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

March 2, 2020

DAIM-ODB-LO

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

Re: LHAAP-18/24 Record of Decision, December 2019
Longhorn Army Ammunition Plant, Karnack, Texas

Dear Mr. Rhotenberry,

Enclosed please find the December 2019 LHAAP-18/24 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 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:

A. Palmie, TCEQ, Austin, TX
P. Bruckwicki, Caddo Lake NWR, TX
P. Werner, HDR
A. Williams, USACE, Tulsa District, OK
A. Maly, USAEC, San Antonio, TX
K. Nemmers, Bhate
R. Smith, USACE, Tulsa District, OK

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

March 2, 2020

DAIM-ODB-LO

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

Re: LHAAP-18/24 Record of Decision, December 2019
Longhorn Army Ammunition Plant, Karnack, Texas

Dear Ms. Palmie,

Enclosed please find the December 2019 LHAAP-18/24 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 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:

W. Rhotenberry, USEPA, Dallas TX
P. Bruckwicki, Caddo Lake NWR, TX
P. Werner, HDR
A. Williams, USACE, Tulsa District, OK
A. Maly, USAEC, San Antonio, TX
K. Nemmers, Bhate
R. Smith, USACE, Tulsa District, OK

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Protecting Texas by Reducing and Preventing Pollution

February 6, 2020

Mr. Thomas E. Lederle
Chief, DCS G-9 BRAC Division
2530 Crystal Drive, Suite 1400
Taylor Bldg./NC3
Arlington, VA 22202

Subject: Record of Decision for LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond, 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-18/24, Burning Ground No. 3 and Unlined Evaporation Pond, Longhorn Army Ammunition Plant Federal Superfund Site in Karnack, Texas on January 9, 2020. 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

P.O. Box 13087 • Austin, Texas 78711-3087 • 512-239-1000 • tceq.texas.gov

Final

Record of Decision

for LHAAP-18/24,
Burning Ground No. 3 and
Unlined Evaporation Pond
Longhorn Army Ammunition Plant
Karnack, Texas

December 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

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Final

RECORD OF DECISION

FOR

LHAAP-18/24, BURNING GROUND NO. 3 AND UNLINED EVAPORATION POND

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

December 2019

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Acronyms and Abbreviations

µg/kg	micrograms per kilogram
µg/L	micrograms per liter
ACD	air curtain destructor
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
CDM	Camp, Dresser & McKee
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	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
DCE	dichloroethylene
DNAPL	dense non-aqueous phase liquid
DPT	Direct push technology
ECP	environmental condition of property
EEQ	ecological effects quotient
EISB	Enhanced in-situ bioremediation
EPC	exposure point concentration
EPS	Environmental Protection Systems
ERH	Electrical resistance heating
ESD	Explanation of Significant Differences
EVO	emulsified vegetable oil
FBR	fluidized bed reactor
FFA	Federal Facility Agreement
FS	Feasibility Study
ft	feet
ft^2	square feet
gpm	gallons per minute
$^{GW}GW_{Ing}$	Tier 1 Residential Groundwater Protecive Concentration Level (PCL)
GWQA	Groundwater Quality Assessment
GWP-Ind	TCEQ soil MSC for industrial use based on groundwater protection
GWTP	Groundwater treatment plant
HDR	HDR Environmental, Operations and Construction, Inc.
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HQ	hazard quotient
ICT	interceptor-collection trench
IRA	Interim Remedial Action
IRIS	Integrated Risk Information System
ISM	In Situ Microcosm
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
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
NA	natural attenuation
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOAEL	no-observed adverse effect level
NPL	National Priorities List
O&M	operation and maintenance
ORC	oxygen release compound
OSHA	Occupational Safety and Health Administration
PCE	tetrachloroethene
PCL	Protective concentration level
PP	Proposed Plan
PPE	Personal protective equipment
PSI	Post-Screening Investigation
RAB	Restoration Advisory Board
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RfD	reference dose
RI	remedial investigation
ROD	record of decision
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SF	slope factor
Shaw	Shaw Environmental, Inc.
SIP	stable isotope probing
STEP	Solutions to Environmental Problems, Inc.
SVE	soil vapor extraction
SVOC	semivolatile organic compound
TAC	Texas Administrative Code
TCA	trichloroethane
TCDD	tetrachlorodibenzo-p-dioxin
TCE	trichloroethylene
TCEQ	Texas Commission on Environmental Quality
TCH	Thermal conduction heating
TEC	toxicity equivalence concentration
TNB	trinitrobenzene
TNT	trinitrotoluene
TOC	total organic carbon
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
UEP	Unlined Evaporation Pond
U.S.	United States
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
UTL	Upper tolerance limit
UU/UE	unlimited use/unrestricted exposure
VC	vinyl chloride
VOC	volatile organic compound
yd^3	cubic yards
ZVI	zero-valent iron

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1. The Declaration

1.1 Site Name and Location

Longhorn Army Ammunition Plant (LHAAP) -18/24, Burning Ground No. 3 and Unlined Evaporation Pond (UEP)
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-18/24, Burning Ground No. 3 and UEP, located at LHAAP in Karnack, Texas. The remedy was chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 (42 U.S.C. §§9601, et seq.), 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 et seq.

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], 2007), baseline ecological risk assessment addendum (BERA) report (AGEISS, 2014), feasibility study (FS) (AECOM, 2017), post-screening investigation (PSI) (AECOM, 2013), updated PSI (AECOM, 2016a), and supplemental to updated PSI (AECOM, 2016b) and proposed plan (PP) (U.S. Department of the Army [U.S. Army], 2019).

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 Texas Commission on Environmental Quality [TCEQ]) entered into the Federal Facility Agreement (FFA) for remedial activities at LHAAP which became effective on December 30, 1991. The USEPA (Region 6) and the 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 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-18/24 includes enhanced groundwater extraction and treatment, Land Use Controls (LUCs), enhanced in-situ bioremediation (EISB) for Shallow Zone and

Wilcox formation groundwater inside and outside the containment area, thermal dense non-aqueous phase liquid (DNAPL) removal, maintenance of the existing cap over the UEP, unsaturated soil excavation and off-site disposal, Monitored Natural Attenuation (MNA) and long term monitoring.

The final selected remedy for LHAAP-18/24 protects human health and the environment by preventing human and ecological receptors from being exposed 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) are volatile organic compounds (VOCs) (trichloroethylene [TCE], methylene chloride [MC], tetrachloroethene [PCE]) and the anion perchlorate. In the Shallow Zone groundwater, COCs include VOCs (MC, TCE, cis-1,2-dichloroethylene [DCE], PCE, benzene, 1,1,2-trichloroethane [TCA], vinyl chloride, bromodichloromethane, 1,3,5-trinitrobenzene [TNB], and 1,4-dioxane), metals (arsenic, barium, chromium, cobalt, and nickel), and the anion perchlorate. In the underlying Wilcox Formation groundwater, COCs include VOCs (MC, TCE, cis-1,2-DCE, PCE, benzene,vinyl chloride, bromodichloromethane, 1,3,5-TNB,and 1,4-dioxane), metals (arsenic and barium), and the anion perchlorate. Residual MC and TCE DNAPL acting as a source material at two locations in the Shallow Zone and Wilcox Formation groundwater may be considered a principal threat waste at LHAAP-18/24.

The components of the selected remedy are summarized below:

- Continued use of the existing groundwater extraction system, as needed, with enhancements (including a potentially phased reactivation of two existing Interceptor-collection trenches (ICTs) [ICT 3 and 9]) until COC concentrations are low enough that MNA can address remaining contamination within the containment area.
- Continued operation of the current groundwater treatment plant (GWTP), or potentially a new GWTP as needed, will be determined during the remedial design phase. Should treatment for 1,4-dioxane be required, an advanced oxidation process will be implemented as a contingency remedy. Development and specific description of the contingency remedy would be presented in a Remedial Design/Remedial Action Work Plan (RD/RAWP).
- Excavation of unsaturated soil exceeding TCEQ soil medium-specific concentration (MSC) for industrial use based on groundwater protection (GWP-Ind). Additional confirmation soil sampling during the remedial design (RD) will be needed to define the final excavation extent and volume of soil contaminated in the two areas south of the UEP and area west of the UEP.
    - If during the Five-Year Review the results of the groundwater remedy indicate that vadose zone soil under the UEP constitutes a continuing source that requires a response, a contingency remedy to excavate soil beneath the UEP would be developed. Development and specific description of the contingency remedy would be presented in a Remedial Design/Remedial Action Work Plan (RD/RAWP).
- Implementation of enhanced in-situ bioremediation (EISB) of Shallow Zone groundwater outside the containment area at several locations; in the Wilcox Formation at three or more locations, and inside the containment at five or more locations or as needed.
- Implementation of in-situ thermal desorption (ISTD), using either Electrical Resistance Heating (ERH) or Thermal Conduction Heating (TCH), to remove DNAPL in two distinct areas inside the containment area.

- MNA for both Shallow Zone and Wilcox Formation groundwater for areas outside the influence of the treatment areas and for areas inside the influence of the treatment areas (after evaluation of EISB) to reduce contaminant levels to confirm protection of human health and the environment by documenting that the 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).
- Groundwater monitoring will be conducted to evaluate inorganic COCs. The need to continue groundwater monitoring for this purpose will be evaluated at five year intervals.
- Maintenance of existing cap over the former UEP. The need to continue cap maintenance will be evaluated at five year intervals.
- Long-term monitoring and reporting would continue until the cleanup levels are achieved.
- The LUC's objectives include maintaining the integrity of any current or future remedial or monitoring systems, preserving the integrity of the surface impoundment cap over the UEP and to restrict intrusive activities (e.g., digging) that would degrade or alter the cap, 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 U.S. Army will maintain the remedial and monitoring systems associated with the groundwater remedies until these components of the remedy are no longer needed to achieve cleanup levels, and when these levels have been achieved. During the period of operation of the groundwater remedy, if any of the elements of the remedial and groundwater monitoring systems are damaged, destroyed, or become ineffective, they will be repaired or replaced with suitable components to ensure that the remedial and groundwater monitoring systems are able to provide data of the quality necessary to determine the progress of and eventual completion of this component of the remedy. The actions to be taken to implement these LUC objectives and requirements will be provided through modifying the "Comprehensive LUC Management Plan, Former Longhorn Army Ammunition Plant, Karnack, Texas" and detailed in the LUC RD. [1]

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

- 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 (UU/UE). A LUC RD will be finalized as the land use component of the RD. Within 21 days of the issuance of the ROD, the U.S. 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 USEPA 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 2-18**.

- 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 UU/UE. [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 UU/UE. [1]

- The LUC for preserving the integrity of the surface impoundment cap shall include restrictions that prevent intrusive activities that may degrade or alter its effectiveness. Restrictions would include restricting intrusive activities (e.g, digging) that would degrade or alter the cap. These restrictions would remain in place until the underlying source soil is removed and/or the cleanup levels for soil listed in **Table 2-10** have been achieved.

CERCLA five-year reviews will be conducted 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 UU/UE.

Under this remedial alternative, two ISTD technologies (ERH or TCH) will be considered during the Remedial Design phase to treat the high concentration of dissolved VOCs and DNAPL in the Shallow Zone and Wilcox Formation groundwater. While the technology is more expensive, it is very effective in low permeability zones where the majority of the residual DNAPL resides. A removal rate of 99.9% is expected. EISB would be applied to the thermally-treated areas as a polishing step after thermal treatment is completed. LUCs would be implemented to restrict land use to nonresidential uses until it is demonstrated that COCs in soil and groundwater are reduced to levels that would allow for UU/UE. Maintenance of the UEP cap will continue. It is estimated that this alternative allows achievement of the remedial action objectives (RAOs) within 20 years. Considering the lithologic variability, particularly the lateral and vertical change from sand to clay, the times to achieve cleanup levels may vary by an order of magnitude. 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 U.S. 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. The long-term groundwater and surface water monitoring and MNA performance monitoring plan will also be presented in the RD. [1]

The U.S. Army will implement, maintain, monitor, report on and enforce LUCs at U.S. Army-owned property. The U.S. Army shall perform those actions related to land use control activities described in this ROD and in the RD for the ROD. For portions of the Site subject to LUCs that are not owned by the U.S. Army, the U.S. Army will monitor and report on the implementation, maintenance, and enforcement of LUCs, and coordinate with federal, state, and local governments and owners and occupants of properties subject to LUCs. The U.S. Army will provide notice of the groundwater and soil (surface and subsurface) contamination and any land use restrictions referenced in the ROD. The U.S. 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 LUCs. The U.S. Army shall provide the initial notice within 90 days of ROD signature. The frequency of subsequent notifications will be described in the RD for the ROD. The U.S. Army remains responsible for ensuring that the remedy remains protective of human health and the environment. The U.S. 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 U.S. Army-owned property, the U.S. Army will provide written notice of the LUCs to property, 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 U.S. Army shall provide the USEPA 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 U.S. 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 LUCs 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]

The U.S. Army and regulators will consult to determine appropriate enforcement actions should there be a failure of a LUC objective at this Site after it has 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-18/24 is independent of any other remedial action at LHAAP to address human health issues. To address ecological risk, LHAAP-18/24 was grouped with several other sites as part of the Industrial Sub-Area. Ecological hazards were found to be acceptable for the Industrial Sub-Area that includes LHAAP-18/24 (Shaw, 2007a). 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). Therefore, no action is required for environmental receptors.

1.5 Statutory Determinations

The selected remedy is protective of human health and the environment, complies with Federal and State requirements that are applicable or relevant and appropriate for the remedial action, is cost-effective, and provides a permanent solution.

In addition, the remedy offers long-term effectiveness through excavation and disposal of contaminated soil; ISTD DNAPL removal; EISB of shallow and Wilcox Formation groundwater; continued use of the existing groundwater extraction system, as needed, with enhancements; contingency use of advanced oxidation process for ex-situ treatment of 1,4-dioxane in groundwater; and, the implementation of LUCs, 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 remedies will be presented in a RD/RAWP. The selected remedy is easily and immediately implementable and has a moderate cost compared to the other alternatives considered for LHAAP-18/24, with the exception of the no action alternative.

The selected remedy would reduce the toxicity, mobility, or volume of contaminants in the groundwater through active and passive remedial actions. This response will permanently reduce the toxicity, mobility, and volume of source materials that constitute the principal threat wastes at the Site. The thermal treatment and EISB components of the selected remedy satisfy the statutory preference for treatment as principal treatment elements 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.

Unsaturated soil known to contain residual contamination posing a low-level threat to groundwater is isolated to locations south of the former UEP, west of the UEP, and underneath the UEP. The potential leaching of contaminants from the unsaturated soil at these locations to groundwater is considered a complete transport pathway that will be addressed by excavation during the remedial action. The high concentrations of TCE and MC in the shallow zone and Wilcox Formation indicate in two locations that residual DNAPL may be acting as a principal threat waste in the groundwater. Therefore, the presence of source materials in groundwater is considered a complete transport pathway that will be addressed with ISTD during the remedial action.

Because hazardous substances, pollutants, or contaminants will remain at the site above levels that allow for UU/UE, a five-year review will be conducted to confirm 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 UU/UE; 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 UU/UE; 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 sites as a result of the selected remedy (**Section 2.6**).
- COCs and their concentrations (**Section 2.7**).
- Baseline risk represented by the COCs (**Section 2.7**).
- Cleanup levels established for COCs and the basis for these levels (**Sections 2.7.3** 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-18/24 which documents the final selected remedy. The undersigned is the appropriate approval authority for this decision.

2 JANUARY 2020
(Date)

Thomas E. Lederle
Division Chief
Base Realignment and Closure Division
Office of the Deputy Chief of Staff, G9 (Installations)
U.S. Army

The United States Environmental Protection Agency approves the selected remedy as provided in the ROD for LHAAP-18/24.

2/25/20
(Date)

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

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2. Decision Summary

2.1 Site Name, Location, and Description

LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond
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-18/24, 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-18/24 is a 34.5-acre cleared area within a heavily wooded section of LHAAP (**Figure 2-2**). The area is vegetated primarily with grass and has asphalt-paved roads. It is situated on a natural topographic high slightly west of the crest of a small topographic divide between Harrison Bayou and Saunders Branch. Topography of the Site has been altered by operations over the past 35 years. The burning ground area is mostly level with more relief near the western corner and near the northern corner that contains the mounded surface of the former UEP. There are no surface water bodies or watercourses running through LHAAP-18/24. Surface drainage occurs in all directions, but flow is generally directed to the north and west by both natural and manmade ditches and drainage swales towards Harrison Bayou. Harrison Bayou drains into Caddo Lake which is located approximately 2.5-miles northeast of LHAAP-18/24 (Jacobs, 2001).

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 trinitrotoluene (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-18/24 is comprised of the former Burning Ground No. 3 (LHAAP-18) and UEP (LHAAP-24). LHAAP-18 Burning Ground No. 3 operated between 1955 and 1998, while LHAAP-24 UEP was operational from 1963 to 1984. The area was used for the treatment, storage, and disposal of solid and liquid explosive, pyrotechnic, and combustible solvent waste by open burning/open detonation, incineration, evaporation, and burial (Jacobs, 2001). The UEP was used to collect water from the washout of rocket motor casings and process waste sumps. Sludge from the UEP was removed in 1986 and the impoundment was capped. The majority of impacts to the soil were remediated during the 1997 LHAAP-18/24 Interim Remedial Action (IRA) when approximately 32,000 yd^3 of soil was removed. A groundwater extraction system incorporating approximately 5,000 feet (ft) of ICTs and a GWTP was installed in 1997 to control the migration of contaminated groundwater and to protect surface water. The area within the ICTs is considered the containment area. Harrison Bayou is located adjacent to the Site and drains to Caddo Lake, a drinking water supply.

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. Pre-Phase I investigations were conducted at LHAAP-18/24 from 1980 to 1987. Data analyses from previous investigations have been summarized by the U.S. Army Corps of Engineers (USACE) -Tulsa District in the report *A Data Summary Report of Investigation Results from 1976 through 1992 for Burning Ground 3 and the Unlined Evaporation Pond* (USACE, 1993). Additionally, Phase I through Phase III investigations were performed after 1993. Pre-Phase I and Phase I - Phase III investigations are summarized below.

- **Pre-Phase I Investigations:**
    - o During the LHAAP-18/24 investigation in 1980, the United States Army Environmental Hygiene Agency (USAEHA) installed monitoring wells and collected

groundwater samples for laboratory analysis of anions, explosive compounds, metals, phenols, and physical/chemical characteristics (USAEHA, 1980).

- In 1982, Environmental Protection Systems (EPS) investigated the Site for the United States Army Toxic and Hazardous Materials Agency (USATHAMA) (EPS, 1984). As part of this investigation, an additional nine groundwater monitoring wells were installed at Site 18/24. Twenty-two groundwater samples were collected, nine from the newly installed monitoring wells and 13 from existing monitoring wells.
- As part of the Groundwater Quality Assessment (GWQA) investigations, Camp, Dresser & McKee (CDM) installed ten monitoring wells around LHAAP-18/24 (CDM, 1986). Groundwater samples from the ten newly installed monitoring wells and 18 existing monitoring wells were collected and analyzed for metals, total organic carbon (TOC), selected anions, VOCs and explosive compounds. CDM concluded that the UEP was a source of groundwater contamination, but not the primary source for all of the contaminants identified, including nitrate and organic contamination in the groundwater (along the western edge of the burning ground) and barium (south of the burning ground boundary).
- In 1987, EPS performed a site investigation at LHAAP-18/24 for the Thiokol Corporation and published a report in May 1988 (EPS, 1988). Groundwater samples were collected from three existing monitoring wells and analyzed for explosive compounds.

- **Remedial Investigation – Phase I, II, and III**
  - Numerous investigations to determine the nature and extent of contamination in the soil, groundwater, surface water, and sediments at LHAAP-18/24 were conducted during Phase I, Phase II, and Phase III investigations in 1993, 1995, and 1998, respectively (Sverdrup Environmental, Inc., 1993, 1996a, 1996b, 1999). Activities included installation of monitoring wells and analysis of groundwater, surface water, soil, and sediment samples. Samples were analyzed for VOCs, semi-volatile organic compounds (SVOCs), metals, explosive compounds, perchlorate, pesticides, PCBs, and/or dioxins/furans, depending on the focus of the investigation. The Phase I, Phase II, and Phase III investigations at LHAAP-18/24 are documented in the Group 2 Sites RI (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 and Screening Ecological 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-18/24 posed a non-carcinogenic hazard and the groundwater posed unacceptable carcinogenic risk and non-carcinogenic hazard to the hypothetical future maintenance worker. The Ecological Risk Assessment did not identify potential risk to ecological receptors at LHAAP-18/24.

- **Baseline Ecological Risk Assessment**: The BERA (Shaw, 2007a) identified chemicals of potential ecological concern (COPECs) for the Industrial Sub-Area. The evaluation was based on environmental investigations from 1993 to 2004.
- **Post-Screening Investigations**: Additional investigations were conducted in 2013, 2014, and 2016 in an attempt to improve the Conceptual Site Model (CSM) and assess for the presence of source areas (unsaturated soil and DNAPL in the saturated Shallow Zone). These investigations are documented in the *Final Post-Screening Investigation Report for LHAAP-18/24* (AECOM, 2013), the *Final Updated Post-Screening Investigation Report – LHAAP-18/24* (AECOM, 2016a) and the *Draft Final Supplemental to the Updated Post-Screening Investigation Report, LHAAP-18/24* (AECOM, 2016b).
- **Baseline Ecological Risk Assessment Addendum**: Conducted in 2014, the BERA Addendum did not change the conclusion of the 2007 BERA (AGEISS, 2014).
- **Natural Attenuation Evaluation**: A preliminary evaluation was conducted to determine the occurrence of NA of MC, TCE, and perchlorate in the Shallow Zone and Wilcox Formation groundwater at LHAAP-18/24. Evaluation was performed for the purpose of determining whether the process is a viable remedial technology to be applied at the Site (AECOM, 2017; Appendix A).
- **Revised Feasibility Study**: The Revised FS was based on all available results from previous investigations through 2016. The CSM was refined and RAOs were developed in the FS. The FS identified and evaluated six remedial alternatives (including the no action alternative) to address the soil contamination and groundwater contamination in the Shallow Zone and Wilcox Formation (AECOM, 2017).

