic feet per minute
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
TCEQ	Texas Commission on Environmental Quality
TCH	Thermal conductance heating
TDS	Total dissolved solids
TEC	toxicity equivalence concentration
TNT	trinitrotoluene
TRRP	Texas Risk Reduction Program
TRRP Residential Groundwater PCL	Texas Risk Reduction Program Tier 1 Residential Groundwater Protective Concentration Level
TRV	toxicity reference level
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. The Declaration

1.1 Site Name and Location

Longhorn Army Ammunition Plant (LHAAP)-29, Former TNT Production Area, Group 2
Longhorn Army Ammunition Plant
Karnack, Texas

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

1.2 Statement of Basis and Purpose

This Record of Decision (ROD) presents the selected remedy for LHAAP-29, Former Trinitrotoluene (TNT) Production Area, Group 2 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 (C. F. R.) Title 40 §300.

The remedy selection was based on documentation available in the Administrative Record for the site, including the remedial investigation (RI) (Jacobs Engineering Group, Inc. [Jacobs], 2001), baseline human health risk assessment (BHHRA) report (Jacobs, 2002), installation-wide baseline ecological risk assessment (BERA) report (Shaw Environmental, Inc. [Shaw], 2007a), feasibility study (FS) (Shaw, 2010), RI Addendum (AECOM Technical Services [AECOM], 2016), Final Baseline Ecological Risk Assessment Addendum (AGEISS, 2014), FS Addendum (AECOM, 2017) and Revised Proposed Plan (PP) (U.S. Department of the Army [U.S. Army], 2018).

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-29 includes excavation and off-site disposal of contaminated soil, flushing, inspection, and plugging of the trinitrotoluene (TNT) cooling water and wastewater lines, in situ thermal desorption (ISTD) treatment of the intermediate groundwater zone dense non-aqueous phase liquid (DNAPL) plume, monitored natural attenuation (MNA) for the shallow zone groundwater plumes and for the intermediate groundwater plume following ISTD, and land use controls (LUCs) for soil and groundwater.

The final selected remedy for LHAAP-29 protects human health and the environment by preventing human and ecological receptor exposure to contaminated soil and contaminated groundwater. The human health risk assessment scenarios evaluated were based on the hypothetical future maintenance worker. In the soil, chemicals of concern (COCs) and chemicals of potential ecological concern (COPECs) are explosives (2,4,6-TNT, 2,4-dinitrotoluene [DNT], and 2,6-DNT). Perchlorate is considered a potential soil COC based on groundwater concentrations. In the shallow groundwater zone, the COCs are Volatile Organic Compounds (VOCs) trichloroethene [TCE], 1,2-dichloroethane (DCA), TCE's daughter products cis-1,2-dichloroethene [DCE]), trans 1,2 DCE, and vinyl chloride [VC]), metals (arsenic, mercury, nickel, selenium), explosives (2,4-DNT, 2,6-DNT, 2-nitrotoluene [NT], 3-NT, 4-NT), and perchlorate. In the intermediate groundwater zone, the COCs are VOCs (methylene chloride (MC), TCE, 1,2-DCA, TCE's daughter products 1,1-DCE, cis-1,2-DCE, trans-1,2 DCE, and VC) and arsenic. COCs in the transite TNT wastewater and vitrified clay cooling water lines include explosives (2,4,6-TNT, 2,4-DNT, 2,6-DNT, 2-amino-4,6-DNT, and 4-amino-2,6-DNT, 1,3-dinitrobenzene). Residual MC DNAPL acting as a source material in the intermediate zone may be considered a principal threat waste at LHAAP-29. There are no COCs associated with the deep groundwater zone.

The components of the selected remedy are summarized below:

- Contaminated soil removal with off-site disposal to protect the hypothetical future maintenance worker and ecological receptors and eliminate the soil-to-groundwater pathway. Additional confirmation soil sampling during the remedial design (RD) will be needed to define the final excavation extent and volume of soil contaminated with explosives near former Building 812-F and in the cooling water outfall/ditch and may identify additional areas for soil removal adjacent to the North and South Cooling water lines as well as the wooden and transite TNT wastewater lines, see **Section 2.12.2**.
- Flushing, inspection, and plugging of the transite TNT wastewater line and the vitrified clay cooling water lines to eliminate potential exposure from residual contamination. Confirmation sampling of the wooden TNT wastewater line during the RD may result in excavation, see **Section 2.12.2**.
- MNA in the shallow groundwater zone to confirm protection of human health and the environment by documenting that contaminated groundwater remains localized with minimal migration and that COCs are being reduced to cleanup levels.
    - Performance objectives will be evaluated after two years of MNA. During those two years, monitoring will be quarterly. If MNA is found to be effective, it will be continued, and long-term monitoring (LTM) will be semiannual for three years. In subsequent years, LTM will be annual until the next five-year review and annually thereafter until recommended otherwise by the five-year review. The monitoring and reporting associated with this remedy will be used to track the effectiveness of MNA and will continue until recommended otherwise at the five-year review.
    - If MNA is found to be ineffective, a contingency remedy to enhance MNA would be developed. The contingency remedy would consist of injection of bioremediation

amendments to enhance degradation of the groundwater contaminants at selected locations based on data available at the time it is determined MNA is not successful. Development and specific description of the contingency remedy would be presented in a Remedial Design/Remedial Action Work Plan (RD/RAWP).

- ISTD treatment will be performed for the DNAPL MC plume in the intermediate groundwater zone to reduce concentrations to levels amenable to MNA. One of two ISTD treatment process options, Electrical Resistance Heating (ERH) or Thermal Conduction Heating (TCH), will be selected during the RD.
- MNA will be implemented in the intermediate groundwater zone following successful implementation of ISTD to confirm protection of human health and the environment by documenting that the contaminated groundwater remains localized with minimal migration and that contaminant concentrations are being reduced to cleanup levels. Trigger level or target value for successful ISTD treatment of MC in the intermediate zone is 8,000 micrograms per liter (µg/L). Performance monitoring will be conducted at a frequency necessary to evaluate the effectiveness of the in-situ treatment, with sampling and LTM conducted as described for the shallow groundwater MNA.
- 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.
- The LUC 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 cleanup 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 assure 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.[1]
- The LUC for prohibition of groundwater use (except for monitoring and testing) shall be implemented and shall remain in place at the Site until the COCs (i.e. including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) in soil and groundwater remaining at the site, are reduced below levels that would support unlimited use and unrestricted exposure. A LUC RD will be finalized as the land use component of the RD. Within 21 days of the issuance of the ROD, the Army will

[1] This paragraph is October 31, 2014 Dispute Decision language that is included despite the ROD not being subject to the dispute.

propose deadlines for completion of the RD Work Plan, RD and Remedial Action Work Plan. The documents will be prepared and submitted to the EPA and the 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.[1] The preliminary boundary for the groundwater LUC is shown on **Figure 2-16**.

- The LUC restricting land use to nonresidential shall be implemented until it is demonstrated that surface and subsurface soil and groundwater COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) are at levels that allow for unlimited use and unrestricted exposure.[1]
- The LUC to maintain the integrity of any current or future remedial or monitoring systems 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 2-10**) in groundwater are met. The LUC to prohibit 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 2-10**) in soil and groundwater allow for unlimited use and unrestricted exposure.[1]

CERCLA five-year reviews are required 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 2-10**) in soil and groundwater allow for unlimited use and unrestricted exposure.

Based on a preliminary natural attenuation evaluation and groundwater modeling, cleanup levels are expected to be met through natural attenuation in the shallow zone groundwater in approximately 70 years (Shaw, 2010), and 5-10 years following ISTD treatment in the intermediate zone groundwater (AECOM, 2017). Specifically, based on the attenuation of 1,2-DCA, MNA is estimated to take approximately 70 years in the shallow groundwater zone. The ISTD treatment in the intermediate zone is estimated to take 65-87 days if ERH is used, and 180 days if TCH is used. MNA will follow the in-situ treatment, and is estimated to take 5-10 years based on the attenuation of TCE. Other COCs are expected to require less time to attenuate, based on the natural attenuation study presented in the Final FS (Shaw, 2010). Considering the lithologic variability, particularly the lateral and vertical change from sand to clay, the time to achieve cleanup levels may vary. In the course of the remedy, the additional monitoring results will allow more accurate time estimates.

No adverse impact is expected to the surface water during the time it would take natural attenuation to reduce contaminant concentrations to cleanup levels.

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.[1]

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.[1]

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.[1]

U.S. Army and regulators will consult to determine appropriate enforcement actions should there be a failure of a LUC objective at the site 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 (Shaw, 2007a). Thus, the implementation of this remedy at LHAAP-29 is independent of any other remedial action at LHAAP to address human health issues. To address ecological risk, LHAAP-29 was grouped with several other sites as part of the Industrial Sub-Area. The final COPECs in soil that require remedial action in the Industrial Sub-Area are 2,4-DNT, 2,6-DNT and 2,4,6-TNT (Shaw, 2010). The remedial actions at LHAAP-29 will be sufficient to remove ecological risks for the sub-area. This management strategy is considered to be endorsed by regulators as evidenced by the regulatory approval of the BERA (Shaw, 2007a) and BERA Addendum (AGEISS, 2014).

1.5 Statutory Determinations

The selected remedy is protective of human health and the environment, complies with Federal and State requirements that are established as applicable or relevant and appropriate requirements (ARARS) for the remedial action, and is cost-effective.

The remedy offers long-term effectiveness through excavation of contaminated soil, thermal treatment of MC DNAPL, flushing, plugging, and abandoning the TNT wastewater and cooling water lines, and the implementation of a LUC, which will minimize the potential risk to the hypothetical future maintenance worker posed by the contaminated soil and groundwater. Evaluation of MNA, including routine monitoring of the attenuation until cleanup levels are met, will document the effectiveness of the selected remedy. In the event that MNA is determined to be ineffective, a contingency remedy consisting of injection of bioremediation amendments to enhance degradation of the groundwater contaminants at selected locations will be developed and implemented.

Development and specific description of the contingency remedy will be presented in a RD/RAWP. The selected remedy is easily and immediately implementable and while it was not the lowest cost alternative, is considered most likely to be effective and successful compared to the other alternatives considered for LHAAP-29.

The thermal treatment (ISTD) component of the selected remedy satisfies 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.

The selected remedy will reduce the toxicity, mobility, or volume of contaminants in the groundwater through active and passive remedial actions. The high concentrations of MC in the intermediate groundwater at LHAAP-29 have indicated that DNAPL residual source material may be residing in the subsurface and acting as a principal threat in the groundwater.

Because hazardous substances, pollutants, or contaminants will remain at the site above levels that allow for unlimited use and unrestricted exposure, a five-year review will be conducted every 5 years to ensure protection of human health and the environment under CERCLA §121(c), U.S. Code (USC) Title 42 §9621(c). In accordance with Texas Administrative Code (TAC) Title 30 §335.566, a notification will be recorded in Harrison County records restricting land use to nonresidential until it is demonstrated that surface and subsurface soil and groundwater COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) are at levels that allow for unlimited use and unrestricted exposure; that a prohibition of groundwater use (except for environmental monitoring and testing) as a potable source 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 2-10**) 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 the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) in groundwater 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 groundwater use that will be available at the site 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 2.7.3** and **2.8**).

- Principal threat wastes that will be 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-29 which documents the final selected remedy. The undersigned is the appropriate approval authority for this decision.

Thomas E. Lederle ________________ 16 Aug 2019 ________
(Date)

Thomas E. Lederle
Division Chief
Base Realignment and Closure Division
Assistant Chief of Staff for Installation Management
U.S. Army

The United States Environmental Protection Agency approves the selected remedy as provided in the ROD for LHAAP-29.

________________ September 19, 2019 ________
(Date)

Wren Stenger
Director
Superfund Division
U.S. Environmental Protection Agency
Region 6

2. Decision Summary

2.1 Site Name, Location, and Description

LHAAP-29, Former TNT Production Area, Group 2
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: Industrial Facility

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 Superfund 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, not including LHAAP-29, 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-29, Former TNT Production Area is an 85-acre site located within a heavily wooded section in the western-central portion of LHAAP (**Figure 2-2**). The surface features at LHAAP-29 include the foundations for the former production facilities and the underground pipelines that were originally built for cooling water drainage and TNT wastewater conveyance.

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. In 1952, the 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-29 was used as a TNT manufacturing facility from October 1942 to August 1945. The facility produced approximately 400 million pounds of flake TNT during its operation using six TNT production lines (five active and one standby). The TNT production facility was inactive from August 1945 to 1959. In 1959, most of the buildings and aboveground storage tanks were removed. The debris was burned or flashed at Burning Ground No. 2/Flashing Area (LHAAP-17). Concrete foundations open-top concrete-lined pits, most of the underground utilities, and a network of underground pipelines still remain at the site. Since the end of World War II, the only activity that has been documented to have occurred at LHAAP-29 is the “soak out” or solvent bath of out-of-specification rocket motors. This took place from 1959 to the mid-1970s and involved the use of MC-based industrial solvent at tank 801-F. Waste from this operation was sent to LHAAP-18/24 (Jacobs, 2001).

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 (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 (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, 988). 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-29 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.

Figure 2-3 and **Figure 2-4** show the sample locations for all investigations. **Figure 2-5** and **Figure 2-6** show well locations and groundwater elevations for the shallow and intermediate groundwater zones, respectively. For some of the earlier investigations, LHAAP sites were organized into groups, and LHAAP-29 was included in Group 2. The group designation was de-emphasized as the complexities of the individual sites increased.

The following summarizes the investigations at LHAAP-29:

- **Multi-phase investigation of Group 2 sites**: Between 1982 and 1998 numerous investigations were conducted in a phased approach by Jacobs, U.S. Army Corps of Engineers (USACE), and Environmental Protection System. Activities included installation of monitoring wells and analysis of groundwater, surface water, soil, and sediment samples. The results are documented in the RI for Group 2 sites (Jacobs, 2001).
- **Plant-wide perchlorate investigation**: The groundwater investigation was conducted from 2000 through 2002 (Solutions to Environmental Problems, Inc. (STEP), 2005) to delineate perchlorate contamination.
- **Baseline Human Health Risk Assessment**: The BHHRA (Jacobs, 2002) used data from the investigations conducted through 2001, including the plant-wide perchlorate investigation results up to that time. The report concluded that the soil at LHAAP-29 posed a non-carcinogenic hazard and the groundwater posed unacceptable carcinogenic risk and non-carcinogenic hazard to the hypothetical future maintenance worker.
- **Environmental Site Assessment**: Media investigated in 2003 included soil and groundwater (Plexus Scientific Corporation, 2005), although no sampling was conducted at LHAAP-29 for this assessment.
- **Baseline Ecological Risk Assessment**: The BERA (Shaw, 2007a) identified COPECs for the Industrial Sub-Area, which includes LHAAP-29. COPECs for the sub-area are addressed in the remedial actions for LHAAP-29. The evaluation was based on environmental investigations from 1993 to 2004.
- **Data Gaps**: Additional investigations were conducted in 2004 after the BHHRA was finalized to further delineate the extent of groundwater contamination identified during previous sampling events. A new monitoring well was installed and a total of 20 wells sampled in August 2004. The results of the 2004 investigation were presented in the *Data Gaps Investigation* (Shaw, 2007b).

Additional investigations were conducted after the 2004 investigation to further delineate contamination as follows:

- Additional investigations were conducted in December 2004 and February 2005 which included sampling soil near the TNT wastewater line, sediments from cooling water lines, the pump house pond, the outfall ditch, and manholes along the cooling water lines. Water was also sampled at the twelve manholes along the cooling water lines. Additional groundwater monitoring well sampling was conducted in May 2005 (Shaw, 2010).
- Sampling of soil at the foundation of former Wash House 806-D was conducted in February 2005 (USACE, 2005). Additional investigations were conducted between August 2006,

February 2007, and February 2008 to further delineate the extent of contamination, and included the activated persulfate oxidation study report (Shaw, 2010).

- Additional groundwater sampling events occurred in October 2008, January 2009, and June 2009 (Shaw, 2010).
- **Feasibility Study**: The FS (Shaw, 2010) was based on all available results from previous investigations through 2009, and the data collected since the risk assessment was evaluated in the FS. Data not formally submitted was incorporated into the FS. The potential soil-to-groundwater pathway was evaluated for the emerging contaminant perchlorate (found in groundwater) and the explosives posing risks or hazards in soil. The concentrations of these chemicals were compared to their TCEQ soil medium-specific concentrations (MSCs) for industrial use based on groundwater protection (GWP-Ind), which is more stringent than the soil MSC for industrial use based on inhalation, ingestion, and dermal contact (SAI-Ind) (TCEQ, 2006). The data collected from the shallow groundwater sampling indicated that MC concentrations were below Safe Drinking Water Act (SDWA) maximum contaminant level (MCLs), and 1,1-DCE concentrations are above the MCL. Additionally, all VOC groundwater data within the plumes were used to evaluate natural attenuation. The FS identified and evaluated 3 remedial alternatives to address the soil and groundwater contamination in the shallow and intermediate zones.
- **Supplemental Investigation**: A Final PP (U.S. Army, 2011) and Draft ROD were prepared in 2011 based on the RI and other investigation results, and the FS. During further evaluation of the RD requirements for the selected alternative, the U.S. Army determined that additional data were needed to refine the extent of the intermediate zone MC plume and also to collect data to evaluate additional treatment technologies, so a supplemental investigation was conducted in 2014. Additional wells were installed in the intermediate zone to define the extent of the MC plume inferred to be DNAPL, measure aquifer parameters, and evaluate thermal treatment of the MC plume, and in-situ bioremediation potential (AECOM, 2016).
- **Baseline Ecological Risk Assessment Addendum:** After the BERA was completed in 2007, a BERA Addendum was completed (AGEISS, 2014). The results of the re-evaluation indicated that that the replacement data collected during the data gaps investigation confirmed the conclusions of the BERA that no explosives compounds in soil should be identified as COPECs in the industrial sub-area.
- **Supplemental FS**: A supplemental FS was prepared in 2017 using the data collected in during the supplemental investigation. A fourth alternative, ISTD, was identified and evaluated to address the MC DNAPL plume in the intermediate groundwater zone (AECOM, 2017). The shallow zone groundwater and soil remediation components of the alternatives did not change from the initial FS.

2.2.3 Site History of CERCLA Enforcement Activities

LHAAP-29 was included in the National Priorities Listing for Longhorn in 1990 and identified as Unit No. 29 in the 1991 FFA. The FS for LHAAP-29 (Shaw, 2010) was issued in April 2010, and the PP (U.S. Army, 2011) was issued in March 2011. A Revised PP was completed in 2018 (U.S. Army, 2018). This ROD follows the Revised PP 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-29 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 Revised PP (U.S. Army, 2018) for the selection of the remedy for LHAAP-29 was released to the Administrative Record and made available to the public for review and comment beginning November 21, 2018. The notice of availability of the Final Revised PP and other related documents in the Administrative Record file was published in *The Shreveport Times* and the *Marshall News Messenger* on November 7, 2018. The newspaper and media notices for the meeting are provided in **Appendix A**. The public comment period for the Revised PP began on November 21, 2018 and ended December 21, 2018. A public meeting was held on December 6, 2018 in a formal format and the meeting recorded by 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**.

The previously completed PP (U.S. Army, 2011) was also released to the Administrative Record, and similar public notices and a public meeting were held. Comments received for the 2011 Proposed Plan are also presented in **Section 3**.

The Administrative Record may be found at http://www.longhornaap.com/ and locally at the information repository maintained at the following location:

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

Business Hours: Monday, Tuesday, Thursday (9:30 AM – 7:30 PM)
Wednesday and Friday (9:00 AM – 5:30 PM)
Saturday (9:30 AM – 3:30 PM)

2.4 Scope and Role of Response Action

The response action will prevent potential unacceptable risks associated with exposure to contaminated soil and groundwater in both the shallow and intermediate zones. The removal of source soils will positively impact groundwater by eliminating the potential for the leaching of contaminants from the soil into the groundwater and will remove the contamination that poses a risk to ecological receptors.

Plugging the inlets and outlets of the underground lines with a bentonite slurry mix, including the manholes of the process cooling water lines, will minimize hypothetical future maintenance workers contact with contaminants and prevent water from infiltrating the lines.

The selected action at LHAAP-29 will prevent potential risks associated with exposure to contaminated groundwater. The groundwater at LHAAP is not currently being used as a drinking water source, nor may it be used in the future based on its reasonably anticipated use as a national wildlife refuge. However, when establishing the remedial action objectives (RAOs) for this response action, the U.S. Army has considered the NCP's expectation to return usable groundwater to its 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 milligrams per liter (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 shallow and intermediate groundwater zones at LHAAP-29 to their potential beneficial uses, which for the purposes of this ROD is considered to be attainment of the SDWA MCLs to the extent practicable, and consistent with 40 C.F.R. § 300.430(e)(2)(i)(B & C). In the absence of federal drinking water standards, clean-up levels will be based on the Texas Risk Reduction Program (TRRP) Tier 1 Residential Groundwater Protective Concentration Level (PCL) (TRRP Residential Groundwater PCL). The TCEQ soil medium specific concentration (MSC) for industrial use based on groundwater protection (GWP-Ind) is used in accordance with 30 TAC 335.559(g)(2). 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 (40 C.F.R. § 300.430(a)(1)(iii)(F)).

The selected remedial action will also ensure containment of the plume to prevent potential impact to surface water. The selected action will also include groundwater monitoring to demonstrate that the plume is not migrating at levels that present a potential impact to surface water bodies and to verify that contaminant levels are being reduced to cleanup levels when the LUC for groundwater use prohibition may be terminated.

In addition, the selected action includes an active remedial component that will mitigate the principal threat waste. By instituting an ISTD treatment of the intermediate groundwater, this active treatment will be applied to the highest concentration area in the MC groundwater plume and will comply with NCP expectations regarding treatment of affected media where principal threat waste may be considered.

2.5 Site Characteristics

This section of the ROD presents a brief comprehensive overview of the LHAAP-29 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, 2001).

2.5.1 Conceptual Site Model

Figure 2-7 illustrates the human health conceptual site model for LHAAP-29. The model presents the human health pathways that are complete and being considered for remediation. Those pathways that are likely to be incomplete or have negligible impact are not being considered for remediation. The ecological conceptual model for LHAAP-29 (**Figure 2-8**) is similar to the one presented for human health in terms of the origin and fate and transport mechanisms of the contaminants present at the site. However, only exposure pathways and routes associated with soil are relevant for ecological risk assessment.

Explosive compound releases resulting from the manufacturing process of TNT as well as releases from process tanks and process waste pipelines are the suspected contamination sources at LHAAP-29. Releases from the rocket motor soak-out process that used methylene chloride-based solvents are also contamination sources. The pipelines include the TNT process wastewater gravity line (“red and/or yellow liquor”) that transported the TNT process wastewater to LHAAP-32 for treatment and two cooling water lines (blue water) that transported the cooling water to an outfall ditch. The remaining potential sources of contamination at the site are explosives compounds in stained soils around the foundation of former Buildings 806A and 806-D, isolated perchlorate-containing soils in the northeastern portion of LHAAP-29 at a depth of 8 feet below ground surface (bgs), and TNT-contaminated sediment in the cooling water outfall ditch at a depth of 7 feet bgs.

The red liquor TNT wastewater line was originally installed as a wooden pipeline at a depth of three to five feet bgs and was taken out of service, clear-flushed and abandoned in 1946 (Bate Stamp 001446, RFA, April, 1988). Several trenches were excavated across the wooden line in 1993, and the wood was found to be soft and severely degraded at most locations (Sverdrup Environmental, Inc. [Sverdrup], 1993). Samples collected at that time resulted in high concentrations of TNT in the liquid and sludge (3,500 µg/L and 3,700 mg/kg, respectively), but that data was later deemed unusable for environmental decision making (Jacobs, 2001). The transite TNT wastewater pipeline was added parallel to and north of the wooden line to carry the TNT wastewater. The transite TNT wastewater line has solid residues contaminated with explosives at concentrations above the GWP-Ind.

Two blue cooling water lines, called cooling water line north and cooling water line south, exist at LHAAP-29 and range from 8 to 18 inches in diameter. These are gravity fed lines and are constructed of vitrified clay pipe with manholes. These lines have solid residues contaminated with explosives at concentrations that are above the GWP-Ind MSC (solid residue).

Contamination in the form of explosive compounds, VOCs, perchlorate, and metals from rocket motor washout and TNT production is present in the shallow groundwater zone at LHAAP-29 and poses potential risk to the hypothetical future maintenance worker. In the intermediate groundwater zone, concentrations of VOCs and arsenic are present, with MC posing the highest risk. At monitoring well 29WW16 the MC concentrations in the intermediate zone are approximately half the solubility limit, which indicates a potential for the presence of DNAPL. The horizontal extent of contamination in the shallow and intermediate groundwater zones is presented in **Figures Figure 2-9,** and **Figure 2-11**.

The soil and groundwater at LHAAP-29 may pose an unacceptable risk for the hypothetical future maintenance workers. Even though no impact to surface water from groundwater has been established (Shaw, 2007c); the migration pathway of groundwater contaminants to surface water is being considered for remediation along with soil, soil to groundwater, and future industrial groundwater use.

2.5.2 Overview of the Site

The site boundary of LHAAP-29 comprises approximately 85 acres in the western-central portion of LHAAP. The surface features include the foundations for the former production facilities and the underground pipelines that were originally built for cooling water drainage and TNT wastewater conveyance. The site is currently heavily wooded. Surface runoff is collected by ditches constructed in 1942 when the production facility was built. Surface runoff from the northern part of the site (about 40 percent of the site) enters Goose Prairie Creek located approximately 1,500 feet to the north and east of the site. Surface water runoff in the southern portion of the site (about 60 percent of the site) flows into a tributary of Central Creek located near the southeast portion of the site. Eventually, runoff from the two creeks enters Caddo Lake.

2.5.3 Geology and Hydrogeology

The local geology at LHAAP-29 consists of a silty to clayey sand at the surface that extends from 3 to 10 feet bgs. A clayey silt grading to a silty clay was encountered extending to a depth of 40 feet bgs with an underlying silty to clayey sand. With the exception of boreholes 29WW02, 29WW10, and 29WW11, a sandy silt to silty clay layer was encountered below the sand deposit at depths ranging 15 to 26 feet bgs. Additional silt, clay and sand layers were encountered with depth in boreholes 29SB52 and 29SB53 that terminated at the top of the Midway formation at depths of 157 and 140 feet bgs, respectively.

There are three groundwater zones at LHAAP-29: shallow, intermediate, and deep. Semi-confining clay or silty clay layers separate the three groundwater zones. The shallow groundwater zone has wells that are screened at two depths (shallow and lower shallow); however, the wells have similar water level elevations and are all considered to be shallow zone wells. The bottom of each of the zones is defined by a continuous or semi-continuous clay layer of varying thickness. The depth of the shallow groundwater zone generally ranges from 17 to 45 feet bgs because of variable ground surface elevations across the site. The intermediate zone is less defined, but its depth has been measured to approximately 88 feet bgs. The deep groundwater zone extends to a depth of approximately 155 feet bgs. Based on the 2007 water levels and historic potentiometric maps, the predominant groundwater flow in the shallow zone is east/southeast and is east/northeast in the intermediate zone. **Figures 2-5** and **2-6** illustrate the groundwater elevations in the shallow zone and intermediate zone, respectively.

2.5.4 Sampling Strategy

Nineteen investigations/sampling events were conducted at LHAAP-29 from 1982 to 2014, as described in **Section 2.2.2**. In the early investigations, soil 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, and sediment sampling, and installing monitoring wells to delineate the groundwater contamination. Samples from all media were analyzed for various analytes including VOCs, SVOCs, metals, explosives, perchlorate, pesticides, and dioxins/furans. In the intermediate groundwater 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. During the 2014 investigation, soil resistivity and total organic carbon data were measured to provide additional data to evaluate ISTD technologies, and microcosm testing was performed to evaluate the potential for in enhanced in-situ bioremediation (EISB). Aquifer pumping tests were also conducted to gather site-specific hydraulic conductivity data to support the evaluation of additional treatment technologies.

2.5.5 Nature and Extent of Contamination

Contamination was found in the soil, groundwater (shallow and intermediate zones), and liquid and solid residue remaining in the cooling water and TNT process wastewater underground lines. The COCs are toxic and carcinogenic. Since there is a high cancer risk associated with exposure to groundwater from this region of the intermediate zone, such residual source material may be considered a principal threat waste at LHAAP-29.

Groundwater

Shallow zone groundwater COCs are VOCs (TCE, 1,2-DCA, and daughter products), perchlorate, explosives (2,4-DNT, 2,6-DNT, 2-NT, 3-NT, 4-NT), and metals (arsenic, mercury, nickel, selenium).

The shallow zone plumes for VOCs and perchlorate are shown on **Figure 2-9**. The most recent maximum concentrations of COCs in shallow groundwater were all detected in samples collected from monitoring well 29WW15, and included TCE at 344 µg/L, 1,2-DCA at 5,520 µg/L and perchlorate at 16,800 µg/L. The calculated volume of the perchlorate plume is 4 million gallons. There are 3 shallow zone plumes for explosives as shown on

Figure 2-10. The highest concentration of 2,4-DNT detected was 50.9 µg/L at monitoring well 29WW05. The highest concentration of 2,6-DNT was 239 µg/L at monitoring well 116. The highest concentrations of 2-NT, 3-NT, and 4-NT are 8,140 µg/L, 451 µg/L, and 1,400 µg/L, respectively, also reported at monitoring well 116. The volume of the VOC, perchlorate, and NT plumes are estimated to be approximately 9 million gallons, assuming a total porosity of 0.25 (or 25 percent) with a thickness ranging from 5 to 10 feet.

Intermediate zone groundwater COCs are MC, TCE and daughter products, 1,2-DCA, and arsenic. The intermediate zone plume for VOCs is shown on **Figure 2-11**. The highest concentration of MC detected was 10,300,000 µg/L at monitoring well 29WW16. The most recently reported MC concentration in a 2014 sample collected from this well was 8,260,000 µg/L. Other COCs identified for the intermediate groundwater zone are degradation (daughter) products of TCE that have been non-detect or have not been detected above their SDWA MCLs; however, due to historic results and the high detection limits at 29WW16, it has been assumed that concentrations of 1,2-DCA and TCE still exceed their SDWA MCLs. The calculated volume of contaminated groundwater that exceeds MCLs is 650,000 gallons, assuming a total porosity of 0.40 (or 40 percent) with an average thickness of 15 feet based on drilling observations.

As demonstrated by previous sampling results, the deep groundwater zone at LHAAP-29 is not affected.

Soil

Soil COCs and COPECs are explosives (2,4,6-TNT, 2,4-DNT, 2,6-DNT) and perchlorate. **Figure 2-12** shows the approximate areas of contaminated soil. The maximum 2,4,6-TNT concentration in the soil is 26,000 milligrams per kilogram (mg/kg). Other explosives, 2,4-DNT and 2,6-DNT, have maximum concentrations of 8,000 mg/kg and an estimated concentration of 15 mg/kg, respectively. Additionally, perchlorate has been detected in the soil at a maximum concentration of 8.6 mg/kg. The estimated volume of impacted soil is 3,900 cubic yards in place.

TNT Wastewater Lines

Line solid residue COCs from the transite TNT wastewater line are explosives (2,4,6-TNT, 2,4-DNT, 1,3 dinitrobenzene, 2-amino-4,6-DNT, 4-amino-2,6-DNT). Contaminated explosive solid residue remains within the transite TNT wastewater line at concentrations above the SAI-Ind and GWP-Ind MSCs, but access to the pipe is limited to the inlets and outlets unless the pipe is penetrated. Additionally, the line is buried 3 feet bgs or deeper. The gravity flow portion of the line is approximately 3,000 linear feet. The pressurized portion of the line is approximately 1,000 linear feet. The line is in good condition. **Figure 2-13** shows the TNT wastewater lines at LHAAP-29, soil, sediment, and solid residue sampling results and MSC values.

The wooden TNT wastewater line was previously flushed and abandoned. The results from limited soil samples collected near the line indicate there has not been a release to the surrounding soil above the cleanup levels. The line is buried 3 feet bgs or deeper, but the deteriorated condition of the line and the potential for residual explosives may present a continuing source of groundwater contamination.

Cooling Water Lines

Line solid residue COCs from the vitrified clay cooling water lines are explosives (2,4,6-TNT, 2,4-DNT, 2,6-DNT, 2-amino-4,6-DNT, 4-amino-2,6-DNT). The solid residues from the manholes are contaminated with explosives at concentrations that are above the GWP-Ind (solid residue). The north and south vitrified clay cooling water lines are accessible through manholes, and the liquid and solid residue contents from the manholes were sampled. There are approximately 5,000 feet of pipe in the main lines, approximately 1,680 linear feet of pipe from each production area to the main line, and 12 manholes. **Figure 2-13** shows the cooling water lines and sampling results of the line contents at LHAAP-29.

2.6 Current and 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 limited.

The reasonably anticipated future use of LHAAP-29 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-29. Presently the Caddo Lake National Wildlife Refuge occupies a little more than 7,100 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

Streams on LHAAP currently support wildlife and aquatic life. While humans may have limited access to some streams during annual hunts, there is no routine human use of streams on LHAAP. The streams do not carry adequate numbers and size of fish to support either sport or subsistence fishing. During the summer months, the streams cease flowing and/or dry up. The streams flow into Caddo Lake. Caddo Lake is a large recreational area that covers 51 square miles and has a mean depth of 6 feet. The watershed of the lake encompasses approximately 2,700 square miles. It is used extensively for fishing and boating. Caddo Lake is a drinking water supply for multiple cities in Louisiana including Vivian, Oil City, Mooringsport, South Shore, Blanchard, Shreveport, and Bossier City.

The anticipated future uses of the streams and lake are the same as the current uses.