Figure 2-3 shows the locations for all of the investigations conducted at LHAAP-18/24.

2.2.3 Site History of CERCLA Enforcement Activities

Due to the releases of chemicals from facility operations, the USEPA placed LHAAP on the Superfund NPL on August 9, 1990. Activities to remediate contamination associated with the listing of LHAAP as a Superfund site began in 1990. After the listing on the NPL, the U.S. Army, the USEPA, and the Texas Water Commission (currently known as the TCEQ) entered a CERCLA §120 FFA for remedial activities at LHAAP. The FFA became effective December 30, 1991. LHAAP-18/24 was one of the originally listed NPL sites in the FFA. The Revised FS for LHAAP-18/24 (AECOM, 2017) was issued in January 2017, and the Proposed Plan (U.S. Army, 2019) was issued in February 2019. This ROD follows that Proposed Plan (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-18/24 and other environmental sites at LHAAP. The outreach program has included fact sheets, media interviews, site visits, invitations to attend quarterly RAB meetings, and public meetings consistent with its public participation responsibilities under Sections 113(k)(2)(B), 117(a), and 121(f)(1)(G) of CERCLA.

The Final Proposed Plan (U.S. Army, 2019) for the selection of the remedy for LHAAP-18/24 was released to the Administrative Record and made available to the public for review and comment beginning April 2, 2019. The notice of availability of the PP and other related documents in the Administrative Record file was published in *The Shreveport Times* and the *Marshall News Messenger* on April, 2 2019. The newspaper and media notices for the meeting are provided in **Appendix A**. The public comment period for the PP began on April 2, 2019 and ended May 2, 2019. A public meeting was held on April 25, 2019 in a formal format and with a court reporter. The transcript for the meeting is part of the Administrative Record. The significant comments received from the public (oral or written) are addressed in the Responsiveness Summary, which is included in this ROD as **Section 3.0**.

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

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 risks associated with exposure to contaminated soil and groundwater in both the Shallow Zone and Wilcox Formation. Present as residual DNAPLs in groundwater near the UEP and the ACD, TCE and MC are highly toxic materials constituting principal threat wastes. Treatment of the residual DNAPLs will remove continuing sources of groundwater contamination. TCE and MC are also present in unsaturated soils in isolated locations south of the former UEP, west of the UEP, and underneath the UEP acting as a low-level threats to groundwater. 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.

The selected action at LHAAP-18/24 will prevent potential risks associated with exposure to contaminated groundwater. Although groundwater at LHAAP is not currently being used as drinking water, nor may it be used in the future based on its reasonably anticipated use as a national wildlife refuge, when establishing the 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 in a timeframe that is reasonable given the particular circumstances of the site (40 C.F.R. § 300.430(a)(1)(iii)(F)). The U.S. Army 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 Zone and Wilcox Formation groundwater zones at LHAAP-18/24 to their potential beneficial uses, which for the purposes of this ROD is considered to be attainment of the Safe Drinking Water Act (SDWA) maximum contaminant levels (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). 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.

The selected remedial action will also ensure containment of the plume to prevent potential impact to surface water. The selected action will 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 excavation that will mitigate the residual contamination in the unsaturated soil that is considered a low-level threat waste. The relevant active remedial components of the selected action include EISB inside and outside the containment area and in the Shallow and Wilcox Formation, ISTD DNAPL removal, and enhanced groundwater extraction and treatment as needed. By instituting these technologies, the selected action 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-18/24 site characteristics with respect to the 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

LHAAP-18/24 is a 34.5-acre site that has been impacted primarily with VOCs and perchlorate. As illustrated on **Figure 2-4**, the CSM 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 as discussed below. The BERA and BERA Addendum did not identify potential risk to ecological receptors at LHAAP-18/24 (Shaw, 2007, AGEISS, 2014).

The area was previously used for the treatment, storage, and disposal of solid and liquid explosive, pyrotechnic, and combustible solvent waste by open burning/open detonation, incineration, evaporation, and burial. Historical waste management units include open burn pits, the UEP, stockpiles of solvent-soaked sawdust, and suspected waste burial pits. The UEP was constructed at the burning ground in 1963 as a holding pond to store explosive wastes resulting from the washout of rocket motor casings. In 1973, the pond also began receiving waste water containing solvent residues and solids. An air curtain destructor (ACD) was built in 1979 for the purpose of disposing of explosive and explosive-contaminated wastes by burning. A groundwater extraction system incorporating approximately 5,000 ft of ICTs and a GWTP was installed in 1997 to control the migration of contaminated groundwater as an IRA (AECOM, 2017).

Contamination from historical activities at LHAAP-18/24 have impacted two groundwater zones: the shallow zone extending from the surface to a depth of approximately 45 ft below ground surface (bgs), and the Wilcox Formation below the shallow zone. These two units are separated by a mostly contiguous clay layer which is believed to be present across the entire Site with the exception of the area to the west and northwest towards Harrison Bayou.

VOCs and associated 1,4-dioxane, metals, and perchlorate releases associated with past operations of the former burn pits, burial trenches, the ACD, and the UEP were the contamination sources in soil at LHAAP-18/24. An IRA performed in 1997 removed approximately 32,000 yd^3 of contaminated source area soil that was treated using low temperature thermal desorption. The majority of the contaminated soil was remediated during the IRA; however, some residual contaminants remain in the unsaturated soil. Based on the results of the BHHRA (Jacobs, 2002), the soil at LHAAP-18/24 does not pose an unacceptable carcinogenic risk or non-cancer hazard; however, the concentrations of contaminants in soil could be an ongoing source of groundwater contamination.

Unsaturated soil known to contain residual contamination posing a low-level threat to groundwater is isolated to locations south of the former UEP, west of the UEP, and underneath the UEP. Therefore, the potential leaching of contaminants from the unsaturated soil at these locations to groundwater is considered a complete transport pathway that will be addressed during the remedial action.

Other than the unsaturated soil locations with residual contamination, the medium of concern at LHAAP-18/24 is the groundwater. The contaminants in the saturated zone occur as dissolved plumes within the containment area and outside the containment area where contaminants have migrated off-site before the installation of the ICTs and GWTP. Additionally, residual DNAPL is present in the UEP and former ACD areas.

Groundwater contamination in the form of VOCs, 1,4-dioxane, metals, and perchlorate in the shallow zone and the Wilcox Formation poses a potential risk to the hypothetical future maintenance worker at LHAAP-18/24. Concentrations of VOCs and perchlorate were detected in wells screened in the shallow zone and in localized areas in the Wilcox Formation, though shallow zone contamination is more widespread. Since the groundwater at LHAAP-18/24 may pose a risk for the hypothetical future maintenance worker, the pathways considered for remediation include future industrial groundwater use.

The contaminants in the shallow zone groundwater migrate toward surface water and may discharge via seepage. Although this transport pathway is currently mostly mitigated by the operation of a groundwater extraction system, the seepage of groundwater to surface water represents a pathway that is addressed by the selected remedial action.

2.5.2 Geology and Hydrogeology

Surficial soils at LHAAP-18/24 consist of sandy silty clays and clays underlain by a sandy silt to silty sand stratum. This clay stratum pinches out to the east of the burning grounds and becomes ill defined at the contact between the Wilcox Group and the alluvium of Harrison Bayou to the west and north of the site (Jacobs, 2001).

The shallow alluvial zone at LHAAP-18/24 is very heterogeneous consisting of discrete sand channels encapsulated in lower permeability silt/clay floodplain sediments. The thickness of the shallow alluvium is variable, because of the irregular contact with underlying Wilcox. Thickness ranges from 10 to 40 ft. The zone is characterized by potentially complex flow paths, gradients depending on where sandy channel deposits intersect and/or diverge. In general, the axes of channel deposits trend toward the north and northeast (AECOM, 2015).

The permeable intervals (sands, silty sands) associated with individual channel fill or point bar sediment packages range in thickness from 10 to 20 ft thick generally. Sands are typically fine to medium grained. Many of the channel fill sand bodies include a percentage of silt. Levee or overbank sand bodies were identified where possible. Typically, the fine levee sands display an abrupt coarsening upward grain size trend, are 5 to 10 ft in thickness, and may have some evidence of root or soil formation in the form of noted “mottling” of the sediments (AECOM, 2015).

A clay unit separating the shallow alluvium from the Wilcox sands occurs at the top of the Wilcox Formation throughout most of the site. However, this clay is missing in the northwestern corner of the site. The clay is missing where fluvial incision has occurred during both the deposition of the shallow Wilcox (incision indicated by a well-defined gravel lag deposit at 18WW06 as well as later incision by the Harrison Bayou. The thickness and extent of the “Wilcox clay” layer varies in thickness from 0 to 20 ft and may be in contact with overlying floodplain silts and clays or incised by overlying channel sands. The sands of the Wilcox Formation are homogenous and vary in grain size from medium to fine silty sands (AECOM, 2015).

Figures 2-5 and **2-6** show the well locations and groundwater elevations for the Shallow Zone and Wilcox Formation, respectively.

2.5.3 Sampling Strategy

Numerous sampling events were conducted at LHAAP-18/24 from 1980 to 2016, as described in **Section 2.2.2**. Early investigations included collection of soil, sediment, and surface water samples, and installation of groundwater monitoring wells and groundwater sampling throughout the site to determine the areas of contamination. Subsequent investigations focused on the areas where contamination was found; performing additional soil, groundwater, surface water and sediment sampling; and installing additional groundwater monitoring wells to further delineate the nature and extent of contamination. Samples from all media were analyzed for various analytes including perchlorate, metals, VOCs, SVOCs, and 1,4-dioxane. In 2014, a treatability study for an In Situ Microcosm (ISM) study using stable isotope probing (SIP) was performed at the Site to determine whether the addition of oxygen release compound (ORC) or emulsified vegetable oil (EVO) would enhance the biodegradation of MC. During 2016, a preliminary evaluation of the occurrence of NA of MC, TCE, and perchlorate present in the shallow zone and Wilcox Formation groundwater at LHAAP-18/24 was performed. This analysis is important in determining if NA should be considered as a remedial process applicable at the site.

2.5.4 Nature and Extent of Contamination

The collective investigative results at LHAAP-18/24 identified groundwater contamination present at concentrations that pose an unacceptable risk to human health or the environment that require remedial action. TCE, MC and perchlorate present the vast majority of the human health risk in groundwater. The concentrations of TCE and MC in some portions of the site are sufficiently high to indicate the possible presence of DNAPL within the saturated zone. 1,4-dioxane is present as isolated plumes while occurrences of other VOCs and metals concentrations in groundwater are intermittent and their distribution is generally not contiguous across the site.

Soil has not been identified as a medium of concern for protection of human health and ecological risk; however, it was identified as a medium of potential concern for the protection of groundwater from potential cross-media transfer. Unsaturated soil exceedances are shown on **Figure 2-7**. Groundwater at LHAAP-18/24 has been identified as the medium of concern because of the risk it poses to a hypothetical future maintenance worker. Contaminant plumes for the shallow zone and the Wilcox Formation contaminants are illustrated on **Figures 2-8** through **2-11** and **Figure 2-12** through **2-15**, respectively. Contamination at LHAAP-18/24, as described in the *Final Revised Feasibility Study* (AECOM, 2017), is as follows:

Soil

- Unsaturated soil in two areas south of the former UEP contain TCE and MC as well as PCE at concentrations that exceed their respective GWP-Ind values and could leach to groundwater at concentrations exceeding the MCLs. The leaching of contaminants from the unsaturated soil to groundwater is considered a complete transport pathway that will be addressed during the remedial action. A more refined extent determination of COCs in the soil in these areas is recommended, but will be defined as part of the RD. The estimated in-place volumes are 414 yd^3 and 602 yd^3, respectively, with both areas having been previously excavated to a depth of 4 ft bgs.
- Unsaturated soil in the area west of the UEP within the former Burn Burial Area contains TCE and MC as well as some perchlorate that could leach to groundwater at concentrations exceeding the MCLs or PCLs. The leaching of contaminants from the unsaturated soil to groundwater is considered a complete transport pathway that will be addressed during the remedial action. Due to the shallow nature of impacted soil, the full extent will be readily determined during the RD phase. The estimated in-place volume is 416 yd^3. Further refinement of the extent will take place during the RD phase.
- Two soil areas beneath the UEP had concentrations of TCE and/or MC that exceed the groundwater protection-industrial MSCs. The leaching of contaminants from the unsaturated soil to groundwater is considered a complete transport pathway. The first area is in the vicinity of 18CPT21 and the second area is in the vicinity of 18CPT25. A conservative extent estimate is 280 ft by 110 ft and a thickness of approximately 10 ft. Thus the estimated in-place soil volume is 11,400 yd^3. These two areas may be considered for remediation in the future as a contingency remedy. Further refinement of the extent would take place during the contingency RD phase, if needed, particularly since an overlapping area where DNAPL exists will be remediated.

Groundwater

- A plume of dissolved perchlorate contamination that exceeds the cleanup level exists under the entire site in the Shallow Zone with additional significant plume areas outside the LHAAP-18/24 footprint. The extent of the contamination in the Shallow Zone is estimated at 67 acres. In the Wilcox Formation, two perchlorate plumes, one occupying the entire west and southwest half of the containment area and the other in the north corner of the containment area, are estimated at a combined 21 acres.
- A plume of dissolved MC contamination exceeding cleanup levels exists in the Shallow Zone and in the Wilcox Formation near the southern area of the UEP. To the west of the ACD, the Wilcox Formation plume has very low MC concentrations. The size of the MC plume in the Shallow Zone is approximately 7.3 acres, and 4.8 acres in the Wilcox Formation.
- A plume of dissolved TCE contamination exceeding the cleanup level exists in the Shallow Zone under the entire site with additional significant plume areas outside the LHAAP-18/24 footprint. The size of the TCE plume in the Shallow Zone is approximately 59 acres. The high

TCE concentrations in shallow groundwater coincide with the two areas of MC contamination: MW-2 south of the former UEP, and monitoring well 120 northwest of the former ACD. A Wilcox Formation dissolved TCE plume has an area of approximately 16.6 acres and covers a large portion of the containment area with the highest concentration found in MW-14 in the former ACD area.

- A plume of dissolved 1,4-dioxane exceeding the cleanup level exists in the Shallow Zone in the ACD area and another plume is present to the south, in the area around MW-7. The size of the 1,4-dioxane plumes in the Shallow Zone is approximately 2.7 acres. A Wilcox Formation dissolved 1,4-dioxane plume has an area of approximately 1.2 acres centered around MW-14 in the former ACD area.
- Isolated detections of metals in the Shallow Zone at concentrations exceeding the MCLs/PCLs occur across the site, but without the clear plume patterns exhibited by VOCs. The major metals in the Shallow Zone are arsenic, barium, and chromium. The other metals (cobalt and nickel) are not detected consistently. In the Wilcox Formation, sporadic detections of arsenic above the MCL/PCL were reported in three wells.
- The source of VOCs in residual DNAPL is estimated to be present in groundwater in the ACD area and southern area of the former UEP, respectively. The aerial extent of the UEP DNAPL extent is estimated at 35,500 square ft (ft^2) and the aerial extent of the ACD DNAPL extent is estimated at 5,000 ft^2. Although the DNAPL investigation in 2014 defined the extent of DNAPL in the vicinity of the ACD, given the high concentrations of TCE and MC in ICT-12-E (97,400 micrograms per liter [µg/L] and 173,000 µg/L in February 2013, respectively) and monitoring well 120 (24,500 µg/L in May 2013 for TCE), the ACD source area may be extended north from the ACD toward ICT-12E and monitoring well 120, increasing the area to be treated for DNAPL. Under this situation, the cost estimate for the DNAPL area in the vicinity of the ACD may become larger and will be considered during the RD phase.

Other than the limited unsaturated soil containing MC and TCE that could leach to groundwater at concentrations exceeding the MCLs, the mass of contaminants can be considered in three parts: 1) mass dissolved in groundwater, 2) mass adsorbed onto soil below the water table, and 3) mass in the form of DNAPL (TCE and MC) or soil contamination (perchlorate). The dissolved and adsorbed mass can be considered accessible mass, readily removed by groundwater extraction, although within the lower permeability zones, limitations of mass removal will reduce the removal rate of contaminants by groundwater extraction. The DNAPL can be considered source mass and is less readily removed.

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 very limited.

The reasonably anticipated future use of LHAAP-18/24 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-18/24. Presently the Caddo Lake National Wildlife Refuge occupies a little more than 7100 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. When flowing, the streams flow into Caddo Lake, a large recreational area that covers 51 square miles and has a mean depth of 6 ft. 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 ft 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 ft 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 ft 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 ft 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 ft 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-18/24 are approximately 2.16 miles, 2.25 miles, and 2.78 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-18/24. 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-18/24 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), and the *Installation-wide Baseline Ecological Risk Assessment* (BERA) (Shaw, 2007) and the BERA Addendum (AGEISS, 2014). The risk assessment was completed using data from samples collected through February 2001 for groundwater and through 1998 for soil. Additional soil samples were collected during the perchlorate investigation in 2002, for the installation-wide BERA, and the sump investigation in 2006. A Preliminary Site Investigation was also conducted in 2013, 2014 and 2016 and additional samples were collected during that investigation. In general, the additional soil sample results do not change the conclusion of the risk assessments that soil poses no unacceptable human health risks to the hypothetical site worker. The discussion of results and risks presented here are therefore 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 2-4**.

2.7.1.1 Identification of Chemicals of Potential Concern

The BHHRA identified chemicals of potential concern (COPCs) for LHAAP-18/24 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 ft bgs), dermal contact with the surface soil, inhalation of particulates, and inhalation of VOCs from the soil (0 to 7 ft 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 **Tables 2-2** and **2-3**, respectively. The toxicity data assumes that exposure would be chronic to be conservative. Sources for the data include the Integrated Risk Information System (IRIS) and Health Effects Assessment Summary Tables (HEAST).

2.7.1.4 Risk Characterization

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

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

where: risk = unitless probability of an individual developing cancer

CDI = chronic daily intake averaged over 70 years, expressed as milligrams per kilogram per day (mg/kg-day)

SF = slope factor, expressed as $(\text{mg/kg-day})^{-1}$

These risks are probabilities that usually are expressed in scientific notation. An excess lifetime carcinogenic risk of 1×10^{-6} indicates that an individual experiencing the reasonable maximum exposure estimate has a 1 in 1,000,000 chance of developing cancer as a result of site-related exposure. This is referred to as an "excess lifetime carcinogenic risk" because it would be in addition to the risks of cancer that individuals face from other causes such as smoking or exposure to too much 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 and non-carcinogenic hazard for groundwater are unacceptable; both the carcinogenic risk and the non-carcinogenic hazard for soil are acceptable. The carcinogenic risks for groundwater and soil are 4.4×10^{-1} and $5.0x10^{-7}$ and, respectively (Jacobs, 2002). The carcinogenic risk for ground water exceeds the USEPA target risk range of 1×10^{-4} to 1×10^{-6}; the carcinogenic risk for soil is less than the risk range. The HIs for groundwater and soil are 3,200 and 0.042, respectively. The groundwater HI is above the acceptable HI of < 1 while the soil HI is less than 1. Chemicals with a risk greater than 1×10^{-4} in groundwater include TCE, and methylene chloride. Chemicals with a HQ greater than 1 in groundwater include chloroform, perchlorate, methylene chloride, TCE, antimony, manganese, and nickel. Methylene chloride, TCE, and perchlorate were the primary contributors to the HI in groundwater; with HQs of 1,600, 800, and 750, respectively.

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 non-carcinogenic effects associated with manganese in groundwater may be due to background.

2.7.1.5 Evaluation of COPCs

Tables 2-6 through **2-9** list the chemicals in Shallow Zone and Wilcox Formation groundwater that exceed those values for the carcinogenic risk and HQ, respectively. There is no carcinogenic risk or non-cancer hazard in soil to the hypothetical maintenance worker. These tables also summarize the justifications for which of the COPCs should be classified as COCs. COPCs in groundwater were identified as COCs when they posed a carcinogenic risk above the acceptable range (risk greater than 1×10^{-4}), when their HQ was greater than 1, or when the EPC was above the MCL or in the absence of federal drinking water standards, the Texas Risk Reduction Program (TRRP) Tier 1 Residential Groundwater Protective Concentration Level (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 Zone and Wilcox Formation groundwater.

Although exposure to soil does not pose an unacceptable carcinogenic risk or non-cancer hazard, the concentrations of contaminants in soil could be an ongoing source of groundwater contamination. To assess this, the potential soil-to-groundwater pathway was evaluated for TCE, MC, PCE and perchlorate. The concentrations of these chemicals were compared to their TCEQ soil MSCs for industrial use based on groundwater protection (GWP-Ind MSC), which are more stringent than the soil MSCs for industrial use based on inhalation, ingestion, and dermal contact (TCEQ, 2006). The evaluation indicated that these contaminants could adversely impact groundwater, and the more stringent GWP-Ind MSC values are the proposed soil cleanup levels.

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 BERA (Shaw, 2007a) and BERA 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 ft) and total soil (0 to 3 ft). 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.

Ecological effects quotients (EEQs) 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-18/24 falls within the Waste Sub-Area. The Installation-Wide BERA did not identify potential risk to ecological receptors at LHAAP-18/24 (Shaw, 2007b). Should there have been any ecological risk, it would have been expressed by this point in time. The BERA Addendum completed in 2014 (AGEISS, Inc., 2014) did not change the conclusion of the 2007 BERA.

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. **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 Wilcox Formation listed separately.

2.8 Remedial Action Objectives

The RAOs for LHAAP-18/24 presented in this ROD for the selected remedy and contingency remedies address contamination associated with the media at the Site and take into account the future uses of LHAAP surface waters, land, and groundwater. The RAOs for groundwater are:

- Protection of human health by preventing human exposure to the groundwater contaminated with COCs,
- Protection of human health and the environment by preventing groundwater contaminated with COCs from migrating into nearby surface water,
- Return groundwater to its 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)).

RAOs for soil are:

- Protection of human health and the environment by preventing the migration of contaminants to groundwater from potential sources in the soil.

The above RAOs recognize 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, the U.S. Army in this case, 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 Tier 1 Residential Groundwater PCL and is protective of human health and the environment.