2.6.3 Current and Future Groundwater Uses

Groundwater in the aquifer (250 to 430 feet bgs) 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 aquifer 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 (**Figure 2-2**). 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 0.3 miles northwest 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 the Caddo Lake National Wildlife Refuge, near the main entrance to LHAAP. The distances from these water supply wells to LHAAP-29 are approximately 0.4 miles, 0.2 miles, and 0.5 miles, respectively (**Figure 2-2**). The three water supply wells were completed at a depth much greater than the zone of contamination described at LHAAP-29. None of these three wells are currently used for drinking water at LHAAP, although they may supply water for non-potable uses. Two additional wells previously supplied water to the installation, but these have been plugged and abandoned.

Although the anticipated future use of the facility as a wildlife refuge does not include the use of the groundwater at LHAAP-29 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

The BHHRA and BERA estimate the risks posed by contaminants at the site if no action were taken. These 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 Human Health and Screening Ecological Risk Assessment for the Group 2 Sites* (Jacobs, 2002), in the *Data Gaps Investigations* (Shaw, 2007b), and in additional data collected in preparation of the *Final Feasibility Study, LHAAP-29* (Shaw, 2010). The risk assessment used data from the investigations conducted through 1998 and the plant-wide perchlorate investigation conducted in 2000. Results from the later investigations conducted through 2014 did not change the overall outcome of the risk assessment and the discussion of results and risks presented here are as presented in the Baseline HHRA and FS. During the risk assessment, soil and groundwater 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 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-29 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, frequency of detection, and exposure point concentrations (EPCs). Analytical results for various congeners of dioxins and furans are expressed as 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxicity equivalence concentration (TEC).

2.7.1.2 Exposure Assessment

The Jacobs risk assessment (Jacobs, 2002) presented the human health risks and hazards to a hypothetical future maintenance worker under an industrial scenario for soil and groundwater.

For soil, reasonable exposure pathways according to the CSM are: incidental ingestion of the surface soil (0 to 2 feet bgs), dermal contact with the surface soil, inhalation of particulates, and inhalation of VOCs from the soil (0 to 7 feet bgs).

For groundwater, reasonable exposure pathways 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 **Table 2-2** and **Table 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 **Table 2-4** and **Table 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 sun. 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 risks for soil and groundwater are 7.3×10^{-6} and 3.9×10^{-1}, respectively (Jacobs, 2002). The carcinogenic risk for soil is within the USEPA target risk range of 1×10^{-4} to 1×10^{-6}. The HIs for soil and groundwater are 1 and 3,000, respectively, and are above the acceptable HI of < 1. The carcinogenic risks for groundwater are unacceptable; the non-carcinogenic risk for both soil and groundwater are unacceptable; therefore, the remedial action acts on both the soil and groundwater. Chemicals with a risk greater than 1×10^{-4} in groundwater include TCE, 1,2-DCA, arsenic, 2,4-DNT, 2,6-DNT, MC, chloroform, and 2,3,7,8-TCDD. Chemicals with a HQ greater than one in groundwater include 2-NT, 3-NT, arsenic, nickel, 2,4-DNT, 2,6-DNT, chloroform, perchlorate, TCE, and 1,2-DCA.

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. Additionally, the uncertainty analysis indicated a portion of the noncarcinogenic effects associated with antimony in groundwater at LHAAP-29 may be due to background.

2.7.1.5 Evaluation of COPCs

To further evaluate the occurrence of COPCs, a data gap investigation was conducted (Shaw, 2007b) and additional investigations were conducted when preparing the FS (Shaw, 2010). While these investigations did not change the overall outcome of the earlier BHHRA, they determined the COPCs to be targeted by the remedial action.

Table 2-6 and **Table 2-7** list the chemicals in groundwater that exceed those values for the carcinogenic risk and HQ greater than 0.1, respectively. There is no carcinogenic risk in soil to the hypothetical maintenance worker. **Table 2-8** lists chemicals in the soil that have an HQ greater than 0.1 for the hypothetical maintenance worker. These tables also summarize the justifications for which of the COPCs should be classified as COCs. COPCs in soil were identified as COCs when they posed a carcinogenic risk above the acceptable range (risk greater than 1×10^{-4}) or when their HQ was greater than 1. 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, or when the EPC was above the MCL or in the absence of federal drinking water standards, the TRRP Residential Groundwater PCL. Recent data obtained after the BHRRA investigation was used when possible. Based on the comparison of the maximum groundwater concentration since the BHHRA to their associated SDWA MCL or PCL, these COCs have been identified on **Table 2-10** to be of concern in the shallow and intermediate groundwater. **Table 2-10** presents the final list of COCs and all media, along with cleanup levels.

The human health risk assessment, which was based on the reasonably anticipated future use as a national wildlife refuge, does not address unrestricted use. In accordance with 30 TAC 335.566, a notification will be recorded in the Harrison County records stating that the site is suitable for nonresidential use.

2.7.2 Summary of Ecological Risk Assessment

The *Final Installation-Wide Baseline Ecological Risk Assessment* (Shaw, 2007a) and Baseline Ecological Risk Assessment Addendum (AGEISS, 2014) evaluated potential hazards to ecological resources at LHAAP by conducting a screening evaluation to identify initial COPECs in the individual sub-areas and watersheds. The potential of these COPECs to adversely affect communities was evaluated for: (1) organisms that have direct contact with the COPECs (e.g., plants and earthworms growing and living in contaminated soil); and (2) organisms that may be exposed to the chemicals via food chain pathways (e.g., ingestion of an earthworm living in the contaminated soil by a shrew). Potential impacts to invertebrate and plant communities were evaluated by comparing COPEC concentrations to benchmark values available from multiple literature sources. For the food chain exposure assessment, a number of measurement receptors were selected as representative species for the various trophic levels in the food web that could be at risk from contaminants in site media. The measurement receptors that were selected and used in the food chain evaluation included the following:

- Deer Mouse
- Raccoon
- Modified Raccoon (as a surrogate for the Louisiana Black Bear)
- Short-Tailed Shrew
- Red Fox
- Muskrat
- River Otter

- Townsend's Big-Eared Bat
- Common Snapping Turtle
- Bank Swallow
- American Woodcock
- Belted Kingfisher
- Red-Tailed Hawk

A food chain model was developed and used to estimate the total dose for each measurement receptor based on species-specific considerations such as diet, body weight, ingestion rates, etc., using conservative exposure estimates. Ecological hazard estimates were developed based on exposure to all media including soil in a particular sub-area and surface water and sediment from any watersheds present in the sub-areas. Two different soil depths were used for modeling exposure to ecological receptors: surface soil (0 to 0.5 foot) and total soil (0 to 3 feet). Each receptor was assumed to be exposed to one of the two depths based on its life history characteristics (e.g., burrowing animals were assumed to be exposed to total soil). Bioaccumulation of chemicals up the food chain was initially estimated using uptake factors obtained from available literature, and then refined using site-specific data obtained during the BERA. **Figure 2-8** presents the ecological conceptual model, which lays out the exposure pathways for selected species.

Ecological effects quotients (EEQ) were developed for each of the measurement receptors. EEQs are similar to HQs for human health, and are calculated by dividing the total dose that the receptor is exposed to by the toxicity reference value (TRV), which is based on a no-observed adverse effect level (NOAEL) or the lowest-observed adverse effect level concentration. If the EEQ exceeds 1 for a receptor (based on the NOAEL TRV), then that chemical is considered to have a realistic potential to cause adverse ecological impacts, and is identified as a final COPEC that should be addressed either through remediation or further investigation. As discussed in the BERA, there are several important uncertainties associated with the assumptions used in the EEQ process, and it should be noted that EEQs greater than 1 do not necessarily mean that ecological impacts have occurred, or are occurring.

Several sub-areas were established within LHAAP for the BERA. LHAAP-29 falls within the Industrial Sub-Area. For the industrial Sub-Area, four chemicals were selected as final COPECs: cadmium, chromium, zinc, and perchlorate. After that selection, additional sampling data became available and further analysis was performed, leading to the calculation of ecological preliminary cleanup levels (EcoPRGs) for several chemicals in soil. The final COPECs that were initially selected were found to not be of concern and EcoPRGs were calculated for six other chemicals: barium, lead, 2,4-DNT, 2,6-DNT, TNT, and 2,3,7,8-TCDD. Ecological hazards were found to be acceptable for the Industrial Sub-Area that includes LHAAP-29; however, elevated concentrations of NTs (TNT, 2,4-DNT and 2,6-DNT) were identified at one location at the site (Shaw, 2007a). Although NTs were not selected in the Industrial Sub-Area as final COPECs due to low frequency of detection and other considerations, the BERA evaluated measurement receptors and included a spatial analysis at this sample location at LHAAP-29. The results of this analysis identified that the NTs at this location and the adjacent areas may represent a small area of highly elevated concentrations (i.e., a hot spot) that could pose a threat to small-range ecological receptors either through acute toxicity, or as a source area for downgradient surface water transport of contamination (Shaw, 2007b). The EcoPRGs are shown on **Table 2-9**. An Excel spreadsheet analysis was performed by ranking the detected concentrations of each final COPEC in the Industrial Sub-Area and iteratively re-calculating the 95% upper confidence limit (UCL) on the mean after removing concentrations until the 95% UCL for the Industrial Sub-Area was lower than the EcoPRG. (Note: as discussed in the BERA, the EcoPRG is not a "not to exceed" value for all concentrations; rather, it is a conservative estimate of the average concentration that results in no adverse effects, and as such is equivalent to the 95% UCL of chemical concentrations, rather than to individual sample concentrations.) The order of chemical concentrations was altered to preferentially remove LHAAP-29 samples in order to reduce the ecological risk in the Industrial-Sub Area. It is assumed that the locations associated with these concentrations will be remediated. The outcome of the analysis is included in **Table 2-10** and indicated on **Figure 2-12**.

After the BERA was completed in 2007, additional data review determined that some explosives results used in the BERA were invalid. Additional samples were collected during a data gaps investigation to replace the invalid results and the results were combined with the previously reported useable data and data from samples collected following completion of the BERA to re-evaluate the ecological risks. The results were reported in the BERA Addendum (AGEISS, 2014). The results of the re-evaluation indicated that that the replacement data collected during the data gaps investigation confirmed the conclusions of the BERA that no explosives compounds in soil should be identified as COPECs in the industrial sub-area. These results do not change the determination that the areas of elevated NTs at LHAAP-29 might pose a risk to small-range ecological receptors and should be addressed as part of the remedial action.

2.7.3 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.

Actions for soil are necessary to address human health risk including the pathway from soil to groundwater and ecological risks. **Table 2-10** presents the COCs and the final cleanup levels for both soil and groundwater with groundwater COCs for the shallow zone and the intermediate zone listed separately, which takes into account both ecological and human receptors.

The SDWA MCL is the cleanup level for the groundwater COCs. In the absence of federal drinking water standards, clean-up levels will be based on TRRP Residential Groundwater PCLs.

2.8 Remedial Action Objectives

The RAOs for LHAAP-29 presented in this ROD for the selected remedy and contingency remedy 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 by preventing human exposure to the contaminants in the soil, sediment, transite TNT wastewater line, vitrified clay cooling water lines, and groundwater
- Protection of human health and the environment by preventing the migration of contaminants to groundwater and surface water from potential sources in the soil, sediment, and process lines (TNT wastewater and cooling water)

- Protection of human health and the environment by preventing contaminated groundwater from migrating into nearby surface water
- Protection of ecological receptors by preventing exposure to the contaminated soil and sediment
- Return of groundwater to its potential beneficial uses, wherever practicable within a timeframe that is reasonable given the particular circumstances of the site (40 C. F. R. § 300.430(a)(1)(iii)(F)).

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

Per these RAOs, and consistent with the NCP, groundwater will be returned to its beneficial use. In the absence of federal drinking water standards, the groundwater clean-up level at the Site is the TRRP Residential Groundwater PCL and is protective of human health and the environment.

2.9 Description of Alternatives

Four alternatives (including No Action) were 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 Action
As required by the NCP, the no action alternative provides a comparative baseline against which the action alternatives can be evaluated. Under this alternative, groundwater would be left "as is" without implementing any additional monitoring, containment, removal, treatment, or other mitigating actions. No actions 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: $0
Cost Estimate Duration: NA
Estimated Present Worth Cost: $0

Alternative 2 – Excavation and Off-site Disposal for Soil; Plug Lines; In-situ Chemical Oxidation, MNA and LUCs for Intermediate Zone and Shallow Zone Groundwater
The major components of this alternative include the following:

- Excavation and off-site disposal of impacted soil from LHAAP-29 to protect human and ecological receptors, and to eliminate the potential soil-to-groundwater pathway
- Cooling water and transite TNT process wastewater lines will be flushed with water, inspected, and plugged using a bentonite slurry. Confirmation sampling of the wooden TNT wastewater line during the RD may result in excavation and disposal.

- Injection of chemical oxidant in targeted locations in the intermediate groundwater zone to oxidize organic constituents in the saturated zone and extraction of groundwater to help distribute oxidant with MNA following treatment
- MNA with LTM in the intermediate zone (after chemical oxidation is complete) to reduce groundwater contamination to cleanup levels
- MNA with LTM in the shallow zone to reduce groundwater contamination to cleanup levels
- A contingency remedy to enhance MNA if MNA is found to be ineffective. The contingency remedy would consist of injection of bioremediation amendments to enhance degradation of the groundwater contaminants at selected locations based on data available at the time it is determined MNA is not successful. Details for the contingency remedy would be presented in a RD/RAWP.
- 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.
- LTM semiannually for 3 years, annually until the next five-year review, then annually until recommended otherwise at the five-year review to evaluate remedy performance and determine if plume conditions remain constant, improve, or worsen. Monitoring will continue until the five-year review demonstrates that cleanup levels are reached
- The LUCs' performance objectives are to prohibit groundwater use (except for environmental testing and monitoring) as a potable source 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 2-10**) in groundwater are met; to restrict land use to nonresidential until it is demonstrated that the surface and subsurface soil and groundwater COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) 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 the levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in **Table 2-10** in groundwater are met.

Estimated Capital Present Worth Cost: $8,070,000
Estimated O&M Present Worth Cost: $1,070,000
Cost Estimate Duration: 30 years
Estimated Present Worth Cost: $9,140,000

Alternative 3 – Excavation and Off-site Disposal of Soil; Plug Lines; Intermediate Zone Groundwater Extraction and Treatment, MNA and LUCs for Intermediate and Shallow Groundwater

The major components of this alternative include the following:

- Excavation and off-site disposal of impacted soil from LHAAP-29 to protect human and ecological receptors, and to eliminate the potential soil-to-groundwater pathway
- Cooling water and transite TNT process wastewater lines will be flushed with water, inspected, and plugged using a bentonite slurry. Confirmation sampling of the wooden TNT wastewater line during the RD may result in excavation and disposal.

- Groundwater extraction to reduce VOC levels throughout the intermediate zone groundwater contaminant plume to favorable conditions for MNA
- MNA with LTM in the intermediate zone (after groundwater extraction) to reduce groundwater contamination to cleanup levels
- MNA with LTM in the shallow zone to reduce groundwater contamination to cleanup levels
- A contingency remedy to enhance MNA if MNA is found to be ineffective. The contingency remedy would consist of injection of bioremediation amendments to enhance degradation of the groundwater contaminants at selected locations based on data available at the time it is determined MNA is not successful. Details for the contingency remedy would be presented in a RD/RAWP.
- 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.
- LTM semiannually for 3 years, annually until the next five-year review, then annually until recommended otherwise at the five-year review to evaluate remedy performance and determine if plume conditions remain constant, improve, or worsen. Monitoring will continue until the five-year review demonstrates that cleanup levels are reached
- The LUCs' performance objectives are to prohibit groundwater use (except for environmental testing and monitoring) as a potable source 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 2-10**) in groundwater are met; to restrict land use to nonresidential until it is demonstrated that the surface and subsurface soil and groundwater COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) 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 the levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) in groundwater are met.

Estimated Capital Present Worth Cost: $1,550,000
Estimated O&M Present Worth Cost: $1,780,000
Cost Estimate Duration: 30 years
Estimated Present Worth Cost: $3,300,000

Alternative 4 - Excavation and Off-site Disposal for Soil; Plug Lines; ISTD, MNA and LUCs for Intermediate Zone Groundwater; MNA and LUCs for Shallow Zone Groundwater
The major components of this alternative include the following:

- Excavation and off-site disposal of impacted soil from LHAAP-29 to protect human and ecological receptors, and to eliminate the potential soil-to-groundwater pathway
- Cooling water and transite TNT process wastewater lines will be flushed with water, inspected, and plugged using a bentonite slurry. Confirmation sampling of the wooden TNT wastewater line during the RD may result in excavation and disposal.
- One of two ISTD process options, ERH (Alternative 4a) or TCH (Alternative 4b) will be selected during the remedial design phase and implemented to remediate the MC DNAPL plume in the intermediate zone to levels amenable to MNA

- MNA with LTM in the intermediate groundwater zone (after ISTD activities are complete) to reduce groundwater contamination to cleanup levels
- MNA with LTM in the shallow zone to reduce groundwater contamination to cleanup levels
- A contingency remedy to enhance MNA if MNA is found to be ineffective. The contingency remedy would consist of injection of bioremediation amendments to enhance degradation of the groundwater contaminants at selected locations based on data available at the time it is determined MNA is not successful. Details for the contingency remedy would be presented in a RD/RAWP.
- 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.
- LTM semiannually for 3 years, annually until the next five-year review, then annually until recommended otherwise at the five-year review to evaluate remedy performance and determine if plume conditions remain constant, improve, or worsen. Monitoring will continue until the five-year review demonstrates that cleanup levels are reached
- The LUCs' performance objectives are to prohibit groundwater use (except for environmental testing and monitoring) as a potable source 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 2-10**) in groundwater are met; to restrict land use to nonresidential until it is demonstrated that the surface and subsurface soil and groundwater COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) 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 the levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) in groundwater are met.

Alternative 4a:

Estimated Capital Present Worth Cost: $3,710,000

Estimated O&M Present Worth Cost: $1,030,000

Cost Estimate Duration: 30 years

Estimated Total Present Worth Cost: $4,740,000

Alternative 4b:

Estimated Capital Present Worth Cost: $4,530,000

Estimated O&M Present Worth Cost: $1,190,000

Cost Estimate Duration: 30 years

Estimated Total Present Worth Cost: $5,720,000

2.9.2 Common Elements and Distinguishing Features

Common Elements of Alternative 2, 3, and 4

Common elements of Alternatives 2, 3, and 4 are described below.

Soil Excavation –Contaminated soil would be excavated at LHAAP-29 under Alternatives 2, 3, and 4 to prevent human and ecological receptor exposure to contaminants in the soil and to eliminate the soil-to-groundwater pathway. As part of the RD, confirmation soil samples will be collected along the north and south cooling water lines as well as the TNT wastewater lines to confirm that leaching has not occurred, which may identify additional soil excavation areas. Disposal will be at a RCRA Subtitle D-permitted landfill.

Process Lines – Transite TNT wastewater line would be flushed, then the inlets and outlets will be inspected and plugged with a bentonite slurry mix or equivalent. The cooling water lines will be evaluated further during the RD in order to base the remedial action on up-to-date data. The lines will be flushed with water, inspected and plugged using a bentonite slurry mix or equivalent. Rinsate water will be containerized and characterized for waste handling. During the RD, samples will be collected from the soil along the deteriorated wooden TNT wastewater line and analyzed for explosives to determine if there are concentrations that represent a potential source for groundwater contamination. If present, above the GWP-Ind, the affected soils may be included in the excavation and disposal activity.

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. The natural attenuation evaluation indicates that MNA is a feasible technology for the groundwater at LHAAP-29 (Shaw, 2010). Monitoring activities associated with MNA 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, and by documenting reduction of the contaminant mass and protection of surface water through containment of the plume. In all three alternatives, contaminant reduction would occur by MNA alone in the shallow zone. For the intermediate zone, to achieve conditions favorable to MNA, MC would be reduced by chemical oxidation in Alternative 2, groundwater extraction in Alternative 3, and thermal destruction in Alternative 4.

MNA performance monitoring would be conducted quarterly for the first two years. After eight quarterly sampling events, MNA effectiveness will be evaluated. The analytical program would consist of VOCs, including chlorinated compounds and degradation products, nitrotoluenes, methane, ethene, and ethane, among others. The full list of MNA parameters would be developed during the RD phase.

Inspection/Long-Term Groundwater Monitoring – Alternatives 2, 3, and 4 include inspection and long-term groundwater monitoring activities. Monitoring would be continued as required to evaluate the effectiveness of the remedy, to demonstrate compliance with applicable or relevant and appropriate requirements (ARARs) and RAOs, and to support five-year reviews.

LUCs – LUCs would be implemented to support the RAOs. The LUC for groundwater would prevent human exposure to residual groundwater contamination presenting an unacceptable risk to human health and ensure that there is no withdrawal or use of groundwater beneath the sites for anything other than environmental monitoring and testing. The LUC to prohibit groundwater use (except for environmental testing and monitoring) as a potable source would remain 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 2-10**) in groundwater are met; to restrict land use to nonresidential until it is demonstrated that the surface and subsurface soil and groundwater COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) 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 the levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) in groundwater are met.

In addition, within 90 days of signature of this ROD, the Army shall request the Texas Department of Licensing and Regulation to notify well drillers of groundwater use prohibitions based on a preliminary LUC boundary. 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 will also be presented in the RD. 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, and the monitoring system 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 this property (LHAAP-29), an Environmental Condition of Property (ECP) document would be prepared and the Environmental Protection Provisions from the ECP would be attached to the letter of transfer. The ECP would include the LUCs 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 might result in 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 LUC objective at these sites after they have been transferred.

Distinguishing Feature of Alternative 2

The distinguishing feature of Alternative 2 compared to Alternatives 3 and 4 is the inclusion of ISCO to treat the MC DNAPL in the intermediate groundwater zone. These actions are described below. Note that the design specifications presented below are used for cost estimating purposes and the final design for the selected remedy will be presented in the Remedial Design document.

In situ chemical oxidation – The components of this action include:

Installation of injection wells. Four intermediate zone injection wells (88 feet bgs) would be installed around existing intermediate monitoring well 29WW16, where MC was detected at the highest concentration. The four wells would be arranged in a square with well 29WW16 in the center of the square. The spacing may be adjusted based on actual field conditions.

Injection of oxidation solution. One pore volume of heat activated (40 degrees Celsius [ºC]) combined persulfate and sodium hydroxide solution at 60 grams per liter (g/L) and 15 g/L, respectively, would be injected into four wells while simultaneously extracting groundwater from well 29WW216. Temporary piping would be used for the injection array. The estimated volume is approximately 187,000 gallons of activated persulfate and sodium hydroxide solution to be injected into the subsurface. The solution is estimated to be 94,000 pounds of persulfate reagent and 23,500 pounds of sodium hydroxide. A second round of injection may be required if monitoring indicates COCs are not being effectively reduced from the initial round. For the cost estimate, a second round is assumed. If contaminant concentrations do not decrease as anticipated, the method would be modified.

Simultaneous extraction of groundwater. Well 29WW16, or an equivalent, would be converted to an extraction well. Prior to conversion, a pumping test would be conducted and hydrogeologic parameters would be measured to assess aquifer conditions. Groundwater flow in the vicinity of 29WW16 and the injection wells would be modeled to determine the scope of the modifications needed at 29WW16 and to assess the time required to extract one pore volume.

For estimating purposes, it is assumed the on-site groundwater treatment plant is operating and can handle 187,000 gallons extracted for one pore volume. A temporary piping system would be used to convey the extracted water to three 5,000-gallon on-site storage tanks. The on-site tanks would be interconnected and would be equipped with a high level shut off to the extraction pump. Once every two days, water would be pumped into a tank truck and transported to the LHAAP groundwater treatment plant for treatment and discharge (**Figure 2-14**). A 20-foot by 50-foot gravel pad would be prepared for the tanks, and a 6-inch-layer of gravel would be placed to upgrade the road to the tanks at LHAAP-29. Based on the pumping test results, the quantities of extracted water and best approach to handle the water would be evaluated.

Monitor effectiveness. To monitor the effectiveness of the in situ chemical oxidation, six wells would be monitored biweekly for three sampling events. The six wells would include one new monitoring well, four injection wells, and 29WW16. The effect of the first chemical injection should be evident within a few weeks. It is anticipated that a second injection may be needed after approximately 2 months.

Distinguishing Feature of Alternative 3

The distinguishing feature of Alternative 3 compared to Alternatives 2 and 4 is the inclusion of groundwater extraction to address contamination in the intermediate groundwater zone.

Groundwater extraction is estimated to require 3 years to reduce concentrations to levels amenable to MNA. These actions are described below. Note that the design specifications presented below are used for cost estimating purposes and the final design for the selected remedy will be presented in the Remedial Design document.

Pre-Design Study: This action would begin with a pre-design study. A pump test would be conducted and hydrogeologic parameters would be measured to better design the system. Groundwater flow would be modeled to set performance evaluation parameters and to assess the likely time required for remediation.

Construction: Groundwater contamination in the intermediate zone at LHAAP-29 primarily consists of a MC plume. A minimum of five additional wells (four extraction and one monitoring) are proposed to be installed in the intermediate zone within the region of greatest MC contamination in order to provide a more effective extraction process. Several groundwater monitoring wells are located throughout the site and some of these could also be converted to extract contaminated groundwater if needed. The final number and locations for extraction wells would be determined as part of the pre-design study.

Storage and transport of extracted groundwater: A piping system would be constructed to transport the extracted water from the extraction wells 5,000-gallon storage tanks to be located on-site at LHAAP-29. The tanks would be interconnected and equipped with a high level shut off to the pump. Once every two days or at a determined frequency, the water would be pumped into a tank truck and transported to the existing groundwater treatment plant for treatment and discharge.

Performance Monitoring: During extraction, samples would be collected from the extraction wells and monitoring wells to monitor the effectiveness of the action. During startup of the extraction system (until the system is operating properly), bimonthly sampling would be conducted. Startup is estimated to be approximately six months. After startup, monitoring would be reduced to quarterly for the remaining 2.5 years.

Water Treatment and Discharge: The extracted groundwater from LHAAP-29 would be treated at the LHAAP groundwater treatment plant, which was originally built to treat groundwater containing VOCs and metals extracted from other LHAAP sites. The plant uses air stripping, carbon adsorption, and thermal oxidation. Perchlorate treatment using a fluidized bed reactor was added in April 2001 to the treatment plant. The extracted water from LHAAP-29 would be discharged from the tank truck into the existing 300,000-gallon equalization tank. This tank receives water from other LHAAP sites and is stored in this tank until treatment. After the water is treated, the effluent would be discharged in accordance with plant procedures. The plant presently operates at a fraction of its maximum capacity of 1 to 1.5 million gallons of water per month. The original groundwater treatment plant components have adequate capacity to accommodate the increase in volume that would be introduced to the system when the contaminated groundwater is transported from LHAAP-29 to the plant. The system capacity is limited by effluent storage and discharge rate, and this concern was addressed. Recent mitigating measures include the replacement of the reinjection pipeline to increase the pipe diameter to 4-inches, and the installation of a sprinkler system. The capacity issue would be revaluated as necessary during the remedial action.

Extraction System: Operation and maintenance would include groundwater extraction system maintenance, groundwater treatment plant operations, and environmental media monitoring. In three years, the extraction wells are anticipated to remove the highest concentrations of VOCs from the groundwater intermediate zone at LHAAP-29, thus reducing the contaminant mass to make conditions favorable for MNA (estimate assumes 3 years). For MNA, four wells would be selected for use as monitoring wells, and monitoring would be implemented to demonstrate that any remaining VOCs are attenuated by natural processes. During the groundwater extraction operations, the extraction wells would require regular maintenance to prevent fouling of well screens, and the extraction pumps would require routine maintenance and may also require replacement. Cleaning of the pipelines, refurbishing pumps and other maintenance activities would be needed on the groundwater collection and transport system during full-scale operation. O&M costs would include the addition of chemicals, power, and labor; equipment cleaning, tank cleaning, general system maintenance, and replacement; and regulatory monitoring and reporting. O&M activities would also be conducted at the LHAAP plant location as part of the routine plant O&M activities.

Distinguishing Feature of Alternative 4

The distinguishing feature of Alternative 4 compared to Alternatives 2 and 3 is the inclusion of ISTD to remediate the MC DNAPL in the intermediate groundwater zone. Alternative 4a, using ERH as the ISTD process, or 4b using TCH as the ISTD process would be selected during the remedial design phase. Thermal desorption operates by heating the subsurface to effectively and quickly volatilize large quantities of VOCs, including those in the form of non-aqueous phase liquid. Available technologies include ERH, TCH, and steam injection, which are typically coupled with a soil vapor extraction (SVE) system and above ground emission controls to capture and/or destroy volatilized VOCs. Pumping of groundwater or multi-phase extraction (MPE) may also be required to contain the mobilized VOCs in groundwater.

These actions are described below. Note that the design specifications presented below are used for cost estimating purposes and the final design for the selected remedy will be presented in the Remedial Design document. The proposed ERH concept developed for this site and used to develop costs presented in the FS does not include a groundwater extraction component, while the proposed TCH concept incorporated groundwater extraction as part of the MPE component. The TCH conceptual design is significantly more robust than the one proposed for ERH, which may in part explain the difference in total cost between Alternatives 4a and 4b. The actual number of heater wells and the need for groundwater extraction would require further evaluation during the remedial design phase. ISTD for either process option would include extraction of vapors and potentially concurrent groundwater extraction. The need for MPE would be determined during the RD phase. Condensate would be removed from the extracted vapors, which would subsequently be treated in a thermal oxidizer for the destruction of the chlorinated VOCs. Hydrogen chloride generated by combustion of chlorinated compounds would be treated in an acid gas scrubber before discharge to ambient air. If groundwater extraction is required, the extracted water would be combined with the condensate removed from the extracted vapors and transported via truck to the existing groundwater treatment plant (GWTP).

Alternative 4a, In-situ thermal desorption using ERH – ERH delivers electricity through subsurface media via an array of electrodes. The heat generated by electrical resistance typically can raise subsurface temperatures to around the boiling point of water. The steam produced from pore-water serves as a medium to carry out volatilized VOCs for capture via SVE and subsequent ex-situ treatment of extracted vapors. Contaminants are also directly volatilized from unsaturated soil and the applied heat can increase hydrolysis of chlorinated solvents, such as MC, and promote in-situ biological activity. Treatment duration is estimated at 65 – 87 days. The components of the ERH technology for Alternative 4a include:

Installation of electrode borings: An array of electrode borings with co-located vapor extraction wells. The specific depths and layout of the array would be determined during the RD. Temperature monitoring probes would also be installed.

Vapors: The extracted vapor would require treatment to remove VOCs. Although activated carbon is proposed in the vendor's conceptual design, it is assumed that the mass loading would require a thermal oxidizer for treatment of the vapors. The airflow rate is estimated at 320 standard cubic feet per minute (scfm).

Storage, transfer, and treatment of extracted water: Condensate from the co-located vapor extraction wells would be collected and stored in an above-ground tank prior to transfer to the GWTP for treatment and disposal.

Alternative 4b, In-situ thermal desorption using TCH - Thermal conduction is the process of heat flow from a high temperature area to a lower temperature area. TCH involves applying heat and vacuum simultaneously to subsurface media with an array of vertical heater/vacuum wells, thus heating up solids (soil and rock) and liquids (water, air and non-aqueous phase liquids). The heat moves out radially from each thermal well until the heat fronts overlap. Thermal conductivities of subsurface materials, such as sands, silt, and clay show little variability, which leads to highly predictable in-situ heating even in challenging heterogeneous settings. Heating of the wells can either be accomplished by electrically-powered heater coils or using combustion of fuels (e.g. natural gas or propane).

Transport of the vaporized contaminants is improved by the creation of permeability, which results from drying and, if clay is present, shrinking of the soil close to the heaters causing the formation of preferential flow paths that allow capture of the vaporized contaminants. The target temperature for TCH is typically the boiling temperature of the groundwater (e.g. 100 degrees Celsius [ºC] at a pressure of 1 atmosphere). The steam produced from the groundwater serves as a medium to carry out volatilized VOCs. In addition, the applied heat can increase hydrolysis and promote in-situ biological activity. Treatment duration estimated at 180 days.

The components of the TCH technology for Alternative 4b include:

Installation of heater wells: An array of heater wells with co-located vapor extraction wells. The specific depths and layout of the array would be determined during the RD. Temperature monitoring probes would also be installed.

Vapor treatment: The extracted vapor would require treatment to remove VOCs. Although activated carbon is proposed in the vendor's conceptual design, it is assumed that the mass loading would require a thermal oxidizer for treatment of the vapors. Assumed airflow rate is 320 scfm

Storage, transfer, and treatment of extracted water: Condensate from the co-located vapor extraction wells would be collected and stored in an above-ground tank prior to transfer to the GWTP for treatment and disposal

2.9.3 Expected Outcomes of Each Alternative

Alternative 1 would allow the site to remain a hazard to human and ecological receptors, since it simply leaves the site as is. Alternatives 2, 3, and 4 provide the same outcome to mitigate exposure to human and ecological receptors by excavation and off-site disposal of the contaminated soil. Soil excavation would also eliminate the potential soil-to-groundwater pathway, preventing further degradation of groundwater from contaminated soil. Alternatives 2, 3, and 4 would significantly and permanently reduce groundwater contaminant concentrations to the applicable cleanup levels and, therefore, provide long-term effectiveness and permanence. This would be achieved by implementing MNA after the implementation of the initial active treatments from Alternatives 2, 3, and 4 to reduce the VOC contaminant concentrations in the intermediate groundwater zone. These include ISCO for Alternative 2, groundwater extraction (pump and treat) for Alternative 3, and ISTD for Alternative 4. Cleanup levels for the shallow zone should be achieved through MNA in approximately 70 years, and in the intermediate zone the cleanup levels should be achieved through MNA following extraction or active treatment in approximately 90 years for Alternatives 2 and 3, and 5-10 years for Alternatives 4a and 4b. However, considering the lithologic variability, particularly the lateral and vertical change from sand to clay, the times to achieve the cleanup levels may vary by an order of magnitude. The similar outcomes are considered to be attainment of the SDWA MCLs to the extent practicable, and consistent with 40 C.F.R. § 300.430(e)(2)(i)(B & C). If no SDWA MCL has been promulgated for a contaminant, the TRRP Residential Groundwater PCL is used in place of the SDWA MCL. In addition, the monitoring activities associated with MNA 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 to the extent practicable, given the particular circumstances of the site, by documenting reduction of the contaminant mass and protection of surface water through containment of the plume.