2.9 Description of Alternatives

Six alternatives (including No Action) are proposed. 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 NA 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 – Enhanced Groundwater Extraction and Ex-Situ Treatment, LUCs, EISB Inside and Outside the Containment Area and in the Wilcox Formation, Unsaturated Soil Excavation, and Off-Site Disposal

The major components of this alternative include the following:

- Continued use of the existing groundwater extraction system with enhancements (reactivate two existing ICTs) until COC concentrations are low enough that MNA can address remaining contamination within and outside the containment area.
- Replacement of the existing GWTP with a new GWTP with the contingency to treat for 1,4-dioxane.
- Excavation of unsaturated soil exceeding groundwater protection-industrial MSC (GWP-Ind).
- Excavation of soil beneath the UEP could be implemented in the future as a contingency remedy (e.g., depending on the results of the Five-Year Review of the groundwater remedy).

- Implementation of ISB of shallow zone groundwater outside the containment area at several locations; in the Wilcox Formation at three or more locations, and inside the containment at five or more locations.
- Implementation of groundwater extraction and removal of residual DNAPL in two distinct areas inside the containment area, as needed.
- Maintenance of existing cap over the UEP.
- MNA for both shallow and intermediate zone groundwater for areas outside the influence of the treatment areas and for areas inside the influence of the treatment areas to reduce groundwater contamination to cleanup levels and confirm contamination remains localized and degrades over time.
- 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.
- MNA with 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 five-year review demonstrate 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; to preserve the integrity of the surface impoundment cap, and to restrict intrusive activities that may degrade or alter the cap until the underlying source soil is removed and/or the cleanup levels for soil listed in **Table 2-10** have been achieved; 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: $10,600,000
Estimated O&M Present Worth Cost: $19,600,000
Cost Estimate Duration: 30 years
Estimated Present Worth Cost: $30,200,000

<u>Alternative 3 – Groundwater Extraction and Treatment, Containment (slurry wall), MNA outside the containment and in Wilcox Formation, and LUCs</u>

The major components of this alternative include the following:

- Continued use of a reduced groundwater extraction system for hydraulic control, as needed.
- Replacement of the existing GWTP with a new GWTP with the contingency to treat for 1,4-dioxane.
- Installation of a slurry wall for containment of groundwater.
- Improvements to the soil cover to promote drainage and reduce infiltration.
- Maintenance of existing cap over the former UEP.
- MNA for groundwater contamination within the Wilcox Formation and outside the slurry wall.
- 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.
- MNA with 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 five-year review demonstrate 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; to preserve the integrity of the surface impoundment cap, and to restrict intrusive activities that may degrade or alter the cap until the underlying source soil is removed and/or the cleanup levels for soil listed in **Table 2-10** have been achieved; 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: $6,410,000
Estimated O&M Present Worth Cost: $12,240,000
Cost Estimate Duration: 30 years
Estimated Present Worth Cost: $18,650,000

Alternative 4 - Enhanced Groundwater Extraction and Treatment, LUCs, EISB Inside & Outside Containment Area and in Wilcox Formation, Unsaturated Soil Excavation and Off-Site Disposal, and Surfactant Enhanced DNAPL Removal

The major components of this alternative include the following:

- Continued use of the existing groundwater extraction system with enhancements (reactivate two existing ICTs) until COC concentrations are low enough that MNA can address remaining contamination within the containment area.
- Replacement of the existing GWTP with a new GWTP with the option to treat for 1,4-dioxane.
- Excavation of unsaturated soil exceeding groundwater protection-industrial MSC (GWP-Ind).
- Excavation of soil beneath the UEP could be implemented in the future as a contingency remedy (e.g., depending on the results of the Five-Year Review of the groundwater remedy).
- Implementation of ISB of shallow zone groundwater outside the containment area at several locations; in the Wilcox Formation at three locations, and inside the containment at five locations.
- Implementation of surfactant flushing for removal of DNAPL in two distinct areas inside the containment area at the site.
- Maintenance of existing cap over the former UEP.
- MNA for both shallow and intermediate zone groundwater for areas outside the influence of the treatment areas and for areas inside the influence of the treatment areas to reduce groundwater contamination to cleanup levels and confirm contamination remains localized and degrades over time.
- 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 five-year review demonstrate 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; to preserve the integrity of the surface impoundment cap, and to restrict intrusive activities that

may degrade or alter the cap until the underlying source soil is removed and/or the cleanup levels for soil listed in **Table 2-10** have been achieved; 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: $13,110,000
Estimated O&M Present Worth Cost: $19,390,000
Cost Estimate Duration: 30 years
Estimated Total Present Worth Cost: $32,500,000

Alternative 5 - Enhanced Groundwater Extraction and Treatment, LUCs, EISB Inside and Outside Containment Area and in Wilcox Formation, Unsaturated Soil Excavation and Off-Site Disposal, Thermal DNAPL Removal

The major components of this alternative include the following:

- Continued use of the existing groundwater extraction system with enhancements (reactivate two existing ICTs) until COC concentrations are low enough that MNA can address remaining contamination within the containment area.
- Replacement of the existing GWTP with a new GWTP with the option to treat for 1,4-dioxane.
- Excavation of unsaturated soil exceeding groundwater protection-industrial MSC (GWP-Ind).
- Excavation of soil beneath the UEP could be implemented in the future as a contingency remedy (e.g., depending on the results of the Five-Year Review of the groundwater remedy).
- Implementation of ISB of shallow zone groundwater outside the containment area at several locations; in the Wilcox Formation at three locations, and inside the containment at five locations.
- Implementation of thermal desorption and removal of DNAPL in two distinct areas inside the containment area at the site.
- Maintenance of existing cap over the former UEP.
- MNA for both shallow and intermediate zone groundwater for areas outside the influence of the treatment areas and for areas inside the influence of the treatment areas to reduce groundwater contamination to cleanup levels and confirm contamination remains localized and degrades over time.
- 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 five-year review demonstrate 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; to preserve the integrity of the surface impoundment cap, and to restrict intrusive activities that may degrade or alter the cap until the underlying source soil is removed and/or the cleanup levels for soil listed in **Table 2-10** have been achieved; 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: $19,520,000
Estimated O&M Present Worth Cost: $13,150,000
Cost Estimate Duration: 20 years
Estimated Total Present Worth Cost: $32,670,000

Alternative 6 - Enhanced Groundwater Extraction and Treatment, LUCs, EISB Inside and Outside Containment Area and in Wilcox Formation, Unsaturated Soil Excavation and Off-Site Disposal, Enhanced DNAPL Remediation using Zero-Valent Iron (ZVI)

The major components of this alternative include the following:

- Continued use of the existing groundwater extraction system with enhancements (reactivate two existing ICTs) until COC concentrations are low enough that MNA can address remaining contamination within the containment area or potentially a new GWTP including contingency use of advanced oxidation process for treatment of 1,4-dioxane.
- Excavation of unsaturated soil exceeding groundwater protection-industrial MSC (GWP-Ind).
- Excavation of soil beneath the UEP could be implemented in the future as a contingency remedy (e.g., depending on the results of the Five-Year Review of the groundwater remedy).
- Implementation of ISB of Shallow Zone groundwater outside the containment area at several locations, in the Wilcox Formation at three locations, and inside the containment at five locations.
- Implementation of ZVI (micron-scale) for in situ treatment of DNAPL in two distinct areas inside the containment area at the Site.
- Maintenance of existing cap over the former UEP.
- MNA for both shallow and intermediate zone groundwater for areas outside the influence of the treatment areas and for areas inside the influence of the treatment areas to reduce groundwater contamination to cleanup levels and confirm contamination remains localized and degrades over time.

- 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 five-year review demonstrate 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; to preserve the integrity of the surface impoundment cap, and to restrict intrusive activities that may degrade or alter the cap until the underlying source soil is removed and/or the cleanup levels for soil listed in **Table 2-10** have been achieved; 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 2-1**0) in groundwater are met.

Estimated Capital Present Worth Cost: $102,230,000
Estimated O&M Present Worth Cost: $19,390,000
Cost Estimate Duration: 30 years
Estimated Total Present Worth Cost: $121,620,000

2.9.2 Common Elements and Distinguishing Features

Common Elements of Alternatives 2 through 6

Common elements of Alternatives 2 through 6 are described below.

Maintenance of the existing cap over the former UEP – The cap would continue to be monitored, maintained, and repaired, as necessary, to ensure long-term effectiveness. This includes inspections of the cap to check for erosion, settlement, and deep-rooted vegetation, and implementation of necessary repairs. Routine maintenance and repair of the cap would include actions needed to ensure that the integrity of the cap is maintained (e.g., mowing, seeding, and settlement/erosion repair)

Operation of the existing GWTP and associated groundwater extraction system – The intensity and duration of continued use varies within the alternatives.

MNA to reduce and control COC concentrations in areas outside the direct influence of the containment area – MNA relies on natural biological, chemical, and physical processes to reduce the mass and concentrations of groundwater COCs under favorable conditions. MNA was evaluated and is a viable option for those areas but not as a primary remedy as additional evidence is needed for MNA to be used as a primary remedy. MNA for 1,4-dioxane has not been established at this time.

MNA sampling would be performed as part of groundwater monitoring plans. MNA sampling would be performed quarterly for the first two years, semiannually for the next three years, then annually until the next Five-Year Review. After that, the sampling frequency may be changed to once every five years if the data suggest less frequent sampling is appropriate. The analytical program would consist of VOCs, metals, perchlorate, and 1,4-dioxane. The following parameters would also be included in the initial analytical program: sulfate, nitrate, nitrites, alkalinity, TOC, and field tests for dissolved oxygen, redox potential, and ferrous iron. These parameters would be dropped when NA is well documented. Additional parameters that will be conducted for two events only in select Wilcox Formation wells (e.g., 18CPTMW01SW and 18CPTMW06SW for TCE and MC wells) to establish biodegradation potential include: reductive TCE and vinyl chloride (VC) gene expression, dehalococcoides and dehalobacter concentration, and compound specific isotope analysis for TCE. Subsequent LTM would be limited to VOCs, metals, and perchlorate.

Inspection and Long-Term Groundwater Monitoring – Alternatives 2 through 6 include inspection and LTM 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. The LUC for preserving the integrity of the surface impoundment cap shall include restrictions that prevent intrusive activities that may degrade or alter its effectiveness. Restrictions would include restricting intrusive activities (e.g., digging) that would degrade or alter the cap. These restrictions would remain in place until the underlying source soil is removed and/or the cleanup levels for soil listed in **Table 2-10** have been achieved.

In addition, within 90 days of signature of this ROD, the U.S. Army shall request the Texas Department of Licensing and Regulation to notify well drillers of groundwater use prohibitions based on a preliminary LUC boundary. Within 21 days of the issuance of the ROD, the U.S. 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. 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, the monitoring system, and the surface impoundment cap at the Site, in accordance with 30 TAC 335.565.

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

Upon transfer of U.S. Army-owned property, the U.S. Army will provide written notice of the LUCs 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 U.S. 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 U.S. 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 LUCs 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-18/24), an Environmental Condition of Property (ECP) document would be prepared and the Environmental Protection Provision from the ECP would be attached to the letter of transfer. The ECP will include cap protection and maintenance, land use, groundwater use and monitoring system maintenance restrictions as part of the Environmental Protection Provisions. The property would be transferred subject to the LUCs identified in the ECP. These restrictions would prohibit or restrict property uses that may result in damage to the existing remedy (surface impoundment cap) or monitoring system or exposure to the contaminated groundwater (e.g., drilling restrictions) or soil (e.g. residential land use prohibition).

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

Distinguishing Features of Alternatives 2, 4, 5, and 6

The distinguishing features of Alternative 2, 4, 5, and 6 compared to Alternative 3 are excavation and removal of contaminated soil, enhanced groundwater extraction, and EISB. The enhanced element of the groundwater extraction and treatment and EISB employed in Alternatives 2, 4, 5, and 6 are described below.

Enhanced Groundwater Extraction – Enhanced extraction involves the reactivation of ICTs. Review of flow rates and contaminant concentrations suggest that reactivating certain ICTs that were turned off could be very productive in removing contaminant mass from the subsurface if the extraction flow rate is sustainable. Two ICTs (ICT 3 and ICT 9) in particular have a high potential for removing a large amount of COC mass from the groundwater at least based on historical results. Sampling of the various inactive ICTs to determine which ICTs would be most effective will be conducted before determining which two ICTs will be activated.

EISB – The components of this action include: EISB would consist of the application of organic substrate (e.g., emulsified vegetable oil (EVO) or other formulations) as a bacterial food source, and a bacterial inoculation mix (e.g., SDC-9 or KB-1 Plus®), in areas of the groundwater plume outside the containment area within areas of high perchlorate and high TCE in the northeast, southwest, and southeast. Inside the containment, EISB would be conducted upgradient of MW-21 and 109 in the northeast boundary, near monitoring wells 120 and MW-14, and in the area of MW-23 and location 18CPT03 where high perchlorate concentrations were detected. EISB will also be applied near 18CPTMW08SW and 18CPTMW22SW into the Wilcox Formation due to the presence of high concentrations of perchlorate in the Wilcox Formation in this area of the Site. It is anticipated that EISB in the treated DNAPL areas will be implemented in a grid fashion with 25 by 25 ft spacing.

Excavation and Off-site Disposal of Contaminated Soil - Unsaturated soil exceeding the cleanup levels for soil listed in **Table 2-1**0 in two areas south of the UEP and two areas to the west of the UEP would be excavated and disposed off-site. The actual implementation of the soil excavation for the location beneath the UEP would be deferred to year 6 of remedy implementation at the earliest. The excavation and disposal activities for the other areas would be completed as part of the RA.

Distinguishing Feature of Alternative 2

The component of this action includes: Vertical extraction wells that will be placed inside the residual DNAPL areas and connected to the extraction manifold to the GWTP. The purpose of these extraction wells is to enhance removal of DNAPL. Free DNAPL, if present, will be removed by the gradient created by the extraction wells if present within the zone of influence. Additionally, a large portion of trapped DNAPL will be removed by enhanced dissolution as fresh groundwater is forced through the zone of influence of the wells.

Distinguishing Feature of Alternative 3

The distinguishing features of Alternative 3 compared to Alternatives 2, 4, 5, and 6 is the inclusion of a slurry wall for containment.

Slurry Wall Containment – The components of this action include: Construction of a slurry wall. A slurry wall is a continuous low permeability subsurface trench formed by mixing clay minerals (typically bentonite) with in situ soil to contain contaminated groundwater. It is constructed very much like an ICT with the exception that the intent is to prevent groundwater movement rather than encourage it. The slurry wall can be installed around the entire area of a shallow plume to effectively contain contaminated groundwater from lateral migration.

Distinguishing Feature of Alternative 4

This alternative is similar to Alternative 2, 5, and 6 with a specific means to enhance the removal of DNAPL from the shallow zone groundwater in the two DNAPL areas of the site. The application of surfactant flushing will accelerate removal of residual DNAPL, reduce remaining COC mass, and reduce the lifecycle of the project.

Surfactant Flushing – The components of this action include: Once a required treatability test to identify and optimize the concentrations of the most compatible surfactant(s)/electrolyte(s) mixture, and application volume to the site groundwater and soil is completed, a pilot-scale test is needed to better understand how well surfactant addition would be distributed in the subsurface and result in solubilization of DNAPL from both coarse and fine-grained soils (i.e., to understand limitations of distributing surfactant due to soil heterogeneity). This is an important step because the majority of the residual DNAPL was identified to occur in fine-grained soils (low permeability zones). Pilot-scale testing will also be used to determine whether DNAPL migration to unintended areas would occur and to determine means to prevent this potential loss of process control. If pilot-scale testing proved successful, remediation will be designed and conducted. It is expected, however, removal of residual DNAPL via surfactant flushing and extraction will not be complete, particularly due to the difficulty in surfactant distribution within the low permeability zones. Removal of up to 90% is plausible based on vendor information, although this has to be confirmed by pilot-scale testing.

Distinguishing Feature of Alternative 5

This alternative is similar to Alternative 4 however, instead of surfactant flushing, Alternative 5 utilizes In Situ Thermal Treatment through ERH to accelerate removal of residual DNAPL. There are various ISTD technologies that could be applicable to the site conditions; however, ERH was selected for costing purposes and discussions, and costs presented in the FS and this ROD are based on this ERH technology.

In Situ Thermal Treatment - ERH – The components of this action include: The application of electrical current through the subsurface, resulting in the generation of heat. ERH uses the natural electrical resistance within the subsurface where energy is dissipated through ohmic, or resistive, losses. This manner of in situ heating allows energy to be focused into a specific source zone. When the subsurface temperature is increased to the boiling point of the pore water or the saturated media in the treatment zone, steam is generated. The steam strips contaminants from the soils and enables them to be extracted from the subsurface. In addition, contaminants are directly volatilized from unsaturated soil. ERH is particularly suited to the treatment of lower permeability strata and to DNAPLs that have become consolidated within zones of low permeability with higher organic content. An ERH system consists of subsurface electrodes connected to direct current through the subsurface, and a vapor extraction system to capture the volatilized water and contaminants. Removal of residual DNAPL via thermal treatment and extraction will remove at least 99.9%. Thermal treatment also enhances mobilization of organic matter from the soil to groundwater, which will act to enhance biodegradation of the COCs. Note that while the focus of this discussion is on ERH, other thermal treatment technologies such as thermal conduction heating could be equally applicable.

Application of thermal treatment in the southern area of the UEP will also remove COCs in the unsaturated zone (e.g., area represented by 18CPT21) that would otherwise be subject to excavation. Therefore, the volume requiring excavation is reduced and would be estimated by approximately 6,000 yd^3.

Distinguishing Feature of Alternative 6

This alternative is similar to Alternative 5 however, instead of In Situ Thermal Treatment, Alternative 6 utilizes ZVI to accelerate removal of residual DNAPL.

ZVI Treatment – The components of this action include: Micron-scale ZVI will be injected into targeted zones using direct push tools and/or injection wells. The radius of influence of the injection point should be known to determine spacing of injection locations and allow overlap of radii of influence. For cost estimation, it is assumed that one injection point is conducted for every 100 ft^2 area (radius of influence of approximately 5.5 ft). The amount of ZVI should be such that excess quantities of iron is introduced to account for the mass of chlorinated VOCs but also for 'natural demand' to ascertain that sufficient residual remains in the formation to treat chlorinated VOCs associated with diffusion from fine-grained soils that would occur over time. A quantity of 0.01 lb/lb of micron-scale ZVI to formation soil is assumed based on treatability testing. Indication of distribution of ZVI can be determined using pH, ORP, and dissolved iron concentrations. Reapplication of ZVI might be required should conditions indicate absence of reducing conditions.

Injection of ZVI into DNAPL areas could have the unintended consequences of mobilizing DNAPL to unimpacted areas by virtue of creating a higher hydraulic head within the injection locations. This would be managed by minimizing the volume of fluid used to inject the ZVI, strategically placing the injection points starting at the perimeter of the area of impact and moving inward, and use of monitoring wells in the areas of injection particularly near the perimeter of the injection area to monitor CoC concentrations.

For cost estimating purposes, two applications of ZVI treatments are assumed with the second injection equal to 40% of the first injection due to mass and volume reduction associated with the first injection. Due to the difficulty in distributing the injected ZVI in low permeability zones, ZVI application is assumed to remove no more than 70% to 80% of the mass of VOCs per application.

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, 4, 5, and 6 provide the same outcome to mitigate exposure to human and ecological receptors by excavation and off-site disposal of the contaminated unsaturated soil to eliminate the potential soil-to-groundwater pathway, preventing further degradation of groundwater from contaminated soil. Alternatives 4, 5, and 6 also would significantly and permanently reduce groundwater contaminant concentrations to the applicable cleanup levels through active treatment using EISB and other technologies, and, therefore, provide long-term effectiveness and permanence within shorter timeframes than Alternatives 2 and 3. Alternative 3 would contain the contaminated groundwater and rely on MNA to reduce contaminant levels over time. Attainment of groundwater cleanup levels would require several hundred years for Alternatives 2 and 3. Groundwater cleanup levels should be in 20 to 30+ years for Alternatives 4, 5, and 6. However, considering the lithologic variability, particularly the lateral and vertical change from sand to clay, the time 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 Tier 1 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, by documenting reduction of the contaminant mass and protection of surface water through containment of the plume. The LUC 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. The LUC for preserving the integrity of the surface impoundment cap shall include restrictions that prevent intrusive activities that may degrade or alter its effectiveness. Restrictions would include restricting intrusive activities (e.g., digging) that would degrade or alter the cap. These restrictions would remain in place until the underlying source soil is removed and/or the cleanup levels for soil listed in **Table 2-10** have been achieved.

2.10 Summary of Comparative Analysis

Nine criteria identified in the NCP §300.430(e)(9)(iii) are used to evaluate the different remediation alternatives individually and against each other in order to select a remedy. This section profiles the relative performance of each alternative against the nine criteria, noting how it compares to the other options under consideration. The nine evaluation criteria are discussed below. **Table 2-11** 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 LUCs.

The six alternatives provide varying levels of human health protection. Alternative 1, no action, does not achieve the RAOs and provides the least protection of all the alternatives; it provides no reduction in risks to human health and the environment because no measures would be implemented to eliminate potential exposure pathways for human exposure to the groundwater contamination or potential migration of COCs from groundwater to surface water.

All five action alternatives protect human health and the environment. The action alternatives implement LUCs to prevent exposure to contaminated groundwater, and continue operation of the groundwater extraction and treatment system until monitoring data verifies that the contaminant plume originating within the containment area is stable and contained. Alternative 3, which relies the most heavily on containment and LUCs, does not provide the same degree of contaminant removal or treatment in groundwater as the other alternatives, but would be protective of human health because the LUCs would prevent human access to the contaminated groundwater. Alternative 3 does not prevent migration of COCs from groundwater outside containment to surface water and it does not prevent migration of COCs from soil sources in the unsaturated and saturated soil to groundwater. Alternatives 2, 4, 5, and 6 provide a similar level of overall protection and can eventually achieve the cleanup levels for the groundwater COCs due to active remediation and continued operation of the groundwater treatment system for contaminant removal; however, the duration to achieve the cleanup levels vary. 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.