The LUC will remain in place to prohibit groundwater use (except for environmental testing and monitoring) as a potable source 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 2-10**) in groundwater are met; to restrict land use to nonresidential until it is demonstrated that the surface and subsurface soil and groundwater COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) 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 the levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) in groundwater are met.

2.10 Summary of Comparative Analysis

Nine criteria identified in the NCP 40 C.F.R. § 300.430(a)(1)(iii)(F) 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 2-11** 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 land use controls.

The four alternatives provide varying levels of human health protection. Alternative 1, no action, does not confirm achievement of the RAO for the return of groundwater to its potential beneficial use because there is no monitoring involved. Alternative 1 also provides the least protection of all the alternatives; it provides no reduction in risks to human health or the environment because no measures would be implemented to eliminate the pathway for human exposure to soil or to the groundwater contamination and potential groundwater impacts to Central Creek and Goose Prairie Creek would not be addressed. Additionally, the soil pathway for ecological receptors would not be addressed.

Alternatives 2, 3, and 4 satisfy the RAOs for LHAAP-29. Alternatives 2, 3, and 4 would remove the contaminated soil and solid residue in lines that pose a hazard, and provide confirmation that human health and the environment would be protected because the monitoring would be conducted to show that MNA is returning the groundwater in the contaminated shallow and intermediate groundwater zones at LHAAP-29 to its potential beneficial use as a drinking water supply to the extent practicable, given the particular circumstances of the site, 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 LUC for groundwater would protect human health by preventing access to the contaminated groundwater 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 2-10**) in soils and groundwater allow for unlimited use and unrestricted exposure. Alternatives 2, 3 and 4 provide treatment of the primary COC, MC, for human health in the intermediate zone.

2.10.2 Compliance with ARARs

Section 121(d) of CERCLA and 40 C.F.R. § 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 the potential to flow into Goose Prairie Creek which flows to Caddo Lake, a drinking water supply, chemical-specific ARARs for surface water consumption are appropriate and relevant. Specifically, Texas surface water quality standards are set forth in 30 TAC 307.6(d)(1), Table 2, for MC, TCE, 1,2-DCA, 1,1-DCE, and VC. For those COCs not listed in Table 2, including perchlorate, cis-1,2-DCE, trans-1,2-DCE, and explosives, the TRRP Residential Groundwater PCLs for those COCs would apply.

Alternative 1 does not comply with chemical-specific ARARs because no remedial action or measures would be implemented. Alternatives 2, 3, and 4 do comply with all chemical-specific ARARs for soil because the contaminated soil above the chemical-specific ARAR would be removed. Alternatives 2, 3, and 4 comply with all chemical-specific ARARs for groundwater because they would return the contaminated shallow and intermediate groundwater zones at LHAAP-29 to their potential beneficial use as 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 or TRRP Residential Groundwater PCLs if no SDWA MCL is available) to the extent practicable, and consistent with 40 C.F.R. § 300.430(e)(2)(i)(B & C) and 30 TAC 335.559(d)(2). 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. While Alternative 3 provides a level of overall protection similar to Alternatives 2 and 4, Alternatives 2 and 4 would accelerate the MC cleanup in the intermediate zone. Alternative 4 would achieve the cleanup in the shortest period of time, 5-10 years of MNA after active treatment is completed, compared with 90 years of MNA for Alternatives 2 and 3.

Location-specific and action-specific ARARs would not apply to Alternative 1 since no remedial activities would be conducted. Alternatives 2, 3, and 4 would comply with all action-specific ARARs. There are no location-specific ARARs for Alternatives 2, 3, or 4.

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 on-site following remediation and the adequacy and reliability of controls.

Alternative 1 would be the least effective and permanent in the long term because no contaminant source removal or treatment would take place and no measures would be implemented to control exposure risks posed by contaminated site soil, sediment, surface water and groundwater. Alternative 1 would also have no effectiveness and permanence with regards to the contaminated soil, since no soil removal would be conducted.

Removing the source soils and either removing the contaminated groundwater through extraction, or using active treatment to destroy VOCs in the DNAPL plume would provide a permanent solution for the contaminants in affected media.

Alternatives 2, 3, and 4 would provide a moderate degree of long-term effectiveness by removing the source soils and providing restoration of the groundwater by treatment and/or MNA. Alternatives 2 and 4 provide a higher level of effectiveness than Alternative 3because the intermediate groundwater zone would reach concentrations amenable to natural attenuation in a shorter time frame. Alternative 4 would provide the highest level of effectiveness since the intermediate zone groundwater would reach cleanup levels in the shortest timeframe. Alternative 2 allows the opportunity to evaluate the impact of the in-situ treatment and re-inject if necessary. The impact of the ISTD performed under either of the process options for Alternative 4 would also be evaluated to determine whether additional treatment may be necessary. Alternative 3 is as effective and permanent as Alternatives 2 and 4, but would require more time to reduce concentrations amenable to MNA than Alternatives 2 or 4 and would require a longer period of active operations and maintenance. Alternatives 2 and 4 would significantly reduce initial groundwater contaminant concentrations and thereafter rely on natural attenuation and LUCs 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 2-10**) in soils and groundwater allow for unlimited use and unrestricted exposure. Monitoring activities associated with MNA 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 to the extent practicable, by documenting reduction of the contaminant mass and protection of surface water through containment of the plume.

LUCs would provide a moderate to high degree of effectiveness by limiting land use and preventing exposure to contaminated media. As a federally owned property that will remain so as a refuge after transfer, the ability to achieve permanence and effectiveness is greatly enhanced.

The removal of contaminated solid residue from the transite wastewater line and from the cooling water lines would provide a high degree of long-term effectiveness and permanence by removing the contaminated solid residue from the site.

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.

Alternative 1 does not employ treatment and would not result in a reduction of toxicity, mobility, or volume of contaminants. Alternative 2 would use excavation, ISCO, and natural attenuation to permanently reduce the mass and concentration of contaminants and, therefore, the toxicity, mobility, and volume of the contaminants. In-situ chemical oxidation is an active treatment process.

Alternative 3 would use excavation, groundwater extraction, and natural attenuation to achieve the same reductions in contamination that are expected from Alternative 2. Groundwater extraction is an active treatment process and would reduce toxicity and volume of the contaminants.

Alternative 4 would use excavation, ISTD, and natural attenuation to permanently reduce the mass and concentration of contaminants and, therefore, the toxicity, mobility, and volume of the contaminants. ISTD is an active treatment process.

Biological activity would generate daughter products that may temporarily increase toxicity or mobility of the contaminant plume. Alternatives 2, 3, and 4 include monitoring so that daughter products would be quantified, documented, and evaluated. The same biological activities would also consume the daughter products, and it is anticipated that these concentrations would be reduced to levels below their associated cleanup levels to return groundwater to its potential beneficial use, wherever practicable.

There is an NCP expectation to use treatment to address principal threat wastes, wherever practicable. Alternatives 2, 3, and 4 satisfy the NCP expectation by including treatment components that address the potential for principal threat wastes associated with the high concentrations of MC in the intermediate groundwater zone.

The soil excavation in Alternatives 2, 3, and 4 would reduce mobility because perchlorate and explosive contaminated soils would be removed from the site and placed in a permitted disposal facility. Toxicity and volume would not be reduced by the excavation portion of the alternatives as the form and quantity of contaminants would not be altered.

The removal of contaminated solid residue from the transite wastewater line and cooling water lines by flushing with water in Alternatives 2, 3, and 4 would reduce mobility because the solid residue would be removed from the site and the rinsate collected, analyzed by the toxicity characteristic leaching procedure (TCLP), and properly disposed. Toxicity and volume would not be reduced since quantity of the contaminants would not be altered.

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.

Alternative 1 would not involve any remedial measures; therefore, no short-term risk to workers, the community, or the environment would exist. The activities associated with Alternatives 2, 3, and 4 would be protective to the surrounding community from short-term risks except for minimal potential short-term risks during transport (possible accident when soil is transported off site) of perchlorate and explosive contaminated soil.

Alternatives 2, 3, and 4 would involve potential short-term risks to remediation workers associated with exposure to contaminated groundwater from monitoring and/or operation of drilling/construction equipment, and with exposure to contaminated soil during excavation work.

Alternative 2 has additional short-term risks due to remediation workers handling chemical oxidants and also requires heating of the target zone to 40 degrees C, which would pose similar risks as those posed by the thermal treatment included under Alternative 4, such as potential exposure to high voltage power sources. The thermal treatment component of Alternative 4 has additional potential short-term risks due to potential exposure to high voltage power sources and exposure to hot fluids extracted during ISTD treatment. In addition, workers could be exposed to toxic air emissions during ISTD operations.

Alternative 3 would have short-term risks to the remediation workers associated with exposure during increased operations at the LHAAP groundwater treatment system, which include chemical handling and operation of a high-temperature catalytic oxidizer and in handling contaminated groundwater during extraction, temporary storage on site, and conveyance to the GWTP 1.5 miles away. The implementation of Alternative 3 would require more time than either Alternative 2 or Alternative 4.

Alternatives 2, 3, and 4 include the LUCs as elements of their remedies and would provide almost immediate protection from the contaminated groundwater by prohibiting groundwater use except for environmental monitoring and testing through LUC implementation through a relatively quick implementation period. The time period to achieve groundwater cleanup levels is the most significant difference between Alternative 1 versus Alternatives 2, 3, or 4. Alternatives 2 and 3 are expected to take less time to achieve RAOs than Alternative 1, and either Alternative 4a or 4b would require the shortest time for the intermediate zone groundwater to achieve cleanup levels.

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 Alternative 1, no remedial action would be taken. Therefore, no difficulties or uncertainties would be associated with its implementation. For Alternatives 2, 3, and 4, soil excavation would require extensive coordination between excavation, sampling, transportation and disposal. Plugging of the TNT transite wastewater line and cooling water lines can be conducted without extensive intrusive activities with equipment, services, and materials readily available to conduct the activities for Alternatives 2, 3, and 4. Alternatives 2, 3, and 4 could all be implemented. There are qualified vendors available to implement the ISTD technology. There are also qualified contractors with the capabilities to design and implement ISCO. Installation of utilities, availability of equipment and supplies, and compliance with any local ordinances or other requirements would need to be identified and addressed during the design and construction process.

Alternative 3 would involve the use of a groundwater treatment system which currently exists at LHAAP and is accessible to the site; however, from a technical standpoint the increased duration for extraction would require three years for Alternative 3 compared to six months for Alternative 2 and

Alternative 4b, or approximately 3 months for Alternative 4a. The U.S. Army will be responsible for LTM and enforcement of the LUCs, long-term evaluation of MNA, long-term sampling, and LTM and operation of sampling equipment. Technically, Alternatives 2, 3, and 4 are readily implementable.

Administratively, all of the alternatives are 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 would 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). Overall present worth costs are developed for each alternative assuming a discount rate of 2.8 percent. The duration used for the estimates is a 30-year period.

The progression of present worth costs from the least expensive alternative to the most expensive alternative is as follows: Alternative 1, Alternative 3, Alternative 4a, Alternative 4b, and Alternative 2. No costs are associated with Alternative 1 because no remedial activities would be conducted.

Alternative 3 has the lowest present worth and capital costs of the active remedial alternatives. The presence of the existing groundwater treatment system at LHAAP greatly reduces the capital costs associated with groundwater extraction in Alternative 3. Alternative 2 has the highest present worth and capital costs primarily due to the activities associated with the injection phase of ISCO. Alternative 4a has a lower present worth than Alternative 4b, however the difference in costs between the ISTD process options may reflect differences between the components included in the proposed designs for ERH and TCH developed for the FS. The proposed ERH concept developed for this site and used to develop costs presented in the FS does not include a groundwater extraction component, while the proposed TCH concept incorporated groundwater extraction as part of the MPE component. The TCH conceptual design is significantly more robust than the one proposed for ECH, which may in part explain the difference in total cost between Alternatives 4a and 4b.

2.10.8 State/Support Agency Acceptance

The USEPA and TCEQ have reviewed the Revised Proposed Plan, which presented Alternative 4 as the preferred alternative. Comments received from the USEPA and TCEQ during the Revised 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. Verbal comments were received during the public meeting held on December 6, 2018 at the Karnack Community Center. No other comments were received during the 30-day public comment period. The topics of the comments included: excavation and disposal of contaminated soils; requirements for vegetation removal and above ground ecological impacts of the remedial actions; the status of the wooden wastewater line; prior treatability studies; groundwater plume stability and migration; ISTD effectiveness; and regulatory drivers for remediation. Comment responses were provided and incorporated into the ROD, including describing soil sampling and evaluating the wooden wastewater lines for removal.

Several sets of written public comments were received during the 30-day public comment period and public meeting held for the 2011 PP, and there were several verbal comments from the March 22, 2011 public meeting. Although the selected remedy has changed, most of the comments remain relevant. The relevant topics of the 2011 comments included: excavation of contaminated soils, groundwater treatment plant operation, additional groundwater sampling for DNT isomers, remediation for flushing and plugging the subsurface TNT wastewater line, and plugging the cooling water lines. Comment responses were provided and are summarized in the Responsiveness Summary (**Section 3**).

2.11 Principal Threat Waste

Laboratory results from the groundwater at LHAAP-29 have indicated that residual DNAPL may be residing as a source material in the subsurface. In a phase separate from groundwater, the hazardous contaminant MC is characterized as a highly toxic source material and, thus, a principal threat waste. In accordance with the NCP, treatment alternatives have been evaluated through the remedy selection process. The preferred remedial alternative includes an active remedial component that would mitigate the potential principal threat. By instituting an ISTD treatment of the groundwater, this active treatment would be applied to the highest concentration area in the MC groundwater plume and would comply with the NCP expectations regarding treatment of affected media where principal threat may be considered.

2.12 The Selected Remedy

2.12.1 Summary of Rationale for the Selected Remedy

Alternative 4 (Excavation and Off-site Disposal for Soil; Plug Lines; ISTD, MNA and LUCs for Intermediate Zone Groundwater; MNA and LUCs for Shallow Zone Groundwater) is the selected alternative for LHAAP-29 and is consistent with the intended future use of the site as a national wildlife refuge. Either Alternative 4a, using ERH, or Alternative 4b, using TCH as the ISTD process option would be selected during the RD. The ISTD would rapidly reduce MC concentrations in the intermediate zone to make conditions more amenable for MNA. The selected alternative offers a high degree of long-term effectiveness and can be easily and immediately implemented. This alternative would satisfy the RAOs for the site through the following:

- Contaminated soil and sediment removal with off-site disposal to protect the hypothetical future maintenance worker and ecological receptors from exposure and eliminate the soil-to-groundwater pathway. Additional confirmation soil sampling during the RD may identify additional soil excavation areas, see **Section 2.12.2**.
- Flushing, inspecting, and plugging of the transite TNT wastewater line and the vitrified clay cooling water lines to eliminate potential exposure from residual contamination. The wooden wastewater lines would be evaluated during the RD for excavation and disposal.
- For intermediate groundwater zone: ISTD treatment of the MC DNAPL plume to reduce to levels amenable to MNA.

- MNA was selected as one component of the remedy based on available groundwater evidence as presented in 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 in individual wells were observed in intermediate groundwater, including the detection of daughter products that suggest the occurrence of complete reductive dechlorination. Concentrations of TCE decreased from 8,800 µg/L to 4,340 µg/L at monitoring well 29WW16 and were completely attenuated at monitoring well 29WW35. Concentrations of MC decreased from 8,770 µg/L to undetectable at 29WW35. These results indicated the intermediate contaminant plume is stable. Thus, natural attenuation was considered feasible for intermediate groundwater, but not as a sole remedy due to the high MC concentrations in groundwater at 29WW16 and vicinity. Additional evaluation would be implemented as part of the MNA component. MNA, together with ISTD, would ultimately restore the intermediate groundwater to attain groundwater cleanup levels. This is anticipated to be completed in approximately 5-10 years. Considering the lithologic variability, particularly the lateral and vertical change from sand to clay, the times to achieve the cleanup levels may vary by an order of magnitude. 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 the intermediate groundwater because it would protect human health and the environment, and would document that further reductive dechlorination is occurring within the groundwater plume and that contaminant concentrations are being reduced to attain groundwater cleanup levels.
- For shallow groundwater zone: MNA to reduce contaminant levels to cleanup levels and return groundwater to its potential beneficial uses, and confirm the contaminated groundwater remains localized with minimal migration to protect surface water. MNA was selected as the remedy based on available groundwater evidence as presented in 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 perchlorate, explosives, and chlorinated solvents in individual wells were observed in shallow groundwater, including the detection of daughter products that suggest the occurrence of complete reductive dechlorination. These results indicated the shallow contaminant plumes are stable, and monitoring wells formerly with COC concentrations above cleanup levels have attained the cleanup levels in the historical sampling record. Noting some of the highest remaining concentrations; perchlorate decreased from 88,000 µg/L to 16,800 µg/L at monitoring well 29WW15, the explosive o-NT decreased from 18,000 µg/L to 1,230 µg/L at monitoring well 29WW05, and the chlorinated solvent 1,2-DCA decreased from 14,000 µg/L to 5,520 µg/L at 29WW15. Thus, natural attenuation was considered feasible for perchlorate, explosives and chlorinated solvents in shallow groundwater. Additional evaluation would be implemented as part of the MNA component. MNA would ultimately restore the shallow groundwater to attain groundwater cleanup levels. This is anticipated to be completed in approximately 70 years

based on attenuation of 1,2-DCA in 29WW15. Considering the lithologic variability, particularly the lateral and vertical change from sand to clay, the times to MCL may vary by an order of magnitude. 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 the shallow groundwater because it would protect human health and the environment and would document that further natural attenuation is occurring within the groundwater plume, and that perchlorate, explosives, and chlorinated solvent concentrations are being reduced to attain groundwater cleanup levels.

- The LUC to prohibit groundwater use (except for environmental testing and monitoring) as a potable source would be implemented to ensure protection of human health by preventing exposure to groundwater 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 2-10**) in groundwater are met. The LUC restricting land use to nonresidential would be implemented until it is demonstrated that the surface and subsurface soil and groundwater COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) are at levels that allow for unlimited use and unrestricted exposure. The LUC to maintain the integrity of any current or future remedial or monitoring systems would be implemented 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 2-10**) in groundwater are met.
- Long-term monitoring and reporting would continue until the cleanup levels are achieved in groundwater to confirm protection of human health by preventing exposure to groundwater until cleanup levels are met.

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

Based on information currently available, the U.S. Army believes 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: 1) is protective of human health and the environment; 2) complies with ARARs; 3) is cost-effective; 4) utilizes a permanent solution; and 5) utilizes an active treatment as a principal element. The selected remedy addresses the statutory preference for treatment to the maximum extent possible. As a component of the intermediate groundwater zone, MC is characterized as a highly toxic source material and, thus, a principal threat waste. In accordance with the NCP, treatment alternatives have been evaluated through the remedy selection process. The preferred remedial alternative includes an active remedial component that would mitigate the potential principal threat. By instituting ISTD treatment of the groundwater, this active treatment would be applied to the highest concentration area in the MC groundwater plume and would comply with NCP expectations regarding treatment of affected media where principal threat may be considered.

In the remedial design, the U.S. Army would present details of the soil excavation, selected ISTD process (ERH or TCH), ISTD design, LUC operations and maintenance, groundwater monitoring, flushing TNT transite wastewater line and cooling water lines, evaluating the deteriorated wooden wastewater line for excavation and disposal, plugging and abandoning TNT wastewater and cooling water lines, and MNA remedy implementation for LHAAP-29.

2.12.2 Description of the Selected Remedy

The selected remedy, Alternative 4, was outlined in **Section 2.9**; that description is expanded in the following discussion. The major components of the remedy include:

Soil Excavation. The excavation would remove explosives and perchlorate contaminated soils for off-site disposal at a RCRA Subtitle D-permitted landfill. This action would achieve the following: 1) removal of soil that is a direct risk to the hypothetical future maintenance worker, thereby protecting human health by preventing inhalation, ingestion, and dermal contact with the COCs; 2) removal of contaminated soil that is a potential source of contaminant migration to groundwater; and 3) removal of soil posing a risk to ecological receptors. The cleanup levels are presented in **Table 2-10**. The approximate excavation locations are highlighted on **Figure 2-12**. The removal of soil contamination would be verified by collecting confirmation samples from the walls and floors of the excavation area and submitting them for laboratory analysis for the COCs of interest. Clean borrow soil would be used as needed to backfill the excavations so they can be graded for proper drainage. Additional sampling would be required during the remedial design phase to further define explosives impacts near former Building 812-F and in the cooling water outfall/ditch as part of the remedial design, and confirmation soil samples would be collected adjacent to the North and South Cooling Water lines as well as the wooden and transite TNT wastewater lines to confirm that leaching from the lines has not occurred. Results from the confirmation soil sampling may identify additional areas exceeding the cleanup levels presented in **Table 2-10**, which would require soil excavation.

Plug and Abandon Lines. The transite TNT wastewater line and the cooling water lines would be flushed with water to remove solid residue. After flushing, the lines would be visually inspected to evaluate if there is any remaining residue and/or liquid in the lines. The inspection and closure details would be included in the RD and may include techniques such as sampling of flush water and video camera inspection if there is any uncertainty about the effectiveness of the flushing. The rinsate water would be containerized. During typical flushing operations, the flush water would be sampled, analyzed and screened to TCLP (or the equivalent TCEQ test) to determine disposal. The inlets and outlets of the transite TNT wastewater line would be plugged with a bentonite slurry mix or equivalent. The manholes and outlets of the cooling water lines would then be plugged with a bentonite slurry mix or equivalent. The deteriorated wooden wastewater line would be sampled to determine whether contaminants in the line exceed soil cleanup levels and require excavation and disposal.

In-situ Thermal Desorption for Intermediate Zone VOC Groundwater Plume. Under Alternative 4 the highest concentration area in the MC plume in the Intermediate Zone groundwater would be treated using ISTD with either the process option ERH (Alternative 4a) or TCH (Alternative 4b) to be determined during the remedial design phase. Groundwater extraction may be implemented as part of the in-situ treatment to physically remove mass and to control the hydraulic gradient.

ERH delivers electricity through subsurface media via an array of electrodes. The heat generated by electrical resistance typically can raise subsurface temperatures to around the boiling point of water. The steam produced from pore-water serves as a medium to carry out volatilized VOCs for capture via SVE and subsequent ex-situ treatment of extracted vapors. In addition, the applied heat can increase hydrolysis of chlorinated solvents, such as MC, and promote in-situ biological activity in two ways. First, biological activity is boosted by moderately high temperatures (30 ºC) found at the periphery of the heated area during active thermal treatment, and throughout the heated area as it cools. Second, high temperatures increase the solubility of DNAPL, resulting in an increase in contaminant concentrations in the dissolved form that the microbes are able to use, provided the concentrations of the dissolved COCs are not toxic to the microorganisms.

TCH involves applying heat and vacuum simultaneously to subsurface media with an array of vertical heater/vacuum wells. The wells are typically heated by electrical coils, but can also be heated by fuel (e.g. natural gas or propane) combustion. Heat generated from heating elements/wells is transferred to the subsurface largely through thermal conduction and radiant heating. Similar to ERH, the heat generated by TCH typically raises subsurface temperatures to around the boiling point of groundwater and the steam produced from the groundwater serves as a medium to carry out volatilized VOCs. In addition, the applied heat can increase hydrolysis and promote in-situ biological activity.

Preliminary conceptual designs including the number and spacing of heater wells (TCH) or electrode borings (ERH), associated vapor and/or dual phase extraction systems, and treatment train for extracted vapors and condensate were developed and used for FS costing. The final ISTD process option would be determined during the remedial design phase, and the specific design parameters, including the number and locations of heater wells (TCH) or electrodes (ERH) and associated treatment train components may change as the system design is refined.

The ERH preliminary conceptual design components include:

- ***Electrode borings.*** Fifteen 12-inch diameter electrode borings would be installed to a depth of 91 feet bgs with co-located vapor extraction wells screened above 48 feet bgs; average electrode spacing would be 18 ft. The electrodes would be used to heat the subsurface to near boiling temperatures to volatilize VOCs from the subsurface, and the vapor extraction wells would extract the steam generated.
- ***Temperature monitoring probes.*** Four probes, with 10 sensors per probe to monitor subsurface temperatures.
- ***Vapor treatment.*** Activated carbon or a thermal oxidizer would be used to treat the vapors. The vendor's conceptual design included activated carbon, but the expected mass loading would require a thermal oxidizer to treat the extracted vapor. Airflow rate is estimated at 320 scfm.
- ***Condensate collection.*** Condensate production is estimated at 0.9 gpm and would be captured and stored in aboveground tanks for transfer to the on-site GWTP.
- ***Power control unit.*** A 480 volt, 3-phase 700 kilowatt power control unit would be required to supply the required power to the electrodes, extraction and treatment components associated with the system operations.

Figure 2-14 shows the conceptual layout for the network of ERH electrodes. The final layout and number of electrodes would be determined as part of the RD if ERH is the selected ISTD process option.

The TCH preliminary conceptual design components include:

- ***Heater borings.*** 25 heater borings would be installed to a depth of 91 feet bgs with co-located vapor extraction wells screened at close to the target zone depth. Average electrode spacing would be 18 feet.

- ***Multi-phase extraction wells.*** 7 multi-phase extraction wells would be installed in 10-inch boreholes to extract vapor and water for treatment.
- ***Temperature monitoring probes.*** 5 temperature monitoring probes with 3 sensors in each probe would be instated in 6-inch boreholes to monitor subsurface temperatures.
- ***Vapor treatment.*** Activated carbon or a thermal oxidizer would be used to treat the vapors. The vendor's conceptual design included activated carbon, but the expected mass loading would require a thermal oxidizer to treat the extracted vapor. Airflow rate is estimated at 320 scfm.
- ***Water collection and treatment.*** The water production rate is estimated at 1-3 gpm and would be captured and stored in aboveground tanks for transfer to the GWTP.
- ***Power control unit.*** A 480-volt, 3-phase 700 kilowatt power control unit would be required to supply the required power to the heater borings, extraction and treatment components associated with the system operations.

Figure 2-15 shows the conceptual layout for the network of TCH heater borings. The final layout and number of electrodes would be determined as part of the RD if TCH is the selected ISTD process option.

Major components of the MNA remedy include:

- ***MNA to return groundwater to its potential beneficial use, wherever practicable given the particular circumstances of the site.*** MNA begins following ISTD activities. Historic data suggest that natural attenuation of COCs is occurring at the site; however, additional data collection is necessary to fully evaluate natural attenuation. Monitoring wells would 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 would 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 two years.*** Each of the general performance objectives must be met as indicated below. If MNA is effective, a baseline would be established from the data to that point in time. Specific evaluation criteria would be developed in the RD. A contingency remedy would be developed and implemented to enhance MNA if it is found to be ineffective. If the criteria are not met to illustrate that MNA is an effective remedy, the contingency action would be initiated.

  The MNA evaluation would be based on the USEPA lines of evidence (USEPA, 1999) 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 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 to enhance MNA to reach the RAOs if MNA is found to be ineffective.*** The area and the elements of the contingency remedy would be selected based on the entire data set available. The contingency remedy would consist of injection of bioremediation amendments to enhance degradation of the groundwater contaminants at

selected locations based on data available at the time it is determined MNA is not successful. Development and specific description of the contingency remedy would be presented in a RD/RAWP.

- ***Initiate LTM.*** Monitoring would be conducted to evaluate the remedy performance and determine if the plume conditions remain constant, improve or worsen after the baseline is established. LTM would be implemented at a frequency of semiannual for three years, then annually until the next five-year review. The performance monitoring plan would be developed in the RD and would be based on USEPA guidance (USEPA, 2004).
  - Continue LTM annually thereafter until recommended otherwise by the five-year review to evaluate remedy performance and determine if plume conditions remain constant, improve, or worsen. The baseline of the plume for future five-year reviews would be established as part of the MNA evaluation program. The initial LTM plan would be developed in the RD.
  - Groundwater monitoring would be conducted to evaluate inorganic COCs. The need to continue groundwater monitoring for this purpose would be evaluated at five year reviews.
- ***Land Use Control.*** The LUC 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 cleanup 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 assure 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 LUC for prohibition of groundwater use (except for monitoring and testing) shall be implemented and shall remain in place at the Site until the COCs (i.e. including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) in soil and groundwater remaining at the site are reduced below levels that would support 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 the EPA and the 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 preliminary boundary for the groundwater LUC is shown on **Figure 2-16**.

- The LUC restricting land use to nonresidential shall be implemented until it is demonstrated that surface and subsurface soil and groundwater COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) are at levels that 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 the levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) in groundwater are met. The LUC to prohibit 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, **Table 2-10**) in soil and groundwater allow for unlimited use and unrestricted exposure.

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 USEPA 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.

LUC implementation and maintenance actions will be described in the RD for LHAAP 29. The LUCs would be included in the property transfer documents and a recordation of them filed in the Harrison County Courthouse. The LUC for groundwater will prevent human exposure to groundwater contaminated with chlorinated solvents, explosives, metals, and perchlorate through the prohibition of groundwater use (except for environmental monitoring and testing), 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 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 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 USEPA 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 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 will confirm that groundwater is not being used. Long-term operational requirements under this alternative will 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 monitoring will be evaluated every 5 years during the reviews. Sampling frequency and analytical requirements will be presented as an appendix to the RD for LHAAP-29.

2.12.3 Cost Estimate of the Selected Remedy

Table 2-12 and **Table 2-13**present the present worth analysis of the cost for the selected remedy, Alternative 4a or 4b. The information in the tables is based on the best available information regarding the anticipated scope of the remedial alternative. The quantities used in the estimates 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. Changes will be documented in accordance with 40 CFR 300.435(c)(2) in the form of a memorandum in the Administrative Record, an Explanation of Significant Difference (ESD), or a ROD amendment, as necessary. 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, capital, and O&M costs for Alternatives 4a and 4b are shown in **Table 2-12** and **Table 2-13**. For Alternative 4a, the capital costs are $3.71M, O&M costs are $1.03M, and total present worth costs are $4,740M. For Alternative 4b, the capital costs are $4.53M, O&M costs are $1.19M, and total present worth costs are $5.72M. The costs were developed using a discount rate of 2.8%. The O&M costs include evaluation of MNA, maintenance of the LUC, and LTM through Year 30. The LTM would 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 document. **Table 2-10** presents the cleanup levels. The cleanup levels for the COCs in the groundwater are the Federal SDWA MCLs, or in the absence of federal drinking water standards, the cleanup level is the TRRP Residential Groundwater PCL. The cleanup level for the soil is the GWP-Ind MSC. The cleanup levels for the COPECs in soil are the EcoPRGs.

The expected outcome of the selected remedy is that contaminants in soil and groundwater will be reduced to the cleanup levels. Achievement of the cleanup levels (**Table 2-10**) is anticipated to be completed in approximately 70 years based on the MNA for 1,2-DCA in the shallow zone. MNA in the intermediate zone is estimated to take 5-10 years following active treatment of the DNAPL plume. Considering the lithologic variability, particularly the lateral and vertical change from sand to clay, the times to achieve the cleanup levels may vary by an order of magnitude. This approximate timeframe to achieve cleanup levels is considered reasonable for the anticipated future land use as a national wildlife refuge.

The LUC for the maintenance of the monitoring system will be maintained until the groundwater cleanup levels are achieved. The LUCs for soil and groundwater 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 2-10**) allow for 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 LUC for groundwater 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 reduce 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 4, will achieve the RAOs for LHAAP-29. For the protection of human health, the remedial action would remove soil that exceeds the cleanup levels; flush and remove residues from the process lines and properly dispose the rinsate; reduce groundwater COCs with ISTD in the intermediate zone followed by MNA; reduce shallow groundwater COCs with MNA, which would eventually achieve the destruction of the COCs present in the groundwater plumes at

LHAAP-29. Continued maintenance of the LUC for groundwater will prevent human access and exposure to groundwater that poses an unacceptable risk to human health, until COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in **Table 2-10**) in soils and groundwater, have sufficiently degraded to levels that allow for unlimited use and unrestricted exposure. At LHAAP-29 the evaluation of historical groundwater contaminant trends indicates that natural attenuation processes are occurring at the site. This remedy provides adequate confirmation that human health and the environment are protected because monitoring would be conducted to document the effectiveness of MNA. The monitoring activities associated with MNA will ensure that COCs and by-product (daughter) contaminants in groundwater do not flow to surface water bodies at such levels that ARARs are exceeded. There are currently no surface water impacts identified. The LUCs for soil and groundwater 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 2-10**) in soil and groundwater allow for unlimited use and unrestricted exposure.

For the protection of ecological receptors, the remedial action would remove soil at select areas (in addition to those areas excavated for the protection of human health) to address ecological risks. The outcome of the removal is that the soil in the Industrial Sub-Area, which includes LHAAP-29, will satisfy the EcoPRGs.

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 2-14**.

Chemical-Specific ARARs

- **Soil**: There are no federally promulgated chemical-specific ARARs for soil. The State of Texas promulgated cleanup standards under 30 TAC 335, Subchapter S, specifically 30 TAC 335.559 (g)(2) which specifies contaminant concentration limits for nonresidential soil and are used as the chemical-specific ARARs for the site soils. The concentrations represent the non-residential soil-to-groundwater cross-media protection concentrations that must be met to demonstrate that a contaminant in soil does not pose the potential for a future release of leachate in excess of the groundwater concentration considered to be protective for nonresidential worker exposure. It is anticipated that removal of contaminated soils above the Texas standards will prevent further contamination of the groundwater from soil at the site.
- **TNT Wastewater Line and Cooling Water Lines**: The removal of explosive-contaminated solid or liquid residue remaining in the line by flushing and disposing of the rinsate based on TCLP criteria or equivalent TCEQ criteria will prevent any further contamination of the groundwater from any explosive-contaminated residue remaining in the lines, in accordance with 40 C.F.R. § 261.2 and 30 TAC 335.559(g)(2).
- **Surface water**: Section 121(d)(2) of CERCLA states that every remedial action shall require a level of control which at least attains surface water quality criteria established under Sections 304 or 303 of the Clean Water Act of 1972 (CWA) where such goals and criteria are relevant and appropriate under the circumstances of the release or threatened release. Therefore, surface water quality criteria may be ARARs if there is a remedial action that

affects surface water, and measures will be implemented during construction to prevent off-site migration of contaminants to surface waters. In the event of remedy failure resulting in or potentially resulting in a release to surface water, 40 C.F.R. §§ 122, 125, 129, and 130-131, 40 C.F.R. §§ 141.61 and 141.62, and 30 TAC 307.4, 307.6, 307.7, 307.8 and 307.9 are considered potential future ARARs.

- **Groundwater**: Cleanup levels are presented in **Table 2-10**. The cleanup goal for groundwater will be the SDWA MCLs as specified in 40 C.F.R. §§ 141.61 and 141.62, which meet health-based standards and criteria. In the absence of federal drinking water standards, clean-up levels will be based on TRRP Residential Groundwater PCLs.

  This alternative will return the contaminated shallow and intermediate groundwater zones at LHAAP-29 to their potential beneficial use as drinking water, wherever practicable, which for the purposes of this ROD is considered to be attainment of the relevant and appropriate SDWA MCLs, and consistent with 40 C. F. R. § 300.430(e)(2)(i)(B&C). If a return to potential beneficial uses is not practicable, this alternative would still meet the NCP expectation to prevent further migration of the plume, prevent exposure to the contaminated groundwater, and evaluate further risk reduction.

Location-Specific ARARs

There are no 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 generation, characterization, management, storage, and disposal activities; well construction and abandonment; and water treatment.

- **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. Control of fugitive emissions and storm water runoff during implementation of these activities will be required. Airborne particulate matter resulting from construction or excavation activities is subject to the fugitive dust and opacity limits listed in 30 TAC 111, Subchapter A. No person may cause, suffer, allow, or permit visible emissions from any source to exceed an opacity of 30 percent for any 6-minute period (30 TAC 111.111[a]). Reasonable precautions must also be taken to achieve maximum control of dust to the extent practicable, including the application of water or suitable chemicals or the complete covering of materials (30 TAC 111.143 and 30 TAC 111.145). Texas has also promulgated general nuisance rules for air contaminants mandating that no person shall discharge from any source whatsoever one or more air contaminants, or combinations thereof, in such concentration and of such duration 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 (30 TAC 101.4). 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 C.F.R. § 122. 26), 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 ensure that discharges meet required parameters.

- **Waste and Disposal Activities:** 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 solid waste (defined as any solid, liquid, semisolid, or contained gaseous material intended for discard [40 C.F.R. § 261.2]) generated during remedial activities must be appropriately characterized to determine whether it contains RCRA hazardous waste (40 C.F.R. § 262.11; 30 TAC 335.62; 30 TAC 335.503[a][4]; 30 TAC 335.504). All wastes must be managed, stored, treated (if necessary), and disposed in accordance with the ARARs for waste management listed in **Table 2-14** 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 and H. Specific provisions 30 TAC §331.9(a); 30 TAC §331.10(a); 30 TAC §331.10(d); 30 TAC §331.21; 30 TAC §331.132(a); 30 TAC §331.132(c); 30 TAC §331.132(d)(1); 30 TAC §331.132(d)(4); 30 TAC §331.133(e) apply. 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-29 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.
- **Water treatment:** Contaminated groundwater and wastewaters collected during well drilling or decontamination activities could be transported to the groundwater treatment plant at LHAAP-18/24 for processing, and would subsequently be discharged in compliance with the effluent limits for that plant. Such waters would be characterized, as required, before transport and managed accordingly in compliance with requirements for the type of waste contaminating the water. To assure compliance with the groundwater treatment plant's discharge limits, the incoming water must meet the waste acceptance criteria for the facility. On-site wastewater treatment units (as defined in 40 C.F.R. § 260.10) that are part of a wastewater treatment facility that is subject to regulation under Section 402 or Section 307(b) of the Clean Water Act of 1972 are not subject to RCRA Subtitle C hazardous waste management standards (40 C.F.R. § 270.1(c)(2)(v) and 40 C.F.R. § 264.1(g)(6).; 30 TAC 335.42[d][1]). The USEPA has clarified that this exemption applies to all tanks, conveyance

systems, and ancillary equipment, including piping and transfer trucks, associated with the wastewater treatment unit (Federal Register Title 53, 34079, September 2, 1988).

2.13.3 Cost-Effectiveness

Table 2-12 and **Table 2-13** present the present worth analysis of the cost estimates for the selected remedy. The information in the tables is based on the best available information regarding the anticipated scope of the remedial alternative. The quantities used in the estimates 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. The least expensive alternative to the most expensive alternative (provided no contingencies are implemented) is as

follows: Alternative 1, Alternative 3, Alternative 4a, Alternative 4b, and Alternative 2. No costs are associated with Alternative 1 because no remedial activities would be conducted. Alternative 3 has the lowest present worth and capital costs of the remediation alternatives (Alternatives 2, 3, 4a, and 4b). The present worth cost for Alternative 3 is lower than that of Alternative 2, as it does not involve chemical treatment or construction costs for a groundwater extraction system. However, costs for operation and maintenance are higher for Alternative 3 than that of Alternative 2. Alternative 3 also estimates assume a 3-year duration for extraction; however, the presence of inferred DNAPL and sorbed MC is expected to require extraction for a longer period of time.

Additionally, although Alternative 3 appears to have lower costs than Alternatives 4a or 4b, this ignores that Alternative 3 will take longer to meet the RAOs in the intermediate zone due to the presence of DNAPL and would instead rely on the MNA component and LUCs to protect human health and the environment. Similarly, Alternative 2 is estimated to have the highest cost and has higher uncertainty of ISCO performance in full-scale application compared to bench-scale testing. Since the DNAPL in the intermediate zone may persist longer, MNA and LUCs may need to remain in place longer as well under Alternatives 2 and 3 than under Alternative 4. A comparison between the sub-alternatives 4a (ERH) and 4b (TCH) for treatment of the MC plume in intermediate zone indicates that sub-alternative 4a may have a lower cost; however, the TCH conceptual design under Alternative 4b appears to be more robust.

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 remedy represents the maximum extent to which permanent solutions and treatment technologies can be utilized in a practicable manner at the site. Soil excavation would remove impacted soils and groundwater extraction and in-situ treatment would irreversibly reduce groundwater contaminant concentrations in the treated portions of the groundwater plume. Removal of contaminated pipeline solid residue would protect the groundwater from contaminant leaching, and MNA will reduce groundwater contaminants to cleanup levels.

The selected remedy would provide reduction in toxicity, mobility, and volume of the groundwater contaminants via active treatment of the most contaminated areas. The selected remedy would document effectiveness through the confirmation of MNA and the routine monitoring of the attenuation and migration of the contaminants in groundwater.

The selected remedy would provide immediate protection because the LUCs would be implemented 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 2-10**) and by-product (daughter) contaminant concentrations in soil and groundwater that allow for unlimited use and unrestricted exposure.

2.13.5 Preference for Treatment as a Principal Element

The selected remedy would reduce the toxicity, mobility, or volume of contaminants in the groundwater through an active remedial process. By utilizing ISTD as a significant portion of the remedy, the statutory preference for remedies that employ treatment as a principal element is satisfied. In addition, there is a potential principal source threat at LHAAP-29 residing as residual source material in the subsurface. As a component of this groundwater, the hazardous contaminant MC is characterized as a highly toxic source material and, thus, potentially a principal threat waste.

2.13.6 Five-Year Review Requirements

Section 121(c) of CERCLA and NCP 40 C.F.R. § 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 on site above levels that allow unlimited use and unrestricted exposure, a review will be conducted at least every five years to confirm that the remedy continues to provide adequate protection of human health and the environment.

2.14 Significant Changes from the Proposed Plan

The Revised Proposed Plan was issued for public comments on November 21, 2018 and identified Alternative 4 as the Preferred Alternative, with either Alternative 4a or 4b to be selected during the RD. The U.S. Army reviewed all verbal comments that were discussed during the public meeting (there were no written 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: Current
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	Chemical	Concentration Detected[1] (mg/L)		Frequency of Detection	Exposure Point Concentration (mg/L)	Statistical Measure
		Minimum	Maximum			
Ingestion, inhalation, dermal contact	***Dioxin/Furan***					
	2,3,7,8-TCDD TEC	2.82E-09	1.25E-08	---	1.25E-08	maximum
	Explosives					
	2,4-Dinitrotoluene	0.0087	0.530	6/50	5.30E-01	maximum
	2,6-Dinitrotoluene	0.0087	0.530	7/50	5.30E-01	maximum
	2-Amino-4,6-dinitrotoluene	0.0059	0.0059	1/50	5.90E-03	maximum
	2-Nitrotoluene	0.002	4.40	9/50	4.40E+00	maximum
	3-Nitrotoluene	0.0021	0.240	7/50	2.40E-01	maximum
	4-Amino-2,6-dinitrotoluene	0.0059	0.0059	1/50	5.90E-03	maximum
	4-Nitrotoluene	0.0054	2.100	8/50	2.10E+00	maximum
	Metals					
	Aluminum	0.21	130	30/43	1.30E+02	maximum
	Antimony	0.005	0.052	40/68	5.20E-02	maximum
	Arsenic	0.008	0.059	7/68	5.90E-02	maximum
	Barium	0.024	6.5	37/68	6.50E+00	maximum
	Beryllium	0.0005	0.0099	6/43	9.90E-03	maximum
	Cadmium	0.0012	0.00623	2/68	6.23E-03	maximum
	Chromium	0.01	7.6	45/68	7.60E+00	maximum
	Lead	0.00241	0.35	26/68	3.50E-01	maximum
	Manganese	0.022	2.41	42/43	2.41E+00	maximum
	Mercury	0.002	0.003	2/68	3.00E-03	maximum
	Nickel	0.04	8.4	29/68	8.40E+00	maximum
	Selenium	0.006	0.35	6/68	3.50E-01	maximum
	Silver	0.01	0.08	5/68	8.00E-02	maximum
	Strontium	0.2	19	43/43	1.90E+01	maximum
	Thallium	0.0011	0.003	14/68	3.00E-03	maximum
	Vanadium	0.12	0.36	2/43	3.60E-01	maximum
	Non-Metallic Anion					
	Perchlorate	8.00E-03	8.80E+01	13/30	8.80E+01	maximum
	Volatile Organics					
	1,2-Dichloroethane	14	14	1/68	1.40E+01	maximum
	Acetone	0.0058	0.0058	1/68	5.80E-03	maximum
	Bromodichloromethane	0.001	0.0022	3/68	2.20E-03	maximum
	Chloroform	0.0012	0.014	7/68	1.40E-02	maximum
	cis-1,2-Dichloroethene	0.0013	0.0013	1/50	1.30E-03	maximum
	Methylene chloride	0.001	6,600	12/68	6.60E+03	maximum
	p-Cymene	0.0029	0.0029	1/43	2.90E-03	maximum
	Trichloroethene	0.0011	1.200	3/68	1.20E+00	maximum

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

Scenario Timeframe: Current
Medium: Soil
Exposure Medium: Soil (0 to 2 feet below ground surface)

Exposure Point	Chemical	Concentration Detected[1] (mg/kg)		Frequency of Detection	Exposure Point Concentration (mg/kg)	Statistical Measure
		Minimum	Maximum			
Ingestion, inhalation, dermal contact	***Dioxin/Furan***					
	2,3,7,8-TCDD TEC	2.63E-07	7.71E-06	---	4.20E-06	95% UCL
	Explosives					
	2,4,6-Trinitrotoluene	3.8	190	5/49	1.90E+02	maximum
	2,4-Dinitrotoluene	0.760	6.2	2/49	6.20E+00	maximum
	2-Amino-4,6-dinitrotoluene	2.6	25	4/49	2.5E+01	maximum
	4-Amino-2,6-dinitrotoluene	1.1	16	3/18	1.60E+01	maximum
	Metals					
	Antimony	1.2	2.5	15/65	1.92E+00	95% UCL
	Mercury	0.12	0.22	3/75	2.20E-01	maximum
	Non-Metallic Anion					
	Perchlorate	2.45E-02	7.03E-02	5/6	7.03E-02	maximum

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

For groundwater, the maximum detected concentrations were used to estimate the exposure point concentration.
For soil, the 95% UCL values were used to estimate the exposure point concentration if the concentration exceeded the average and was below the maximum detected; otherwise, the maximum detected concentration was used to estimate the exposure point concentration.

---: No information available
95% UCL: 95% upper confidence level of the mean
mg/kg: milligrams per kilogram
mg/L: milligrams per liter
TCDD: tetrachlorodibenzo-p-dioxin
TEC: toxicity equivalence concentration

References:
Jacobs Engineering Group, Inc. (Jacobs), 2002, *Baseline Human Health and Screening Ecological Risk Assessment for the Group 2 Sites (Sites 12, 17, 18/24, 29, 32, 49, Harrison Bayou, and Caddo Lake), Longhorn Army Ammunition Plant, Karnack, Texas*, Final, Oak Ridge, TN, August.

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, as well as 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, 2002).

Table 2-2. Carcinogenic Toxicity Data Summary

Pathway: Ingestion, Dermal Contact

Chemical of Concern	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Dermal Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight of Evidence/ Carcinogen Guideline Description	Source/ Date
Dioxin/Furans				
2,3,7,8-TCDD TEC	1.50E+05	3.00E+05	Not Classified	---
Explosives				
2,4,6-Trinitrotoluene	3.00E-02	5.00E-02	C	TCEQ, 2001
2,4-Dinitrotoluene	6.80E-01	8.00E-01	B2	TCEQ, 2001
2,6-Dinitrotoluene	6.80E-01	8.00E-01	B2	TCEQ, 2001
2-Amino-4,6-dinitrotoluene	1.00E-02	2.00E-02	Not Classified	---
2-Nitrotoluene	NTV	NTV	Not Classified	---
3-Nitrotoluene	NTV	NTV	Not Classified	---
4-Amino-2,6-dinitrotoluene	1.00E-02	2.00E-02	Not Classified	---
4-Nitrotoluene	NTV	NTV	Not Classified	---
Metals				
Aluminum	NTV	NTV	Not Classified	---
Antimony	NTV	NTV	Not Classified	---
Arsenic	1.50E+00	1.58E+00	A	TCEQ, 2001
Barium	NC	NC	D	TCEQ, 2001
Beryllium	NTV	NTV	B1	TCEQ, 2001
Cadmium (water)	NTV	NTV	B1	TCEQ, 2001
Chromium (total)	NC	NC	Not Classified	---
Lead	NTV	NTV	Not Classified	---
Manganese (non-diet)	NC	NC	D	TCEQ, 2001
Mercury	NC	NC	D	TCEQ, 2001
Nickel	NTV	NTV	A	TCEQ, 2001
Selenium	NC	NC	D	TCEQ, 2001
Silver	NC	NC	D	TCEQ, 2001
Strontium	NTV	NTV	Not Classified	---
Thallium	NC	NC	Not Classified	---
Vanadium	NTV	NTV	Not Classified	---
Non-Metallic Anions				
Perchlorate	NTV	NTV	Not Classified	---
Volatile Organics				
1,2-Dichloroethane	9.10E-02	9.10E-02	B2	TCEQ, 2001
Acetone	NC	NC	D	TCEQ, 2001
Bromodichloromethane	6.20E-02	6.33E-02	B2	TCEQ, 2001
Chloroform	6.10E-03	3.05E-02	B2	TCEQ, 2001
cis-1,2-Dichloroethene	NC	NC	D	TCEQ, 2001
Methylene chloride	7.50E-03	7.89E-03	B2	TCEQ, 2001
p-Cymene	NTV	NTV	Not Classified	---
Trichloroethene	1.10E-02	1.10E-02	B2	TCEQ, 2001

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

Pathway: Inhalation

Chemical of Concern	Unit Risk Factor $(mg/m^3)^{-1}$	Weight of Evidence/ Carcinogen Guideline Description	Source/Date
Dioxin/Furans			
2,3,7,8-TCDD TEC	3.30E+04	Not Classified	---
Explosives			
2,4,6-Trinitrotoluene	NTV	C	TCEQ, 2001
2,4-Dinitrotoluene	NTV	B2	TCEQ, 2001
2,6-Dinitrotoluene	NTV	B2	TCEQ, 2001
2-Amino-4,6-dinitrotoluene	NTV	Not Classified	---
2-Nitrotoluene	NTV	Not Classified	---
3-Nitrotoluene	NTV	Not Classified	---
4-Amino-2,6-dinitrotoluene	NTV	Not Classified	---
4-Nitrotoluene	NTV	Not Classified	---
Metals			
Aluminum	NTV	Not Classified	---
Antimony	NTV	Not Classified	---
Arsenic	4.30E+00	A	TCEQ, 2001
Barium	NC	D	TCEQ, 2001
Beryllium	2.40E+00	B1	TCEQ, 2001
Cadmium (water)	1.80E+00	B1	TCEQ, 2001
Chromium (total)	NC	Not Classified	---
Lead	NTV	Not Classified	---
Manganese (Non-diet)	NC	D	TCEQ, 2001
Mercury	NC	D	TCEQ, 2001
Nickel	4.80E-01	A	TCEQ, 2001
Selenium	NC	D	TCEQ, 2001
Silver	NC	D	TCEQ, 2001
Strontium	NTV	Not Classified	---
Thallium	NC	Not Classified	---
Vanadium	NTV	Not Classified	---
Non-Metallic Anions			
Perchlorate	NTV	Not Classified	---
Volatile Organics			
1,2-Dichloroethane	2.60E-02	B2	TCEQ, 2001
Acetone	NC	D	TCEQ, 2001
Bromodichloromethane	NTV	B2	TCEQ, 2001
Chloroform	2.30E-02	B2	TCEQ, 2001
cis-1,2-Dichloroethene	NC	D	TCEQ, 2001
Methylene chloride	4.70E-04	B2	TCEQ, 2001
p-Cymene	NTV	Not Classified	---

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

Pathway: Inhalation

Chemical of Concern	Unit Risk Factor $(mg/m^3)^{-1}$	Weight of Evidence/ Carcinogen Guideline Description	Source/Date
Volatile Organics (continued)			
Trichloroethene	1.70E-03	B2	TCEQ, 2001

Notes:
--- : No information available
mg/kg-day: milligrams per kilogram per day
mg/m^3: milligrams per cubic meter
NC: Chemical not classified as a carcinogen
NTV: no toxicity value available
TCDD: tetrachlorodibenzo-p-dioxin
TEC: toxicity equivalence concentration

Weight of Evidence/Carcinogen Guideline Description:
A - Human carcinogen
B1 - Probable human carcinogen – Indicates that limited human data are available
B2 - Probable human carcinogen – Indicates sufficient evidence in animals and inadequate or no evidence in humans
C - Possible human carcinogen
D - Not classifiable as a human carcinogen

References:
Jacobs Engineering Group, Inc. (Jacobs), 2002, *Baseline Human Health and Screening Ecological Risk Assessment for the Group 2 Sites (Sites 12, 17, 18/24, 29, 32, 49, Harrison Bayou, and Caddo Lake)*, Longhorn Army Ammunition Plant, Karnack, Texas, Final, Oak Ridge, TN, August.

Texas Commission on Environmental Quality (TCEQ), 2001, Update to 1998 Consistency Memorandum. Toxicity Factors Table, 15 March 2001. Medium specific concentrations have been recalculated using updated toxicity values through March 2010.

Summary of Toxicity Assessment:
The table provides carcinogenic risk information which is relevant to the contaminants of potential concern in soil and ground water. 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, 2002).

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)	Target Endpoint	Combined Uncertainty/ Modifying Factors	Source/Date
Dioxin/Furans						
2,3,7,8-TCDD TEC	chronic	NTV	NTV	NA	NA	---
Explosives						
2,4,6-Trinitrotoluene	chronic	5.00E-04	3.00E-04	Liver effects	1000/1	USEPA-IRIS, 2001
2,4-Dinitrotoluene	chronic	2.00E-03	1.70E-03	Central nervous system effects	100/1	USEPA-IRIS, 2001
2,6-Dinitrotoluene	chronic	1.00E-03	8.50E-04	Central nervous system effects	3000/1	USEPA-HEAST, 1997
2-Amino-4,6-dinitrotoluene	chronic	1.67E-04	8.33E-05	NA	NA	---
2-Nitrotoluene	chronic	1.00E-02	5.00E-03	Spleen lesions	10000/1	USEPA-HEAST, 1997
3-Nitrotoluene	chronic	1.00E-02	5.00E-03	Spleen lesions	10000/1	USEPA-HEAST, 1997
4-Amino-2,6-dinitrotoluene	chronic	1.67E-04	8.33E-05	NA	NA	---
4-Nitrotoluene	chronic	1.00E-02	5.00E-03	Spleen lesions	10000/1	USEPA-HEAST, 1997
Metals						
Aluminum	chronic	1.00E+00	1.00E-01	NA	NA	---
Antimony	chronic	4.00E-04	6.00E-05	Longevity, blood glucose, and cholesterol	1000/1	USEPA-IRIS, 2001
Arsenic	chronic	3.00E-04	2.85E-04	Skin effects	3/1	USEPA-IRIS, 2001
Barium	chronic	7.00E-02	4.90E-03	Increased kidney weight	3/1	USEPA-IRIS, 2001
Beryllium	chronic	2.00E-03	1.40E-05	Small Intestine	300/1	USEPA-IRIS, 2001
Cadmium (water)	chronic	5.00E-04	1.25E-05	Proteinuria	10/1	USEPA-IRIS, 2001
Chromium (total)	chronic	1.50E+00	1.95E-02	No effects observed	100/10	USEPA-IRIS, 2001
Lead	chronic	NTV	NTV	NA	NA	---
Manganese (non-diet)	chronic	4.70E-02	2.82E-03	Central nervous system effects	1/1	USEPA-IRIS, 2001
Mercury	chronic	3.00E-04	2.10E-05	Autoimmune effects	1000/1	USEPA-IRIS, 2001
Nickel	chronic	2.00E-02	8.00E-04	Decreased Body Weight	300/1	USEPA-IRIS, 2001
Selenium	chronic	5.00E-03	2.50E-03	Skin	3/1	USEPA-IRIS, 2001
Silver	chronic	5.00E-03	2.00E-04	Argyria	3/1	USEPA-IRIS, 2001
Strontium	chronic	6.00E-01	1.20E-01	Rachitic bone	300/1	USEPA-IRIS, 2001
Thallium	chronic	8.00E-05	8.00E-05	Blood	3000/1	USEPA-IRIS, 2001
Vanadium	chronic	7.00E-03	1.82E-04	NA	NA	---

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

Pathway: Ingestion, Dermal Contact

Chemical of Concern	Chronic/ Subchronic	Oral RfD Value (mg/kg-day)	Dermal RfD (mg/kg-day)	Target Endpoint	Combined Uncertainty/ Modifying Factors	Source/Date
Non-Metallic Anions						
Perchlorate	chronic	9.00E-04	9.00E-04	NA	NA	---
Volatile Organics						
1,2-Dichloroethane	chronic	3.00E-02	3.00E-02	NA	NA	---
Acetone	chronic	1.00E-01	8.30E-02	Liver and kidney effects	1000/1	USEPA-IRIS, 2001
Bromodichloromethane	chronic	2.00E-02	1.96E-02	Renal cytomegaly	1000/1	USEPA-IRIS, 2001
Chloroform	chronic	1.00E-02	2.00E-03	Cyst formation in the liver	1000/1	USEPA-IRIS, 2001
cis-1,2-Dichloroethene	chronic	1.00E-02	1.00E-02	Decreased hematocrit and hemoglobin in the blood	3000/1	USEPA-IRIS, 2001
Methylene chloride	chronic	6.00E-02	5.70E-02	Liver toxicity	100/1	USEPA-IRIS, 2001
p-Cymene	chronic	1.00E-01	8.00E-02	NA	NA	---
Trichloroethene	chronic	6.00E-03	6.00E-03	NA	NA	---

Pathway: Inhalation

Chemical of Concern	Chronic/ Subchronic	Inhalation RfC (mg/m^3)	Target Endpoint	Combined Uncertainty/ Modifying Factors	Source/ Date
Dioxin/Furans					
2,3,7,8-TCDD TEC	chronic	NTV	---	---	---
Explosives					
2,4,6-Trinitrotoluene	chronic	0.0001	NA	NA	---
2,4-Dinitrotoluene	chronic	0.00015	NA	NA	---
2,6-Dinitrotoluene	chronic	0.00015	NA	NA	---
2-Amino-4,6-dinitrotoluene	chronic	0.0001	NA	NA	---
2-Nitrotoluene	chronic	0.011	NA	NA	---
3-Nitrotoluene	chronic	0.011	NA	NA	---
4-Amino-2,6-dinitrotoluene	chronic	0.0001	NA	NA	---
4-Nitrotoluene	chronic	0.011	NA	NA	---
Metals					
Aluminum	chronic	0.0035	NA	NA	---
Antimony	chronic	0.0005	Pulmonary toxicity, chronic interstitial inflammation	300/1	USEPA-IRIS, 2001
Arsenic	chronic	NTV	---	---	---
Barium	chronic	0.00049	Fetus, developmental effects	1000/1	USEPA-HEAST, 1997

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

Pathway: Inhalation

Chemical of Concern	Chronic/ Subchronic	Inhalation RfC (mg/m³)	Target Endpoint	Combined Uncertainty/ Modifying Factors	Source/ Date
Metals (continued)					
Beryllium	chronic	0.00002	Beryllium sensitization and progression to Chronic Beryllium Disease	10/1	USEPA-IRIS, 2001
Cadmium (water)	chronic	0.0002	NA	NA	---
Chromium (total)	chronic	0.0001	NA	NA	---
Lead	chronic	NTV	---	---	---
Manganese (non-diet)	chronic	0.00005	Impairment of neurobehavioral function	1000/1	USEPA-IRIS, 2001
Mercury	chronic	0.0003	Hand tremor, memory loss	30/1	USEPA-IRIS, 2001
Nickel	chronic	0.0002	Respiratory effects	NA	ATSDR, 1997
Selenium	chronic	0.0002	NA	NA	---
Silver	chronic	0.00001	NA	NA	---
Strontium	chronic	NTV	---	---	---
Thallium	chronic	0.0001	NA	NA	---
Vanadium	chronic	0.00005	NA	NA	---
Non-Metallic Anions					
Perchlorate	chronic	NTV	---	---	---
Volatile Organics					
1,2-Dichloroethane	chronic	0.005	NA	NA	---
Acetone	chronic	0.59	NA	NA	---
Bromodichloromethane	chronic	NTV	---	---	---
Chloroform	chronic	0.000301	NA	NA	---
cis-1,2-Dichloroethene	chronic	0.793	NA	NA	---
Methylene chloride	chronic	3	Liver toxicity	100/1	USEPA-HEAST, 1997
p-Cymene	chronic	0.3	NA	NA	---
Trichloroethene	chronic	NTV	---	---	---

Notes:
---: No information for a compound with no toxicity value (NTV)
IRIS: Integrated Risk Information System, USEPA
mg/kg-day: milligrams per kilogram per day
mg/m³: milligrams per cubic meter
NA: Information not available
NTV: No toxicity value available
RfC: Reference concentration
RfD: Reference dose
TCDD: tetrachlorodibenzo-p-dioxin
TEC: toxicity equivalence concentration

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

Jacobs Engineering Group, Inc. (Jacobs), 2002, *Baseline Human Health and Screening Ecological Risk Assessment for the Group 2 Sites (Sites 12, 17, 18/24, 29, 32, 49, Harrison Bayou, and Caddo Lake)*, Longhorn Army Ammunition Plant, Karnack, Texas, Final, Oak Ridge, TN, August.

USEPA-HEAST, 1997. Health Effects Summary Table (HEAST). FY 1995, Annual Office of Emergency and Remedial Response. Washington, D.C. EPA/340/R-95-036.

USEPA-IRIS, 2001. Integrated Risk Information System (IRIS). United States Environmental Protection Agency Online Database for Toxicity Information on Hazardous Chemicals, 2001.

Summary of Toxicity Assessment:
This table provides non-carcinogenic risk information relevant to the contaminants of concern in both soil and ground water. 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, 2002). The uncertainty factor and modifying factor are used in the development of a references dose. The uncertainty factor adjusts results from dose-response studies in animals to make them applicable to humans. The modifying factor is used to account for uncertainties in the available toxicity data from which the reference dose is derived. In the risk assessment, the reference doses and concentrations were for the chronic case, to be conservative.

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	Carcinogenic Risk			
				Ingestion	Inhalation	Dermal	Exposure Routes Total
Ground-water	Ground-water	Ingestion or exposure through showering	***Dioxin/Furan***				
			2,3,7,8-TCDD TEC	6.5E-06	NE	5.4E-05	6.1E-05
			Explosive				
			2,4,6-Trinitrotoluene	ND	ND	ND	NA
			2,4-Dinitrotoluene	1.3E-03	NE	NE (Kp<=0.01)	1.3E-03
			2,6-Dinitrotoluene	1.3E-03	NE	NE (Kp<=0.01)	1.3E-03
			2-Amino-4,6-dinitrotoluene	2.1E-07	NE	NE (Kp<=0.01)	2.1E-07
			2-Nitrotoluene	NTV	NTV	NTV	NA
			3-Nitrotoluene	NTV	NTV	NTV	NA
			4-Amino-2,6-dinitrotoluene	2.1E-07	NE	NE (Kp<=0.01)	2.1E-07
			4-Nitrotoluene	NTV	NTV	NTV	NA
			Metals				
			Aluminum	NTV	NE	NE (Kp<=0.01)	NA
			Antimony	NTV	NE	NE (Kp<=0.01)	NA
			Arsenic	3.1E-04	NE	NE (Kp<=0.01)	3.1E-04
			Barium	NC	NE	NE (Kp<=0.01)	NA
			Beryllium	NTV	NE	NE (Kp<=0.01)	NA
			Cadmium (water)	NTV	NE	NE (Kp<=0.01)	NA
			Chromium (total)	NC	NE	NE (Kp<=0.01)	NA
			Lead	NTV	NE	NE (Kp<=0.01)	NA
			Manganese	NC	NE	NE (Kp<=0.01)	NA
			Mercury	NC	NE	NE (Kp<=0.01)	NA
			Nickel	NTV	NE	NE (Kp<=0.01)	NA
			Selenium	NC	NE	NE (Kp<=0.01)	NA
			Silver	NC	NE	NE (Kp<=0.01)	NA
			Strontium	NTV	NE	NE (Kp<=0.01)	NA
			Thallium	NC	NE	NE (Kp<=0.01)	NA
			Vanadium	NTV	NE	NE (Kp<=0.01)	NA
			Non-Metallic Anion				
			Perchlorate	NTV	NE	NE (Kp<=0.01)	NA
			Volatile Organics				
			1,2-Dichloroethane	4.5E-03	2.2E-02	2.0E-03	2.9E-02
			Acetone	NC	NC	NE (Kp<=0.01)	NA
			Bromodichloro-methane	4.8E-07	NTV	2.5E-07	7.2E-07
			Chloroform	3.0E-07	2.0E-05	1.2E-06	2.1E-05
			Cis-1,2-Dichloroethene	NC	NC	NE (Kp<=0.01)	NA
			Methylene chloride	1.7E-01	1.9E-01	NE (Kp<=0.01)	3.6E-01
			p-Cymene	NTV	NTV	NTV	NA
			Trichloroethene	4.6E-05	1.2E-04	6.2E-05	2.3E-04
						Groundwater risk total =	3.9E-01

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

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

Medium	Exposure Medium	Exposure Point	Chemical of Concern	Carcinogenic Risk			
				Ingestion	Inhalation	Dermal	Exposure Routes Total
Soil (0 to 2 feet)	Soil and particulates	Incidental Ingestion, inhalation of particulates, and dermal contact	***Dioxin/Furan***				
			2,3,7,8-TCDD TEC	2.2E-07	7.3E-12	8.4E-08	3.0E-07
			Explosive				
			2,4,6-Trinitrotoluene	2.0E-06	NTV	2.1E-06	4.1E-06
			2,4-Dinitrotoluene	1.5E-06	NTV	1.1E-06	2.6E-06
			2,6-Dinitrotoluene	ND	ND	ND	NA
			2-Amino-4,6-dinitrotoluene	8.7E-08	NTV	1.1E-07	2.0E-07
			2-Nitrotoluene	ND	ND	ND	NA
			3-Nitrotoluene	ND	ND	ND	NA
			4-Amino-2,6-dinitrotoluene	5.6E-08	NTV	7.2E-08	1.3E-07
			4-Nitrotoluene	ND	ND	ND	NA
			Metals				
			Aluminum	ND	ND	ND	NA
			Antimony	NTV	NTV	NTV	NA
			Arsenic	ND	ND	ND	NA
			Barium	ND	ND	ND	NA
			Beryllium	ND	ND	ND	NA
			Cadmium (water)	ND	ND	ND	NA
			Chromium (total)	ND	ND	ND	NA
			Lead	ND	ND	ND	NA
			Manganese (non-diet)	ND	ND	ND	NA
			Mercury	NC	NC	NC	NA
			Nickel	ND	ND	ND	NA
			Selenium	ND	ND	ND	NA
			Silver	ND	ND	ND	NA
			Strontium	ND	ND	ND	NA
			Thallium	ND	ND	ND	NA
			Vanadium	ND	ND	ND	NA
			Non-Metallic Anion				
			Perchlorate	NTV	NTV	NTV	NA
			Volatile Organics				
			1,2-Dichloroethane	ND	ND	ND	NA
			Acetone	ND	ND	ND	NA
			Bromodichloro-methane	ND	ND	ND	NA
			Chloroform	ND	ND	ND	NA

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

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

Medium	Exposure Medium	Exposure Point	Chemical of Concern	Carcinogenic Risk			
				Ingestion	Inhalation	Dermal	Exposure Routes Total
			Cis-1,2-Dichloroethene	ND	ND	ND	NA
			Volatile Organics (continued)				
			Methylene chloride	ND	ND	ND	NA
			p-Cymene	ND	ND	ND	NA
			Trichloroethene	ND	ND	ND	NA
						Soil risk total =	7.3E-06
						Total risk (soil and groundwater) =	3.9E-01

Notes:

Kp	Dermal permeability coefficient
NA	Not applicable
NC	Not classified as a carcinogen
ND	Not detected in associated media or not selected as a chemical of potential concern
NE	Not evaluated through this exposure pathway. Chemical is not identified as volatile.
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)
NTV	No toxicity value available
TCDD	Tetrachlorodibenzo-p-dioxin
TEC	Toxicity equivalence concentration

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 VI Risk Assessment Guidance, May 5, 1995*.