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 Harrison Bayou 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) for TCE (5 µg/L), 1,2-DCA (5 µg/L), 1,1-DCE (7 µg/L), and VC (2 µg/L) for LHAAP-18/24. These standards are equivalent to the MCLs. In the absence of a federal drinking water standard, the perchlorate clean-up level will be based on TRRP Tier 1 Groundwater Residential PCL.

Alternative 1 does not comply with chemical-specific ARARs for groundwater, unsaturated soils, or secondary source within the saturated soil because no remedial measures would be implemented.

Alternative 3 is not expected to return groundwater concentrations within the slurry wall to less than the cleanup levels, so it does not meet the return to beneficial use RAO within the slurry wall. Alternative 3 will require an ARAR waiver for the groundwater within the slurry wall.

Alternatives 2, 4, 5, and 6 comply with the chemical-specific ARARs for groundwater, unsaturated soil, and secondary groundwater source (residual DNAPL) because they prevent exposure to groundwater that exceeds ARARs and would eventually return groundwater and soil concentrations to less than cleanup levels and return the groundwater in the shallow zone and Wilcox Formation to the potential beneficial use as drinking water wherever practicable.

All of the action alternatives would comply with the action-specific ARARs and any non-ARAR considerations.

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 removal or treatment would take place and no measures would be implemented to control exposure to risks posed by contaminated groundwater or the potential for contaminated groundwater to migrate to Harrison Bayou.

Alternative 2 offers a moderate degree of long-term effectiveness through operation of an enhanced groundwater extraction and treatment system, combined with unsaturated soil removal, residual DNAPL source removal, and LUCs implementation, which would minimize the potential risk posed by the contaminated groundwater. Reduction of the residual DNAPL source with groundwater extraction is not highly effective and therefore, the magnitude of residual risk will remain unacceptable.

Alternative 3 offers a degree of long-term effectiveness through physical containment of contaminated groundwater using a slurry wall and gradient control by pumping, combined with MNA to monitor effectiveness and LUCs to prevent groundwater use. Alternative 3 is designed to contain contaminated groundwater in place in perpetuity and would require a waiver of the restoration RAO prior to implementation. This alternative is effective in containing the contaminants but not practical as operation of the GWTP will have to occur in perpetuity.

Alternative 4 offers a higher degree of long-term effectiveness compared to Alternatives 2 and 3 through surfactant flushing of residual DNAPL, ISB of groundwater inside and outside the containment and in the Wilcox Formation including as a polishing step for the residual DNAPL areas in the shallow zone, unsaturated soil excavation, enhanced groundwater extraction and treatment system, and LUCs implementation. Alternative 4 is likely to achieve groundwater cleanup levels in a shorter period of time than Alternative 2. However, the period of time remains long because the effectiveness of surfactant flushing of residual DNAPL in low permeability zones is uncertain due to the difficulty in reaching into the low permeability zones.

Alternative 5 offers the highest degree of long-term effectiveness through thermal remediation of VOCs in residual DNAPL saturated soil areas in groundwater, ISB of groundwater inside and outside the containment and in the Wilcox Formation including as a polishing step for the residual DNAPL areas in the shallow zone, unsaturated soil excavation, enhanced groundwater extraction and treatment system, and LUCs implementation. Alternative 5 will achieve groundwater cleanup levels in a shorter period of time than Alternatives 3 or 4 because 99.9% removal of VOCs from the residual DNAPL areas is possible.

Alternative 6 also offers a high degree of long-term effectiveness through application of ZVI to the residual DNAPL saturated soil areas, ISB of groundwater inside and outside the containment and in the Wilcox Formation including as a polishing step for the residual DNAPL areas in the shallow zone, unsaturated soil excavation, enhanced groundwater extraction and treatment, and LUCs implementation. Alternative 6 relies on effective distribution of injected ZVI to all impacted areas. However, the ability to distribute injected ZVI into low permeability zones with high residual DNAPL may not be effective, and achieving results comparable to the treatability study results of greater than 99% reduction of TCE and high percentage reduction of MC and perchlorate is unlikely.

Alternative 5 is expected to have the shortest duration to shutdown of the GWTP. Alternatives 4 and 6, while rapidly addressing COCs in residual DNAPL areas, suffer from the difficulty of distributing the injected material to low permeability zones and may not be as effective as would be expected from a treatability test results where contact between the contaminants and the material is not limiting. Alternative 2 will not achieve the RAOs within an acceptable period of time (e.g., within 30 years). Alternative 3 would not reach cleanup levels within the slurry wall, and, due to the risk of containment failure, would be the least permanent remedy.

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 in groundwater and would not result in a reduction of toxicity, mobility, or volume of contaminants. All of the action alternatives provide some degree of reduction of toxicity, mobility or volume through treatment.

Alternative 2 provides a reduction in toxicity, mobility and volume via continued operation of an enhanced groundwater extraction and treatment system but the rate of reduction expected within the residual DNAPL areas will be slow.

Alternative 3 provides mobility reduction through the installation of a slurry wall and continued hydraulic control as needed. Reduction of volume through treatment is limited to NA mechanisms of contaminants outside the slurry wall and ex situ treatment of extracted groundwater from within the containment area.

Alternative 4 provides faster permanent reduction in toxicity and volume of the groundwater contaminants than Alternatives 2, and 3. This is achieved through surfactant flushing of saturated source soil to remove DNAPL that may serve as a long-term source of groundwater contamination, excavation of unsaturated soil, and implementation of ISB in areas inside and outside the containment and within the Wilcox Formation. In addition to enhanced groundwater extraction, all the above technologies will result in a reduction in contaminant toxicity, mobility, and volume. However, reduction of mass of residual DNAPL via surfactant flushing is expected to be partial due to difficulty of surfactants to reach low permeability zones. NA mechanisms of contamination outside the containment area will continue to act to reduce contaminant mass.

Alternative 5 provides the greatest reduction in toxicity, mobility, and volume of the groundwater contaminants compared to the other alternatives. This is achieved through thermal treatment of saturated source soil to treat DNAPL that may serve as a long-term source of groundwater contamination, excavation of unsaturated soil, and implementation of ISB in areas inside and outside the containment and within the Wilcox Formation. In addition to enhanced groundwater extraction, this technology will result in a reduction in contaminant toxicity, mobility, and volume. NA mechanisms of contamination outside the containment area will continue to act to reduce contaminant mass.

Alternative 6 provides a high level of reduction in toxicity, mobility, and volume of the groundwater contaminants compared to the other alternatives but is expected to be less than that achieved by Alternative 5. Reduction of mass of residual DNAPL via ZVI injection is expected to be partial due to difficulty of ZVI to effectively reach low permeability zones. Excavation of unsaturated soil and implementation of ISB in areas inside and outside the containment and within the Wilcox Formation, in addition to enhanced groundwater extraction will result in a reduction in contaminant toxicity, mobility, and volume. NA mechanisms of contamination outside the containment area will continue to act to reduce contaminant mass.

Biological activity would generate daughter products that may temporarily increase toxicity or mobility of the contaminant plumes. Alternatives 3, 4, 5, and 6 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.

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.

Because Alternative 1 does not involve remedial measures, no short-term risk to workers, the community, or the environment would exist.

All of the action alternatives involve potential short-term risks to workers associated with exposure to contaminated groundwater, vapor (i.e., volatilized and extracted VOCs), from monitoring and/or operation of drilling/construction equipment.

Alternative 2 presents risks associated with drilling new extraction wells, trenching for placement of conduits, and potential exposure to contaminated groundwater or heavy equipment. Alternative 2 presents potential risks associated with soil excavation (particulate emissions, heavy equipment) and off-site disposal which represents a greater exposure potential to LHAAP-18/24 workers, a greater potential for runoff releases to the environment and the potential for off-site traffic accidents and impacts on communities between LHAAP and the disposal facility. Risks are also associated with handling of chemicals used for ISB, although these chemicals are typically food grade and not harmful. Use of application equipment can also present risk.

Alternative 3 involves risks associated with the heavier equipment used in slurry wall construction and with handling the bentonite slurry used in construction. Alternative 4 requires a large construction footprint and will result in disturbing a wide area along the path of construction which will have an impact on the environment. Control of run-on and run-off would be critical to prevent cross-contamination of surface water. Risks associated with subsurface utilities are another concern of slurry wall installation.

Alternative 4 involves the same risks as Alternative 2 with the additional risks associated with surfactant flushing implementation which includes potential exposure to the surfactant and extracted fluids from the subsurface which would require surface handling, storage, treatment, and disposal.

Alternative 5 presents similar risks like Alternative 2 but has additional risks associated with implementation of thermal treatment technology which requires use of high voltage equipment and results in volatilization of VOCs that requires treatment at the ground surface.

Alternative 6 presents risks similar to Alternative 2 but with additional risk associated with use and handling of ZVI.

Alternatives 2 through 5 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.

By planning the construction, excavation, and transportation activities in accordance with industry and occupational safety and health administration (OSHA) codes and requirements, risks from contaminant exposure and construction operations would be controlled to acceptable levels. Dust control and sediment deposition into adjacent surface water bodies can be controlled during earthwork and construction activities. Erosion control measures would include surface grading; emplacement of silt fences; covering surfaces with straw, mulch, riprap, and/or geotextile fabrics. Following completion of all construction and excavation, disturbed areas would be regraded with clean backfill and revegetated with native grasses. Appropriate personal protective equipment (PPE) would be required for remediation workers. Overall risk can be mitigated by developing a health and safety plan in compliance with OSHA requirements, communicating the hazards to involved parties, and providing the know-how and tools to mitigate those hazards.

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.

Alternative 1, No Action, would involve shutting down the groundwater extraction system, which is assumed to be administratively unacceptable to the U.S. Army and to the regulatory agencies.

The action alternatives for groundwater are all technically implementable with varying degrees of difficulty.

Reactivation of existing ICTs for Alternatives 2, 4, 5, and 6 should be easy to implement as the tools and skilled resources are available. Similarly, implementation of additional extraction points for Alternative 2 should not pose any difficulties to drill the wells and connect the wells to the GWTP. ISB is specified for Alternatives 2, 4, 5, and 6. ISB has been implemented at other LHAAP sites and should not pose any difficulties to implement at LHAAP-18/24. Success of ISB was determined by conducting treatability testing and bioaugmentation at the laboratory scale. Treatability testing at the bench-scale and pilot-scale will also be required for surfactant remediation to select and optimize surfactant dose and provide proof of concept for Alternative 4 (i.e., loss of control for DNAPL migration, generation of adverse chemicals, and penetration effectiveness in low permeability zones). Thermal treatment (Alternative 5) does not require treatability testing and its implementability hinges on the availability of power to supply the electrodes with sufficient power to heat the saturated soils. Considering that power reliability has been a concern at the GWTP, this would be an important design consideration for this technology. Implementation of ZVI for Alternative 6 faces similar implementability considerations such as ISB implementation.

Alternative 3 has two significant implementation issues:

- The slurry wall would need to key into the confining layer for the shallow zone.
- Any significant discontinuities in the confining layer would need to be addressed.

There are areas at LHAAP-18/24 where both issues exist. Technologies are available to address both issues, but it will be difficult to ensure the quality of containment throughout the system.

For Alternative 2, 4, 5, and 6 soil excavation would also require coordination between excavation, sampling, transportation and disposal. However, because the volumes are not large, resources are readily available to implement.

2.10.7 Cost

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

The costs include both capital costs (including fixed-price remedial construction) and long-term O&M costs (post-remediation). Overall 30-year present value costs are developed for each alternative assuming a discount rate of 3.0 percent. Total present value costs for each alternative are presented in Appendix D of the FS and a summary is presented below. It should be noted that some alternatives have extensive capital costs but could result in a serious reduction in the alternative lifecycle to achieve the RAOs (e.g., less than 30 years). Other alternatives that do not rely on intensive upfront remediation technologies have a very long remediation lifecycle (i.e., well beyond 30 years) that would outweigh the alternatives with high capital cost. Because cost determination was limited to 30 years per CERCLA requirements, the alternatives with high capital costs (e.g., Alternatives 5 and 6) appear to be as or more expensive on a 30-year basis than alternatives with low capital costs but long lifecycle duration (e.g., Alternatives 2 and 3).

The progression of total present value costs from the least expensive alternative to the most expensive alternative is as follows: Alternative 1, Alternative 3, Alternative 2, Alternative 4, Alternative 5, and Alternative 6. There are no costs associated with Alternative 1 because no remedial activities would be conducted. Alternative 6 has highest capital costs due to the high cost of ZVI, but lower O&M costs than all other alternatives with the exception of Alternatives 3 and 5. Alternative 5 has an O&M cost over 20 years after which the GWTP and extraction would be shut down. Alternative 5 has a higher capital cost associated with thermal treatment compared to Alternatives 2, 3, and 4. Alternatives 2, 3, and 4 have the lowest capital costs of the active remedial alternatives, with Alternative 3 having the lowest capital cost associated with slurry wall construction and lowest O&M cost due to the greater cost reductions in O&M associated with reduction in GWTP operation and reduction in monitoring costs (this alternative does not require full extraction of groundwater). Alternatives 2, 4, and 6 have the highest O&M costs of all the alternatives because it is assumed that GWTP operations will continue for 30 years with no reduction in extraction rates.

2.10.8 State/Support Agency Acceptance

The USEPA and TCEQ have reviewed the PP, which presented Alternative 5 as the preferred alternative. Comments received from the USEPA and TCEQ during the Proposed Plan development have been incorporated. Both agencies concur with the selected remedial action.

2.10.9 Community Acceptance

Community acceptance is an important consideration in the final evaluation of the selected remedy. Comments were received during the 30-day public comment period held for the PP from April 2, 2019 to May 2, 2019, and verbal comments were received during the public meeting held on April 25, 2019.

Comment responses were provided and are summarized in the Responsiveness Summary (**Section 3.0**).

2.11 Principal Threat Waste

Laboratory results from the groundwater at LHAAP-18/24 have indicated that possible “pools” of DNAPL may be residing as residual source material in fractures and pores in the subsurface. As a component of this groundwater, the hazardous contaminants, TCE and MC, are 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 two identified areas of DNAPL in the groundwater 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 5 – Enhanced groundwater extraction and treatment as needed, LUCs, EISB inside and outside containment area and in Wilcox Formation, unsaturated soil excavation, and thermal DNAPL removal is the preferred alternative for LHAAP-18/24 and is consistent with the intended future use of the site as a national wildlife refuge. The ISTD will rapidly reduce TCE and MC concentrations at two locations within the containment area to make conditions more amenable for EISB and/or MNA. The selected alternative offers a high degree of long-term effectiveness and can be easily and immediately implemented. This alternative is expected to achieve site RAOs in the shortest period of time compared to the other alternatives.

This alternative would satisfy the RAOs for the Site through the following:

- Continued use of the existing groundwater extraction system as needed with enhancements (including a potentially phased reactivation of two existing ICTs (ICT 3 and 9) until COC concentrations are low enough that MNA can address remaining contamination within the containment area.
- Continued operation of the current or potentially a new GWTP, including contingency use of advanced oxidation process for treatment of 1,4-dioxane.
- Excavation of unsaturated soil exceeding groundwater protection-industrial MSC (GWP-Ind) will result in the removal of soil that is a potential source of TCE and MC contamination to groundwater. The locations south of the former UEP, west of the UEP, and underneath the UEP have concentrations of residual contamination that pose a low-level threat to groundwater. The potential leaching of contaminants from the unsaturated soil at these locations to groundwater is considered a complete transport pathway. With the removal of this soil, the potential migration of TCE and MC from soil to groundwater would be eliminated and long-term operations/management for impacted soil would not be required
- Implementation of EISB of shallow zone groundwater outside the containment area at several locations; in the Wilcox Formation at three or more locations, and inside the containment at five or more locations or as needed to reduce to levels amenable to MNA.
- Implementation of ISTD to remove DNAPL that poses a principal threat to groundwater in two distinct areas inside the containment area at the site to reduce to levels amenable to MNA.
- MNA for both shallow zone and Wilcox Formation groundwater for areas outside the influence of the treatment areas and for areas inside the influence of the treatment areas (after evaluation of EISB) to reduce contaminant levels to cleanup levels and confirm the contaminated groundwater remains localized with minimal migration.
- Maintenance of the existing cap over the former UEP to reduce infiltration.
- The LUC to prohibit groundwater use (except for environmental testing and monitoring) as a potable source will 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 will 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 will 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. The LUC for preserving the integrity of the surface impoundment cap shall include restrictions that prevent intrusive activities that may degrade or alter its effectiveness. Restrictions would include restricting intrusive activities (e.g., digging) that would degrade or alter the cap. These restrictions would remain in place until the underlying source soil is removed and/or the cleanup levels for soil listed in **Table 2-10** have been achieved.

- 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. If necessary, after the five year review, the Army, EPA, and TCEQ will assess the successfulness of the groundwater remedy. At that time, the FFA parties will determine if the activation of a contingency remedy is appropriate.

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. The high concentrations of TCE and MC in the shallow zone and Wilcox Formation indicate that residual DNAPL material may be acting as a principal threat waste. Therefore, the presence of residual DNAPLs in groundwater near the UEP and the ACD are considered sources of groundwater contamination that will be addressed during the remedial action. 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 TCE and MC groundwater plume and would comply with NCP expectations regarding treatment of affected media where principal threat may be considered.

Unsaturated soil known to contain residual contamination posing a low-level threat to groundwater is isolated to locations south of the former UEP, west of the UEP, and underneath the UEP. The potential leaching of contaminants from the unsaturated soil at these locations to groundwater is considered a complete transport pathway that will be addressed during the remedial phase.

In the RD, the U.S. Army will present details of the soil excavation, selected ISTD process (ERH or TCH), ISTD design, LUC O&M, groundwater monitoring, EISB implementation, GWTP operation and modifications, and MNA remedy implementation for LHAAP-18/24.

2.12.2 Description of the Selected Remedy

The selected remedy, Alternative 5, was outlined in **Section 2.9**; that description is expanded in the following discussion. The assumptions and specifications presented for the remedy were used for cost estimating purposes and are subject to change in the remedial design process. The major components of the remedy include:

Continued use of the existing groundwater extraction system with enhancements, as needed. The use of the existing groundwater extraction system will continue where extraction will not interfere with in situ remedies and where needed to control the plume during in situ treatment. The extraction plan detailing which ICTs will be operational during each phase of remedy implementation will be further developed during the remedial design phase. The groundwater extraction system would continue to operate with additional ICTs inside the containment area brought back on line (i.e., modifications implemented as part of the pilot study implemented in 2008 (Shaw) will be partially reversed), or potentially a new GWTP replacing the existing GWTP would be designed and used to treat extracted groundwater.

Preliminary results from the pilot study indicate that certain ICTs that were turned off could be very productive in removing contaminant mass from the subsurface if the extraction flow rate is sustainable. Based on historical results, two ICTs (ICT 3 and ICT 9) in particular have a high potential for removing a large amount of COC mass from the groundwater. Sampling of the various inactive ICTs to determine which ICTs would be most effective will be conducted before determining which two ICTs will be activated. The criteria for evaluating the ICT sample results and basis for recommending ICTs to be reactivated will be developed and presented in the RD. Groundwater extraction acts to remove source mass and contain the contamination within the shallow zone only. **Figure 2-16** shows the location of the ICTs, extraction wells, and pipelines that convey the extracted groundwater to the GWTP.

Continued operation of the current or potentially a new GWTP, including contingency use of advanced oxidation process for treatment of 1,4-dioxane. The existing groundwater extraction system currently removes water from 21 interception trenches and two vertical extraction wells (EW-1 and 18WW17). This groundwater extraction hydraulically controls migration of contaminants. The extracted groundwater is pumped to the GWTP, stored in an equalization tank for batch treatment, sent through precipitation to remove metals, subjected to air stripping to remove VOCs, and treated in a biological reactor to remove perchlorate. The treated effluent is discharged to Harrison Bayou or the INF Pond or released to Burning Ground No. 3 via a sprinkler system. Five other interception trenches that were previously used to extract groundwater (ICT-1, ICT-3, ICT-5, ICT-10, and ICT-12A) were deactivated on February 18, 2008 as part of a pilot test to encourage subsurface flow across the most contaminated portions of LHAAP-18/24. On December 5, 2012, ICT-12A was restored and is currently extracting groundwater.

Based on the estimates for the timeframe that will be required to remove the mass of contaminants within the containment area, it is expected that the GWTP will be operated for a minimum of 20 years. The current GWTP is nearly 17 years old and is aging, requiring frequent maintenance with anticipated more maintenance requirements with recapitalization for major item replacement in the near future. Additionally, the existing GWTP is oversized with a design capacity of up to 300 gallons per minute (gpm) while current operations recover an average flow of 20 gpm. Due to the age of the plant, frequent maintenance requirements, and idling conditions, Alternative 5 includes the potential for capitalization of a smaller foot print GWTP to replace the existing plant. The specific design and capacity of a new GWTP would be determined based on current and projected extraction rates and volumes.

The continued operation of the current GWTP or potentially a new GWTP will be determined through a cost/benefit analysis conducted during the remedial design phase. If the new GWTP is selected, the new GWTP will be designed for a 50 gpm flow rate, which should accommodate the anticipated increase in groundwater extraction rates (reactivation of two ICTs and additional extraction wells in the DNAPL areas in addition to any extraction from LHAAP-17 that could go on line for a duration of 18 months). The system will consist of the same processes of metals precipitation, VOC stripper, and fluidized bed reactor (FBR) for removal of perchlorate. Should treatment for 1,4-dioxane be required, an advanced oxidation process using the HiPOx^{TM} technology consisting of hydrogen peroxide with ozone will be implemented as a contingency remedy. The determination about whether 1.4-dioxane treatment is required will be made as part of the remedial design.

Soil Excavation. Soil at two locations to the south of the former UEP (**Figure 2-16**) identified by TCE and MC exceedances between the depths of 8 and 12 ft bgs and depths of 5.5 and 12 ft bgs will be excavated. Additionally, soil in the former burn pit area to the west of the former UEP at depths ranging from 4 to 14 ft bgs will be excavated. The soil will be removed to meet the cleanup levels presented in **Table 2-10**. The shallow soil will be removed and stockpiled for use as backfill if clean. However, the backfill soil will be characterized before reuse. Excavation side walls and bottom will be sampled to confirm clean soil before backfilling with clean soil. Additional excavation will be conducted if contaminants are detected in the excavation walls or bottom. The contaminated soil will be stockpiled, sampled for characterization, and then hauled off-site for disposal at either a RCRA Subtitle C or Subtitle D landfill depending on soil characteristics. The in-place volume is estimated at 1,350 yd^3.

A contingency remedy to excavate soil beneath the UEP. If during the Five-Year Review the results of the groundwater remedy indicate a continuing source from the UEP, a contingency remedy to excavate soil beneath the UEP would be developed if COCs are present at concentrations exceeding the GWP-Ind. Criteria to be used to determine whether the contingency remedy should be implemented, as well as development and specific description of the contingency remedy would be presented in a RD/RAWP.

Implementation of EISB of shallow zone groundwater inside and outside the containment area and in the Wilcox Formation. EISB is planned in locations shown on **Figure 2-17** and where needed as a polishing step in thermal treatment areas. Final selection of the areas that will receive EISB will be developed during the remedial design phase. The locations on **Figure 2-17** are presented for costing purposes. ISB would consist of the application of organic substrate (e.g., EVO or other formulations) as a bacterial food source, and a bacterial inoculation mix (e.g., SDC-9 or KB-1 Plus®), in areas of the groundwater plume outside the containment area within areas of high perchlorate and high TCE in the northeast, southwest, and southeast. Inside the containment, ISB would be conducted upgradient of MW-21 and 109 in the northeast boundary, near monitoring wells 120 and MW-14, and in the area of MW-23 and location 18CPT03 where high perchlorate concentrations were detected. Enhanced bioremediation will also be applied near 18CPTMW08SW and 18CPTMW22SW into the Wilcox Formation due to the presence of high concentrations of perchlorate in the Wilcox Formation in this area of the Site. **Figure 2-17** shows the area targeted for ISB treatment based on existing information.

ISB would be applied using direct push technology (DPT) injections. Injection via deep boreholes that are surface cased may be required for the Wilcox Formation. Tracer tests will be conducted to determine whether the proposed injection locations are within or outside the capture zone of the extraction system with the goal to prevent injected substrate from being pulled into the extraction ICTs. Additionally, in order to minimize loss of ISB amendments, extraction wells would be temporarily shut down when ISB treatment amendment begins to appear in the wells. If ISB amendments reached extraction sumps this may result in biofouling problems that subsequently lead to groundwater extraction complications. Therefore, nearby ICTs and monitoring wells will be monitored for the occurrence of treatment amendments during implementation of enhanced ISB.

ISB will enhance biodegradation of perchlorate in situ that would ultimately reduce the concentration of perchlorate and VOCs to a level that would allow NA to take over and reduce concentrations to below the cleanup levels.

ISB amendments that result in creating geochemical changes (reducing conditions) favorable for anaerobic biodegradation could also have the potential to result in mobilization of arsenic to groundwater. Under anaerobic reducing conditions, immobilized ferric iron becomes reduced and mobile in the form of ferrous iron. Arsenic generally co-precipitates with ferric iron and as the iron is solubilized in the form of ferrous iron, arsenic tends to come off the soil matrix into solution. Therefore, monitoring for arsenic in groundwater will be an integral part of this process.

ISB will enhance biodegradation of MC, TCE, and perchlorate in situ and ultimately reduce the concentrations of those chemicals to a level that would allow NA to take over and reduce contaminant levels to below the cleanup levels. **Figure 2-17** shows the multiple areas targeted for ISB treatment based on existing information.

For cost estimating purposes, the ISB is assumed to be implemented using a biobarrier injection configuration. The spacing of injection points is assumed to be 20 ft. For the purposes of costing, five ISB biobarriers are assumed one in the northeast (900 ft), one in the southwest (600 ft), two 300-foot biobarriers in the northwest in the vicinity of 18CPTMW23 and 18CPTMW15 and AWD-4, 150 ft ISB in the vicinity of monitoring well 120, and one in the south (200 ft) for a total length of 2,450 ft and 122 DPT injection points. For the two grid areas, each grid is 200 ft by 200 ft in area and the injection points are 25 ft apart for a total of 81 injection points in each grid. In the Wilcox aquifer, the ISB is assumed to use a biobarrier injection in two rows each 100 ft long and 50 ft apart. Injection would occur upgradient of 18CPTMW08SW based on the potentiometric surface for the Wilcox Formation in this area of the Site. Another 200 ft ISB is assumed in the vicinity of 18CPTMW22SW and 150 ft ISB for MW-14. The ISB biobarrier and grid layout will be determined during the remedial design.

Two applications of ISB treatment are assumed for costing purposes. The first application will be DPT injection of a slow releasing organic substrate (EVO) during year 1 in the areas depicted on **Figure 2-17** Bioaugmentation is anticipated to be conducted 3 months after establishment of sustainable anaerobic conditions. It is assumed the first injection will reduce perchlorate concentrations by 90% and TCE and MC concentrations by 75%. The second application will be DPT injections of EVO and bioaugmentation during year 3 in the same areas. It is assumed the second injection will reduce perchlorate by 90% and TCE and MC by an additional 75%. After the first 2 injections, it is assumed that MNA will control any remaining dissolved COCs. However, evaluation of whether additional applications would be required will be made from performance data.

Depending on the cleanup level achieved with thermal treatment for VOCs, it is anticipated that enhanced ISB in the treated DNAPL areas be implemented in a grid fashion with 25 by 25 ft spacing. Two events as described for other enhanced ISB will be implemented. Additionally, enhanced ISB would be required in the treated DNAPL areas due to the presence of perchlorate which is not readily removed by thermal treatment. Enhanced ISB application will occur when the temperature of the thermally treated area cools to below 30 °C.

In-situ Thermal Desorption for DNAPL. Under Alternative 5 the two identified areas of DNAPL groundwater will be treated using ISTD. These areas include the former UEP area extending approximately 35,500 ft^2 (ERH or Conductive Heating Area 1 on **Figure 2-16**) and the former ACD area extending approximately 5,000 ft^2 (ERH or Conductive Heating Area 2 on **Figure 2-16**) with a depth of impact to approximately 50 ft in the former UEP area and to 30 ft in the former ACD area. 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 soil vapor extraction (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 °C) 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.

The remedial design will finalize the selection of thermal technology. The conceptual design used to develop initial costs assumed that 25 vapor extraction points will be used to a depth of 15 ft bgs using stainless steel material. Extraction would be conducted using a liquid ring vacuum pump and a thermal oxidizer would be used to treat the vapors. Air flow capacity is estimated at 4,000 cubic ft per minute.

Removal of residual DNAPL via thermal treatment and extraction will remove at least 99.9% according to the thermal vendors even within low permeability zones. Thermal treatment also enhances mobilization of organic matter from the soil to groundwater, which will act to enhance biodegradation of the COCs. Additionally, higher ambient soil temperature imposed by the thermal treatment process during startup and cool down periods will increase the biodegradation rate by a factor of 2 for every 10 °C increase in ambient soil temperature up to approximately 25 °C above which bacterial activity would decrease. Application of thermal treatment in the southern area of the UEP will also remove COCs in the unsaturated zone (e.g., area represented by 18CPT21) that would otherwise be subject to excavation. Therefore, the volume requiring excavation could be reduced by approximately 6,000 yd^3.

Groundwater extraction near the thermally treated areas might have to be ceased temporarily to reduce the groundwater flux through the area, which requires additional heating capacity.

The presence of DNAPL in the ACD area may extend farther to the north toward ICT-12E and monitoring well 120, increasing the area to be treated for DNAPL. Therefore, the cost estimate for the DNAPL area in the vicinity of the ACD may become larger and will be considered during the RD phase.

MNA for both shallow zone and Wilcox Formation groundwater for areas outside the influence of the treatment areas and for areas inside the influence of the treatment areas (after treatment). For the MNA performance evaluation, USEPA 1999 is cited as the guiding document for evaluating effectiveness of MNA. A monitoring program will be designed and implemented to evaluate enhanced MNA of VOCs and perchlorate in the shallow zone inside and outside the containment area after completion of active remediation as may be necessary. The monitoring program will also monitor for COCs in the upper Wilcox Formation. LTM will be conducted to confirm that contaminant concentrations are being reduced to acceptable levels over time.

No NA information is available for Wilcox Formation wells at this time because the majority of Wilcox Formation wells that are impacted were installed since May 2013 and only two to three data points are available for these wells. New data will need to be evaluated for NA in the Wilcox Formation.

For this alternative, it is assumed that a monitoring program will be designed and implemented in accordance with USEPA guidance (USEPA, 1998; USEPA, 2004) to evaluate the effectiveness of NA at the Site. A total of 92 monitoring wells are currently available to provide groundwater data (32 Wilcox Formation wells and 60 shallow zone wells).

MNA sampling would be a part of groundwater monitoring plans. MNA sampling will be performed quarterly for the first two years, semi-annually for the next three years, annually for the next five years and then every two years. After that, the sampling frequency may be changed to once every five years if the data suggest less frequent sampling is appropriate. For costing purposes, a 30-year monitoring program is assumed. The analytical program will consist of VOCs, metals, perchlorate, and 1,4-dioxane, among others. The full list of MNA parameters would be developed during the RD phase. For cost estimating purposes, 4 Wilcox monitoring wells and 12 shallow monitoring wells were assumed for sampling (20 samples with QC). The MNA network is expected to be more expansive than assumed for costing purposes, and the locations and number of wells to be used for MNA will be developed during the RD phase.

Annual reports will be prepared to document the program. The second year annual report will include a review of the first eight rounds of sampling and provide the rationale for MNA as an effective part of the remedial alternative. Sampling frequency, reporting frequency, or analytical suite may be modified based on the results of the sampling program.

Major components of the MNA remedy include:

- **MNA to return groundwater to its potential beneficial use, wherever practicable.** Historic data suggest that NA of COCs is occurring at the Site; however, additional data collection is necessary to fully evaluate NA. Monitoring wells will be sampled for eight consecutive quarters to evaluate and confirm the occurrence of NA in conjunction with historical data. Data from the eight quarterly events will be combined with historic data to evaluate the effectiveness of various natural physical, chemical, and biological processes in reducing contaminant concentrations. If MNA is not found to be effective in areas outside of direct active treatment, a contingency remedy may be implemented. The contingency remedy would be determined based on aquifer conditions at that time. The monitoring details associated with MNA will be presented in the RD.

- **Performance objectives to evaluate the MNA remedy performance after two years.** Each of the general performance objectives must be met as indicated below. If the criteria are not met to illustrate that MNA is an effective remedy, the contingency action will be initiated. If MNA is effective, a baseline will be established from the data to this point in time. Specific evaluation criteria will be developed in the RD. The MNA evaluation will be based on 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 will be conducted to evaluate the remedy performance and determine if the plume conditions remain constant, improve or worsen after the baseline is established. LTM will be implemented at a frequency of semiannual for three years, then annually until the next five-year review. The performance monitoring plan will be developed in the RD and will be based on USEPA guidance (USEPA, 2004).
  - Continue LTM 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 will be established as part of the MNA evaluation program. The initial LTM plan will be developed during 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, maintaining the surface impoundment cap over the UEP, 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 U.S. 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 U.S. 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 USEPA 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 2-18**.
    - 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, 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.
    - The LUC for preserving the integrity of the surface impoundment cap shall include restrictions that prevent intrusive activities that may degrade or alter its effectiveness. Restrictions would include restricting intrusive activities (e.g., digging) that would degrade or alter the cap. These restrictions would remain in place until the underlying source soil is removed and/or the cleanup levels for soil listed in **Table 2-10** have been achieved.

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 U.S. Army-owned property, the U.S. Army will provide written notice of the LUCs 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 U.S. 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 U.S. 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 LUCs 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-18/24. The LUCs would be included in the property transfer documents and a recordation of them filed in the Harrison County Courthouse. The LUCs 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 U.S. Army shall request the Texas Department of Licensing and Regulation to notify well drillers of groundwater use prohibitions based on a preliminary LUC boundary. Within 21 days of the issuance of the ROD, the U.S. 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 U.S. Army shall: 1) request the Texas Department of Licensing and Regulation to notify well drillers of the final boundary of groundwater use prohibitions; and 2) notify the Harrison County Courthouse of the LUCs to include a map showing the area of groundwater use prohibition at the site, in accordance with 30 TAC 335.565.

Monitoring activities associated with the LUCs would be undertaken to confirm that groundwater is not being used. Long-term operational requirements under this alternative would include maintenance of the LUCs. Groundwater monitoring will demonstrate no migration of the plume and the eventual reduction of contaminates to levels below cleanup levels. The need for continued groundwater 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-18/24.

Maintenance of the existing cap over the former UEP. The closure cap over the UEP will be maintained in good condition, preventing erosion and maintaining vegetative cover to reduce infiltration in this area and prevent any contamination present in the unsaturated soil beneath the UEP from migrating to groundwater.

The former UEP was closed as a surface impoundment under RCRA in 1986 and capped by 1987. The UEP cap design consisted of removing the sludge, filling the UEP with common fill, covering the common fill with 4 ft of compacted clay, then applying 1 foot of sand, covered by 1 foot of topsoil. The surface of the cap has an average slope of three percent on top while the sides have a vertical to horizontal ratio of 1:4. It is graded and equipped with a sand drainage layer to promote sheet flow runoff to minimize erosion.

This cap would continue to be monitored, maintained, and repaired, as necessary, to ensure long-term effectiveness. This includes inspections of the cap to check for erosion, settlement, and deep-rooted vegetation, and implementation of necessary repairs. Routine maintenance and repair of the cap will include actions needed to ensure that the integrity of the cap is maintained (e.g., mowing, seeding, and settlement/erosion repair). A LUC restricting intrusive activities would be implemented to ensure the integrity of the cap. These restrictions would remain in place until the underlying source soil is removed and/or the cleanup levels for soil listed in **Table 2-10** have been achieved.

The importance of maintaining the cap is to prevent contaminants present in the unsaturated soil from leaching to groundwater. Three locations within the UEP identified the presence of contaminants within the unsaturated zone above the water table (18CPT21, 18CPT25, and 18CPTUEP05). The highest contamination was reported in 18CPT21. The presence of the cap provides a significant protection of this soil as long as cap maintenance continues to minimize infiltration of rain water. The runoff water from the UEP cap will be drained to off-site locations to avoid infiltration of rain water inside the containment.

2.12.3 Cost Estimate of the Selected Remedy

Table 2-12 presents the present worth analysis of the cost for the selected remedy, Alternative 5. The information in the table is based on the best available information regarding the anticipated scope of the remedial alternative. The quantities used in the estimate are for estimating purposes only. Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternative. 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 Alternative 5 is shown in **Table 2-12** below. The costs were developed using a discount rate of 3%. 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 Tier 1 Groundwater Residential PCL ($^{GW}GW_{Ing}$). The cleanup level for the soil is the GWP-Ind MSC

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 20 years, however considering the lithologic variability, particularly the lateral and vertical change from sand to clay, the time 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. In the short-term (prior to the groundwater achieving cleanup levels), it is anticipated 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. Until that time, the LUC for groundwater will prohibit the use of the site's groundwater except for environmental monitoring and testing. When the groundwater remedial action goals are achieved, the LUC will be removed.

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 5, will achieve the RAOs for LHAAP-18/24. Implementation of the LUCs would restrict intrusive activities at the surface impoundment cap and prevent human access and exposure to contaminated soil beneath the cap and groundwater that poses an unacceptable risk to human health until the remedy achieves the RAOs. The LUCs would include land use notification at the Harrison County courthouse and periodic surveillance of LHAAP-18/24 to ensure that use restrictions are not being violated. The U.S. Army would include the notice with any transfer letter to the USFWS for the intended future use as a national wildlife refuge. If transferred out of U.S. government control, deed restrictions would be placed on the property to prohibit or restrict property uses that may result in exposure to groundwater (e.g., drinking water well installation). Continued maintenance of the LUC for groundwater would 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.

With implementation of ISB on three sides outside the containment, in the Wilcox Formation, and inside the containment in five areas, removal of potential unsaturated source soils, ISTD remediation of secondary source areas in the saturated soil inside the containment area in two distinct areas (former UEP and former ACD), and enhanced groundwater extraction inside the containment as needed, this alternative should accelerate the process of achieving the RAOs. No reliance on NA is proposed for this alternative. Since NA is occurring at the site, its use as part of the remedy is inevitable. NA inside the containment is a feasible option to polish the residual COCs remaining after ISTD and ISB implementation are completed.

Groundwater use restrictions would remain in place until groundwater extraction, as needed and eventually NA reduces contaminant levels inside and outside the containment and in the Wilcox Formation to allow unrestricted use and unlimited exposure. 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.

A monitoring program that would track the continual attenuation of the groundwater COCs and verify that contamination is not reaching Harrison Bayou will be implemented. The LTM program would provide information to support Five-Year Reviews and the termination of the remedy when cleanup levels have been met.

The treatment system and enhanced groundwater extraction, as needed, would continue to be operated to prevent migration of COCs from the containment area and reduce the concentrations of those COCs over time inside and outside the containment area. The treatment system and other active remedies would eventually achieve concentrations throughout the containment area and outside the containment area that could be addressed via NA.

2.13.2 Compliance with ARARS

The selected remedy complies with all ARARs. The ARARs and non-procedural considerations are presented below and in **Table 2-13**.

Chemical-Specific 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 Tier 1 Residential Groundwater PCLs.

  This alternative will return the contaminated shallow and intermediate groundwater zones at LHAAP-18/24 to their potential beneficial use as drinking water, wherever practicable, given the particular circumstances of the site, 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.

- **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.

- **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 and 30 TAC 307.4, 307.6, 307.7, 307.8 and 307.9 are considered potential future ARARs. 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). For COCs that are not listed in Table 2 of 30 TAC §307.6(d)(1), the TRRP Tier 1 Residential Groundwater PCL for those COCs would apply.

  The extracted groundwater will be treated to the levels established by TCEQ Water Quality Division. The treated water will be discharged to Harrison Bayou. **Table 2-14** identifies the current discharge criteria, however the discharge criteria will be established during the RD phase.

Location-Specific ARARs

The discharge limits for extracted and treated groundwater, calculated by the TCEQ Water Quality Division, are also considered location-specific ARARs and discussed under the chemical-specific ARARs.

Action-Specific ARARs

The selected remedy has potential action-specific ARARs related to the following activities: site preparation and soil excavation activities, waste and disposal activities, well construction, and water treatment.

- **Site Preparation, Construction, and Excavation Activities.** Certain on-site preparation, construction, and/or excavation activities will be necessary 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 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 and 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 nonhazardous 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). If feasible, secondary waste streams generated due to dewatering, well development activities, or from decontamination activities will be sent to the LHAAP-18/24 wastewater treatment facility for further treatment in accordance with applicable regulations. All wastes must be managed, stored, treated (if necessary), and disposed of in accordance with the ARARs for waste management listed in **Table 2-13** 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 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-18/24 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 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); 40 C.F.R. § 264.1(g)(6); 30 TAC 335.429(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).
- **Post-Closure Care.** Substantive requirements of closure and post-closure ARARs include 30 TAC 335.174 and 40 CFR § 264.228 addressing surface impoundments storing hazardous waste. Closure requirements were met during implementation of the cap. Post-closure requirements are relevant and appropriate, and include 40 CFR § 264.228(b)(1), (3) and (4). In addition, those substantive requirements of 40 CFR §§ 264.117-120 related to post-closure for the remedy in place are relevant and appropriate.

Other Considerations

Activities that would be conducted under Alternative 5 are similar to current activities of groundwater extraction, treatment monitoring, and discharge and would comply with all procedural considerations described in **Table 2-13**. ISB source area remediation, and soil excavation will be implemented in areas that have already been disturbed. No activities would take place in sensitive environments such as wetlands, and no impacts to archeological resources or threatened and endangered species are anticipated. Compliance with the substantive requirements with waste generation, temporary storage, characterization, and off-site disposal are being carried out at this site and will be complied with during implementation of the remedy.

2.13.3 Cost-Effectiveness

Table 2-12 presents the present worth analysis of the cost estimate for the selected remedy. The information in the table is based on the best available information regarding the anticipated scope of the remedial alternative. The capital cost for the selected remedy is $19.52M, with O&M costs of $13.13M, and total cost of $32.667M. The quantities shown 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 progression of total present value costs from the least expensive alternative to the most expensive alternative is as follows (provided no contingencies are implemented): Alternative 1, Alternative 3, Alternative 2, Alternative 4, Alternative 5, and Alternative 6.

There are no costs associated with Alternative 1 because no remedial activities would be conducted. Alternative 6 has highest capital costs due to the high cost of ZVI, but lower O&M costs than all other alternatives with the exception of Alternatives 3 and 5. Alternative 5 has an O&M cost over 20 years after which the GWTP and extraction would be shut down. Alternative 5 has a higher capital cost associated with thermal treatment compared to Alternatives 2, 3, and 4. Alternatives 2, 3, and 4 have the lowest capital costs of the active remedial alternatives, with Alternative 3 having the lowest capital cost associated with slurry wall construction and lowest O&M cost due to the greater cost reductions in O&M associated with reduction in GWTP operation and reduction in monitoring costs (this alternative does not require full extraction of groundwater). Alternatives 2, 4, and 6 have the highest O&M costs of all the alternatives because it is assumed that GWTP operations will continue for 30 years with no reduction in extraction rates.

Although Alternative 5 is not the least expensive alternative, it is expected to achieve site RAOs in the shortest period of time compared to the other alternatives. Costs for Alternatives 2, 4, and 5 differ by approximately $2M, or vary from one another by approximately 5% or less, suggesting that cost may be a less significant differentiator for these alternatives than other criteria.

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 in-situ treatment and groundwater extraction, as needed would irreversibly reduce groundwater contaminant concentrations in the treated portions of the groundwater plume. MNA will reduce groundwater contaminants to cleanup levels. 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).

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 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 and EISB 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-18/24 residing as residual DNAPLs in groundwater. The DNAPLs will be addressed during remediation with ISTD.

2.13.6 Five-Year Review Requirements

Section 121(c) of CERCLA and NCP §300.430(f)(5)(iii)(C) provide the statutory and legal bases for conducting five-year reviews. Because this remedy will result in contaminants that remain 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 Proposed Plan for LHAAP-18/24 was released for public comments on April 2, 2019. The Proposed Plan identified Alternative 5 as the Preferred Alternative for groundwater remediation.