Summary of Risk Characterization:

The table provides risk estimates for the significant routes of exposure at LHAAP-29. 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 soil and 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 3.9×10^{-01}. A risk below 1×10^{-4} is generally considered to be acceptable (USEPA, 1989). The total groundwater risk is unacceptable.

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	Target End-point	Non-Carcinogenic Hazard Quotient			
					Ingestion	Inhalation	Dermal	Exposure Routes Total
Ground-water	Ground-water	Ingestion or exposure through showering	***Dioxin/Furan***					
			2,3,7,8-TCDD TEC	NA	NTV	NE	NTV	NA
			Explosive					
			2,4,6-Trinitrotoluene	Liver effects	ND	ND	ND	NA
			2,4-Dinitrotoluene	NA	2.6E+00	NE	NE (Kp<=0.01)	2.6E+00
			2,6-Dinitrotoluene	NA	5.2E+00	NE	NE (Kp<=0.01)	5.2E+00
			2-Amino-4,6-dinitrotoluene	NA	3.5E-01	NE	NE (Kp<=0.01)	3.5E-01
			2-Nitrotoluene	Spleen lesions	4.3E+00	6.8E+01	4.1E-01	7.3E+01
			3-Nitrotoluene	Spleen lesions	2.3E-01	3.7E+00	2.2E-02	4.0E+00
			4-Amino-2,6-dinitrotoluene	NA	3.5E-01	NE	NE (Kp<=0.01)	3.5E-01
			4-Nitrotoluene	Spleen lesions	2.1E+00	3.3E+01	1.9E-01	3.5E+01
			Metals					
			Aluminum	NA	1.3E+00	NE	NE (Kp<=0.01)	1.3E+00
			Antimony	Longevity, blood glucose, and cholesterol	1.3E+00	NE	NE (Kp<=0.01)	1.3E+00
			Arsenic	Skin effects	1.9E+00	NE	NE (Kp<=0.01)	1.9E+00
			Barium	Fetus, developmental effects, increased kidney weight	9.1E-01	NE	NE (Kp<=0.01)	9.1E-01
			Beryllium	Beryllium sensitization and progression to Chronic Beryllium Disease	4.8E-02	NE	NE (Kp<=0.01)	4.8E-02
			Cadmium(water)	Proteinuria	1.2E-01	NE	NE (Kp<=0.01)	1.2E-01
			Chromium (total)	Proteinuria	5.0E-02	NE	NE (Kp<=0.01)	5.0E-02
			Lead	Gastrointestinal	NTV	NE	NE (Kp<=0.01)	NA

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

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

Medium	Exposure Medium	Exposure Point	Chemical of Concern	Target End-point	Non-Carcinogenic Hazard Quotient			
					Ingestion	Inhalation	Dermal	Exposure Routes Total
			Metals (continued)					
			Manganese (non-diet)	CNS	5.0E-01	NE	NE (Kp<=0.01)	5.0E-01
			Mercury	CNS	9.8E-02	NE	NE (Kp<=0.01)	9.8E-02
			Nickel	Respiratory effects, decreased body weight	4.1E+00	NE	NE (Kp<=0.01)	4.1E+00
			Selenium	NA	6.8E-01	NE	NE (Kp<=0.01)	6.8E-01
			Silver	Argyria	1.6E-01	NE	NE (Kp<=0.01)	1.6E-01
			Strontium	Rachitic bone	3.1E-01	NE	NE (Kp<=0.01)	3.1E-01
			Thallium	Blood	3.7E-01	NE	NE (Kp<=0.01)	3.7E-01
			Vanadium	NA	5.0E-01	NE	NE (Kp<=0.01)	5.0E-01
			Non-Metallic Anion					
			Perchlorate	---	9.6E+02	NE	NE (Kp<=0.01)	9.6E+02
			Volatile Organics					
			1,2-Dichloroethane	NA	4.6E+00	4.8E+02	2.1E+00	4.9E+02
			Acetone	NA	5.7E-04	1.7E-03	NE (Kp<=0.01)	2.3E-03
			Bromodichloro-methane	---	1.1E-03	NTV	5.6E-04	1.6E-03
			Chloroform	NA	1.4E-02	8.0E+00	5.4E-02	8.0E+00
			cis-1,2-Dichloroethene	NA	1.3E-03	2.8E-04	NE (Kp<=0.01)	1.6E-03
			Methylene chloride	Decreased hematocrit and hemoglobin in the blood	1.1E+03	3.8E+02	NE (Kp<=0.01)	1.5E+03
			p-Cymene	NA	2.8E-04	1.7E-03	2.7E-04	2.2E-03
			Trichloroethene	Liver and kidney effects	2.0E+00	NTV	2.6E+00	4.6E+00
			Groundwater Hazard Index Total =					3.0E+03

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

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

Medium	Exposure Medium	Exposure Point	Chemical of Concern	Target Endpoint	Non-Carcinogenic Hazard Quotient			
					Ingestion	Inhalation	Dermal	Exposure Routes Total
Soil (0 to 2 feet)	Soil and particulate s	Incidental ingestion, inhalation of particulates, dermal contact	***Dioxin/Furan***					
			2,3,7,8-TCDD TEC	NA	NTV	NTV	NTV	NA
			Explosive					
			2,4,6-Trinitrotoluene	Liver effects	3.7E-01	2.8E-04	4.0E-01	7.7E-01
			2,4-Dinitrotoluene	IA	3.0E-03	6.1E-06	2.3E-03	5.3E-03
			2,6-Dinitrotoluene	IA	ND	ND	ND	NA
			2-Amino-4,6-dinitrotoluene	NA	1.5E-01	3.7E-05	1.9E-01	3.3E-01
			2-Nitrotoluene	Spleen lesions	ND	ND	ND	NA
			3-Nitrotoluene	Spleen lesions	ND	ND	ND	NA
			4-Amino-2,6-dinitrotoluene	NA	9.4E-02	2.4E-05	1.2E-01	2.1E-01
			4-Nitrotoluene	Spleen lesions	ND	ND	ND	NA
			Metals					
			Aluminum	NA	ND	ND	ND	NA
			Antimony	ongevity, blooc lucose, and holesterol	4.7E-03	5.7E-07	2.0E-03	6.7E-03
			Arsenic	;kin effects	ND	ND	ND	NA
			Barium	etus, evelopmental ffects, ıcreased kidne veight	ND	ND	ND	NA
			Beryllium	eryllium ensitization an rogression to :hronic eryllium)isease	ND	ND	ND	NA
			Cadmium (water)	'roteinuria	ND	ND	ND	NA
			Chromium (total)	'roteinuria	ND	ND	ND	NA
			Lead	;astrointestinal	ND	ND	ND	NA
			Manganese (non-diet)	CNS	ND	ND	ND	NA
			Mercury	CNS	7.2E-04	1.1E-07	6.6E-04	1.4E-03
			Nickel	Respiratory effects, decreased body weight	ND	ND	ND	NA
			Selenium	NA	ND	ND	ND	NA

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

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

Medium	Exposure Medium	Exposure Point	Chemical of Concern	Target Endpoint	Non-Carcinogenic Hazard Quotient			
					Ingestion	Inhalation	Dermal	Exposure Routes Total
			Metals (continued					
			Silver	Argyria	ND	ND	ND	NA
			Strontium	Rachitic bone	ND	ND	ND	NA
			Thallium	Blood	ND	ND	ND	NA
			Vanadium	NA	ND	ND	ND	NA
			Non-Metallic Anion					
			Perchlorate	---	7.6E-05	NTV	4.9E-06	8.1E-05
			Volatile Organics					
			1,2-Dichloroethane	NA	ND	ND	ND	NA
			Acetone	NA	ND	ND	ND	NA
			Bromodichloromethane	---	ND	ND	ND	NA
			Chloroform	NA	ND	ND	ND	NA
			cis-1,2-Dichloroethene	NA	ND	ND	ND	NA
			Methylene chloride	Decreased hematocrit and hemoglobin in the blood	ND	ND	ND	NA
			p-Cymene	NA	ND	ND	ND	NA
			Trichloroethene	Liver and kidney effects	ND	ND	ND	NA
Soil Hazard Index Total =								1.3E+00
Hazard Index Total (soil and groundwater) =								3.0E+03

Notes:

CNS	central nervous system
Kp	Dermal permeability coefficient
NA	Not applicable
ND	Not detected in associated media or not selected as a chemical of potential concern
NE	Not evaluated through this exposure pathway. Chemical is not identified as a volatile.
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)
NTV	No toxicity value
TCDD	Tetrachlorodibenzo-p-dioxin
TEC	Toxicity equivalence concentration

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.

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-29. 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 for groundwater is 3.0E+03 and for soil is 1. Both values are unacceptable and indicate that the potential for adverse non-carcinogenic effects could occur from exposure to contaminants in those mediums.

Table 2-6. Chemicals Contributing to Carcinogenic Risk in Groundwater

Chemical	Baseline Risk Assessment			Data Since Risk Assessment			Comparison Levels		Retained as COC ?
	Cancer Risk Groundwater [a]	EPC (µg/L)	Well	Maximum (µg/L)	Well	Adjusted Risk	MCL (µg/L)	TRRP Tier 1 Residential Groundwater PCLs (µg/L)	
Methylene chloride	3.6×10^{-1}	6,600,000	29WW16	10,300,000	29WW16	5.6×10^{-1}	5	5	Yes, 1
1,2-Dichloroethane	2.9×10^{-2}	14,000	29WW15	<12,500	29WW16	--	5	5	Yes, 1
2,4-Dinitrotoluene	1.3×10^{-3}	530	29WW20	50.9 32.4	29WW05 29WW20	1.2×10^{-4}	--	1.3	Yes, 2
2,6-Dinitrotoluene	1.3×10^{-3}	530	29WW20	239 112	116 29WW20	5.9×10^{-4}	--	1.3	Yes, 2
Arsenic	3.1×10^{-4}	59	29WW25	141	29WW25	7.4×10^{-4}	10	10	Yes, 5
Trichloroethene	2.3×10^{-4}	1,200	29WW15	<12,500	29WW16	--	5	5	Yes, 1
2,3,7,8-TCDD	6.1×10^{-5}	1.25×10^{-5}	29WW03	NR	--	--	3.0×10^{-5}	--	No, 4
Chloroform	2.1×10^{-5}	14	29WW21	9.75 ND	29WW15 29WW21	1.5×10^{-5}	80 [b]	1,000	No, 4

Notes and Abbreviations:

1. Identified as COC because most recent maximum concentration is above the Safe Drinking Water Act (SDWA) MCL.
2. Identified as COC because carcinogenic risk is $>10^{-4}$.
3. Excluded because detections are isolated.
4. Excluded because EPC is below the SDWA MCL.
5. Identified as a COC subject to further verification.

[a] From Baseline Risk Assessment Table C-71 (Jacobs, 2002)
[b] SDWA MCL for total trihalomethanes was used for chloroform.

µg/L micrograms per liter
COC contaminant of concern
EPC exposure point concentration
MCL Safe Drinking Water Act maximum contaminant level
NR not resampled for this constituent since Baseline Risk Assessment

Table 2-7. Chemicals with Hazard Quotient Greater than 0.1 in Groundwater

Chemical	Baseline Risk Assessment			Data Since Risk Assessment			Comparison Levels		Retained as COC ?
	Hazard Quotient Groundwater [a]	EPC [a] (µg/L)	Well	Maximum (µg/L)	Well	Adjusted Hazard Quotient	MCL (µg/L)	TRRP Tier 1 Residential Groundwater PCLs (µg/L)	
Methylene chloride	1,500	6,600,000	29WW16	7,110,000	29WW16	1600	5		Yes, 1
Perchlorate	960	88,000	29WW15	16,800	29WW15	180		17	Yes, 2
1,2-Dichloroethane	490	14,000	29WW15	5,520	29WW15	190	5		Yes, 1
4-Nitrotoluene (p-)	35	2,100	29WW20	1,400 374	116 29WW20	23		57	Yes, 2
Chloroform	8.0	14	29WW21	9.75 ND	29WW15 29WW21	5.6	80 [b]		No, 3
2-Nitrotoluene (o-)	7.3	4,400	116	8,140	116	14		4.1	Yes, 2
2,6-Dinitrotoluene	5.2	530	29WW20	239 112	116 29WW20	2.3		1.3	Yes, 2
Trichloroethene	4.6	1,200	29WW15	344	29WW15	1.3	5		Yes, 1
Nickel	4.1	8,400	29WW11	3,190 40	29WW07 29WW11	1.6 <0.1		490	Yes, 9
3-Nitrotoluene (m-)	4.0	240	29WW05	451 123	116 29WW05	7.5		240	Yes, 2
2,4-Dinitrotoluene	2.6	530	29WW20	50.9 32.4	29WW05 29WW20	0.33		1.3	Yes, 5
Arsenic	1.9	59	29WW25	141	29WW25	4.5	10		Yes, 9
Aluminum	1.3	130,000	115	713	29WW08 [c]	<0.1		24,000	No, 6
Antimony	1.3	52	29WW09	1.45	29WW08	<0.1	6		No, 7
Barium	0.91	6,500	116	1,100 48.5 J	115 116	0.15 <0.1	2,000		No, 6
Selenium	0.68	350	118	75.3	118	0.15	50		Yes, 9
Manganese	0.50	2,410	115	1,310	114 [c]	0.27		1,100	No, 4
Vanadium	0.50	360	115	7.5 J	29WW04 [c]	<0.1		44	No, 8
Thallium	0.37	3.0	29WW03	0.339 J	29WW25 [c]	<0.1	2		No, 7

Table 2-7. Chemicals with Hazard Quotient Greater than 0.1 in Groundwater

Chemical	Baseline Risk Assessment			Data Since Risk Assessment			Comparison Levels		Retained as COC ?
	Hazard Quotient Groundwater [a]	EPC [a] (µg/L)	Well	Maximum (µg/L)	Well	Adjusted Hazard Quotient	MCL (µg/L)	TRRP Tier 1 Residential Groundwater PCLs (µg/L)	
2-Amino-4,6-dinitrotoluene	0.35	5.9	29WW05	ND	29WW05	-		4.1	No, 8
4-Amino-2,6-dinitrotoluene	0.35	5.9	29WW05	16.3	29WW05	0.97		4.1	Yes, 1
Strontium	0.31	19,000	119	NR	-	-		15,000	Yes, 1
Silver	0.16	80	29WW09	ND	All wells resampled [c]	-		120	No, 8
Cadmium	0.12	6.23	119	1.2 1.12	115 116	< 0.1 < 0.1	5		No.6

Notes and Abbreviations:

1. Identified as COC because EPC is above the Safe Drinking Water Act (SDWA) MCL or TRRP Tier 1 Residential Groundwater PCL
2. Identified as COC because HQ is > 1.0
3. Excluded because EPC is below the SDWA MCL
4. Excluded because EPC is below the 95% UTL value for Manganese of 7,820 *µg/L from Final Evaluation of Perimeter Well Data for Use as Groundwater Background (Shaw, 2007)* and HQ is <1.0.
5. Already identified as a COC due to carcinogenic risk (**Table 2-2**)
6. More recent sample results indicate lower concentrations of chemical, reducing HQ to <1.0
7. More recent sample results indicate lower concentrations of chemical below the MCL
8. Excluded because EPC and/or most recent maximum is below the TRRP Tier 1 Residential Groundwater PCL and HQ is <1.0
9. Identified as a COC subject to further verification.

[a] From Baseline Risk Assessment Table C-68 (Jacobs, 2002)
[b] SDWA MCL for total trihalomethanes was used for chloroform
[c] Well with maximum in Baseline Risk Assessment was dry in most recent sampling event and the identified well has the most recent maximum

µg/L	micrograms per liter
COC	contaminant of concern
EPC	exposure point concentration
HQ	hazard quotient
J	estimated; the analyte was positively identified; the concentration is estimated
MCL	Safe Drinking Water Act maximum contaminant level
ND	not detected in associated media or not selected as a chemical of potential concern
NR	chemical not resampled in most recent sampling event

Table 2-8. Chemicals with Hazard Quotient Greater than 0.1 in Soil

Chemical	Baseline Risk Assessment			Data Through 2008			Retained as COC ?
	Soil Hazard Quotient [a]	EPC (mg/kg)	Soil Sample Location	Adjusted Hazard Quotient [b]	Maximum (mg/kg)	Soil Sample Location	
2,4,6-Trinitrotoluene	0.77	190	29SD13	105	26,000	29SD46	Yes, 2
2-Amino-4,6-dinitrotoluene	0.33	25	29SD13	0.63	48	29SD46	No, 1
4-Amino-2,6-dinitrotoluene	0.21	16	29SD13	0.21	16	29SD13	No, 1
2,4-Dinitrotoluene	0.0053	6.2	29SB15	6.8	8,000	29SD46	Yes, 3
Perchlorate [c]	8.1×10^{-5}	0.0703	Max from BHHRA Table 3-66	0.0099	8.6	29SB86	Yes, 4

Notes and Abbreviations:

1. Not identified as contaminant of concern (COC) because HQ is less than 1.0.
2. Identified as COC because risk assessment HQ is almost 1 and most recent sample concentration is greater than the SAI-Ind GWP-Ind.
3. Identified as COC because EPC is above the SAI-Ind and GWP-Ind values and Hazard Quotient is greater than 1.0.
4. Identified as COC because contaminant is COC in groundwater and exceeds the GWP-Ind.

[a] HQ from Baseline Risk Assessment Table C-68 (Jacobs, 2002)
[b] calculated HQ based on the most recent maximum concentration.
[c] Even though HI <0.1, listed because recent maximum concentration is greater than EPC

BHHRA Baseline Human Health Risk Assessment
EPC Exposure Point Concentration from Baseline Risk Assessment (Jacobs, 2002)
GWP-Ind Soil medium-specific concentration for industrial use based on groundwater protection
HQ hazard quotient
mg/kg milligrams per kilogram.
SAI-Ind Soil medium-specific concentration for industrial use based on inhalation, ingestion, and dermal contact

Table 2-9. Chemicals in Soil Compared to EcoPRGs

Chemical	SS EcoPRG[a] (mg/kg)	TS EcoPRG[a] (mg/kg)	Maximum[b] (mg/kg)	Retained as Contaminant of Potential Ecological Concern?
2,4,6-Trinitrotoluene	6.1	4.7	26,000	Yes
2,4-Dinitrotoluene	—	12	8,000	Yes
2,6-Dinitrotoluene	2.7	6.8	15	Yes

Notes and Abbreviations:

[a] From Baseline Ecological Risk Assessment Table 16-1 (Shaw, 2007b).

[b] Maximum soil concentrations from samples collected in the upper 3 feet of soil at 29SD46 collected (Shaw, 2007a)

EcoPRG Ecological Preliminary Cleanup Level
mg/kg milligrams per kilogram.
SS surface soil from 0-0.5 feet (applicable to deer mouse)
TS total soil from 0-3 feet (applicable to short-tailed shrew)

Table 2-10. Cleanup Levels at LHAAP-29

Medium	Chemical of Concern	Cleanup Level
Shallow Zone Groundwater		**MCL (µg/L)**
	Trichloroethene	5
	1,2-Dichloroethane	5
	1,1-Dichloroethene*	7
	cis-1,2-Dichloroethene*	70
	trans-1,2-Dichloroethene*	100
	Vinyl chloride*	2
	Arsenic	10
	Mercury	2
	Selenium	50
		TRRP Tier 1 Residential Groundwater PCL - (µg/L)
	2,4-Dinitrotoluene	1.3
	2,6-Dinitrotoluene	1.3
	2-Nitrotoluene	4.1
	3-Nitrotoluene	240
	4-Nitrotoluene	57
	Perchlorate	17
	Nickel	490
Intermediate Zone Groundwater		**MCL (µg/L)**
	Methylene chloride	5
	Trichloroethene	5
	1,2-Dichloroethane	5
	1,1-Dichloroethene*	7
	cis-1,2-Dichloroethene*	70
	trans-1,2-Dichloroethene*	100
	Vinyl chloride*	2
	Arsenic	10
Soil		**GWP-Ind (mg/kg)**
	2,4,6-Trinitrotoluene	4.7[a] 5.1[b]
	2,4-Dinitrotoluene	0.042
	2,6-Dinitrotoluene	0.042
	Perchlorate**	7.2

Table 2-10. Cleanup Levels at LHAAP-29 (continued)

Medium	Chemical of Concern	Cleanup Level
Transite TNT Wastewater Line		**GWP-Ind (mg/kg)**
Solid Residue	1,3-Dinitrobenzene	1
	2,4,6-Trinitrotoluene	5.1
	2,4-Dinitrotoluene	0.042
	2-amino-4,6-Dinitrotoluene	1.7
	4-amino-2,6-Dinitrotoluene	1.7
Cooling Water Drain Line		**GWP-Ind (mg/kg)**
Solid Residue	2,4,6-Trinitrotoluene	5.1
	2,4-Dinitrotoluene	0.042
	2,6-Dinitrotoluene	0.042
	2-amino-4,6-Dinitrotoluene	1.7
	4-amino-2,6-Dinitrotoluene	1.7

Notes:

* Trichloroethene daughter products

** Potential COC in soil due to high perchlorate concentration in groundwater

[a] applies to 0-3 feet below ground surface
[b] applies from 3 feet below ground surface to groundwater interface

GWP-Ind Texas Commission on Environmental Quality soil medium specific concentration for industrial use based on groundwater protection
µg/L micrograms per liter
MCL Safe Drinking Water Act (SDWA) maximum contaminant level
mg/kg milligrams per kilogram
MSC medium-specific concentration

Table 2-11. Comparative Analysis of Alternatives

Criteria	Alternative 1 No Action	Alternative 2 Excavation and off-site disposal for soil; plug lines; in situ chemical oxidation, MNA and LUCs for intermediate zone groundwater; and MNA and LUCs for shallow zone groundwater	Alternative 3 Excavation and off-site disposal for soil; plug lines; groundwater extraction, MNA and LUCs for groundwater	Alternative 4a Excavation and Offsite Disposal for Soil; Plug Lines; Electrical Resistance Heating (ERH) , MNA and LUCs for Intermediate Zone Groundwater; MNA and LUCs for Shallow Zone Groundwater	Alternative 4b Excavation and Offsite Disposal for Soil; Plug Lines; Thermal Conduction Heating (TCH) and MNA for Intermediate Zone Groundwater; MNA and LUCs for Shallow Zone Groundwater
Overall protection of human health and the environment	No protection. Does not achieve RAOs.	Achieves RAOs. Protection of human health and environment provided by soil removal and remediation of groundwater COCs to cleanup levels	Achieves RAOs. Protection of human health and environment provided by soil removal and remediation of groundwater COCs to cleanup levels.	Achieves RAOs in shallow soil/sediment, shallow zone groundwater and intermediate zone groundwater. LUCs can be removed upon completion of active treatment and post-treatment MNA.	Achieves RAOs in shallow soil/sediment, shallow zone groundwater and intermediate zone groundwater. LUCs can be removed upon completion of active treatment and post-treatment MNA.
Compliance with ARARs	No compliance with chemical-specific ARARs.	Complies with all ARARs.	Complies with all ARARs.	Complies with all ARARs.	Complies with all ARARs.

Criteria	Alternative 1 No Action	Alternative 2 Excavation and off-site disposal for soil; plug lines; in situ chemical oxidation, MNA and LUCs for intermediate zone groundwater; and MNA and LUCs for shallow zone groundwater	Alternative 3 Excavation and off-site disposal for soil; plug lines; groundwater extraction, MNA and LUCs for groundwater	Alternative 4a Excavation and Offsite Disposal for Soil; Plug Lines; Electrical Resistance Heating (ERH) , MNA and LUCs for Intermediate Zone Groundwater; MNA and LUCs for Shallow Zone Groundwater	Alternative 4b Excavation and Offsite Disposal for Soil; Plug Lines; Thermal Conduction Heating (TCH) and MNA for Intermediate Zone Groundwater; MNA and LUCs for Shallow Zone Groundwater
Long-term effectiveness and permanence	Is not effective at protection of human health and the environment and does not provide permanence.	Soil removal is a permanent remedy for shallow soil. Excavation of soil is effective long-term and permanent as contamination would be removed from the site and placed in a permitted landfill. In situ chem-ox for intermediate zone should be effective and permanent; however, uncertainty exists concerning the effectiveness of in situ treatment for reducing groundwater contaminant concentrations to cleanup levels. Treatability and pilot studies would be required to further assess the effectiveness of this treatment method and a pre-design would be required to determine the optimum extraction technique configuration. Evaluation of natural attenuation suggests that contaminants are degrading naturally. MNA sampling would be conducted to confirm its effectiveness. Flushing and plugging the process lines would effectively remove any remaining contaminants and there would be no remaining potential for release to surrounding soils. Land use controls would be effective and reliable so long as they are maintained.	Soil removal is a permanent remedy for shallow soil. Excavation of soil is effective long-term and permanent as contamination would be removed from the site and placed in a permitted landfill. Groundwater extraction should be effective and permanent for intermediate zone, based on the efficiency exhibited by the current groundwater treatment system. A pre-design study would be required to determine the optimum extraction technique/configuration. Evaluation of natural attenuation suggests that contaminants are degrading naturally. MNA sampling would be conducted to confirm its effectiveness. Flushing and plugging the process lines would effectively remove any remaining contaminants and there would be no remaining potential for release to surrounding soils. Land use controls would be effective and reliable so long as they are maintained.	Soil removal is a permanent remedy for shallow soil. Excavation of soil is effective long-term and permanent as contamination would be removed from the site and placed in a permitted landfill. MNA has been demonstrated to be effective in managing residual contamination in shallow zone groundwater. ERH is expected to be effective on DNAPL in intermediate zone, MNA demonstrated to be effective in reducing concentrations in intermediate zone groundwater outside of DNAPL zone. Flushing and plugging the process lines would effectively remove any remaining contaminants and there would be no remaining potential for release to surrounding soils. LUCs would remain in place until MNA is completed.	Soil removal is a permanent remedy for shallow soil. Excavation of soil is effective long-term and permanent as contamination would be removed from the site and placed in a permitted landfill. MNA has been demonstrated to be effective in managing residual contamination in shallow zone groundwater. ERH is expected to be effective on DNAPL in intermediate zone, MNA demonstrated to be effective in reducing concentrations in intermediate zone groundwater outside of DNAPL zone. Flushing and plugging the process lines would effectively remove any remaining contaminants and there would be no remaining potential for release to surrounding soils. LUCs would remain in place until MNA is completed.

Table 2-11. Comparative Analysis of Alternatives (continued)

Criteria	Alternative 1 No Action	Alternative 2 Excavation and off-site disposal for soil; plug lines; in situ chemical oxidation, MNA and LUCs for intermediate zone groundwater; and MNA and LUCs for shallow zone groundwater	Alternative 3 Excavation and off-site disposal for soil; plug lines; groundwater extraction, MNA and LUCs for groundwater	Alternative 4a Excavation and Offsite Disposal for Soil; Plug Lines; Electrical Resistance Heating (ERH) , MNA and LUCs for Intermediate Zone Groundwater; MNA and LUCs for Shallow Zone Groundwater	Alternative 4b Excavation and Offsite Disposal for Soil; Plug Lines; Thermal Conduction Heating (TCH) and MNA for Intermediate Zone Groundwater; MNA and LUCs for Shallow Zone Groundwater
Reduction of toxicity, mobility, or volume through treatment	No reduction.	Provides permanent and irreversible reduction of intermediate zone. Provides active reduction of toxicity and volume of groundwater contaminants through biological degradation component of MNA.	Extraction and treatment of contaminated groundwater intermediate zone reduces toxicity, mobility, and volume of groundwater contaminants in this area outside of natural processes. Provides active reduction of toxicity and volume of groundwater contaminants through biological degradation component of MNA.	Reduced toxicity, mobility, and volume through excavation, in situ hydrolysis of DNAPL and DNAPL removal followed by ex-situ destruction, and MNA.	Reduced toxicity, mobility, and volume through excavation, in situ hydrolysis of DNAPL and DNAPL removal followed by ex-situ destruction, and MNA.
Short-term effectiveness	No short-term impacts.	Greater potential for impacts to the community or hypothetical future maintenance worker through off-site transportation of contaminated soil. Release to environment can be controlled during construction.	Greater potential for impacts to the community or hypothetical future maintenance worker through off-site transportation of contaminated soil. Release to environment can be controlled during construction.	Greater potential for impacts to the community or LHAAP workers through off-site transportation of excavated soil. Release to environment can be controlled during construction. Potential for impacts to workers from exposure to hot fluids and high voltage power during ERH application. Duration of MNA and LUCs expected to be 5-10 years following active remediation.	Greater potential for impacts to the community or LHAAP workers through off-site transportation of excavated soil. Release to environment can be controlled during construction. Potential for impacts to workers from exposure to hot fluids during TCH application. Duration of MNA and LUCs expected to be 5-10 years following active remediation.
Implementability	Inherently implementable.	Implementable, but uncertainty exists whether in situ chemical oxidation would lower contaminant concentrations to cleanup levels. Specialized knowledge required for implementation. Use of on-site storage tanks may limit storage capacity. A groundwater treatment system is already operating at LHAAP.	Implementable. Use of on-site storage tanks may limit storage capacity. A groundwater treatment system is already operating at LHAAP. Potential exists for limited groundwater recovery which may affect ability of system to remove contaminants to cleanup levels. A pre-design study would be required.	Soil excavation readily implemented with standard Earthmoving equipment. ERH has been proven to be effective on DNAPL and within low hydraulic conductivity zones.	Soil excavation readily implemented with standard Earthmoving equipment. TCH has been proven to be effective on DNAPL and within low hydraulic conductivity zones.
Cost* (present worth)					

Table 2-11. Comparative Analysis of Alternatives (continued)

Criteria	Alternative 1 No Action	Alternative 2 Excavation and off-site disposal for soil; plug lines; in situ chemical oxidation, MNA and LUCs for intermediate zone groundwater; and MNA and LUCs for shallow zone groundwater	Alternative 3 Excavation and off-site disposal for soil; plug lines; groundwater extraction, MNA and LUCs for groundwater	Alternative 4a Excavation and Offsite Disposal for Soil; Plug Lines; Electrical Resistance Heating (ERH) , MNA and LUCs for Intermediate Zone Groundwater; MNA and LUCs for Shallow Zone Groundwater	Alternative 4b Excavation and Offsite Disposal for Soil; Plug Lines; Thermal Conduction Heating (TCH) and MNA for Intermediate Zone Groundwater; MNA and LUCs for Shallow Zone Groundwater
Capital	$0	$2,109,000	$1,360,000	$3,710,000	$4,530,000
O&M	$0	$919,000	$1,558,000	1,030,000	1,190,000
Total	$0	$3,028,000	$2,918,000	$4,740,000	$5,720,000
State Acceptance	This criterion will be evaluated in the Proposed Plan after state agency comments are provided.				
Community Acceptance	This criterion will be evaluated in the Proposed Plan after community comments are provided.				

Notes and Abbreviations:

* Costs have been rounded to nearest $1,000

ARAR applicable or relevant and appropriate requirement
COC contaminant of concern
LHAAP Longhorn Army Ammunition Plant
LUC land use controls
MNA monitored natural attenuation
O&M operation and maintenance
RAO remedial action objective

Table 2-12. Remediation Cost Table Selected Remedy (Alternative 4a) Present Worth Analysis

Year	Capital Costs		Excavation & Pipeline Flushing		Operation and Maintenance Costs			Present Value (NPV)		
	Design, Permitting, Construction Management, Sub G&A	Electrical Resistance Heating (ERH)			MNA/LUC	O&M GWTP (condensate treatment)	Total O&M	Discount Rate 2.8%	Capital	O&M
Estimate Base Year	2010 (FS)	2014	2010 (FS)		2010 (FS)	2010 (FS				
Escalation Factor *	1.14	1.02	1.14		1.14	1.14				
1	814,530	1,443,282	670,076		252,638	23,005	275,643	**NPV**	**3,710,000**	**1,030,000**
2		799,659			127,777		127,777			
3		0			66,717		66,717		**Total NPV**	**$4,740,000**
4		0			58,711		58,711			
5		0			115,041		115,041			
6		0			40,147		40,147			
7		0			40,147		40,147			
8		0			40,147		40,147			
9		0			40,147		40,147			
10		0			88,471		88,471			
11		0					0			
12		0					0			
13		0					0			
14		0					0			
15		0			89,078					
16		0					0			
17		0					0			
18		0					0			
19		0					0			
20		0			89,078					
21		0					0			
22		0					0			
23		0					0			

Table 2-12. Remediation Cost Table Selected Remedy (Alternative 4a) Present Worth Analysis (continued)

Year	Capital Costs		Excavation & Pipeline Flushing	Operation and Maintenance Costs			Present Value (NPV)		
	Design, Permitting, Construction Management, Sub G&A	Electrical Resistance Heating (ERH)		MNA/LUC	O&M GWTP (condensate treatment)	Total O&M	Discount Rate 2.8%	Capital	O&M
24		0				0			
25		0		89,078					
26		0				0			
27		0				0			
28		0				0			
29		0				0			
30		0		89,078					
	814,530	2,242,941	670,076	1,225,755	23,005	1,248,761			

*Escalation based on construction cost index published by RS Means (https://www.rsmeansonline.com/references/unit/refpdf/hci.pdf)

Notes:

LUC land use control
MNA monitored natural attenuation
NPV net present value
O&M operation & maintenance
VOC volatile organic compound

Major assumptions are as described below. Quantities and assumptions are for cost estimating purposes only.