Verbal comments were discussed during the public meeting held on April 25, 2019, and the U.S. Army provided responses as recorded in the meeting transcript, available in the Administrative Record (http://www.longhornaap.com/admin-record). The U.S. Army reviewed all written comments submitted during the public comment period. 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 at that time.

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			---	2.32E-09	maximum
	Explosives					
	2,4-Dinitrotoluene	ND	ND	0/4	5.30E-01	maximum
	1,3,5-Trinitrobenzene	0.001	0.001	1/6	1.00E00	
	2,6-Dinitrotoluene	ND	ND	0/4	5.30E-01	maximum
	4-Nitrotoluene	ND	ND	0/4+	2.10E+00	maximum
	Metals					
	Antimony	0.012	0.333	5/26	3.33E-01	maximum
	Barium	0.039	6.0	25/26	6.00E+00	maximum
	Chromium	0.01	18.0	20/26	1.8E+01	maximum
	Cobalt	0.11	0.28	2/6	2.8E-01	
	Lead	0.002	0.018	9/26	1.8E-02	maximum
	Manganese	0.022	2.41	6/6	8.27E+00	maximum
	Nickel	0.044	9.6	7/26	9.60E+00	maximum
	Silver	0.01	0.48	4/26	4.8E-01	maximum
	Strontium	0.12	4.4	6/6	4.4E+00	maximum
	Thallium	0.0017	0.0037	6/26	3.70E-03	maximum
	Non-Metallic Anion					
	Perchlorate	8.00E-03	8.80E+01	13/30	6.90E+01	maximum
	Volatile Organics					
	Bromodichloromethane	0.005	0.007	3/26	7.0E-03	maximum
	Chloroform	0.009	0.028	6/26	2.80E-02	maximum
	cis-1,2-Dichloroethene	0.250	0.250	1/6	2.50E-01	maximum
	Methylene chloride	0.0029	730	8/26	7.30E+03	maximum
	Toluene	0.003	0.003	1/26	3.00E-03	maximum
	Trichloroethene	0.0039	210	8/26	2.10E+02	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 0.5 feet below ground surface)

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	2.63E-07	7.71E-06	---	1.79E-06	maximum
	Metals					
	Barium				2.81E+02	95% UCL
	Lead				1.29E+03	maximum
	Mercury	0.12	0.22	3/75	1.10E+00	maximum
	Thallium				2.14E+00	maximum
	Semi-Volatile Organics					
	Benzo(b)flouoranthene	2.45E-02	7.03E-02	5/6	7.50E-01	maximum

[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				
1,3,5-Trinitrobenzene	NTV	NTV	Not Classified	
2,4-Dinitrotoluene	6.80E-01	8.00E-01	B2	TCEQ, 2001
2,6-Dinitrotoluene	6.80E-01	8.00E-01	B2	TCEQ, 2001
4-Nitrotoluene	NTV	NTV	Not Classified	---
Metals				
Antimony	NTV	NTV	Not Classified	---
Barium	NC	NC	D	TCEQ, 2001
Chromium (total)	NC	NC	Not Classified	---
Cobalt				
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
Silver	NC	NC	D	TCEQ, 2001
Strontium	NTV	NTV	Not Classified	---
Thallium	NC	NC	Not Classified	---
Non-Metallic Anions				
Perchlorate	NTV	NTV	Not Classified	---
Semi-Volatile Organics				
Benzo(b)fluoranthene	7.3E-01	8.2E-01	B2	TNRCC, 2001
Volatile Organics				
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
Trichloroethene	1.10E-02	1.10E-02	B2	TCEQ, 2001

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			
1,3,5-Trinitrobenzene	NTV	Not Classified	---
2,4-Dinitrotoluene	NTV	B2	TNRCC, 2001
2,6-Dinitrotoluene	NTV	B2	TNRCC, 2001
4-Nitrotoluene	NTV	Not Classified	---

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

Pathway: Inhalation (cont'd.)			
Chemical of Concern	Unit Risk Factor $(mg/m^3)^{-1}$	Weight of Evidence/ Carcinogen Guideline Description	Source/Date
Metals			
Aluminum	NTV	Not Classified	---
Antimony	NTV	Not Classified	---
Barium	NC	D	TNRCC, 2001
Chromium (total)	NC	Not Classified	---
Lead	NTV	Not Classified	---
Manganese (Non-diet)	NC	D	TNRCC, 2001
Mercury	NC	D	TNRCC, 2001
Nickel	4.80E-01	A	TNRCC, 2001
Silver	NC	D	TCEQ, 2001
Strontium	NTV	Not Classified	---
Thallium	NC	Not Classified	---
Non-Metallic Anions			
Perchlorate	NTV	Not Classified	---
Semi-Volatile Organics			
Benzo(b)fluoranthene	8.80E-02	B2	TNRCC, 2001
Volatile Organics			
1,2-Dichloroethane	2.60E-02	B2	TNRCC, 2001
Bromodichloromethane	NTV	B2	TNRCC, 2001
Chloroform	2.30E-02	B2	TNRCC, 2001
cis-1,2-Dichloroethene	NC	D	TNRCC, 2001
Methylene chloride	4.70E-04	B2	TNRCC, 2001
Toluene	NC	D	TNRCC, 2001
Trichloroethene	1.70E-03	B2	TNRCC, 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.

TNRCC), 2001, Update to 1998 Consistency Memorandum. Toxicity Factors Table, 15 March 2001. .

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						
1,3,5-Trinitrobenzene	chronic	3.00E-02	1.95E-02	Methemoglobinemia and spllenerthyroid cell hperplasia	100/1	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
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
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
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
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

Pathway: Ingestion, Dermal Contact

Non-Metallic Anions						
Perchlorate	chronic	9.00E-04	9.00E-04	NA	NA	---
Semi-Volatile Organics						
Benzo(b) fluoranthene	chronic	NTV	NTV	NA	NA	
Volatile Organics						
1,2-Dichloroethane	chronic	3.00E-02	3.00E-02	NA	NA	---
Bromodichloromethane	chronic	2.00E-02	1.96E-02	Renal cytomegaly	1000/1	USEPA-IRIS, 2001

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

Pathway: Ingestion, Dermal Contact (cont'd.)

Chemical of Concern	Chronic/ Subchronic	Oral RfD Value (mg/kg-day)	Dermal RfD (mg/kg-day)	Target Endpoint	Combined Uncertainty/ Modifying Factors	Source/Date
Volatile Organics (cont'd.)						
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
Toluene	chronic	2.00E-01	1.6E-01	Liver and kidney effects	1000/1	USEPA-IRIS, 2001
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					
1,3,5-Trinitrobenzene	NTV	-	-	-	-
2,4-Dinitrotoluene	chronic	0.00015	NA	NA	---
2,6-Dinitrotoluene	chronic	0.00015	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
Barium	chronic	0.00049	Fetus, developmental effects	1000/1	USEPA-HEAST, 1997
Chromium (total)	chronic	0.0001	NA	NA	---
Cobalt	chronic	0.0000175	BA	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
Silver	chronic	0.00001	NA	NA	---
Strontium	chronic	NTV	---	---	---
Thallium	chronic	0.0001	NA	NA	---

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

Pathway: Inhalation (cont'd.					
Chemical of Concern	Chronic/ Subchronic	Inhalation RfC (mg/m3)	Target Endpoint	Combined Uncertainty/ Modifying Factors	Source/ Date
Non-Metallic Anions					
Perchlorate	chronic	NTV	---	---	---
Semi-Volatile Organics					
Benzo(b)fluoranthene	NTV	--	--	--	--
Volatile Organics					
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
Toluene	chronic	0.4	Neurological effects	300/1	USEPA-IRIS, 2001---
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	1.2E-06	NE	1.0E-05	1.1E-05
			Pesticides				
			4,4'-DDD	5.8E-07	NE	7.6E-07	1.3E-06
			Volatile Organics				
			Bromodichloromethane	1.5E-06	NTV	7.8E-07	2.3E-06
			Chloroform	6.0E-07	3.9E-05	2.3E-06	4.2E-05
			Methylene chloride	1.9E-01	2.1E-01	NE (Kp<=0.01)	4.0E-01
			Trichloroethene	8.1E-03	2.3E-01	1.1E-02	4.4E-01
Groundwater risk total =							4.4E-01
Soil (0 to 0.5 feet)	Soil and particulates	Incidental Ingestion, inhalation of particulates, and dermal contact	*Dioxin/Furan*				
			2,3,7,8-TCDD TEC	9.4E-08	3.1E-12	3.6E-08	1.3E-07
			Semi-volatiles				
			Benzo(b)fluoranthene	1.9E-07	3.5E-12	1.8E-07	3.7E-07
Soil risk total =							5.0E-07

Notes:

Kp Dermal permeability coefficient
NA Not applicable
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-18/24. 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 4.4×10^{-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	*Explosive*					
			1,3,5-Trinitrobenzene		3.3E-01	NE	NE (Kp<=0.01)	3.3E-01
			Metals					
			Antimony		8.1E+00	NE	NE (Kp<=0.01)	8.1E+00
			Barium		8.4E-01	NE	NE (Kp<=0.01)	8.4E-01
			Chromium (total)		1.2E-01	NE	NE (Kp<=0.01)	1.2E-01
			Cobalt		1.4E-01	NE	NE (Kp<=0.01)	1.4E-01
			Manganese		1.7E+00	NE	NE (Kp<=0.01)	1.7E+00
			Nickel		4.7E+00	NE	NE (Kp<=0.01)	4.7E+00
			Silver		9.4E-01	NE	NE (Kp<=0.01)	9.4E-01
			Strontium		7.2E-02	NE	NE (Kp<=0.01)	7.2E-02
			Thallium		4.5E-01	NE	NE (Kp<=0.01)	4.5E-01
			Non-metallic Anions					
			Perchlorate		7.5E+02	NE	NE (Kp<=0.01)	7.5E+02
			Volatiles					
			Bromodichloromethane		3.4E-03	NTV	1.8E-03	5.2E-03
			Chloroform		2.7E-02	1.6E+01	1.1E-01	1.6E+01
			Cis-1,2-dichloroethene		2.4E-01	5.4E-02	NE (Kp<=0.01)	3.0E-01
			Methylene chloride		1.2E+03	4.2E+02	NE (Kp<=0.01)	1.6E+03
			Toluene		1.5E-04	1.3E-03	2.8E-05	1.5E-03
			Trichloroethene		3.4E+02	NTV	4.6E+02	8.0E+02
Groundwater Hazard Index Total =								3.2E+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 0.5 feet)	Soil and particulates	Incidental ingestion, inhalation of particulates, dermal contact	*Metals*					
			Barium		3.9E-03	8.5E-05	3.6E-03	7.6E-03
			Mercury		3.6E-03	5.4E-07	3.3E-03	6.9E-03
			Thallium		2.6E-02	3.2E-06	1.7E-03	2.8E-02
Soil Hazard Index Total =								4.2E-02
Hazard Index Total (soil and groundwater) =								3.2E+03

Notes:

CNS	central nervous system
Kp	Dermal permeability coefficient
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-18/24. 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 3.2E+03 and for soil is 4.2E-02. These values \indicate that the potential for adverse non-carcinogenic effects could occur from exposure to groundwater.

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

Chemical	ELCR [a]	EPC [a] (µg/L)	Well	Revised ELCR	Recent Maximum (µg/L)	Date	Well	MCL (µg/L)	TRRP PCL (µg/L)	Retained as a COC?
Methylene chloride	4.0×10^{-1}	7,300,000	MW-2	b	21,300	06/24/16	MW-2	5	—	Yes, 1
Trichloroethene	4.1×10^{-2}	210,000	MW-2	b	17,100	06/16/16	120	5	—	Yes, 1
2,3,7,8-TCDD	1.1×10^{-5}	530	95 UCL[d]	None More Recent				3.0×10^{-5}	—	No, 2
4,4'-DDD	1.3×10^{-6}	59	MW-2	None More Recent				—	3.8	No, 2
Tetrachloroethene[3]	—	—	—	—	85.1	06/24/16	MW-2	5	—	Yes, 1
Benzene[3]	—	—	—	—	< 62.6	06/24/16	MW-2	5	—	Yes, 1
1,1,2-Trichloroethane[3]	—	—	—	—	< 50	06/07/16	AWD1B	5	—	Yes, 1
Vinyl Chloride[3]	—	—	—	—	256	06/07/16	AWD-1	2	—	Yes, 1
1,4-Dioxane[3]	—	61.7	95 UCL[d]	—	412	06/07/16	MW-14	—	9.1	Yes, 1
Chloroform [d]	4.2×10^{-5}	28	95 UCL[d]	b	58.1	06/24/16	MW-2	—	240	No, 2, 4
Chemicals Retained on a Provisional Basis										
Bromodichloromethane [c]	2.3×10^{-6}	530	18WW09	b	< 125	06/24/16	MW-2	—	15	Yes, 1

Notes and Abbreviations:

1. Identified as a COC since EPC and/or Recent Results are above the MCL or PCL.
2. Combined Shallow Zone ELCR of Chemicals with no MCL is within acceptable range of 1×10^{-6} to 1×10^{-4}.
3. Included as contributing chemicals due to their frequency of detection above the MCL or PCL in recent sampling events.
4. Excluded as a COC as maximum concentration in the shallow zone is below MCL/PCL.

a. From Baseline Risk Assessment Table C-53 (Jacobs, 2002).
b. Revised ELCR not calculated for chemicals with an MCL.
c. All other wells were < 15 ug/L (the majority were below detection). Bromodichloromethane will be re-evaluated when data with lower reporting limit are obtained for MW-2.
d. Using ProUCL for the results of samples collected in June 2016.

95 UCL indicates that the EPC was calculated rather than the maximum concentration at a specific well.

COC	contaminant of concern
ELCR	excess lifetime cancer risk
EPC	exposure point concentration
TRRP PCL	Texas Risk Reduction Program Tier 1 Residential Groundwater Protective Concentration Level
MCL	maximum contaminant level from the Safe Drinking Water Act
µg/L	micrograms per liter
µg/L	micrograms per liter
COC	contaminant of concern
EPC	exposure point concentration
MCL	Safe Drinking Water Act maximum contaminant level

Table 2-7. Chemicals Contributing to Carcinogenic Risk in Wilcox Formation Groundwater

Chemical	Shallow Zone ELCR [a]	Shallow Zone EPC [a] (µg/L)	Shallow Zone Well	Recent Maximum in Wilcox Formation (µg/L)	Date	Well	MCL (µg/L)	TRRP PCL (µg/L)	Retained as a COC?
Methylene chloride	4.0×10^{-1}	7,300,000	MW-2	746	06/24/2016	18CPTMW01SW	5	—	Yes, 1
Trichloroethene	4.1×10^{-2}	210,000	MW-2	15,900	06/07/2016	MW-14B	5	—	Yes, 1
2,3,7,8-TCDD	1.1×10^{-5}	530	95 UCL	—	—		3.0×10^{-5}	—	No, 2
4,4'-DDD	1.3×10^{-6}	59	MW-2	—	—		—	3.8	No, 2
Benzene[3]	—	—	—	6.13	06/08/2016	18CPTMW03SW	5	—	Yes, 1
1,1,2-Trichloroethane[3]	—	—	—	0.858	06/15/2016	18CPTMW23	5	—	No, 5
Vinyl Chloride[3]	—	—	—	8.97	06/08/2016	18CPTMW08SW	2	—	Yes, 1
1,4-Dioxane[3]	—	61.7	95 UCL[c]	412	06/07/16	MW-14B	—	9.1	Yes, 1
Chloroform	4.2×10^{-5}	28	95 UCL	13.2	06/07/16	MW-14B	—	240	No, 2,5
Chemicals Retained on a Provisional Basis									
Tetrachloroethene	—	—	—	< 50	06/07/2016	MW-14B	5	—	Yes, 4
Bromodichloromethane[b]	2.3×10^{-6}	530	18WW09	< 40	06/07/16	MW-14B	—	15	Yes, 4

Notes and Abbreviations:

1. Identified as a COC since recent results are above the MCL or PCL and the compound is identified as a COC in the Shallow Zone.
2. Combined Shallow Zone ELCR of Chemicals with no MCL is within acceptable range of 1×10^{-6} to 1×10^{-4}.
3. Included as contributing chemicals due to their frequency of detection above the MCL or PCL in recent sampling events.
4. Identified as a COC due to high reporting limit in Wilcox Formation well(s) and presence in shallow zone groundwater. Retained on a provisional basis.
5. Excluded as a COC as maximum concentration in Wilcox Formation is below MCL/PCL.

a. From Baseline Risk Assessment Table C-53 (Jacobs, 2002).
b. All other wells were < 15 ug/L (the majority were below detection). Bromodichloromethane will be re-evaluated when data with lower reporting limit are obtained.
c. Using ProUCL for the results of samples collected in June 2016.

95 UCL indicates that the EPC was calculated rather than the maximum concentration at a specific well.

COC	contaminant of concern
ELCR	excess lifetime cancer risk
EPC	exposure point concentration
TRRP PCL	Texas Risk Reduction Program Tier 1 Residential Groundwater Protective Concentration Level
MCL	maximum contaminant level from the Safe Drinking Water Act
µg/L	micrograms per liter
B	Sample collected from the bottom of well screen

Table 2-8 Chemicals with Hazard Quotient Greater than 0.1 in Shallow Zone Groundwater

Chemical	HQ	EPC [a] (µg/L)	Well	Revised HQ	Recent Maximum (µg/L)	Date	Well	MCL (µg/L)	TRRP PCL (µg/L)	Retained as a COC?
Methylene chloride	1600	7,300,000	MW-2	b	21,300	06/24/16	MW-2	5	—	Yes, 1
Trichloroethene	800	210,000	MW-2	b	17,100	06/16/16	120	5	—	Yes, 1
Perchlorate	750	69,000	18WW17	2,500	82,900	06/21/16	18WW17	—	17	Yes, 2
Chloroform	16	28	95 UCL[d]	b	58.1	06/24/16	MW-2	—	240	No, 5
cis-1,2-Dichloroethene	0.3	250	95 UCL[d]	b	43,600	06/24/16	MW-2	70	—	Yes, 1
1,4-Dioxane[6]	—	61.7	95 UCL[d]	—	220	06/16/16	120	—	9.1	Yes, 1
Antimony	8.1	333	95 UCL[d]	b	1.49	06/17/16	MW-16	6	—	No, 5
Barium	0.84	6,000	MW-1	b	10,300	06/13/16	18CPTMW24	2,000	—	Yes, 1
Chromium	0.12	18,000	MW-1	b	4,620	06/16/16	18WW16	100	—	Yes, 1
Manganese	1.7	8,270	MW-1	1.1	5,290	06/29/16	18WW25	—	1,100*	No, 7
Nickel	4.7	9,600	MW-1	7.0	14,300	06/16/16	18WW16	—	490	Yes, 3
Silver	0.94	480	MW-1	< 0.002	< 1	June 2016	All wells	—	120	No, 4
Thallium	0.47	3.7	MW-2	b	0.821	06/17/16	109	2	—	No, 5
Chemicals Retained on a Provisional Basis										
Arsenic[6]	—	—	—	—	16.1	06/21/16 06/13/16	18CPTMW18 18CPTMW24	10	—	Yes, 1
Cobalt	0.14	280	MW-1	0.178	355	06/16/16	18WW16	—	240	Yes, 1
1,3,5-Trinitrobenzene	0.33	1,000	MW-2	No Recent Data				—	730	Yes, 3

Notes and Abbreviations:
1. Identified as a COC since EPC and/or Recent Results are above the MCL or PCL.
2. Identified as COC since hazard quotient (HQ) is > 0.1 and EPC and recent results are above the TRRP PCL.
3. Retained as a COC since revised HQ > 0.1 and sum of HQs may exceed 1.0.
4. Excluded since Revised HQ < 0. 1 using recent maximum concentration and chemical concentration is < PCL.
5. Excluded since Recent results are all less than the MCL or PCL, and pattern of detections does not indicate association with site contamination.
6. Included as contributing chemicals due to their frequency of detection above the MCL or PCL in recent sampling events (see Table 2-3).
7. Excluded because maximum concentrations of recent results are below the background 95%UTL.

a. From Baseline Risk Assessment Table C-50 (Jacobs, 2002).
b. Revised HQ not calculated for chemicals with an MCL or PCL.
c. Using ProUCL for the results of samples collected in June 2016

Table 2-8. Chemicals with Hazard Quotient Greater than 0.1 in Shallow Zone Groundwater (continued)

Notes and Abbreviations: (cont'd.)
95 UCL indicates that the EPC was calculated rather than the maximum concentration at a specific well.
COC contaminant of concern
EPC exposure point concentration
HQ hazard quotient
MCL maximum contaminant level from the Safe Drinking Water Act
ND non detect
TRRP PCL Texas Risk Reduction Program Tier 1 Residential Groundwater Protective Concentration Level
UCL upper confidence limit
µg/L micrograms per liter

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

Table 2-9. Chemicals with Hazard Quotient Greater than 0.1 in Wilcox Formation Groundwater

Chemical	SZ HQ [a]	SZ EPCz [a] (µg/L)	SZ Well	Revised Wilcox Frmn HQ	Recent Wilcox Frmn Maximum (µg/L)	Date	Well	MCL (µg/L)	TRRP PCL (µg/L)	Retained as a COC?
Methylene chloride	1600	7,300,000	MW-2	0.16	746	06/24/2016	18CPTMW01SW	5		Yes, 1
Trichloroethene	800	210,000	MW-2	61	15,900	06/07/2016	MW-14B	5		Yes, 1
Perchlorate	750	69,000	18WW17	2,490	229,000	06/07/16	MW-14B		17	Yes, 1
Chloroform	16	28	95 UCL	7.5	13.2	06/07/16	MW-14B		240	No, 5
cis-1,2-Dichloroethene	0.3	250	95 UCL	3.1	2,600	06/07/16	MW-14T	70		Yes, 1
1,4-Dioxane[6]	—	102.4	95 UCL[b]	—	412	06/07/16	MW-14B	—	9.1	Yes, 1
Antimony	8.1	333	95 UCL[b]	<0.00002	<0.001	June 2016	All Wells	6		No, 4
Arsenic[6]	—	—	—	c	17.3	06/24/16	18CPTMW01SW	10		Yes, 1
Barium	0.84	6,000	MW-1	0.22	1,560	06/14/14	C-03	2,000		Yes, 3
Chromium	0.12	18,000	MW-1	0.000063	9.5	06/14/16	18CPTMW04SW	100		No, 4
Cobalt	0.14	280	MW-1	0.005	9.64	06/24/16	18CPTMW12SW		240	No, 4
Manganese	1.7	8,270	MW-1	0.38	1,850	06/14/16	C-03		1,100*	No, 6
Nickel	4.7	9,600	MW-1	0.0036	7.44 J	06/24/16	18CPTMW12SW		490	No, 4
Silver	0.94	480	MW-1	< 0.002	< 1	June 2016	All Wells		120	No, 4
Thallium	0.47	3.7	MW-2	< 0.025	< 0.200	June 2016	All Wells	2		No, 4
Chemicals Retained on a Provisional Basis										
1,3,5-Trinitrobenzene	0.33	1,000	MW-2		No Recent Data				730	Yes, 2

Notes and Abbreviations:
1. Identified as a COC since Recent Results are above the MCL or PCL.
2. Identified as COC since Shallow Zone hazard quotient (HQ) is > 0.1 and no recent data available.
3. Retained as a COC since Revised Wilcox Formation HQ > 0.1 and sum of HQs may exceed 1.0.
4. Excluded since Revised Wilcox Formation HQ < 0. 1 using recent maximum concentration and chemical concentration is < PCL.
5. Excluded as a COC as maximum concentration in Wilcox Formation is below MCL/PCL., and pattern of detections does not indicate association with site contamination.
6. Excluded because maximum concentrations of recent results are below the background 95%UTL.

a. From Baseline Risk Assessment Table C-50 (Jacobs, 2002).
b. Using ProUCL for the results of samples collected in June 2016.

Table 2-9. Chemicals with Hazard Quotient Greater than 0.1 in Wilcox Formation Groundwater (continued)

Notes and Abbreviations: (cont'd.)
95 UCL indicates that the EPC was calculated rather than the maximum concentration at a specific well.

SZ	shallow zone
COC	contaminant of concern
EPC	exposure point concentration
HQ	hazard quotient
MCL	maximum contaminant level from the Safe Drinking Water Act
UCL	upper confidence limit
TRRP PCL	Texas Risk Reduction Program Tier 1 Residential Groundwater Protective Concentration Level
µg/L	micrograms per liter
B	Sample collected from the bottom of well screen
T	Sample collected from top of well screen

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

Table 2-10. Cleanup Levels at LHAAP-18/24

Medium	Chemical of Concern	Cleanup Level
Shallow Zone Groundwater		MCL (µg/L)
	Methylene chloride	5
	Trichloroethylene	5
	cis-1,2-Dichloroethene*	70
	Tetrachloroethene	5
	Benzene	5
	1,1,2-Trichloroethane	5
	Vinyl chloride*	2
	Arsenic	10
	Barium	2,000
	Chromium	100
		TRRP $^{GW}GW_{Ing}$ PCL (µg/L)
	Bromodichloromethane	15
	1,3,5-trinitrobenzene	730
	1,4-Dioxane	9.1
	Cobalt	240
	Nickel	490
	Perchlorate	17
Wilcox Formation Groundwater		MCL (µg/L)
	Methylene chloride	5
	Trichloroethylene	5
	cis-1,2-Dichloroethene*	70
	Tetrachloroethene	5
	Benzene	5
	Vinyl chloride*	2
	Arsenic	10
	Barium	2,000
		TRRP $^{GW}GW_{Ing}$ PCL (µg/L)
	Bromodichloromethane	15
	1,3,5-trinitrobenzene	730
	1,4-Dioxane	9.1
	Perchlorate	17
Soil		GWP-Ind (mg/kg)
	Methylene Chloride[1]	0.5
	Trichloroethylene	0.5
	Perchlorate	7.2
	Tetrachloroethene	0.5

Notes:
* Trichloroethene daughter products
**TRRP $^{GW}GW_{Ing}$ PCL from April 2018, https://www.tceq.texas.gov/remediation/trrp/trrppcls.html
GWP-Ind MSC Texas Commission on Environmental Quality soil medium-specific concentration (MSC) 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	No Action	Alternative 2 Enhanced Groundwater Extraction and Treatment, ISB Inside & Outside Containment and in Wilcox, Unsaturated Soil Excavation, LUC.	Alternative 3 Containment, Groundwater Extraction and Treatment, MNA, LUC	Alternative 4 Enhanced Groundwater Extraction and Treatment, ISB Inside & Outside Containment and in Wilcox, Unsaturated Soil Excavation, Enhanced DNAPL Removal by Surfactant Flushing, LUC	Alternative 5 Enhanced Groundwater Extraction and Treatment, ISB Inside & Outside Containment and in Wilcox, Unsaturated Soil Excavation, Enhanced DNAPL Removal by Thermal Treatment, LUC	Alternative 6 Enhanced Groundwater Extraction and Treatment, ISB Inside & Outside Containment and in Wilcox, Unsaturated Soil Excavation, Enhanced DNAPL Removal by Application of ZVI, LUC
Overall protection of human health and the environment	No protection. Does not achieve RAOs.	Achieves RAOs but over a very long time. Protection of human health and environment provided by in situ bioremediation, ex situ groundwater treatment, DNAPL source removal, and maintenance of LUC. LTM to verify progress and hydraulic containment.	Achieves RAO for protecting human health by preventing exposure to contaminated groundwater. RAO for restoration of groundwater within the slurry wall area is not achieved within a reasonable time. Protection of human health and environment provided by physical containment of groundwater, and maintenance of LUC. MNA to treat areas outside slurry well and in Wilcox Formation. LTM to verify progress and containment.	Achieves RAOs. Protection of human health and environment provided by in situ bioremediation, ex situ groundwater treatment, DNAPL source removal, and maintenance of LUC. LTM to verify progress and hydraulic containment.	Achieves RAOs. Protection of human health and environment provided by in situ bioremediation, ex situ groundwater treatment, DNAPL source removal, and maintenance of LUC. LTM to verify progress and hydraulic containment.	Achieves RAOs. Protection of human health and environment provided by in situ bioremediation, ex situ groundwater treatment, DNAPL source removal, and maintenance of LUC. LTM to verify progress and hydraulic containment.
Compliance with ARARs	No compliance with chemical-specific ARARs.	Complies with all ARARs.	Will require an ARAR waiver for groundwater inside the slurry wall.	Complies with all ARARs.	Complies with all ARARs.	Complies with all ARARs.
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. In situ and ex situ groundwater treatment permanently removes or destroys contaminants. DNAPL source removal permanently removes contaminants though effectiveness is limited and progress slow. LUC would be effective and reliable so long as they are maintained and enforced.	Containment would be permanent and effective so long as the slurry wall and hydraulic control are maintained. LUC would be effective and reliable so long as they are maintained and enforced.	Soil removal is a permanent remedy. In situ and ex situ groundwater treatment permanently removes or destroys contaminants. DNAPL source removal permanently removes contaminants although small amounts of residual DNAPL would remain in low permeability zones. LUC would be effective and reliable so long as they are maintained and enforced.	Soil removal is a permanent remedy. In situ and ex situ groundwater treatment permanently removes or destroys contaminants. DNAPL source removal permanently removes contaminants. LUC would be effective and reliable so long as they are maintained and enforced.	Soil removal is a permanent remedy. In situ and ex situ groundwater treatment permanently removes or destroys contaminants. DNAPL source removal permanently removes contaminants although small amounts of residual DNAPL would remain in low permeability zones. LUC would be effective and reliable so long as they are maintained and enforced.
Reduction of toxicity, mobility, or volume through treatment	No reduction outside of natural processes.	Reduced toxicity, mobility, and volume through in situ treatment, DNAPL and soil removal, and operating groundwater treatment system.	Very limited reduction of toxicity and volume with no treatment of source areas. Reduced mobility within slurry wall.	Reduced toxicity, mobility, and volume through in situ treatment, DNAPL and soil removal, and operating groundwater treatment system.	Reduced toxicity, mobility, and volume through in situ treatment, DNAPL and soil removal, and operating groundwater treatment system.	Reduced toxicity, mobility, and volume through in situ treatment, DNAPL and soil removal, and operating groundwater treatment system.
Short-term effectiveness	No short-term impacts.	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. Some potential for impacts to workers during in situ treatment applications. Duration several hundred years.	Potential for impacts to the community through increased construction activity. Some potential for impacts to workers during construction of slurry wall. Outside slurry wall area COC removal estimated ≤ 20 years. Duration inside containment > 500 years.	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. Some potential for impacts to workers during in situ treatment applications. Duration 30+ years.	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. Some potential for impacts to workers during in situ treatment applications. Duration ≤ 20 years.	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. Some potential for impacts to workers during in situ treatment applications. Duration ≤ 30 years.
Implementability	Technically implementable; administratively unacceptable.	Soil excavation readily implemented with standard earthmoving equipment. In situ bioremediation is a commercially available treatment technology. Extraction and treatment of groundwater is already implemented at the site. The effectiveness of extraction on DNAPL source removal is limited and controlled by the dissolution rate of DNAPL.	Implementable, but uncertainty exists in the effectiveness of slurry wall containment. Uncertain overall duration and cleanup levels possibly not attainable inside slurry wall.	Soil excavation readily implemented with standard earthmoving equipment. In situ bioremediation is a commercially available treatment technology. Injection of surfactants uses similar tools as in situ bioremediation. Dual phase extraction is an established technology.	Soil excavation readily implemented with standard earthmoving equipment. In situ bioremediation is a commercially available treatment technology. Thermal treatment is a commercially available technology but planning well in advance is required.	Soil excavation readily implemented with standard earthmoving equipment. In situ bioremediation is a commercially available treatment technology. Injection of ZVI uses similar tools as in situ bioremediation.
*Costs						
Capital	$0	$10,600,000	$6,410,000	$13,110,000	$19,520,000	$102,230,000
O&M	$0	$19,600,000	$12,240,000	$19,390,000	$13,150,000	$19,390,000
Total	$0	$30,200,000	$18,650,000	$32,500,000	$32,670,000	$121,620,000
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					

Table 2-12. Remediation Cost Table Selected Remedy (Alternative 5) Present Worth Analysis

Year	Capital Costs	O&M Costs				Present Value (NPV)	
		Monitoring	GWTP	5-Yr Review	Total	Discount Rate Capital 3.0%	O&M
	Fees, Workplan, Documentation, Reactivate						
	ICT 3 and 9, Soil Excavation, New GWTP,						
1	$17,441,249 ERH, EISB - 1st Event	$646,751	$534,987		$1,181,738	NPV $19,520,000	$13,150,000
2		$646,751	$551,037		$1,197,787	Total Capital and O&M	$32,670,000
3	$1,768,144 EISB - 2nd event	$323,084	$567,568		$890,652		
4		$323,084	$584,595		$907,679		
5		$323,084	$602,133	$40,983	$966,200		
6		$166,045	$620,197		$786,242		
7		$166,045	$638,803		$804,848		
8		$166,045	$657,967		$824,012		
9		$166,045	$677,706		$843,751		
10	$326,379 Major Equipment Replacement	$166,045	$698,037	$40,983	$905,065		
11			$575,183		$575,183		
12		$166,045	$592,438		$758,483		
13			$610,211		$610,211		
14		$166,045	$628,517		$794,562		
15	$336,171 Major Equipment Replacement		$647,373	$40,983	$688,356		
16		$166,045	$666,794		$832,839		
17			$686,798		$686,798		
18		$166,045	$707,402		$873,447		
19			$728,624		$728,624		
20		$166,045	$750,483	$40,983	$957,511		
21					$0		
22		$166,045			$166,045		
23					$0		
24		$166,045			$166,045		
25				$32,787	$32,787		
26		$166,045			$166,045		
27					$0		
28		$166,045			$166,045		
29					$0		
30		$166,045		$32,787	$198,832		
	$19,871,943	$4,753,426	$12,726,853	$229,507	$17,709,787		

Table 2-13. Description of ARARs for Selected Remedy

Citation	Activity or Prerequisite/Status	Requirement
Soil		
TCEQ Texas Risk Reduction Rules 30 TAC 335.558 and 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 for cross-media contamination pathways such as soil to groundwater and for hypothetical future maintenance workers.	Near surface (i.e., 0-2 feet bgs) non-residential (industrial) soils shall conform to the non-residential soil MSCs (SAI-Ind) based upon worker ingestion of soil, inhalation of particulates and volatiles and the non-residential soil-to-groundwater cross media protection concentration. The concentration of contamination in soil shall not exceed the non-residential soil-to-groundwater protection MSC (GWP-Ind). See Table 2-10 for specific numeric criteria.
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 MC, TCE, PCE, cis-1,2-DCE, benzene, 1,1,2-TCA and VC are provided in 40 C.F.R. § 141.61(a) and the MCLs for inorganic contaminants arsenic, barium and chromium are provided in 40 C.F.R. § 141.62 (b) and Table 2-10 of this report.
Surface Water		
Texas Surface Water Quality Criteria (30 TAC §307.6(d)(1))	Applicable to chemicals in surface water (Harrison Bayou) for water that could potentially be used for human consumption.	Chemicals must not exceed the Texas surface water quality standards in waters of the Harrison Bayou. The surface water quality standards for MC, TCE, PCE, Benzene, 1,1,2-TCA and VC are provided in 30 TAC §307.6(d)(1).
Texas Surface Water Quality Criteria (30 TAC §307.6(d)(1))	Applicable to industrial groundwater—**relevant and appropriate** to meet Texas surface water quality criteria	Interim Record of Decision effluent discharge limits. The discharge criteria (Table 2-14) for the COCs will be re-evaluated based on most current TCEQ standards
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.
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

Table 2-13. Description of ARARs for Selected Remedy (continued)

Citation	Activity or Prerequisite/Status	Requirement
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.
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, 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.
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.
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.
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.

Table 2-13. Description of ARARs for Selected Remedy (continued)

Citation	Activity or Prerequisite/Status	Requirement
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.
Well Construction		
Well Construction Standards—Monitoring or Injection Wells 16 TAC 76.1000	Construction of water wells—applicable to construction of new monitoring or injection wells, if needed.	Injection wells shall be completed in accordance with the technical requirements of Section 76.1000, as appropriate. Substantive requirements applicable to the injection wells will be adhered to.
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.

Table 2-13. Description of ARARs for Selected Remedy (continued)

Citation	Activity or Prerequisite/Status	Requirement
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.**	Disposal is not prohibited if such wastes are managed in a treatment system subject to regulation under Section 402 of the CWA that subsequently discharges to waters of the United States.
Closure		
Standards for Plugging Wells that Penetrate Undesirable Water or Constituent Zones 16 TAC 76.1004(a) through (c)	Plugging and abandonment of wells—**applicable to plugging and closure of monitoring and/or extraction wells.**	If a well is abandoned, all removable casing shall be removed and the entire well pressure filled via a tremie pipe with cement from bottom up to the land surface. In lieu of this procedure, the well shall be pressure-filled via a tremie tube with bentonite grout of a minimum 9.1 lb/gal weight followed by a cement plug extending from land surface to a depth of not less than 2 feet. Undesirable water or constituents or the freshwater zone(s) shall be isolated with cement plugs.
Post Closure Care Requirements for Hazardous Waste Landfills 40 CFR § 264.228(b)(1)(3)(4) 30 TAC § 335.174(b) 40 CFR §§ 264.117 - 264.120	Closure of a RCRA landfill **– relevant and appropriate** to closure or post closure under CERCLA of surface impoundments containing RCRA hazardous waste	Owner or operator must • Maintain the effectiveness and integrity of the final cover including making repairs to the cap as necessary to correct effects of settling, erosion, etc.; • Prevent run-on and runoff from eroding or otherwise damaging final cover; and • Maintain and monitor a groundwater monitoring system.

Abbreviations:

ARAR	applicable or relevant and appropriate requirement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
CWA	Clean Water Act of 1972
GWP	Groundwater Protection
MCL	Maximum Contaminant Level
lb/gal	pound per gallon
%	percent
PCL	Texas Residential Groundwater Protective Concentration Level
PPE	personal protective equipment
ppm	part per million
RCRA	Resource Conservation and Recovery Act of 1976
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
USC	United States Code
USEPA	U.S. Environmental Protection Agency

Table 2-14. Current Effluent Limitations for the Discharge of Remediated Groundwater from the Groundwater Treatment Plant

Chemical	Units are (µg/L)		
	Daily Average Concentration	Daily Maximum Concentration	Reporting Limit
VOCs			
1,1,1-Trichloroethane	3,417	7,230	1
1,1,2-Trichloroethane	102.5	216.9	1
1,1-Dichloroethane	6,633	14,032	1
1,1-Dichloroethene	119	253	1
1,2-Dichloroethane	85	181	1
Acetone	1,132	2,395	2
Benzene	85	181	1
Carbon tetrachloride	85	181	1
Chlorobenzene	22,300	47,180	1
Chloroform	1,708	3,615	1
Ethylbenzene	26,954	57,025	1
m,p-xylenes	39.5	83.6	2
Methylene chloride (dichloromethane)	803	1,699	2
o-xylene	39.5	83.6	1
Styrene	2,829	5,987	1
Tetrachloroethene	85.4	180.7	1
Toluene	1,980	4,189	1
Trichloroethene	85	181	1
Vinyl chloride	34	72	1
Metals			
Barium (total)	1,000	2,000	4
Chromium (6+)	58	124	10
Lead (total)	2.2	4.6	2
Selenium (total)	5.7	12	2
Silver	1.4	3	2
Perchlorate			
Perchlorate	278	589	4
SVOCs			
1,4-Dioxane	NA	134.2	1

Table 2-14. Current Effluent Limitations for the Discharge of Remediated Groundwater from the Groundwater Treatment Plant (continued)

Chemical	Units are (µg/L)		
	Daily Average Concentration	Daily Maximum Concentration	Reporting Limit
Anions			
Chloride	NA	N/A	10,000
Sulfate	NA	N/A	10,000

Notes:

Daily average concentration – the arithmetic average of all effluent samples, composite or grab as required by this permit within a period of one calendar month, consisting of at least four separate representative measurements. When four samples are not available in a calendar month, the arithmetic average (weighted by flow) of all values taken during the month shall be utilized as the daily average concentration.

Daily maximum concentration – the maximum concentration measured on a single day, by composite sample, unless otherwise specified elsewhere in the permit.

TAC reference – most of the limitations are based upon water quality standards found at TAC 307 for the protection of human health and aquatic life. The limit for barium is from TAC 319 – Subchapter B.

Reporting limit - the minimum analytical level. All testing must be completed utilizing USEPA approved methods which can detect the pollutant to the referenced concentration.

N/A – not applicable.

The allowable flow rate of GWTP effluent that can be discharged to Harrison Bayou is given by:

$$Q_E = \frac{C_C(Q_E + Q_S) - Q_S C_A}{C_E}$$

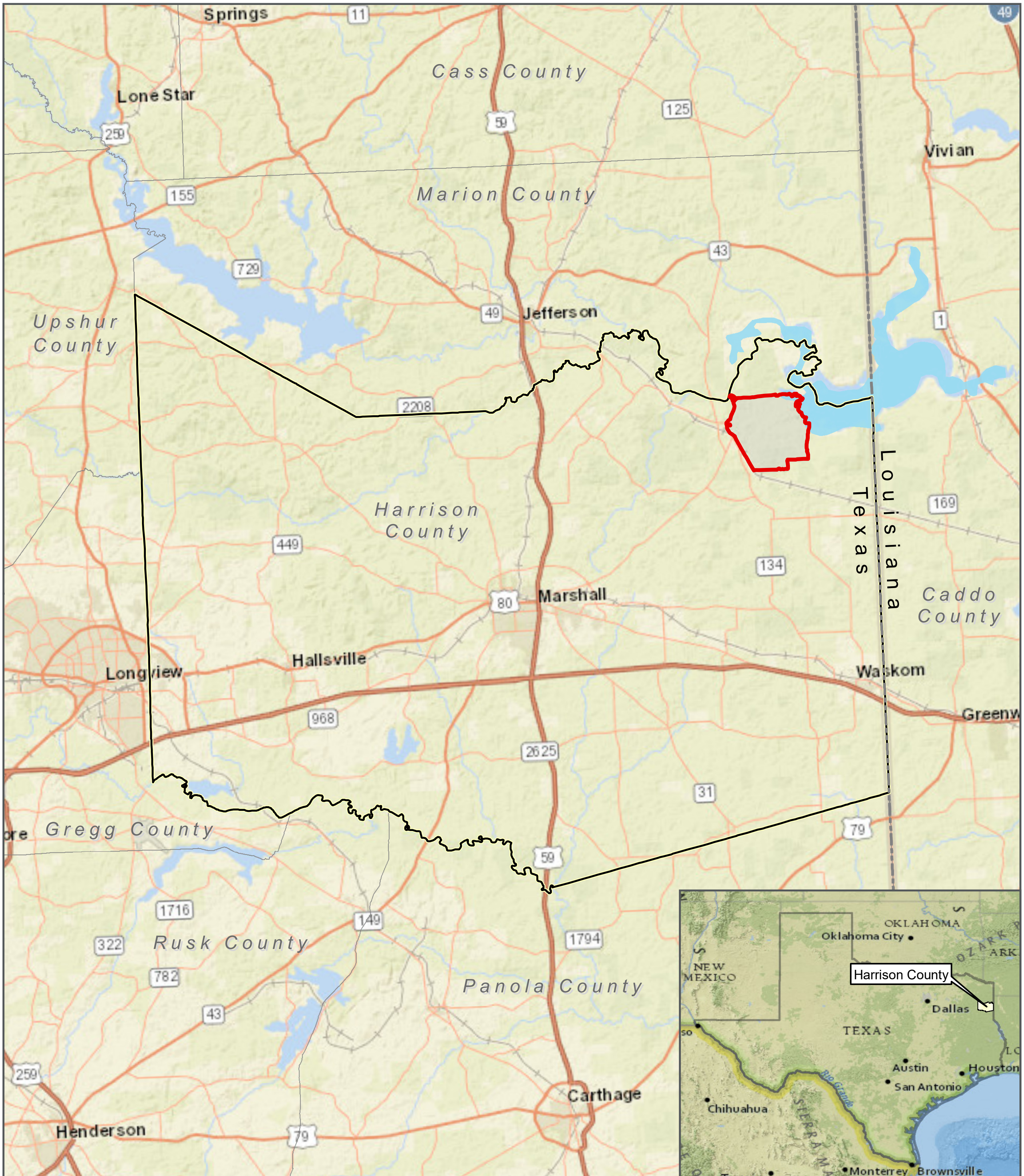
where Q_E = GWTP effluent flow

Q_S = Harrison Bayou flow

C_C = Criteria concentration (100 mg/L for chloride, 50 mg/L for sulfate)