Capital costs include: excavation evaluation, excavation and disposal activities, flow tests, engineering support, and construction management. The soil is assumed to be classified as nonhazardous for disposal purposes.

Monitoring costs are based on the assumption that sampling is conducted at five shallow zone wells and three intermediate zone wells, with one quality control sample in each zone. In the shallow zone, monitoring begins 6 months into Year 2 when groundwater extraction ends and MNA begins. The sampling frequency is quarterly for 2 years, then semiannually for 3 years, then annually for Years 7 through 10, and finally every 5 years (Years 15, 20, 25, and 30). Analysis of the shallow zone groundwater is for VOCs and perchlorate. In the intermediate zone, monitoring begins at the start of Year 1 when MNA begins. The sampling frequency is quarterly for 2 years (Years 1 and 2), then semiannually for 3 years (Years 3 through 5), then annually for Years 6 through 10, and finally every 5 years (Years 15, 20, 25, and 30). Analysis of the intermediate zone groundwater is for VOCs.

The discount rate of 2.8% is based on the Office of Management and Budget Circular No. A-94, January 2008.

The information in this cost estimate summary table is based on the best available information regarding the anticipated scope of the remedial alternative. 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. Changes will be documented in accordance with 40 CFR 300.435(c)(2) in the form of a memorandum in the Administrative Record, an Explanation of Significant Difference (ESD), or a ROD amendment, as necessary. This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.

Table 2-13. Remediation Cost Table Selected Remedy (Alternative 4b) Present Worth Analysis

Year	Capital Costs		Excavation & Pipeline Flushing	Operation and Maintenance Costs			Present Value (NPV)		
	Design, Permitting, Construction Management, Sub G&A	Thermal Conduction Heating (TCH)		MNA/LUC	O&M GWTP (condensate treatment)	Total O&M	Discount Rate 2.8%	Capital	O&M
Estimate Base Year	2010 (FS)	2014	2010 (FS)	2010 (FS)	2010 (FS				
Escalation Factor *	1.14	1.02	1.14	1.14	1.14				
1	997,004	1,889,115	670,076	250927	175,509	470,436	**NPV**	**4,530,000**	**1,190,000**
2		1,003,601		126,415		126,415			
3		0		66,266		66,266		**Total NPV**	**$5,720,000**
4		0		66,266		66,266			
5		0		114,262		114,262			
6		0		39,875		39,875			
7		0		39,875		39,875			
8		0		39,875		39,875			
9		0		39,875		39,875			
10		0		87,871		88,871			
11		0				0			
12		0				0			
13		0				0			
14		0				0			
15		0		88,475		88,475			
16		0				0			
17		0				0			
18		0				0			
19		0				0			
20		0		88,475		88,475			
21		0				0			
22		0				0			
23		0				0			
24		0				0			

Table 2-13. Remediation Cost Table Selected Remedy (Alternative 4b) Present Worth Analysis (continued)

Year	Capital Costs		Excavation & Pipeline Flushing	Operation and Maintenance Costs			Present Value (NPV)		
	Design, Permitting, Construction Management, Sub G&A	Thermal Conduction Heating (TCH)		MNA/LUC	O&M GWTP (condensate treatment)	Total O&M	Discount Rate 2.8%	Capital	O&M
25		0		88,475		88,475			
26		0				0			
27		0				0			
28		0				0			
29		0				0			
30		0		88,475		88,475			
	997,004	2,892,716	670,076	1,225,406	175,509	1,404,915			

*Escalation based on construction cost index published by RS Means (https://www.rsmeansonline.com/references/unit/refpdf/hci.pdf)

Notes:

LUC land use control
MNA monitored natural attenuation
NPV net present value
O&M operation & maintenance
VOC volatile organic compound

Major assumptions are as described below. Quantities and assumptions are for cost estimating purposes only.

Capital costs include: excavation evaluation, excavation and disposal activities, flow tests, engineering support, and construction management. The soil is assumed to be classified as nonhazardous for disposal purposes.

Monitoring costs are based on the assumption that sampling is conducted at five shallow zone wells and three intermediate zone wells, with one quality control sample in each zone. In the shallow zone, monitoring begins 6 months into Year 2 when groundwater extraction ends and MNA begins. The sampling frequency is quarterly for 2 years, then semiannually for 3 years, then annually for Years 7 through 10, and finally every 5 years (Years 15, 20, 25, and 30). Analysis of the shallow zone groundwater is for VOCs and perchlorate. In the intermediate zone, monitoring begins at the start of Year 1 when MNA begins. The sampling frequency is quarterly for 2 years (Years 1 and 2), then semiannually for 3 years (Years 3 through 5), then annually for Years 6 through 10, and finally every 5 years (Years 15, 20, 25, and 30). Analysis of the intermediate zone groundwater is for VOCs.

The discount rate of 2.8% is based on the Office of Management and Budget Circular No. A-94, January 2008.

The information in this cost estimate summary table is based on the best available information regarding the anticipated scope of the remedial alternative. 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. Changes will be documented in accordance with 40 CFR 300.435(c)(2) in the form of a memorandum in the Administrative Record, an Explanation of Significant Difference (ESD), or a ROD amendment, as necessary. This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.

Table 2-14. Description of ARARs for Selected Remedy

Citation	Activity or Prerequisite/Status	Requirement
Soil		
TCEQ Texas Risk Reduction Rules 30 TAC 335.558 and 30 TAC 335.559(g)(2)	Ensures adequate protection of human health and the environment from potential exposure to contaminants associated with releases – **relevant and appropriate** for remediation of contaminated soil and contaminated pipeline solid residue for cross-media contamination pathways such as soil to groundwater and for hypothetical future maintenance workers.	Non-residential (industrial) soils shall conform to the non-residential soil-to-groundwater cross media protection concentration. Non-residential (industrial) soils shall conform to the non-residential soil-to-groundwater cross media protection concentration MSC (GWP-Ind) values for 2,4,6-TNT for soils less than 3 ft bgs and for soils deeper than 3 ft bgs; 2,4-DNT and 2,6-DNT and Perchlorate in accordance with 30 TAC 335.559(g)(2) and as listed in **Table 2-10** of this report. The concentration of contamination in soil and pipeline solid residue shall not exceed the non-residential soil-to-groundwater protection MSC (GWP-Ind) for the COCs listed in **Table 2-10.** COCs in soil and pipeline solid residue COCs include 2,4,6-TNT, 2,4-DNT, 2,6-DNT, 1,3-DNB, 2-amino-4.6-DNT and 4-amino-2,6-DNT.
Groundwater		
Federal Safe Drinking Water Act (SDWA) MCLs 40 C. F. R. §§ 141.61 and 141.62	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 SDWA MCLs for water designated as a current or potential source of drinking water. The MCLs for organic contaminants TCE, MC, 1,2-DCE, 1,2-DCA; 1,1-DCE; cis-1,2-DCE; trans-1,2-DCE; and VC are provided in 40 C. F. R. § 141.61(a) and the MCLs for inorganic contaminants arsenic; mercury; and, selenium are provided in 40 C. F. R. § 141.62 (b) and **Table 2-10** of this report.
General Site Preparation, Construction, and Excavation Activities		
Opacity Standard 30 TAC 111.111(a)(8)(A)	Fugitive emissions from land-disturbing activities (e.g., excavation, construction)—**applicable**.	Visible emissions shall not be permitted to exceed opacity of 30% for any 6-minute period from any source.
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.
Fugitive Particulate Matter Standard 30 TAC 111.145	Fugitive emissions from land-disturbing activities (e.g., excavation, construction)—**applicable**.	No person may cause, suffer, allow, or permit a structure, road, street, alley or parking area to be constructed, altered, repaired, or demolished, or land to be cleared without taking at least the following precautions to achieve control of dust emissions: • Use of water or of suitable oil or chemicals for control of dust in the demolition of structures, in construction operations, in work performed on a road, street, alley, or parking area, or in the clearing of land; and • Use of adequate methods to prevent airborne particulate matter during sandblasting of structures or similar operations
Storm Water Runoff Controls 40 C.F.R. § 122.26	Storm water discharges associated with construction activities—**applicable** to disturbances of equal to or greater than 1 acre of land.	Specific to areas of excavation of contaminated soil. 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.

Table 2-14. Description of ARARs for Selected Remedy (continued)

Citation	Activity or Prerequisite/Status	Requirement
Waste Generation, Management, and Storage		
Characterization of Solid Waste 40 C.F.R. § 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 C. F. R. § 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.
Characterization of Hazardous Waste 40 C.F.R. §.264.13(a)(1); 40 C.F.R. § 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., 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 C. F. R. §264 and 268. Must also determine whether the waste is restricted from land disposal under 40 C. F. R. § 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 C. F. R. § 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 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 C. F. R. § 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.
Requirements for the Use and Management of Containers 40 C. F. R. § 264.171–264.173 30 TAC 335.69(e) 30 TAC 335.152(a)(7)	On-site storage/treatment of RCRA hazardous waste in containers for greater than 90 days—**applicable** if hazardous waste is generated (e.g., PPE) and is stored in containers.	Design and operating standards of 40 C. F. R. § 264.175(c) and 40 C. F. R. § 264.171, §.264.172, and §.264.173(a) and (b) must be met for the use and management of hazardous waste in containers.
Wells		
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.

Table 2-14. Description of ARARs for Selected Remedy (continued)

Citation	Activity or Prerequisite/Status	Requirement
Wells (continued)		
Class V Injection Wells 30 TAC §331.9(a); 30 TAC §331.10(a); 30 TAC §331.10(d); 30 TAC §331.21; 30 TAC §331.132(a); 30 TAC §331.132(c); 30 TAC §331.132(d)(1); 30 TAC §331.132(d)(4); 30 TAC §331.133(e)	Installation, operation, and closure of injection wells for in situ chemical oxidation 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.
Well Construction Standards—Extraction Wells 16 TAC 76.1000(a) and (c) through (h) 16 TAC 76.1002(a) through (c) 16 TAC 76.1008(a) through (c)	Construction of water wells—**applicable** to construction of extraction (recovery) wells.	Substantive requirements applicable to extraction (recovery) wells will be adhered to. Wells shall be completed in accordance with the technical requirements of Section 76.1000, as appropriate. Water wells completed to produce undesirable water shall be cased to prevent the mixing of water or constituent zones. The annular space between the casing and the wall of the borehole shall be pressure grouted with cement or bentonite grout to the land surface. Bentonite grout may not be used if a water zone contains chloride water above 1500 parts per million (ppm) or if hydrocarbons are present. Wells producing undesirable water or constituents shall be completed in such a manner that will not allow undesirable fluids to flow onto the land surface. During installation of a water well pump, installer shall make a reasonable effort to maintain integrity of groundwater and to prevent contamination by elevating the pump column and fittings, or by other means suitable under the circumstances. Pump shall be constructed so that no unprotected openings into the interior of the pump or well casing exist.
Treatment/Disposal		
Disposal of Wastewater (e.g., contaminated groundwater, dewatering fluids, decontamination liquids) 40 C. F. R. § 268.1(c)(4)(i) 30 TAC 335.431(c)	RCRA-restricted characteristically hazardous waste intended for disposal—**applicable** if extracted groundwater is determined to be RCRA characteristically hazardous.	Appropriate and relevant in the event of a spill. 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		

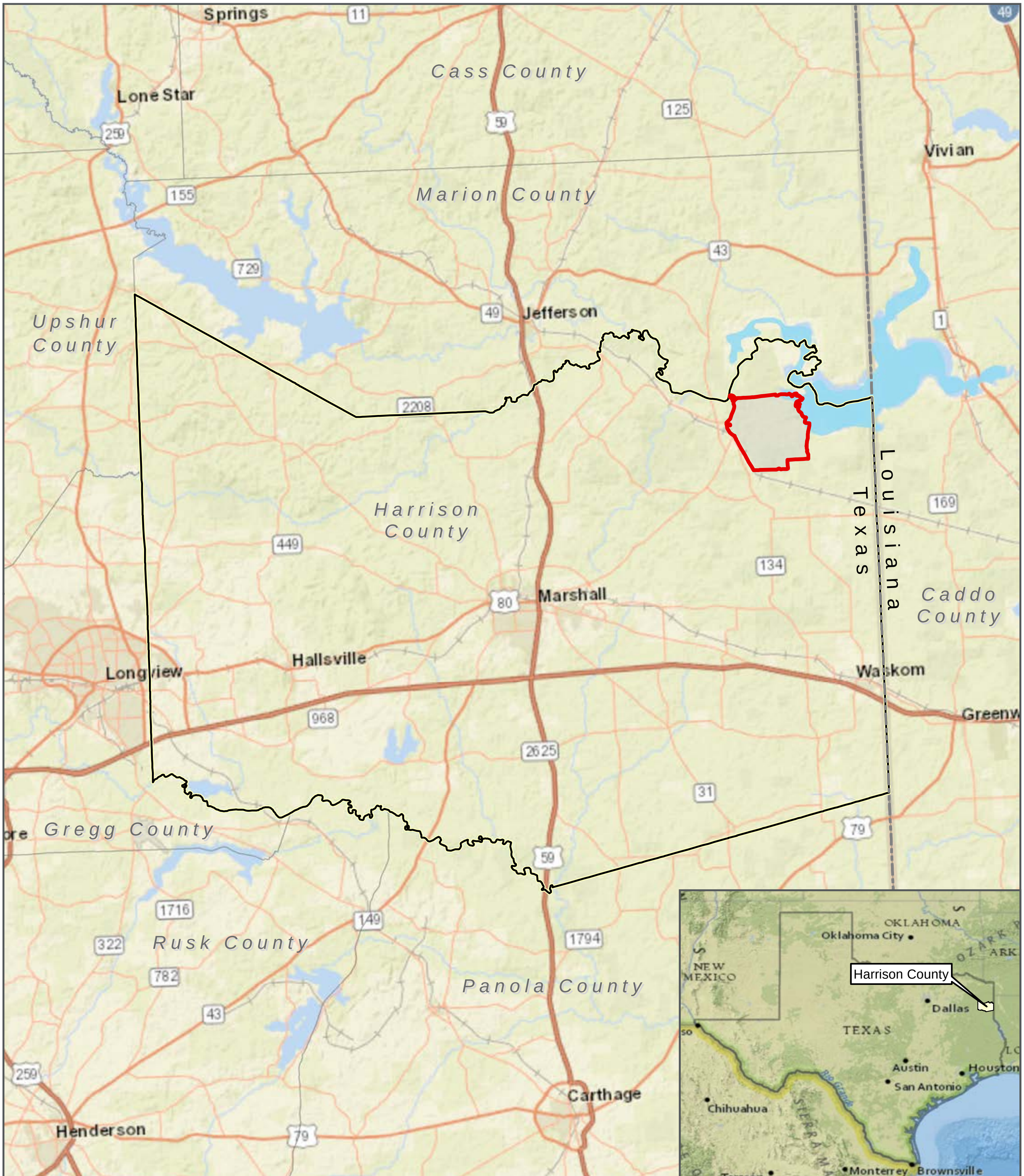
Table 2-14. Description of ARARs for Selected Remedy (continued)

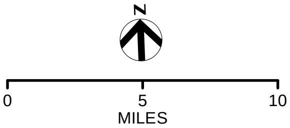
Citation	Activity or Prerequisite/Status	Requirement
Standards for Plugging Wells that Penetrate Undesirable Water or Constituent Zones 16 TAC 76.1004(a) through (c)	Plugging and abandonment of wells—**applicable** to plugging and closure of monitoring and/or extraction wells.	If a well is abandoned, 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.

Abbreviations:

ARAR	*applicable or relevant and appropriate requirement*	*MCLG*	*maximum contaminant level goal*
bgs	*below ground surface*	*MSC*	*medium-specific concentration*
C. F. R.	*Code of Federal Regulations*	*%*	*percent*
CWA	*Clean Water Act of 1972*	*PPE*	*personal protective equipment*
USEPA	*U.S. Environmental Protection Agency*	*ppm*	*part per million*
FR	*Federal Register*	*RCRA*	*Resource Conservation and Recovery Act of 1976*
lb/gal	*pound per gallon*	*SDWA*	*Safe Drinking Water Act*
LHAAP	*Longhorn Army Ammunition Plant*	*TAC*	*Texas Administrative Code*
MCL	*maximum contaminant level*	*TCEQ*	*Texas Commission on Environmental Quality*

Figure 2 -1. LHAAP Site Location





LEGEND

- LHAAP Installation Boundary
- Harrison County
- State Boundary

SITE LOCATION

LONGHORN ARMY
AMMUNITION PLANT
KARNACK, TEXAS

DATA SOURCES: AECOM, 2017, Draft Final Feasibility Study Addendum LHAAP-29, Former TNT Production Area, Group 2 Longhorn Army Ammunition Plant, Karnack, Texas. August

DISCLAIMER: Map information was compiled from the best available sources. No warranty is made for its accuracy or completeness.

FIGURE 2-1

PATH: J:\2018\18-025_LHAAP_SITES29_47_18AND24_ROD_(WERNER)\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\LHAAP29\LHAAP_29_ROD_LHAAP_SITE_LOCATION.MXD - USER: KLOFGREN - DATE: 5/17/2019

Figure 2-2. LHAAP-29 TNT Production Facility Site Location

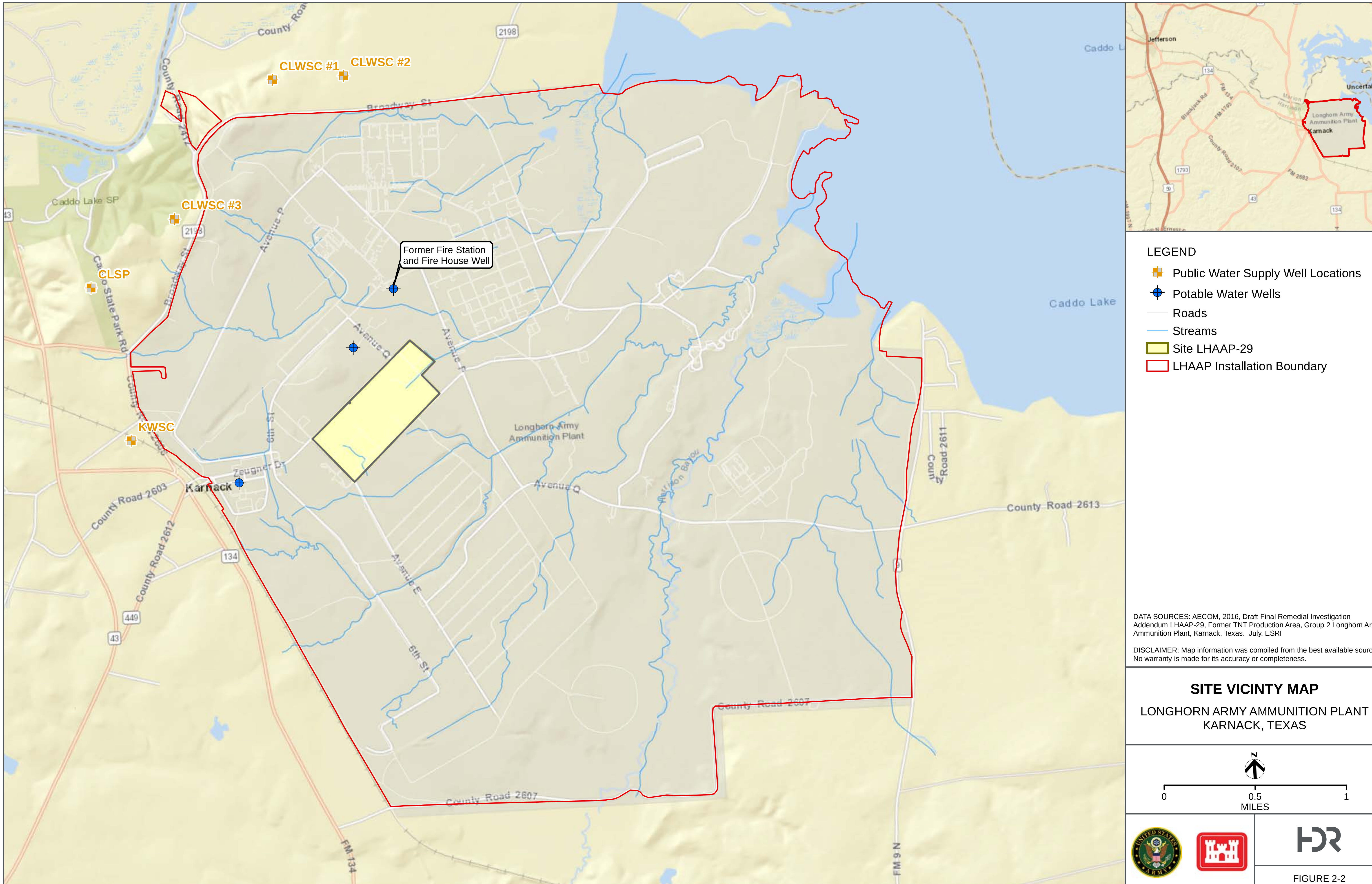


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Figure 2-3. LHAAP-29 Soil Sample Locations

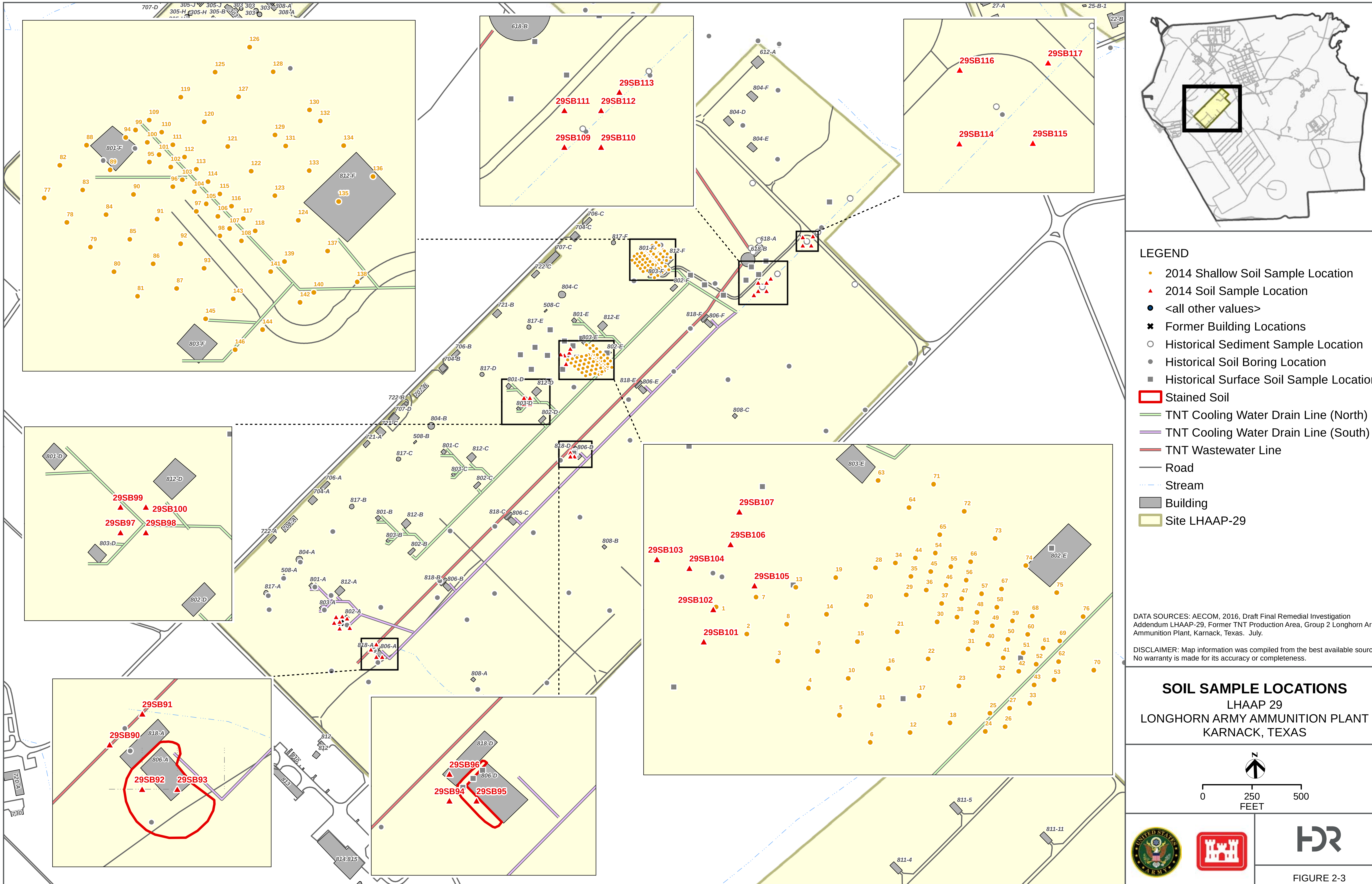

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Figure 2-4. LHAAP Surface Water and Sediment Sample Locations

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Figure 2-5. LHAAP-29 Shallow Zone Wells and Groundwater Elevations

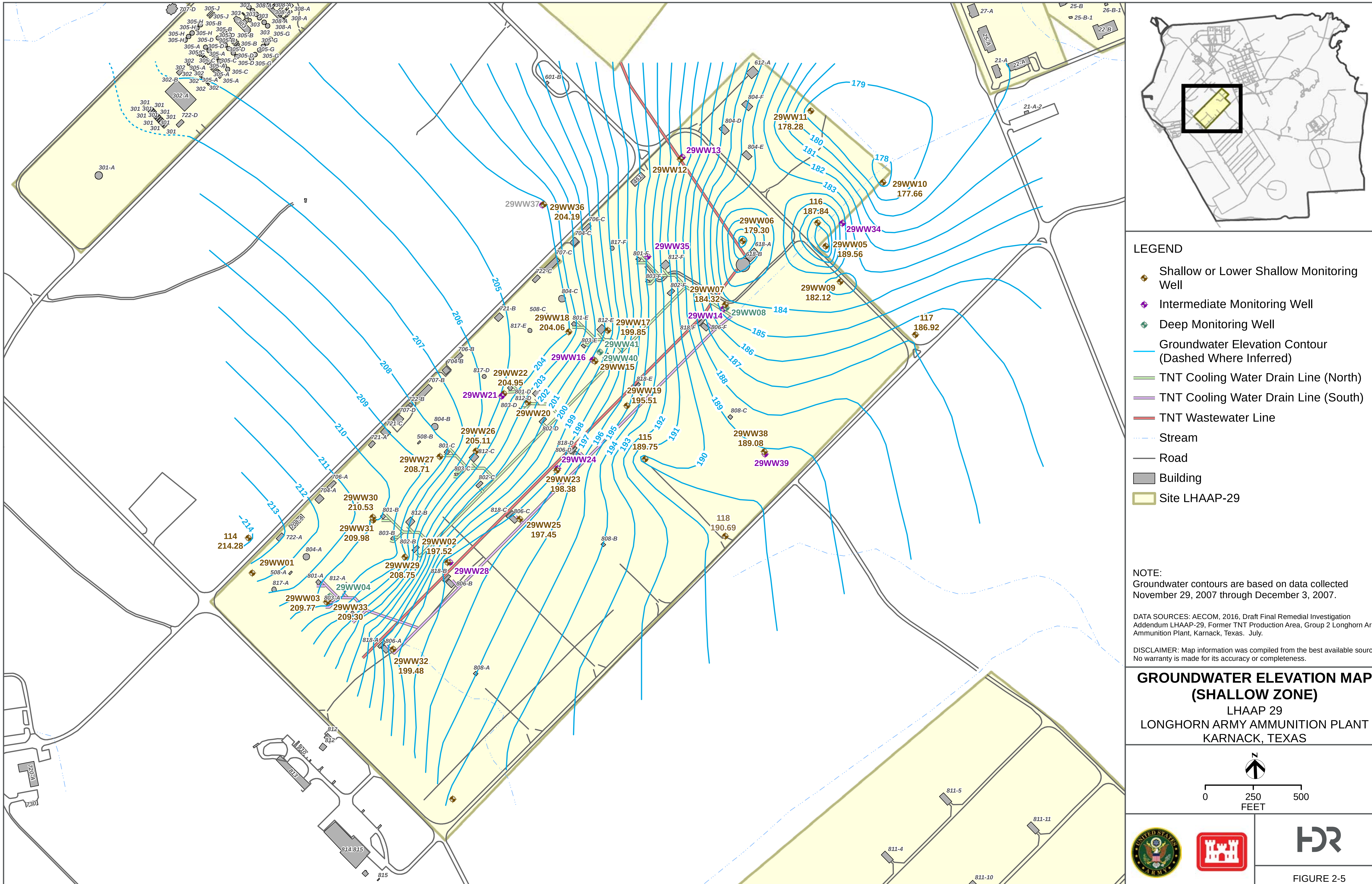

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Figure 2-6. LHAAP-29 Intermediate Groundwater Zone Wells and Elevations

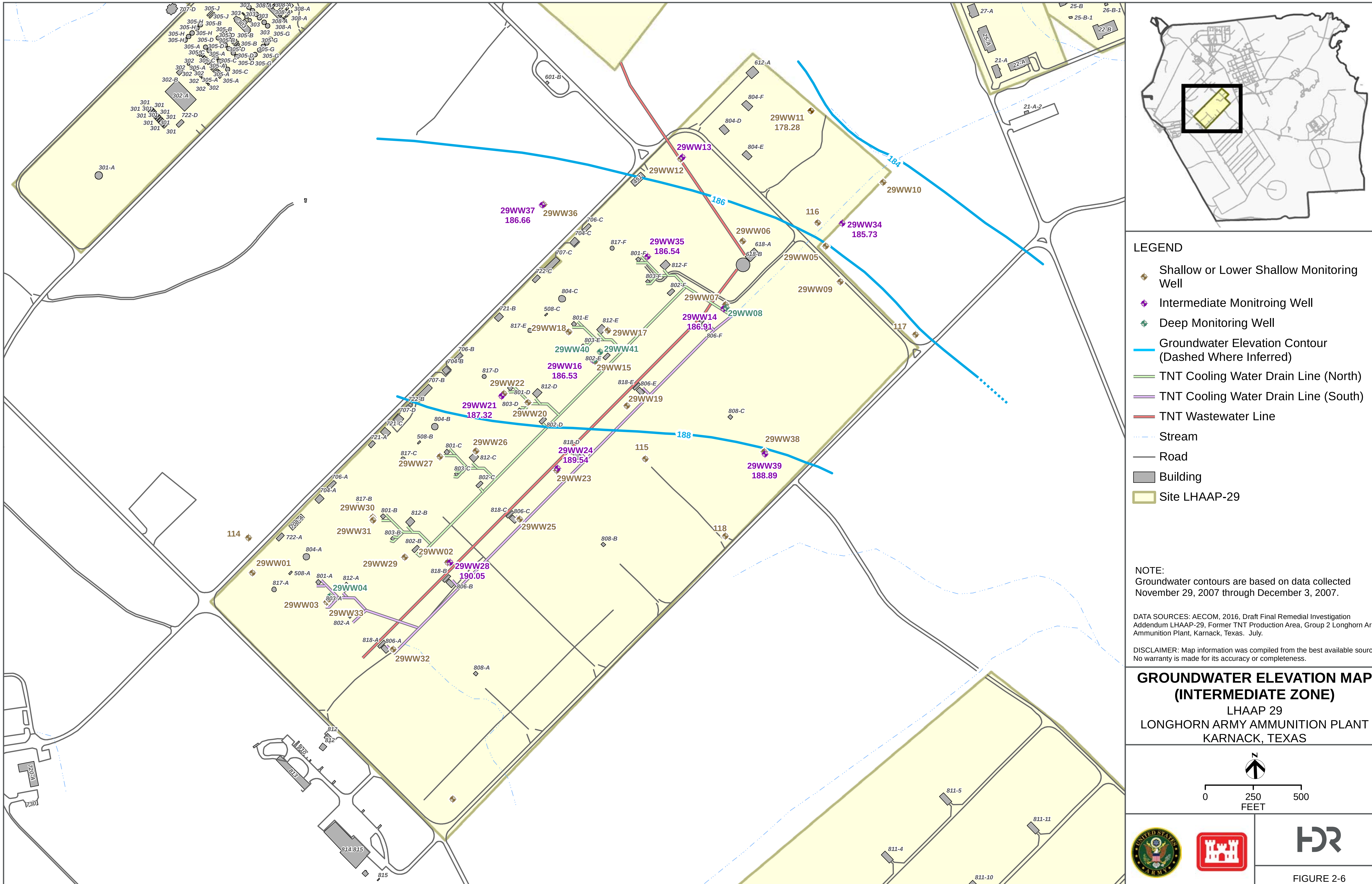

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Figure 2-7. LHAAP-29 Human Health Conceptual Site Model

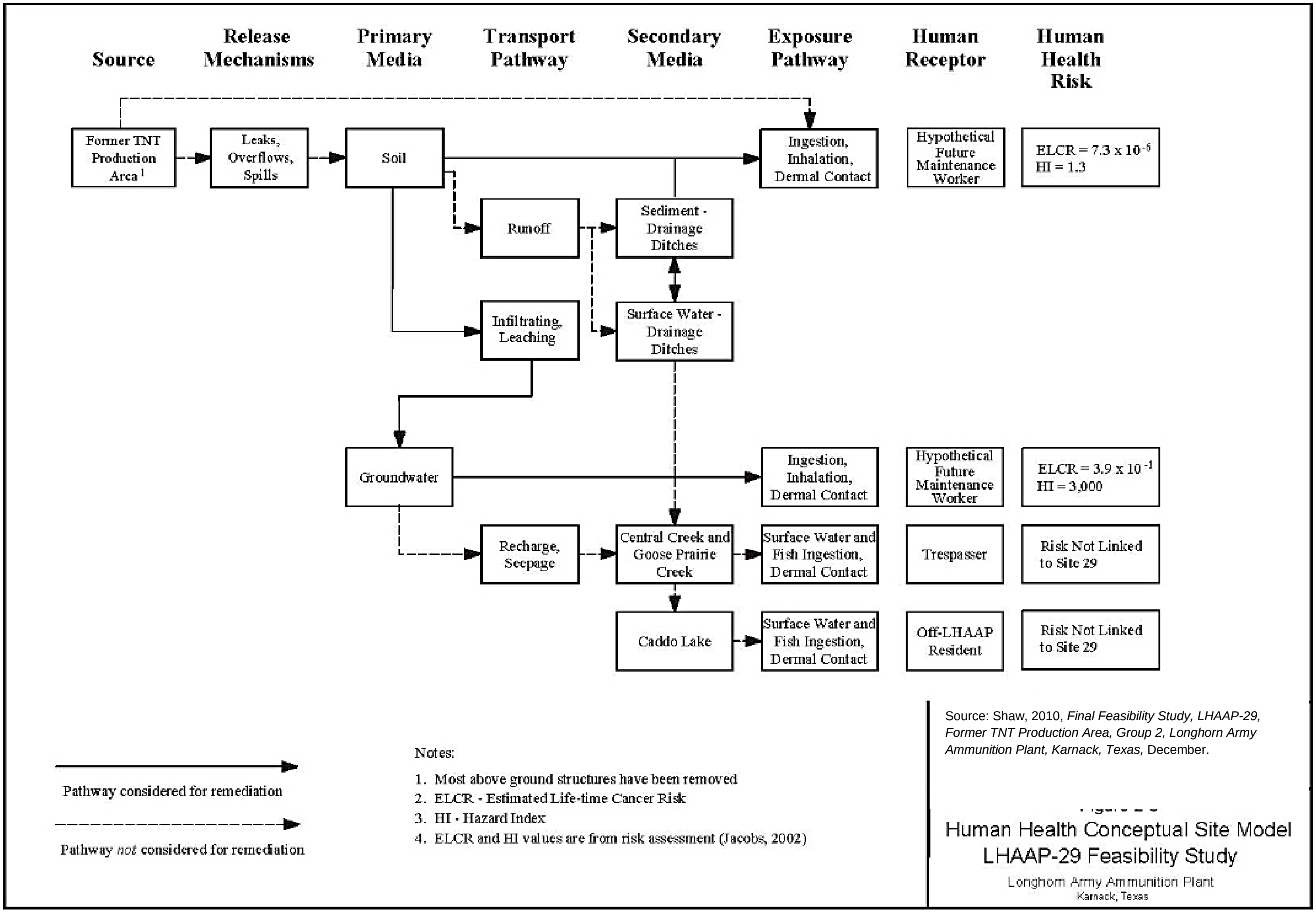
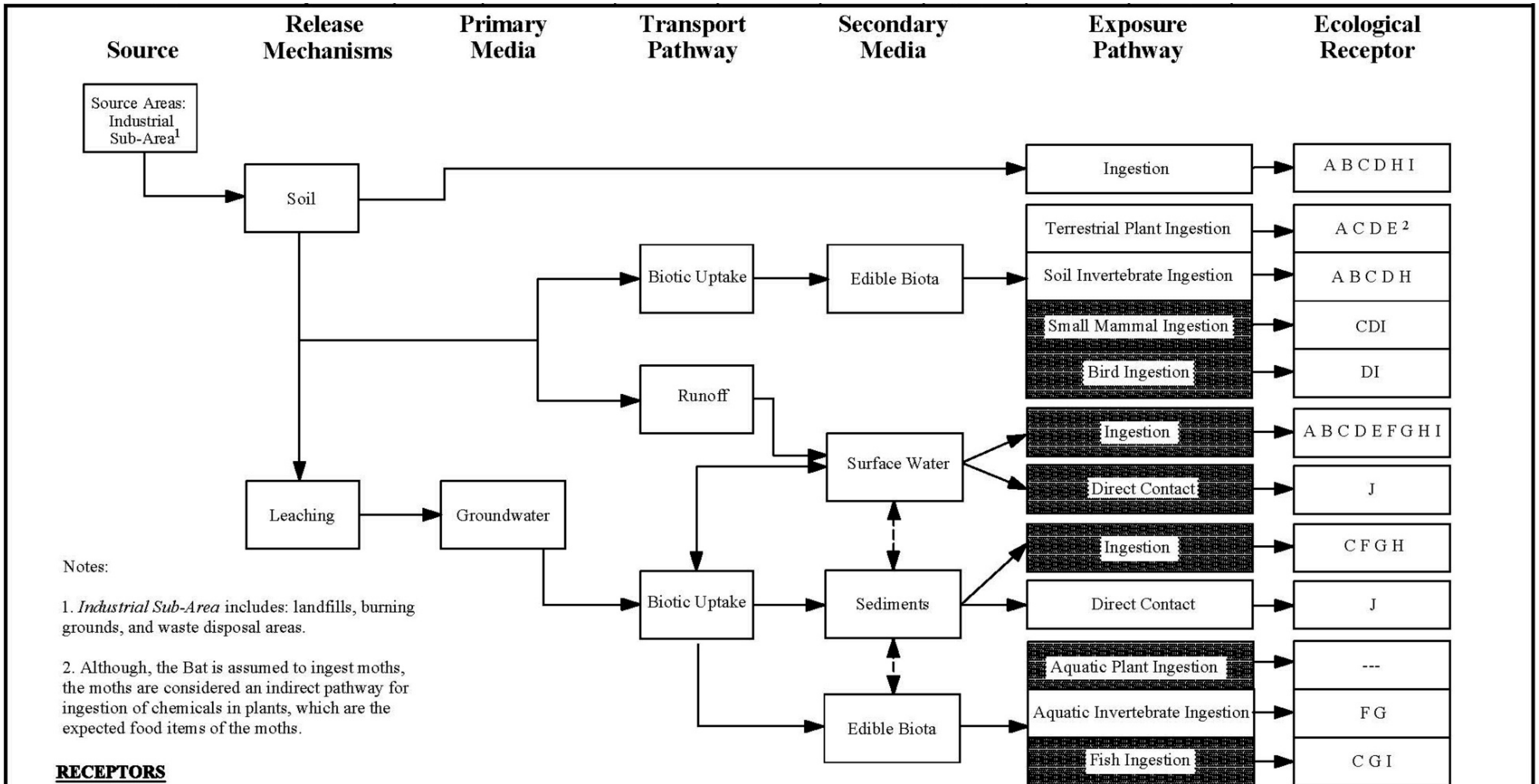


Figure 2-8. LHAAP-29 Ecological Conceptual Exposure Model



Notes:

1. *Industrial Sub-Area* includes: landfills, burning grounds, and waste disposal areas.

2. Although, the Bat is assumed to ingest moths, the moths are considered an indirect pathway for ingestion of chemicals in plants, which are the expected food items of the moths.

RECEPTORS

A. Deer Mouse
B. Short-Tailed Shrew
C. Racoon (& Racoon [Louisiana Black Bear])
D. Red Fox
E. Townsend's Big-Eared Bat
F. Bank Swallow
G. Belted Kingfisher
H. American Woodcock
I. Red-Tailed Hawk
J. Aquatic Life (benthic invertebrates)

--- = All receptors exposed to this pathway were determined not to be of concern.

Shaded cells indicate pathways that were not identified as significant, are background related, or were refined via site-specific investigations.

Source: Shaw, 2010, *Final Feasibility Study, LHAAP-29, Former TNT Production Area, Group 2, Longhorn Army Ammunition Plant, Karnack, Texas,* December.

Ecological Conceptual Exposure Model
LHAAP-29 Feasibility Study
Longhorn Army Ammunition Plant
Karnack, Texas

Figure 2-9. VOCs and Perchlorate in Shallow Zone Groundwater

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Figure 2-10. Nitrotoluenes in Shallow Zone Groundwater

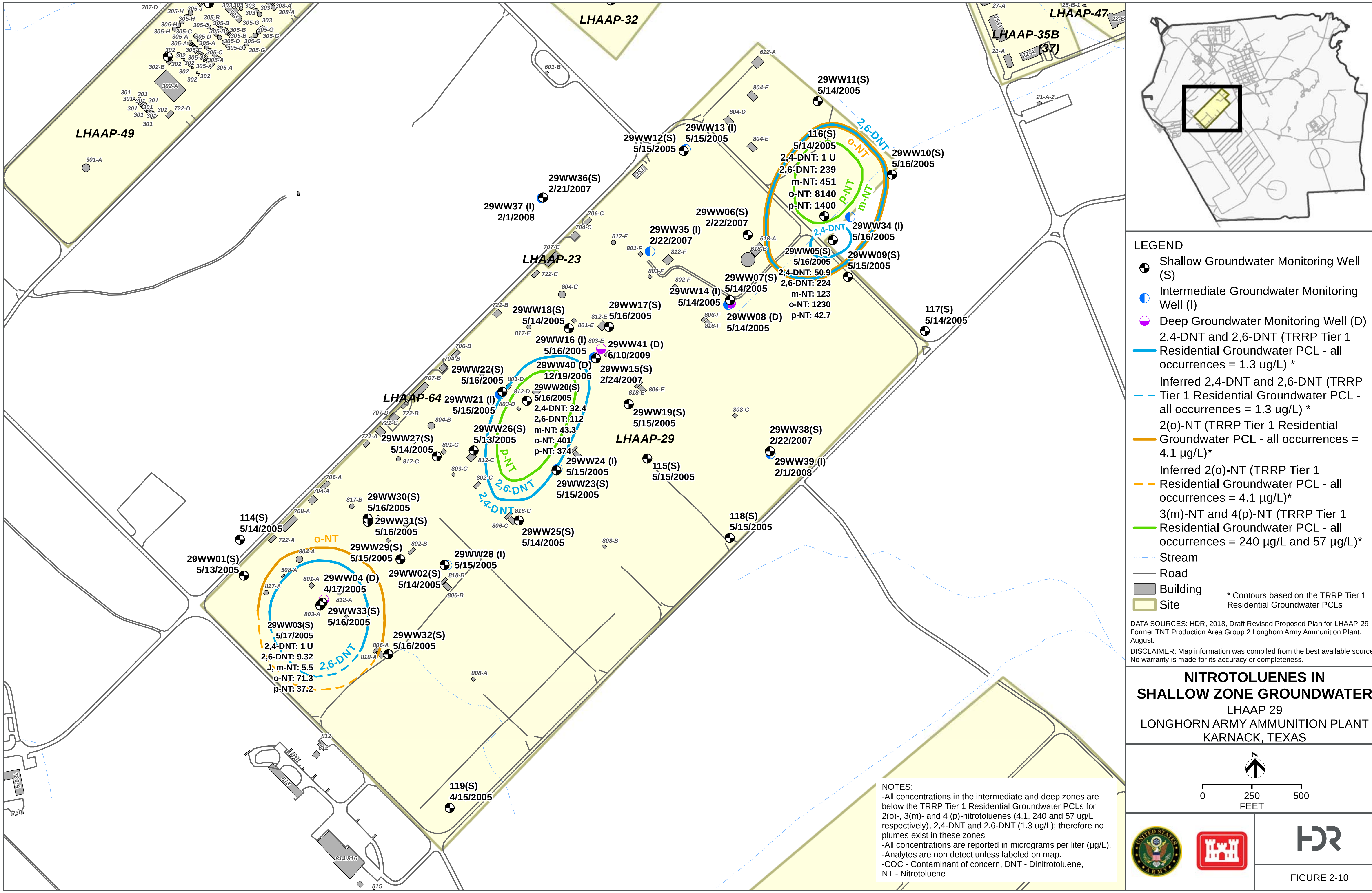

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Figure 2-11. VOCs in Intermediate Zone Groundwater

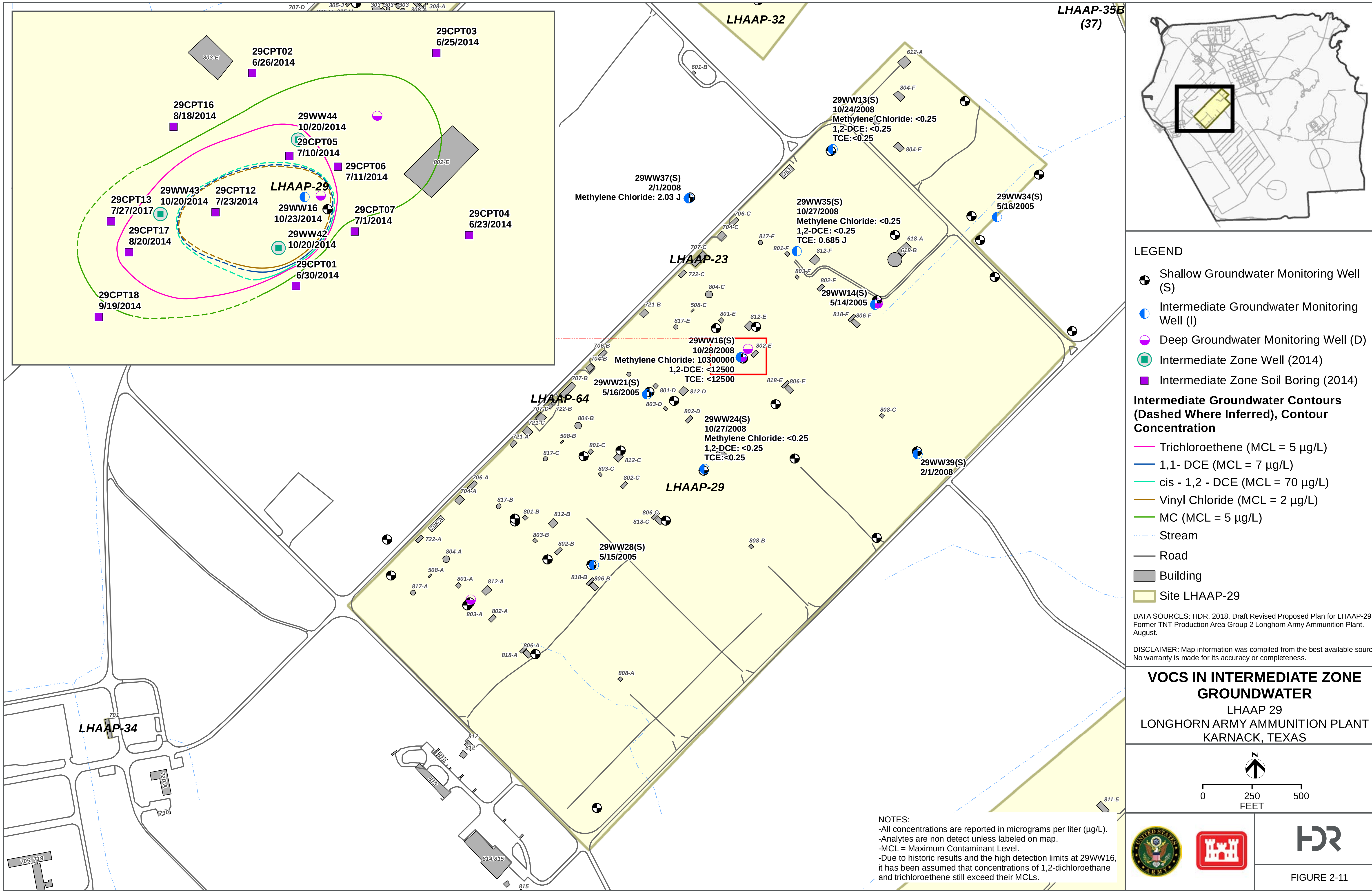

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Figure 2-12. Soil Contamination and Areas of Soil Remediation

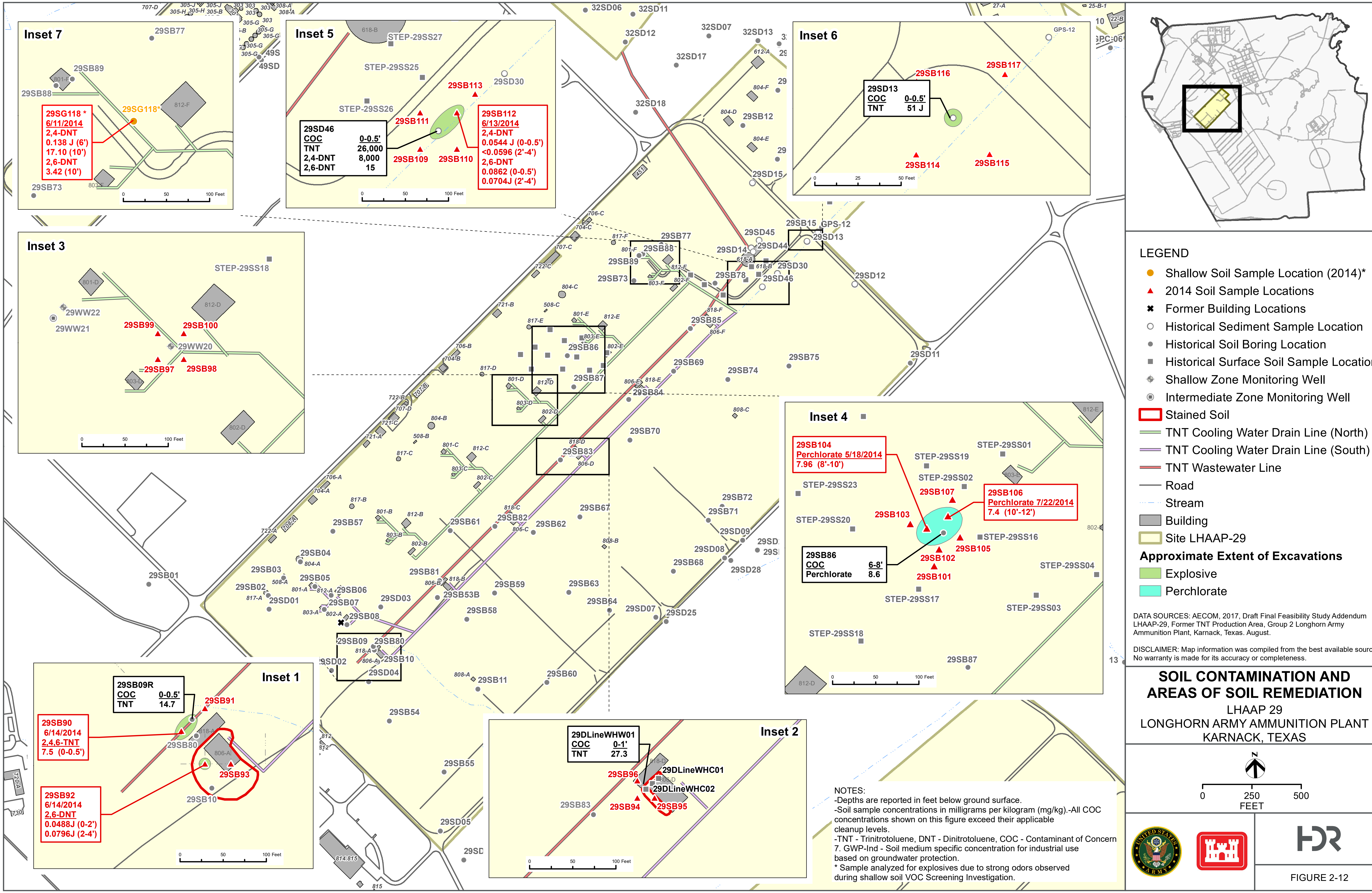

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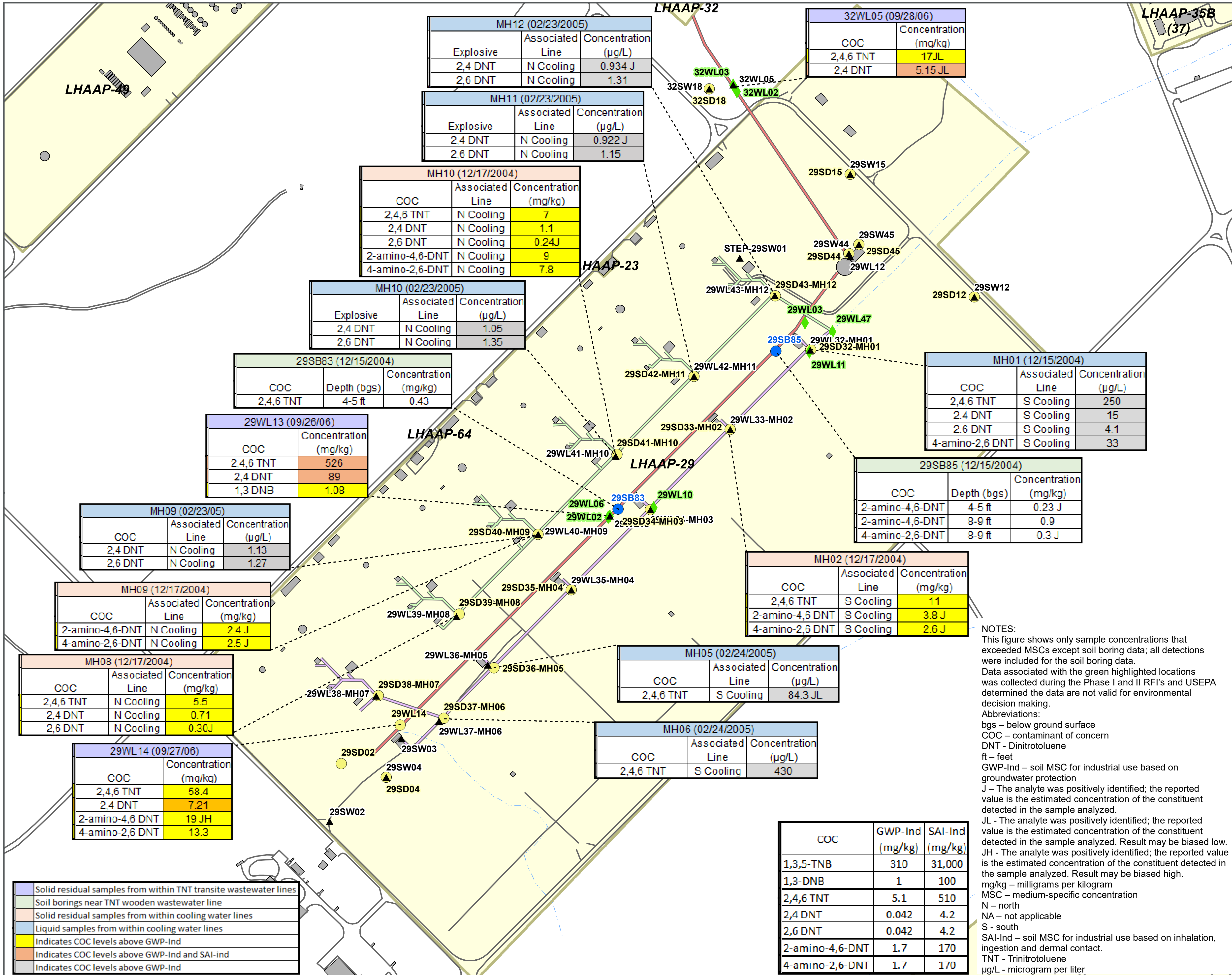
Figure 2-13. Wastewater and Cooling Lines Sample Results



MH12 (02/23/2005)

Explosive	Associated Line	Concentration (µg/L)
2,4 DNT	N Cooling	0.934 J
2,6 DNT	N Cooling	1.31

MH11 (02/23/2005)

Explosive	Associated Line	Concentration (µg/L)
2,4 DNT	N Cooling	0.922 J
2,6 DNT	N Cooling	1.15

MH10 (12/17/2004)

COC	Associated Line	Concentration (mg/kg)
2,4,6 TNT	N Cooling	7
2,4 DNT	N Cooling	1.1
2,6 DNT	N Cooling	0.24J
2-amino-4,6-DNT	N Cooling	9
4-amino-2,6-DNT	N Cooling	7.8

MH10 (02/23/2005)

Explosive	Associated Line	Concentration (µg/L)
2,4 DNT	N Cooling	1.05
2,6 DNT	N Cooling	1.35

29SB83 (12/15/2004)

COC	Depth (bgs)	Concentration (mg/kg)
2,4,6 TNT	4-5 ft	0.43

29WL13 (09/26/06)

COC	Concentration (mg/kg)
2,4,6 TNT	526
2,4 DNT	89
1,3 DNB	1.08

MH09 (02/23/05)

COC	Associated Line	Concentration (µg/L)
2,4 DNT	N Cooling	1.13
2,6 DNT	N Cooling	1.27

MH09 (12/17/2004)

COC	Associated Line	Concentration (mg/kg)
2-amino-4,6-DNT	N Cooling	2.4 J
4-amino-2,6-DNT	N Cooling	2.5 J

MH08 (12/17/2004)

COC	Associated Line	Concentration (mg/kg)
2,4,6 TNT	N Cooling	5.5
2,4 DNT	N Cooling	0.71
2,6 DNT	N Cooling	0.30J

29WL14 (09/27/06)

COC	Concentration (mg/kg)
2,4,6 TNT	58.4
2,4 DNT	7.21
2-amino-4,6 DNT	19 JH
4-amino-2,6 DNT	13.3

32WL05 (09/28/06)

COC	Concentration (mg/kg)
2,4,6 TNT	17JL
2,4 DNT	5.15 JL

MH01 (12/15/2004)

COC	Associated Line	Concentration (µg/L)
2,4,6 TNT	S Cooling	250
2.4 DNT	S Cooling	15
2.6 DNT	S Cooling	4.1
4-amino-2,6 DNT	S Cooling	33

29SB85 (12/15/2004)

COC	Depth (bgs)	Concentration (mg/kg)
2-amino-4,6-DNT	4-5 ft	0.23 J
2-amino-4,6-DNT	8-9 ft	0.9
4-amino-2,6-DNT	8-9 ft	0.3 J

MH02 (12/17/2004)

COC	Associated Line	Concentration (mg/kg)
2,4,6 TNT	S Cooling	11
2-amino-4,6 DNT	S Cooling	3.8 J
4-amino-2,6 DNT	S Cooling	2.6 J

MH05 (02/24/2005)

COC	Associated Line	Concentration (µg/L)
2,4,6 TNT	S Cooling	84.3 JL

MH06 (02/24/2005)

COC	Associated Line	Concentration (µg/L)
2,4,6 TNT	S Cooling	430

Solid residual samples from within TNT transite wastewater lines	
Soil borings near TNT wooden wastewater line	
Solid residual samples from within cooling water lines	
Liquid samples from within cooling water lines	
Indicates COC levels above GWP-Ind	
Indicates COC levels above GWP-Ind and SAI-Ind	
Indicates COC levels above GWP-Ind	

COC	GWP-Ind (mg/kg)	SAI-Ind (mg/kg)
1,3,5-TNB	310	31,000
1,3-DNB	1	100
2,4,6 TNT	5.1	510
2,4 DNT	0.042	4.2
2,6 DNT	0.042	4.2
2-amino-4,6-DNT	1.7	170
4-amino-2,6-DNT	1.7	170

NOTES:
This figure shows only sample concentrations that exceeded MSCs except soil boring data; all detections were included for the soil boring data.
Data associated with the green highlighted locations was collected during the Phase I and II RFI's and USEPA determined the data are not valid for environmental decision making.
Abbreviations:
bgs – below ground surface
COC – contaminant of concern
DNT - Dinitrotoluene
ft – feet
GWP-Ind – soil MSC for industrial use based on groundwater protection
J – The analyte was positively identified; the reported value is the estimated concentration of the constituent detected in the sample analyzed.
JL - The analyte was positively identified; the reported value is the estimated concentration of the constituent detected in the sample analyzed. Result may be biased low.
JH - The analyte was positively identified; the reported value is the estimated concentration of the constituent detected in the sample analyzed. Result may be biased high.
mg/kg – milligrams per kilogram
MSC – medium-specific concentration
N – north
NA – not applicable
S - south
SAI-Ind – soil MSC for industrial use based on inhalation, ingestion and dermal contact.
TNT - Trinitrotoluene
µg/L - microgram per liter

LEGEND
- Soil Boring
- Water Sample from Line or Man Hole
- Solid residual Sample from Line or Man Hole
- Water Line Sample
- TNT Cooling Water Drain Line (North)
- TNT Cooling Water Drain Line (South)
- TNT Wastewater Line
- Stream
- Road
- Building
- Site LHAAP-29

DATA SOURCES: Shaw, 2010, Final Feasibility Study, LHAAP-29, Former TNT Production Area, Group 2, Longhorn Army Ammunition Plant, Karnack, Texas, December.

DISCLAIMER: Map information was compiled from the best available sources. No warranty is made for its accuracy or completeness.

WASTEWATER AND COOLING WATER LINES SAMPLE RESULTS
LHAAP 29
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

0 250 500
FEET

FIGURE 2-13

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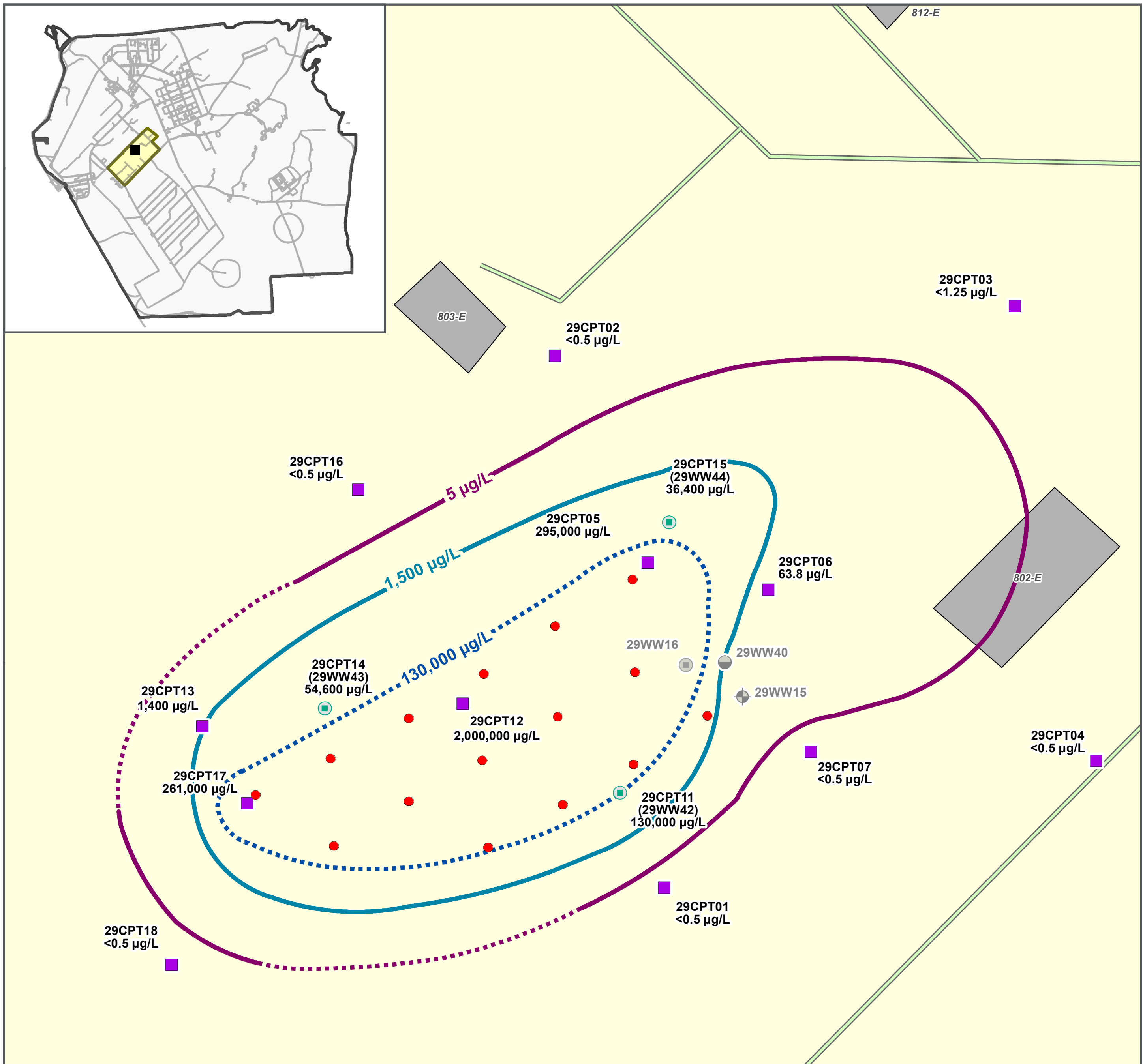
Figure 2-14. Conceptual Layout for ERH Electrodes



LEGEND

- Electrode Boring with Co-Located SVE Well
- Intermediate Zone Soil Boring (2014)
- Intermediate Zone Well (2014)
- Deep Zone Well (2006)
- Intermediate Zone Well (1998)
- Shallow Zone Well (1998)
- Inferred MC DNAPL Zone Contour (130,000 µg/L ~ 1% Solubility)
- MC Isoconcentration Contour (MCL = 5 µg/L) (Dashed Where Inferred)
- Approximate Outline of MC Exceeding 1,500 µg/L
- TNT Cooling Water Drain Line (North)
- Buildings
- Site LHAAP-29

N

0 15 30
FEET

Notes:
µg/L = Concentrations in micrograms per liter.
< = Concentration below laboratory reporting limit.
DNAPL = Dense Non-Aqueous Phase Liquid
MC = Methylene Chloride

DATA SOURCES:

DISCLAIMER: Map information was compiled from the best available sources. No warranty is made for its accuracy or completeness.

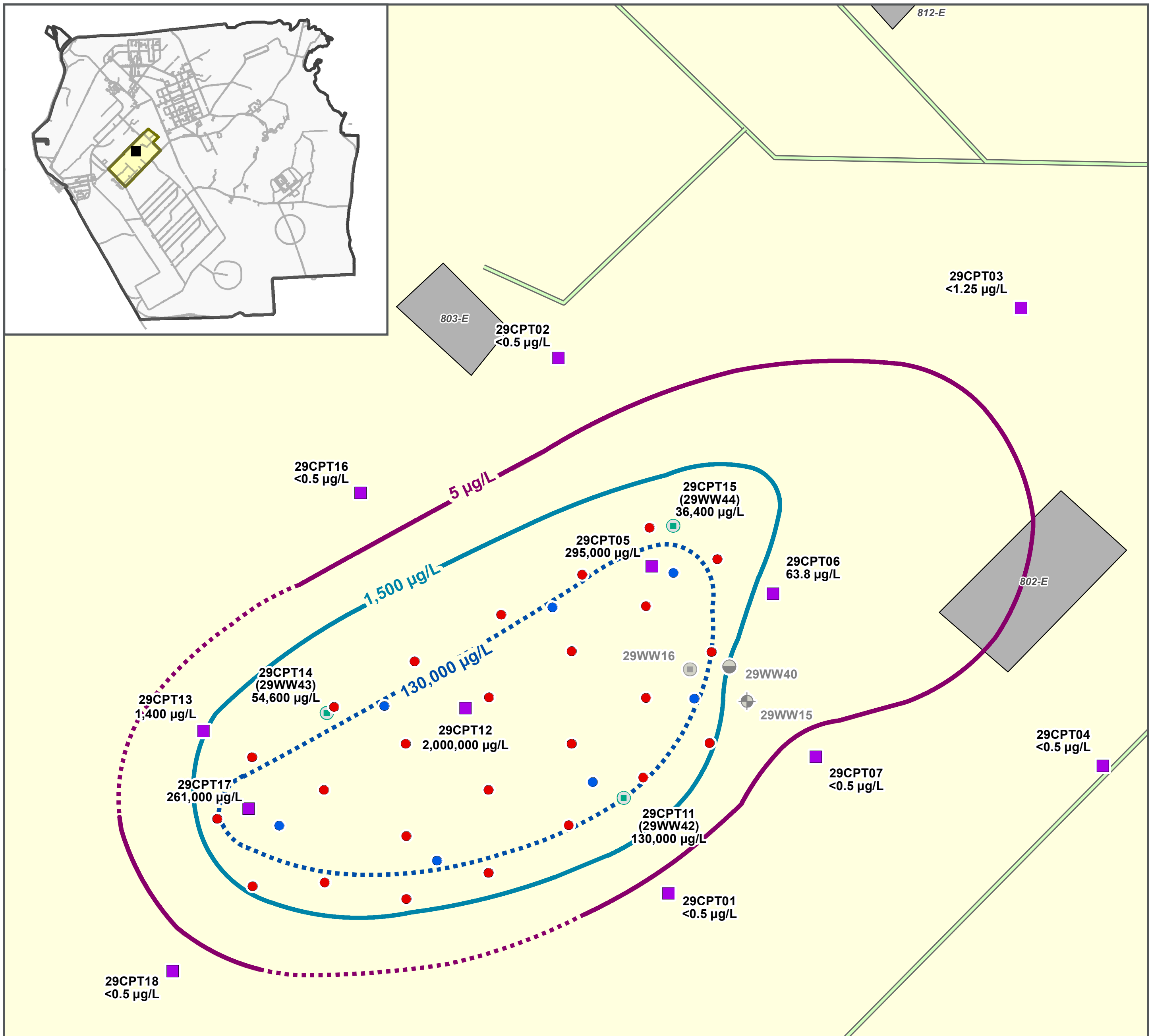
CONCEPTUAL LAYOUT OF ELECTRICAL RESISTANCE HEATING (ERH) WELL NETWORK

LHAAP 29
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

FIGURE 2-14

PATH: J:\2018\18-025_LHAAP_SITES29_47_18AND24_ROD_(WERNER)\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\LHAAP29\LHAAP_29_ROD_CONCEPTUAL_LAYOUT_OF_ERH_WELL_NETWORK.MXD - USER: KLOFGREN - DATE: 5/17/2019

Figure 2-15. Conceptual Layout for TCH Heater Wells



LEGEND

- Heater Boring with Co-Located SVE Well (Proposed)
- Multi-phase Extraction Well
- Intermediate Zone Soil Boring (2014)
- Intermediate Zone Well (2014)
- Deep Zone Well (2006)
- Intermediate Zone Well (1998)
- Shallow Zone Well (1998)
- Inferred MC DNAPL Zone Contour (130,000 µg/L ~ 1% Solubility)
- MC Isoconcentration Contour (MCL = 5 µg/L) (Dashed Where Inferred)
- Approximate Outline of MC Exceeding 1,500 µg/L
- TNT Cooling Water Drain Line (North)
- Buildings
- Site LHAAP-29

N

0 15 30
FEET

Notes:
µg/L = Concentrations in micrograms per liter.
< = Concentration below laboratory reporting limit.
DNAPL = Dense Non-Aqueous Phase Liquid
MC = Methylene Chloride

DATA SOURCES:

DISCLAIMER: Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.

CONCEPTUAL LAYOUT OF THERMAL CONDUCTION HEATING (TCH) WELL NETWORK

LHAAP 29
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

FIGURE 2-15

PATH: J:\2018\18-025_LHAAP_SITES29_47_18AND24_ROD_(WERNER)\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\LHAAP29\LHAAP_29_ROD_CONCEPTUAL_LAYOUT_OF_TCH_WELL_NETWORK.MXD - USER: KLOFGREN - DATE: 5/17/2019

Figure 2-16. Preliminary Land Use Control Boundary, LHAAP-29

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3. 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-29 as presented in the Revised 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. Two public comment periods and public meetings were held, one for the LHAAP-29 PP and one for the Revised PP. Responsiveness summaries for both meetings are provided.

The U.S. Army, USEPA, and TCEQ provide information regarding LHAAP-29 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-29, 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 for the two comment periods and public meetings:

- Transcript of the public meeting held on March 22, 2011
- Presentation slides from the March 22, 2011 public meeting
- Written questions and comments from the public during the public comment period pertinent to the revised PP, and the U.S. Army response to those comments are provided in **Section 3.1**.
- Transcript of the public meeting held for the Revised Proposed Plan on December 6, 2018
- Presentation slides from the December 6, 2018 public meeting
- Verbal questions and comments (no written questions provided) from the public during the public comment period, and the U.S. Army response to those comments are provided in **Section 3.1**.

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.

2018 Revised Proposed Plan Comments

No written comments were received on the Revised Proposed Plan. Verbal comments and questions were discussed and addressed during the public meeting on December 6, 2018 and are summarized below.

Question/comment: Will the contaminated soil remain at the site?

Response: The estimated 3,900 cubic yards of contaminated soil will be excavated and disposed at a permitted landfill. The Landfill will be selected as part of the remedial design process.

Question/comment: Are they going to fill in the excavation areas?

Response: *What is typically done in these situations is to backfill with clean soil and re-vegetate the area. The specific details will be developed as part of the remedial design, which hasn't happened yet.*

Question/comment: The information presented states the wooden wastewater line has been flushed and abandoned. I would think the wood has rotted by now. Does it still exist, and is there anything more to be done there?

Response: *As part of the Remedial Design, the soil along the wooden TNT wastewater lines will be sampled to confirm that leaching from the lines has not occurred. Results from the confirmation soil sampling may identify additional areas exceeding the cleanup levels, which would require soil excavation and disposal. Additionally, as part of the Remedial Design, the deteriorated wooden wastewater line will be sampled to determine whether contaminants in the line exceed soil cleanup levels and require excavation and disposal.*

Question/comment: Does the cooling water line made of clay still exist? Has it been flushed?

Response: *Yes, the clay line will be flushed and the water sampled.*

Question/comment: I guess they're expecting that there could be some holes in that old clay pipe, so they're going to check it with a camera. And if they see a hole, then they'll check the soil around where that hole was. Because I'm wondering how aren't these falling apart and disintegrated over time.

Response: *The lines haven't disintegrated. They will be flushed and inspected, and if any breaks are found, soil in the vicinity will be sampled to determine if contaminants have leached into the soil.*

Question/comment: There was a process where they were trying microorganisims out in the area near the fire station about three or four years ago. Did that prove to be successful in any way?

Response: *We've performed a treatability study at the old Chemlab. It's different than what we are doing now. We do enhanced bioremediation at two areas, and will begin in a third area soon. We've had good success with this process in these areas. The treatability study at Site 37 was not successful. That bioremediation at LHAAP-37 was aerobic as opposed to anaerobic process, which has been used at the other three plumes. For Site 29, the contaminant is methylene chloride, which is almost at the DNAPL phase (that is a separate phase and not dissolved in groundwater). The concentrations are so high that it is toxic to the microorganisms and they can't degrade the methylene chloride. They can survive around the edges of the plume but not in the main portion. The data and posters provided show that concentrations decrease rapidly as you get further from the center of the plume where the DNAPL is present and indicates that degradation is probably occurring.*

One thing to note about the shallow and intermediate plumes at Site 29 is that they appear to be stable and not migrating due to the geology. The contaminant plumes appear to be contained by clay lenses. This is fairly unusual but in this case is helpful.

Question/comment: *In heating up the ground that deep is that going to harm the animals or vegetation?*

Response: *We don't expect the soil at or near the ground surface to be heated up to temperatures that could harm animals or vegetation. The heating will occur in the subsurface in the contaminated zone at 45 feet below ground surface. The heater wells or electrodes will be placed at that depth so that only the main part of the plume will be targeted to be heated to the highest temperatures (up to 140 degrees F). There will be a halo of warmed up soil and groundwater around the primary area though. That is considered possibly beneficial to help with destruction of VOCs in the shallower groundwater zone, but we're not sure just how much that might happen or the extent of the warming to shallower depths.*

Question/comment: Are we going to see clearing of that land and taking trees and dirt and everything out for these heating wells?

Response: *Much of the surface area was cleared of low-growing vegetation for the previous investigations and well installation. Some regrowth has occurred and there will have to be some vegetation or tree removal in specific areas that will be excavated, for well installation, and equipment access. That will need to be determined during the remedial design phase. We will try to minimize the amount of environmental damage. We were discussing how to do the work with minimal impact with the regulators and USFWS but we still have to balance that with the need to remove the contamination.*

Question/comment: Are you going to protect this area using fencing or other means?

Response: *During remedial activities, there will be an exclusion zone established to keep people out for safety reasons. One of the gates might need to be closed for a time while there is work going on.*

Question/comment: Is thermal desorption new, is it a proven practice?

Response: *This technology has been around for five to ten years. Because we have DNAPL at depth and there aren't many options to clean it up, we're anticipating that this approach will be able to vaporize the DNAPL so we can remove it.*

Question/comment: Earlier you mentioned that deep groundwater, beyond 88 feet is not contaminated, that this DNAPL is in the intermediate zone?

Response: *That is correct. There are monitoring wells in the deep zone that confirm the contamination does not extend to that zone.*

Question/comment: Once the decision has been made, will you go out with another contractor or will this company be the one to do the work?

Response: *We will have a separate remedial design and potentially a separate remedial action contract.*

Question/comment: This contamination has been here so long, hasn't the damage been done? Is the fear of migrating what is urging us to want to remove it completely? Not a lot has been damaged so why are we doing all this and planning to spend millions of dollars for this?

Response: *At other sites there is a visible risk to surface water. At this site the DNAPL in the intermediate groundwater is actually considered a principal threat waste because it will continue to* *contaminate groundwater. The EPA regulations require that a principal threat waste must be remediated. In addition, even though the plumes aren't moving, there are Federal and State of Texas regulatory requirement to return groundwater to beneficial uses whether we're using it or not, so remedial action is still required. Before 2009 if the groundwater wasn't being used you could let it go, but EPA's rules changed with regard to groundwater and now it is required to return all groundwater to its beneficial use. We have a small area of soil that is an ecological risk that must be remediated.*

Question/comment: You've said you don't know what future uses [of groundwater] might be and that scares me. We went through a long process for this to become a refuge and now you're saying there is an opportunity for someone to come in and take the property and use it for another use?

Response: *That is not the intent at all. There are only two ways the property could come out of refuge property, a congressional act or some type of transfer to another federal agency. There is very limited potential for this to happen and is not anticipated. Everything that's being done has the anticipated use as a refuge and the regulatory requirement with regard to returning groundwater to beneficial uses is the driver for the remedial action planning. There are sites throughout the nation where this is required so Longhorn is not being required to do more than other sites.*

Question/comment: The Caddo Lake Institute has a third party contaminant expert who reviews these documents and he finds this to be a good plan. His largest question is the depth and extent of the DNAPL and that has been answered. I wanted to share with the community that he found this to be a good plan.

Response: *Thank You*

2011 Proposed Plan Comments

Question/comment: Remedial Alternatives 2 and 3 includes Excavation and Offsite Disposal of Soil, but no amount is given. How many acres within site 29 are we talking about? How deep would the excavation go? How many cubic yards are proposed to be removed from site 29?

Response: *Based on comparison of concentrations versus cleanup levels, several excavation locations are identified to various depths. Confirmation samples will be collected to verify the cleanup levels are met. Excavation will continue until the cleanup levels are attained in both the vertical (floor) and horizontal (walls) directions. Thus, the actual excavation size and depth may vary from the proposed excavations.*

The proposed excavation areas to mitigate human health risk are:

- *Area around 29SD46 – explosives contaminated soil with the approximate dimensions of 120 feet by 20 feet to a depth of 1 foot and an estimated total volume of 90 cubic yards (cy).*
- *Area around 29SB86 – perchlorate contaminated soil with approximate dimensions of 100-foot diameter circle to a depth of 10 feet and an estimated volume of approximately 2,900 cy.*

The proposed excavation areas to mitigate ecological risk by removal of explosives contaminated soil are:

- *Area around 29SB08 (former Building 802-A) – approximate dimensions of a 60-foot diameter circular area and an estimated volume of approximately 200 cy.*
- *Area around 29DLineWHW01 – stained soil around former Building 806-D and former Building 806-A, with an estimated volume of approximately 30 cy.*
- *Area around 29SD13, 29SB15, and GPS-12 (cooling water ditch north of Avenue D), 150 feet by 20 feet, approximately 440 cy.*

In total, the areas are less than a half-acre with a volume of approximately 3,900 cy.

Question/comment: It is a poor plan for the Army to waste money flushing and plugging the old TNT wastewater, and cooling water lines at site 29 in hope it removes the dangerous chemicals contaminating the groundwater. This is not a cure for the problem. Given the high concentration levels of dangerous chemicals listed, these lines should be dug up and disposed of. Any contaminated soil adjacent to the lines caused by leakage from the lines should be dug up as well and disposed of. By doing this, it for sure resolves the problem by preventing further contamination to groundwater.

Response: *The contamination in the lines has the potential to cause contamination in the groundwater only if there is no action and the contamination remains in the lines and the line deteriorates to allow water to infiltrate or the contamination to come into contact with the soil. Currently, there is no evidence that the explosive residue in the lines has caused the isolated shallow explosive groundwater plumes, as they are not located adjacent to the lines. Explosive soil contamination that poses a potential to leach into the groundwater was identified in the surface soil. (These areas are proposed for excavation as described in the previous response.) The samples collected from the subsurface soil adjacent to the TNT wastewater lines do not have explosive concentrations exceeding the groundwater protection standard, or do not indicate contamination that poses a potential to leach into the groundwater.*

Additionally, as part of the RD, confirmation soil samples will be collected adjacent to the North and South Cooling Water lines as well as the TNT wastewater lines to confirm that leaching from the lines has not occurred.

Over time, the lines may eventually deteriorate or break down. After line flushing, no contamination (no solid or liquid residue) will remain in the lines; therefore, there will be no groundwater infiltration and transport of contaminants as the lines deteriorate. The lines will remain buried below ground and since the lines do not contain any liquid or soil residue, they cannot leak and cannot be a conduit for contaminating the surrounding soil or groundwater from past operations at the site.

Question/comment: Several comments have been received regarding the mitigation of the TNT transite process wastewater line and the two cooling water lines (North and South) as follows:

- All Lines –
  - What is the procedure to plug the lines? Plugging the inlets and outlets to prevent water from infiltrating and transporting may not be correct because the lines may develop leaks, as the seals will eventually fail.

  - What is the length of the lines, diameter, how deep they are buried, and about how much it would cost to remove or excavate and dispose of the lines off site?
- TNT process wastewater line – How will it be determined whether high concentrations of contaminants remain in the TNT wastewater line after it is flushed? How will lines be sampled if not accessible by a manhole?
- Cooling water lines –
  - For the RD evaluation only two locations along the northern cooling water line will be sampled. This is not sufficient to characterize contamination along the entire northern line. High concentrations of contaminants have been found at other locations along the northern line. Most of the line has not been sampled because it is not accessible through manholes.
  - The southern cooling water line will not be sampled for the RD evaluation even though high concentrations of contaminants have been found in the line. As with the northern line, most of the southern line has not been sampled because it is not accessible through manholes.
  - If the cooling water lines are flushed, the Army has not explained how it will determine whether high concentrations of contaminants remain in the lines after flushing.

Response: *To clearly describe the lines and the approach to the selected remedy, it must be understood that there are two distinctly different processes that generated the liquid flowing through these lines and remaining residue. Thus, a discussion of each line to address the above comments is presented below:*

<u>TNT Process Wastewater Line</u> – The TNT wastewater line carried away process wastewater from the washing process during TNT production (also known as “red water, yellow water, red liquor and yellow liquor”). The TNT wastewater line carried wash water from the process and is expected to have some solids in it (5 to 15%). The wastewater was pumped and treated at the wastewater treatment plant (LHAAP-32). This line was originally installed as a wooden line before the transite line was installed. Historical documentation (Bate Stamp 001446, RCRA FA, April 1988) indicated a wooden TNT line (a.k.a. red water line) was used for a short time before the transite line was put into service. The wooden line was “clear-flushed” in 1946 and abandoned. It was determined that no further action was necessary for this line (Bate Stamp 001446). During investigation activities, the wooden TNT wastewater line was found 5 feet south of the transite TNT process wastewater line. The wooden line was cut to allow sampling of the contents. Although the sample results indicated the presence of explosives, the data was later determined by EPA to be unsuitable for environmental decision-making. Because the line is deteriorated and has been cut in multiple locations, the line cannot be flushed. Instead, the line contents and surrounding soil will be sampled and then excavated and disposed offsite if required.

The TNT transite process wastewater line is approximately 3 feet bgs. The gravity flow portion of the line is approximately 3,000 linear feet. The pressurized portion of the line is approximately 500 linear feet, and the lines are in good condition. The diameter of the TNT transite process wastewater line along the entire line is not known but should range from 8 inches to 18 inches based on the original *design of the wooden stave line. There are no manholes in the transite line, and the line will be cut at select locations for any additional sampling and the implementation of the remedy.*

For the investigation, the gravity fed portion of the line was cut at two locations and a thick viscous residue was observed. Samples were collected at these two locations. Samples were also collected at two points along the pressurized portion of the line that extends from the former pump house location to LHAAP-32, located north of LHAAP-29. Since explosives were identified in the viscous residue in the gravity fed portion of the line, it is assumed that this residue remains throughout the line and the samples were representative.

Thus, the selected remedy is to flush the line with potable water. The exact procedure will be developed in the RD, but generally the flushing will be conducted in segments since the line was broken during the investigation phase and the line is no longer a single continual run of pipe. Visual verification that the residue is not sticking to the sides of the pipe will also be conducted. The flush water will be containerized, sampled for waste characterization, and properly treated or disposed. Flushing will ensure that no residual material is left in the lines. Thus, even if the pipes break in the future, there is no contamination remaining to leach. After flushing, the inlets and outlets of the TNT wastewater line will be plugged with a bentonite slurry mix or cementitous grout to stop future infiltration. The procedures for the plugging activities will be included in the RD.

The transite TNT wastewater line is a combination of cement and asbestos that, when disturbed, can become friable and pose additional risk. Exposure to friable asbestos requires special handling and disposal requirements, increasing risks to workers through exposure by the process of digging the lines out of the ground (causing the material to become friable), handling the pieces onsite and during the subsequent transportation and disposal. The location of the line remaining in place will be surveyed and filed with the County. Since the TNT wastewater line is asbestos, the county notification will provide information on the existence and location of the transite line in order to avoid disturbing the line in the event future excavation or other activities are being planned in the area. Additionally, the depth of the line is deeper than the 2 feet bgs, the depth used for industrial use. Since no residue would remain in the lines after flushing, no contamination would remain in the line or have the potential to contaminate the surrounding soil or groundwater even if the line would deteriorate. Additionally, the removal of the line will impact a large area of the site that is currently covered with mature trees and native vegetation.

<u>Cooling Water Lines</u> – The TNT manufacturing process generated a lot of heat; cold water was used to cool the reaction equipment. It flowed over the equipment and down a drain into the cooling water drain lines. Thus, the cooling water lines carried water and would not have carried solids. There were two lines, the North and South Cooling Water (a.k.a. blue cooling water lines) lines, that were gravity fed lines constructed of vitrified clay pipe with manholes. The cooling water from six production plants flowed into the two main collection lines (North and South). The main cooling water lines are approximately 5,000 feet, with approximately 280 feet of smaller line at each of the six production plants. The lines are approximately 8 feet bgs and range from 8 to 18 inches in diameter. The lines drain into a ditch along 16th Street which eventually flows into Goose Prairie Creek.

Small amounts of solid sediment residue and water were found during the investigations of the pipeline. Samples collected from some of the manholes detected explosives in both the solid residue and water at concentrations above the cleanup levels. These lines only carried water, and the solids found in the manholes during investigations are expected to be from open inlets after demolition of *the facility and through the open manholes. The manholes are low spots in the lines where several lines intersect and solid residue would collect at these locations. It stands to reason that minimal solid residue is expected to be found in the actual lines between the manholes. An attempt will be made to collect additional solid residue samples from the manholes during the remedial action.*

For the selected remedy, each manhole and outlet will be inspected prior to flushing. The exact procedure will be developed in the RD, but generally the flushing will be conducted between two manholes. The rinsate water will be containerized, transported, sampled, analyzed, and treated at the onsite groundwater treatment plant or appropriately disposed off-site based on the explosives concentrations. After flushing of the lines, there would be no solid residue remaining in the pipe to conduct additional sampling of the solids; however, the flush water will be tested. Thus, even if the pipes break in the future, there is no contamination remaining to leach. The manholes will then be plugged with a bentonite slurry mix or cement grout. The procedures for the plugging activities will be included in the RD.

Question/comment: The Army claims that "…soil samples collected near the line indicate there has not been a release to the surrounding soil." This is incorrect. Sample collected from soil borings along the line were found to contain TNT, 2-amino-4,6-DNT, and 4-amino-2,6-DNT.

Response: *The commenter is referencing the samples collected near the wooden TNT process wastewater line, which is 3 feet bgs. Soil samples were collected in 2004 near the line 4 to 5 feet bgs to evaluate the potential of contaminants leaching from the line and contaminating the surrounding soil. Table 2-6 from the FS summarizes the detected results. Even though samples were found to contain TNT, 2-amino-4,6-DNT, and 4-amino-1,6-DNT, the concentrations are less than both the SAI-Ind and GWP-Ind. Sampling of the wooden TNT process wastewater line and associated soil will take place during the remedial design phase, and if the results indicate unacceptable levels of explosives are present, excavation and disposal off-site of the material will take place during the remedial action phase.*

Question/comment: *The Army estimates that it will take 90 years for natural attenuation to reduce contaminant concentrations acceptable levels. It is not reasonable to propose a plan that could require the maintenance of LUCs for almost a century.*

Response: *All alternatives evaluated have a long time for restoration. Given the nature of the residual contaminants that are present at LHAAP-29, 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. The reasonably anticipated future use of the site is as a national wildlife refuge (i.e. Caddo Lake National Wildlife Refuge). 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. This proposed transfer as a national wildlife refuge, which by its very nature includes physical access and use restrictions, is subject to control and continual inspection by Refuge personnel. Also, the property is intended to remain under ownership and management of a federal government agency. The LUC 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.*

Question/comment: The extremely high concentration of methylene chloride in the intermediate groundwater zone indicates that DNAPL may by present. If so, it may be very difficult to clean up the groundwater. The Army does not appear to have developed any plans to deal with DNAPL. The Army should explain how it will deal with any DNAPL that may be present.

Response: *The current active remedy to conduct in-situ thermal desorption will reduce contaminant concentrations even if DNAPL is present.*

Question/comment: High concentrations of arsenic, mercury, and selenium exist in the shallow groundwater zone. High concentrations of arsenic exist in the deep groundwater zone. The metals are not subject to natural attenuation by biodegradation and the Army has not explained how they will be cleaned up. The Army should explain how it will cleanup these metals.

Response: *The elevated concentrations of metals were suspected to be a result of sampling methodology and/or turbid samples which could falsely elevate the metals concentration result due to excess solids in the sample. Subsequent sampling and redevelopment of some of the wells resulted in lowered concentrations of some metals.*

The arsenic sample collected from the deep well had high aluminum concentrations; the geochemical relationship between the high aluminum in the same sample as the arsenic indicates arsenic may be naturally occurring. Mercury detections are intermittent and appear to be isolated and the calculated Hazard Index for mercury is less than 1, based on the Final Baseline Human Health and Screening Ecological Risk Assessment for Group 2 Sites, from Jacobs Engineering Corp., 2002.

The extent of arsenic and mercury in groundwater will be assessed site-wide during the remedial design. Selenium was only detected above the MCL in one shallow well and the concentrations have fluctuated over the years. The most recent concentration has an associated adjusted hazard quotient value of 0.15. Selenium will be added as a contaminant of concern.

Question/comment: The current distribution of groundwater contaminants at site 29 is not well known. This is because the Army has not sampled many of the monitor wells (18 of 47) since 2005, and has not sampled any monitor well since 2009. In addition, many of the most recent sample analyses are incomplete. No wells have been analyzed for explosives or perchlorate since February 2007.

The only way to ensure that the current distribution of contaminants is known is to sample all the monitor wells at the site. They should be sample for solvents (e.g., methylene chloride, TCE), explosives (e.g., TNT, 2,4-DNT), metals (e.g., arsenic, mercury), and perchlorate. The Army should do this before it completes the design of the groundwater cleanup plan.

Response: *The analytical suites selected for investigations were based on the past operations that could cause potential contamination at LHAAP-29. Initial investigations had several analytical suites which were reduced to refine the nature and extent of those chemicals that were detected above screening levels. During the remedial design phase, additional data will be gathered to verify plume boundaries, develop monitoring networks, and determine concentrations for the treatment.*

Question/comment: The Army's proposed cleanup plan does not address high concentrations of dangerous chemicals in surface water. The Army should either 1) explain why it is unnecessary to cleanup surface water, or 2) prepare a plan to clean it up.

Response: *The surface water sample collected at 29SW46 has the highest contamination and is located at the cooling water ditch outfall. Both surface water and sediments at this location were sampled and concentrations in the surface water and sediments were above the groundwater MSC for residential use and GWP-Ind levels for explosives, respectively. This location is the outfall of the cooling water lines and is collocated with the high sediment levels which will be removed as part of the selected remedy. The next sample location downgradient of 29SW46 did not show high concentrations of contaminants in the surface water. Thus, the action to remove residual contamination from the cooling water lines (so water cannot infiltrate them and carry contamination into the ditch) and to remove the contaminated sediment where the surface water sample was collected will mitigate impacts to surface water along the cooling water ditch. Also, as part of this action, surface water monitoring will be conducted downgradient of this mitigated area.*

Question/comment: Major components of the cleanup are yet to be determined. These include the evaluation of the cooling water lines, and details of: the plan to monitor metals near the in-situ oxidation area, the soil excavation plan, the groundwater monitoring plan, and MNA implementation. These components will be presented in the RD, which will be completed after the Record of Decision is published. Given the importance these components, the Army should make the RD available for public review and comment as soon as possible.

Response: *The public will be provided with updates on remedial design and remedial action status through the RAB meetings and any concerns can be addressed through this forum. The RAB meetings provide the forum for dissemination of information and discussion. The RD will include performance objectives, schedule and other design criteria and will follow established regulatory guidance for the components of the remedy. The RD will also become part of the Administrative Record and will be available to the public at the Marshall Public Library, the public repository for the LHAAP Administrative Record.*

Question/comment: Recommend expanding environmental testing to include all six isomer of DNT (2,4-DNT, 2,6-DNT, 3,4-DNT, 2,3-DNT, 2,5-DNT and 3,5-DNT), site characterization and evaluation of human health risk should incorporate and consider all six isomers of DNT in all media, and corresponding enforceable remedial goals should be established for the four minor isomers of DNT for soils, sediments, groundwater, and surface water. In the event the presence of minor isomers of DNT is confirmed, there may be potential impacts to aquatic ecosystems that should be addressed.

Response: *The selected remedy will address and monitor the explosive contaminated shallow groundwater and surface water. At this time, there are no Federal or State of Texas promulgated screening levels for DNT isomers, other than for 2,4-DNT and 2,6-DNT. However, as part of the CERCLA process, the statutory five-year reviews will evaluate the effectiveness of the remedy, including any changes in applicable or relevant and appropriate requirements (ARARs) concerning DNT isomers, and would recommend implementation of other measures if needed.*

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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Appendix A

Public Notice Affidavits

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THE MARSHALL NEWS MESSENGER
The Marshall News Messenger
309 E Austin
Marshall, TX 75670

Phone:**(903) 935-7914** Fax:**(903) 935-6242** Email:

11/02/18

AFFIDAVIT OF PUBLICATION

State of Texas)

County of Harrison)

This Affidavit of Publication for the Marshall News Messenger, a daily newspaper of general circulation, printed and published at Marshall, hereby certifies that the attached legal notice, ad # 623368, was published in said newspaper on November 7, 2018, and that copies of each paper in which said Public Notice was published were delivered by carriers to the subscribers of said paper, according to their accustomed mode of business in this office.

Dianne Gray
for the Marshall News Messenger

The above Affidavit and Certificate of Publication was subscribed and sworn to before me by the above-named Dianne Gray, who is personally known to me to be the identical person in the above certificate on this 12th day of November, 2018.

Dana Morton
Notary Public in and for
State of Texas)
County of Harrison)

My commission expires 3-21-21

DANA MORTON
Notary Public, State of Texas
Comm. Expires 03-21-2021
Notary ID 2485572

NOTARY PUBLIC STATE OF TEXAS

ad id: 623368

PUBLIC NOTICE

THE UNITED STATES ARMY INVITES PUBLIC COMMENT ON THE REVISED PROPOSED PLAN FOR ENVIRONMENTAL SITE LHAAP-29, FORMER TNT PRODUCTION AREA LONGHORN ARMY AMMUNITION PLANT, TEXAS PUBLIC MEETING ON December 6, 2018 AT THE KARNACK COMMUNITY CENTER, KARNACK, TX

The U.S. Army is the lead agency for environmental response actions at Longhorn Army Ammunition Plant. In partnership with the U.S. Environmental Protection Agency Region 6 (USEPA), the lead Oversight Agency, and Texas Commission on Environmental Quality the Supporting Agency the U.S. Army has developed the Revised Proposed Plan for site LHAAP-29, Former TNT Production Area. Although the Revised Proposed Plan identifies the preferred remedy for the site, the U.S. Army welcomes the public's review and comments. Beginning on November 21, 2018, copies of the Revised Proposed Plan and supporting documentation will be available for public review at the Marshall Public Library, 300 S. Alamo, Marshall, Texas, 75670 and on the LHAAP website at http://www.longhornaap.com/LHAAP29. The public comment period is November 21, 2018, through December 21, 2018. **The public meeting will be held on Thursday, December 6, 2018 at the Karnack Community Center, Karnack, TX beginning at 6:00 PM and ending at 7:30 PM.** The Karnack Community Center is located at Highway 134 and Spur 449 near the front gate of the Caddo Lake National Wildlife Refuge. Questions, comments, and responses on the Revised 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 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 production of secondary explosives, rocket motor propellants, and various pyrotechnics. 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-29, former TNT Production Area, encompasses approximately 85 acres in the west-central portion of LHAAP. The site was used as a TNT manufacturing facility from October 1942 to August 1945. The facility produced approximately 400 million pounds of flake TNT during its operation using six TNT production lines. Since the end of World War II, the only activity that has been documented to have occurred at LHAAP-29 is the "wash out" of solvent bath of out-of-specification rocket motors. This took place from 1959 to the mid-1970s and involved the use of a methylene chloride-based industrial solvent.

The Revised Proposed Plan for LHAAP-29 addresses contamination in soil, process lines, and groundwater at LHAAP-29. The full list of alternatives evaluated is: 1) No action; 2) Excavation and off-site disposal of soil, flushing and plugging of process lines, monitored natural attenuation (MNA) for shallow groundwater, in situ chemical oxidation followed by MNA for intermediate groundwater, and land use controls (LUCs); 3) Excavation and offsite disposal of soil, flushing and plugging of process lines, groundwater extraction for intermediate groundwater, MNA for shallow groundwater, and LUCs; 4) Excavation and offsite disposal of soil, flushing and plugging of process lines, in situ thermal desorption for intermediate groundwater, MNA for shallow groundwater, and LUCs. Based on available information, the preferred remedy is Alternative 4, which would remove contaminated soil from LHAAP-29 with off-site disposal; flush and plug process lines thereby eliminating potential for contaminants to leach into groundwater; reduce groundwater contamination throughout the intermediate groundwater contaminant plume via in situ thermal desorption and MNA; use MNA for shallow groundwater to assure protection of human health and the environment by documenting that the contaminated groundwater remains localized and contaminant concentrations are being reduced to cleanup levels; and implement LUCs to protect human health by preventing exposure to contaminated media.

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 email rose.m.zeiler.civ@mail.mil.

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The Times

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Notice published in the Times on 11/07/18

(Signed)[signature]

[signature] 11/7/2018

(Notary)

MELANIE C ALTZ
MY COMMISSION EXPIRES
NOV. 19 2019
NOTARY PUBLIC, STATE OF NEW JERSEY

PUBLIC NOTICE

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November 7, 2018