C_A = Ambient concentration = 10 mg/L

C_E = Chloride or sulfate concentration in GWTP effluent



N

0 5 10
MILES

LEGEND

- LHAAP Installation Boundary
- Harrison County
- State Boundary

SITE LOCATION

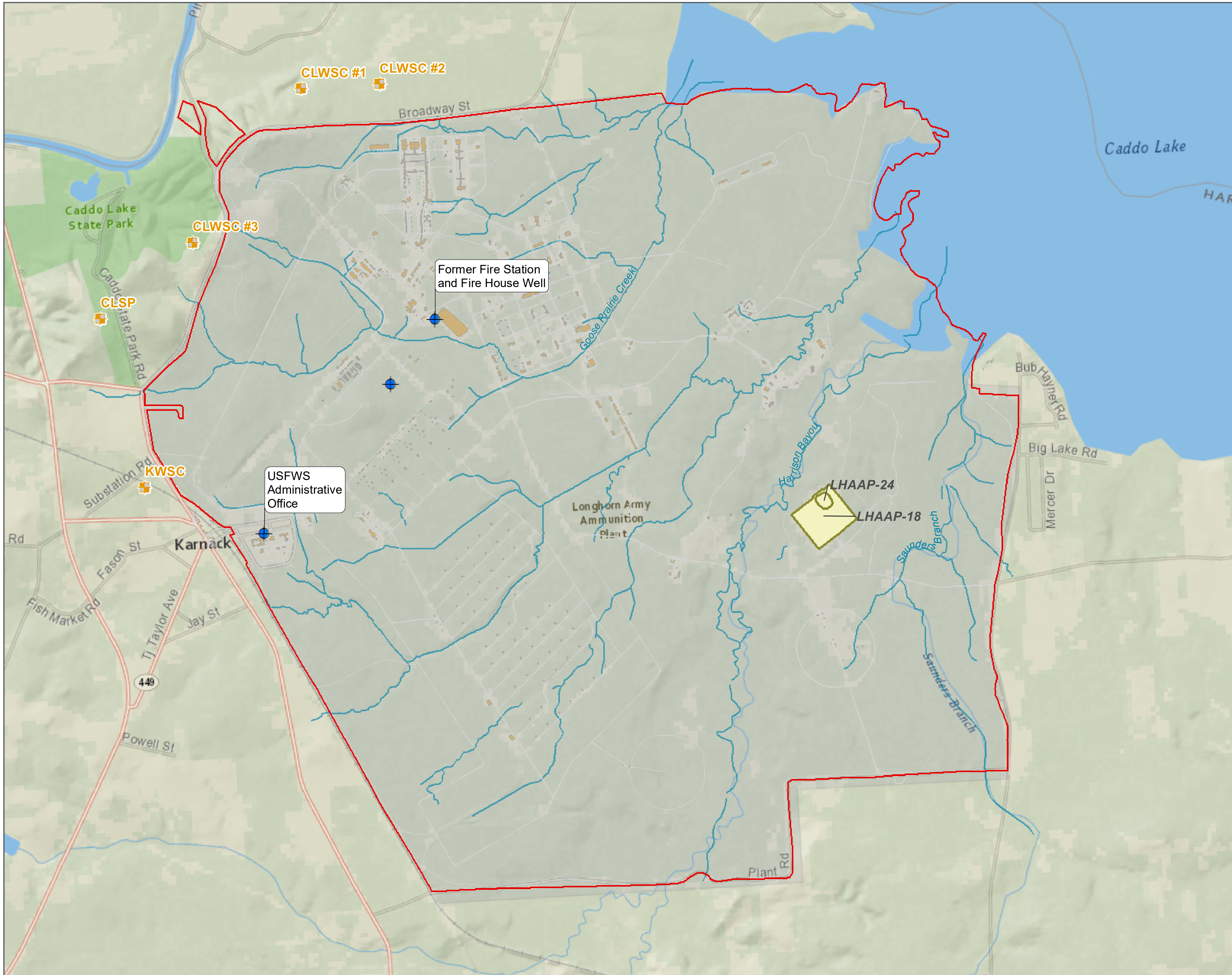
LONGHORN ARMY
AMMUNITION PLANT
KARNACK, TEXAS

DATA SOURCES: AECOM, ESRI, LHAAP

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: EBOWLIN - DATE: 7/24/2019



LEGEND

- Public Water Supply Well Locations
- Potable Water Wells
- Roads
- Building
- Site
- LHAAP Installation Boundary

CLWSC – Caddo Lake Water Supply Corporation
KWSC – Karnack Water Supply Corporation

DATA SOURCES: AECOM, 2017. Final Revised Feasibility Study for LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas, January.

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

SITE VICINTY

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

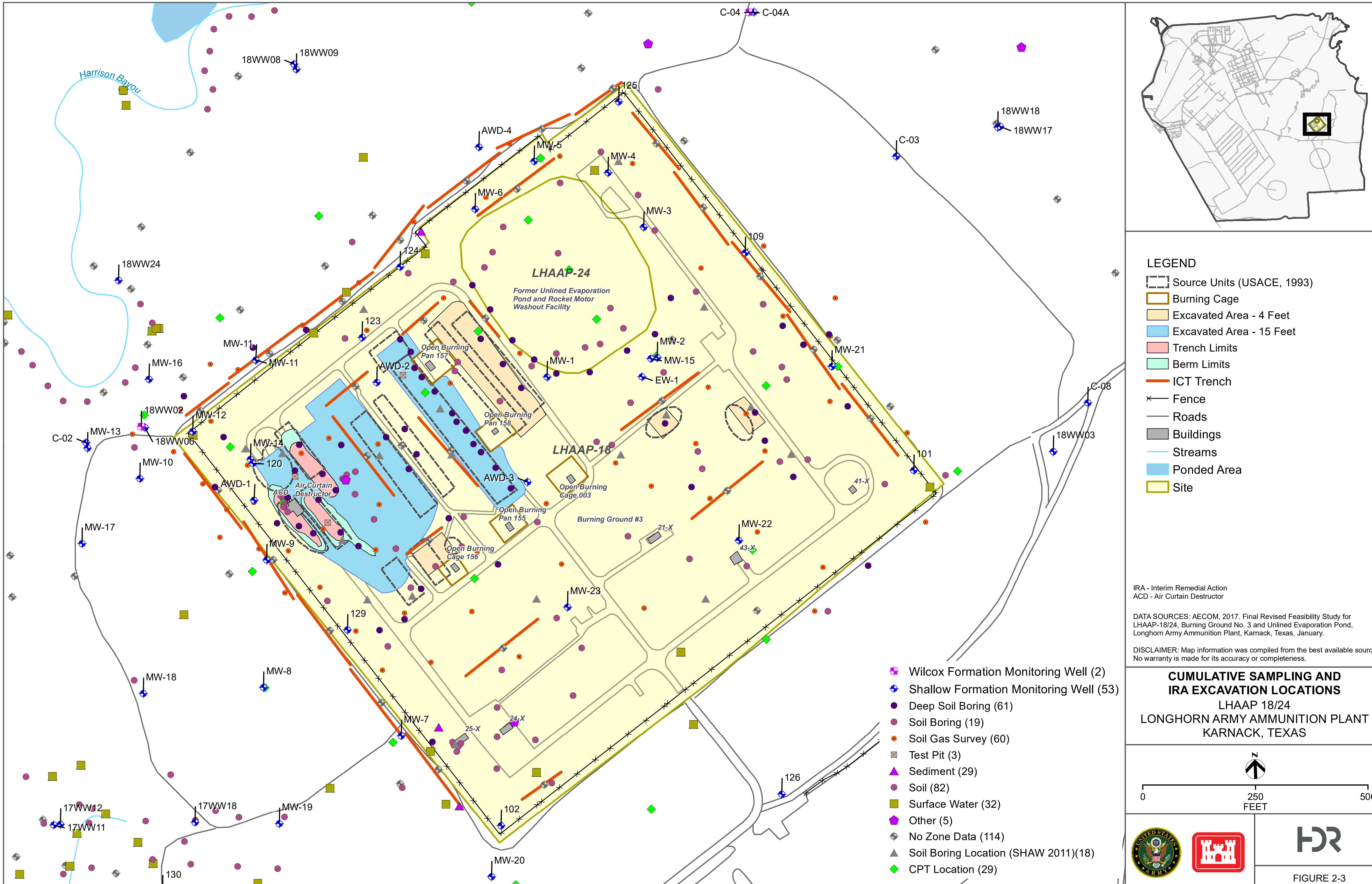
N

0 0.5 1
MILES

HDR

FIGURE 2-2

PATH: J:\2018\18-025_LHAAP_SITES29_47_18AND24_ROD_(WERNER)\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\LHAAP18_24\LHAAP_18_24_ROD_SITE_VICINTY.MXD - USER: KLOFGREN - DATE: 11/21/2019



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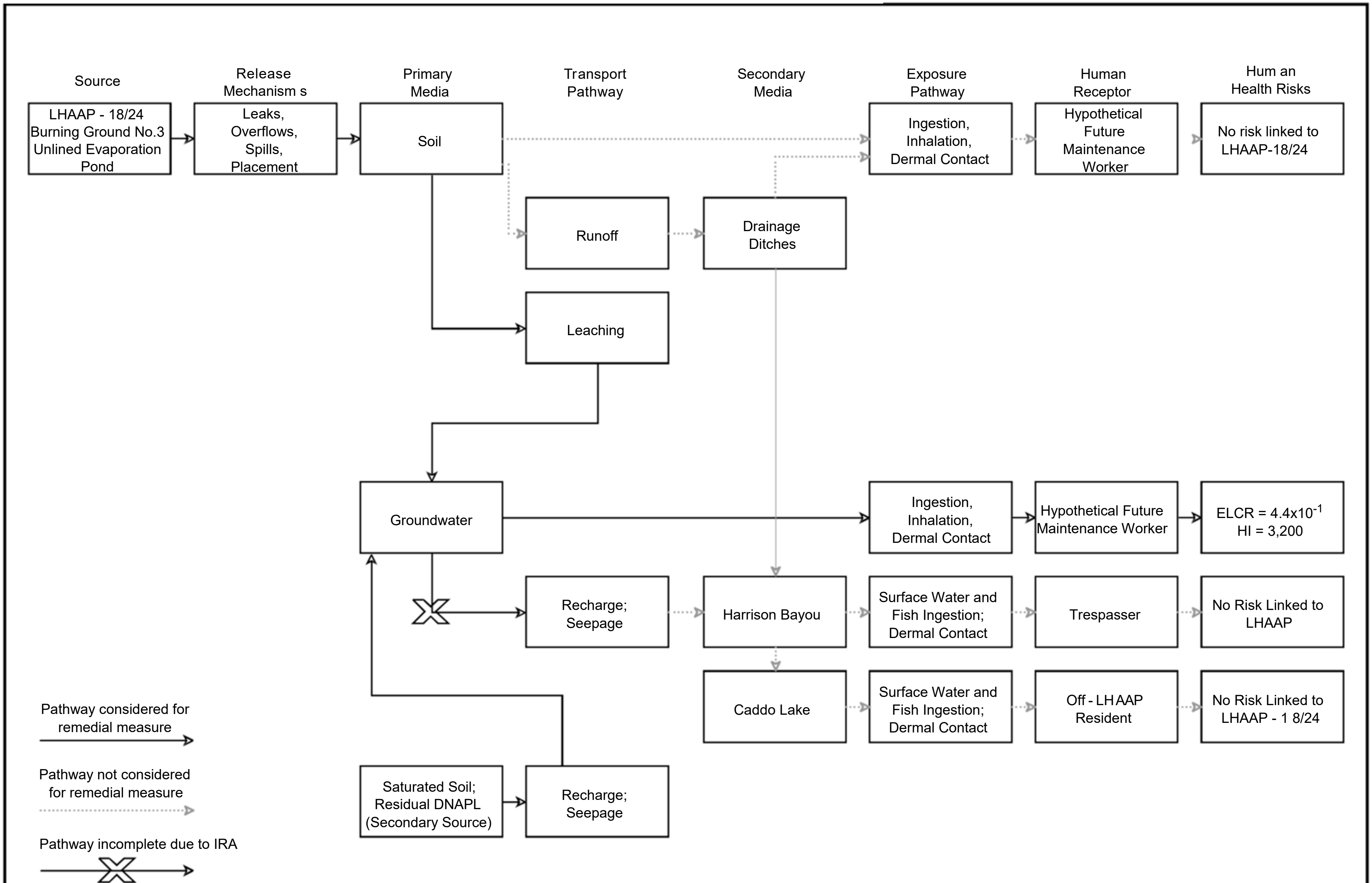
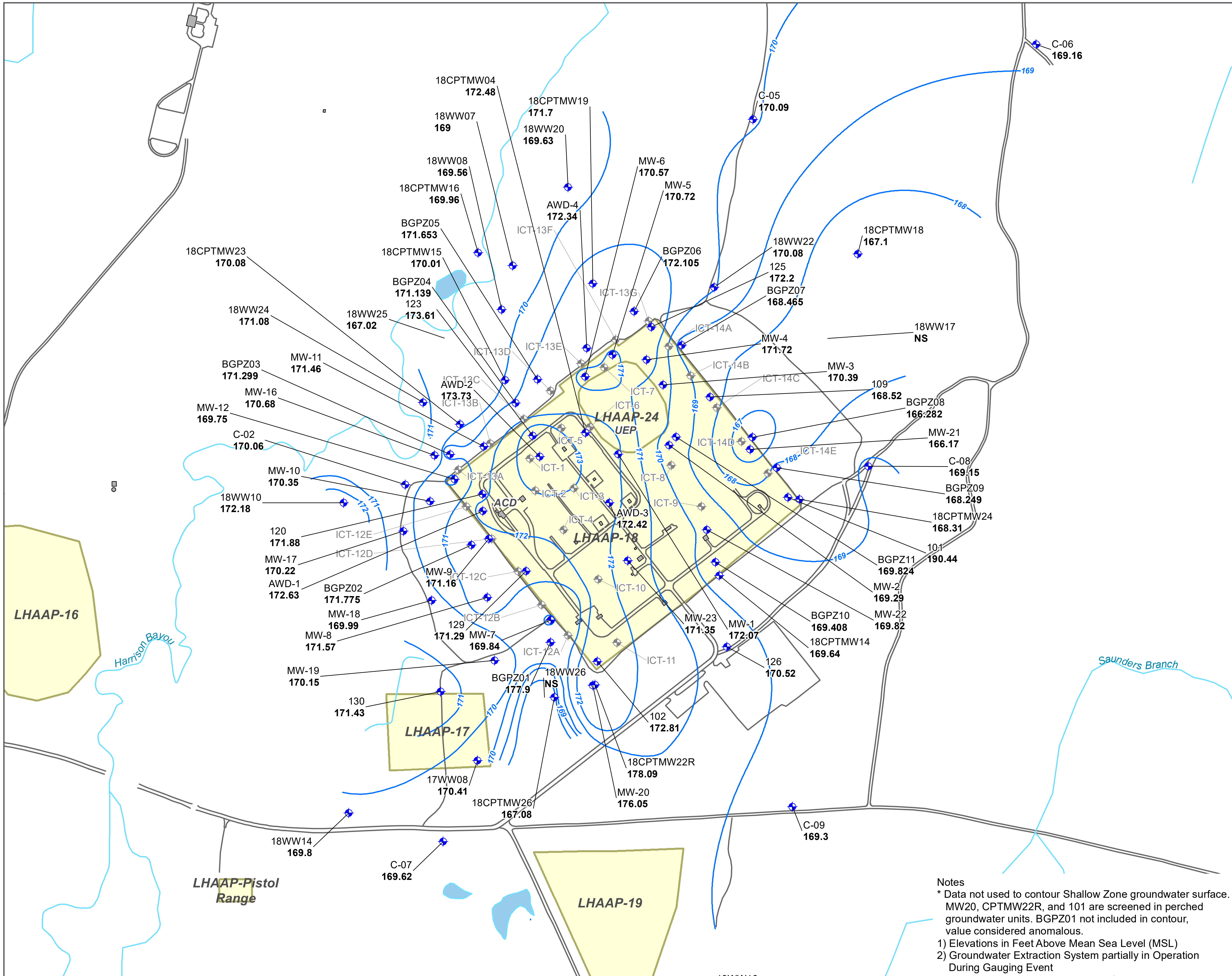


Figure 2-4 Conceptual Site Model LHAAP-18/24

Longhorn Army Ammunition Plant
Karnack, Texas



LEGEND

- Shallow Zone Monitoring Well
- ICT Extraction Location
- Groundwater Contour (dashed where inferred)
- Streams
- Ponded Area
- Roads
- Buildings
- Site

ACD – Air Curtain Destructor
UEP – Unlined Evaporation Pond

DATA SOURCES: AECOM, 2017. Final Revised Feasibility Study for LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas, January.

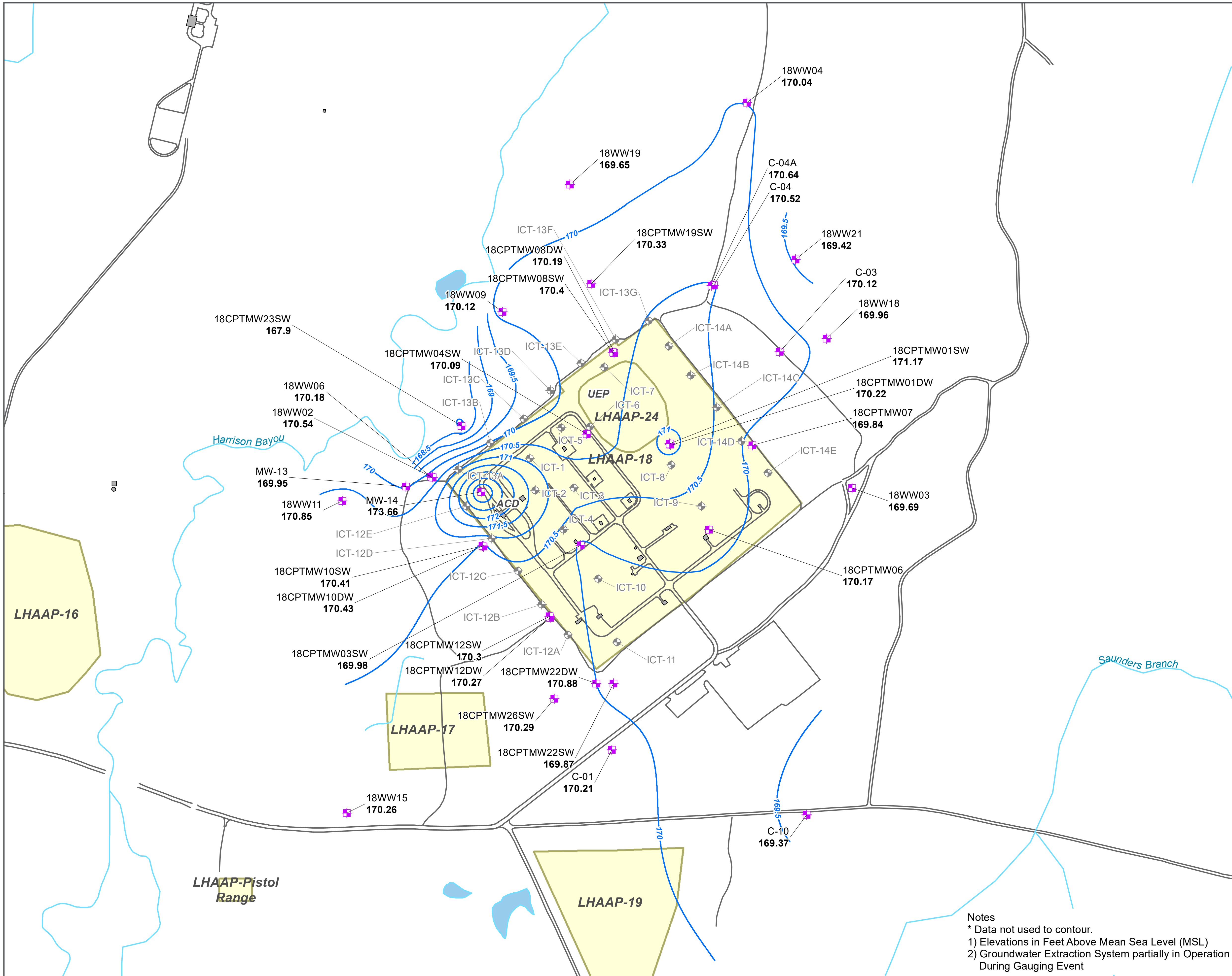
DISCLAIMER: Map information was compiled from the best available sources. No warranty is made for its accuracy or completeness.

Notes
* Data not used to contour Shallow Zone groundwater surface. MW20, CPTMW22R, and 101 are screened in perched groundwater units. BGPZ01 not included in contour, value considered anomalous.
1) Elevations in Feet Above Mean Sea Level (MSL)
2) Groundwater Extraction System partially in Operation During Gauging Event

GROUNDWATER POTENTIOMETRIC SHALLOW ZONE (JUNE 2016)
LHAAP 18/24
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

N
0 250 500
FEET

FIGURE 2-5



Notes
* Data not used to contour.
1) Elevations in Feet Above Mean Sea Level (MSL)
2) Groundwater Extraction System partially in Operation
During Gauging Event

LEGEND

- Wilcox Formation Monitoring Well
- ICT Extraction Location
- Groundwater Contour (dashed where inferred)
- Streams
- Ponded Area
- Roads
- Buildings
- Site

ACD – Air Curtain Destructor
UEP – Unlined Evaporation Pond

DATA SOURCES: AECOM, 2017. Final Revised Feasibility Study for LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas, January.

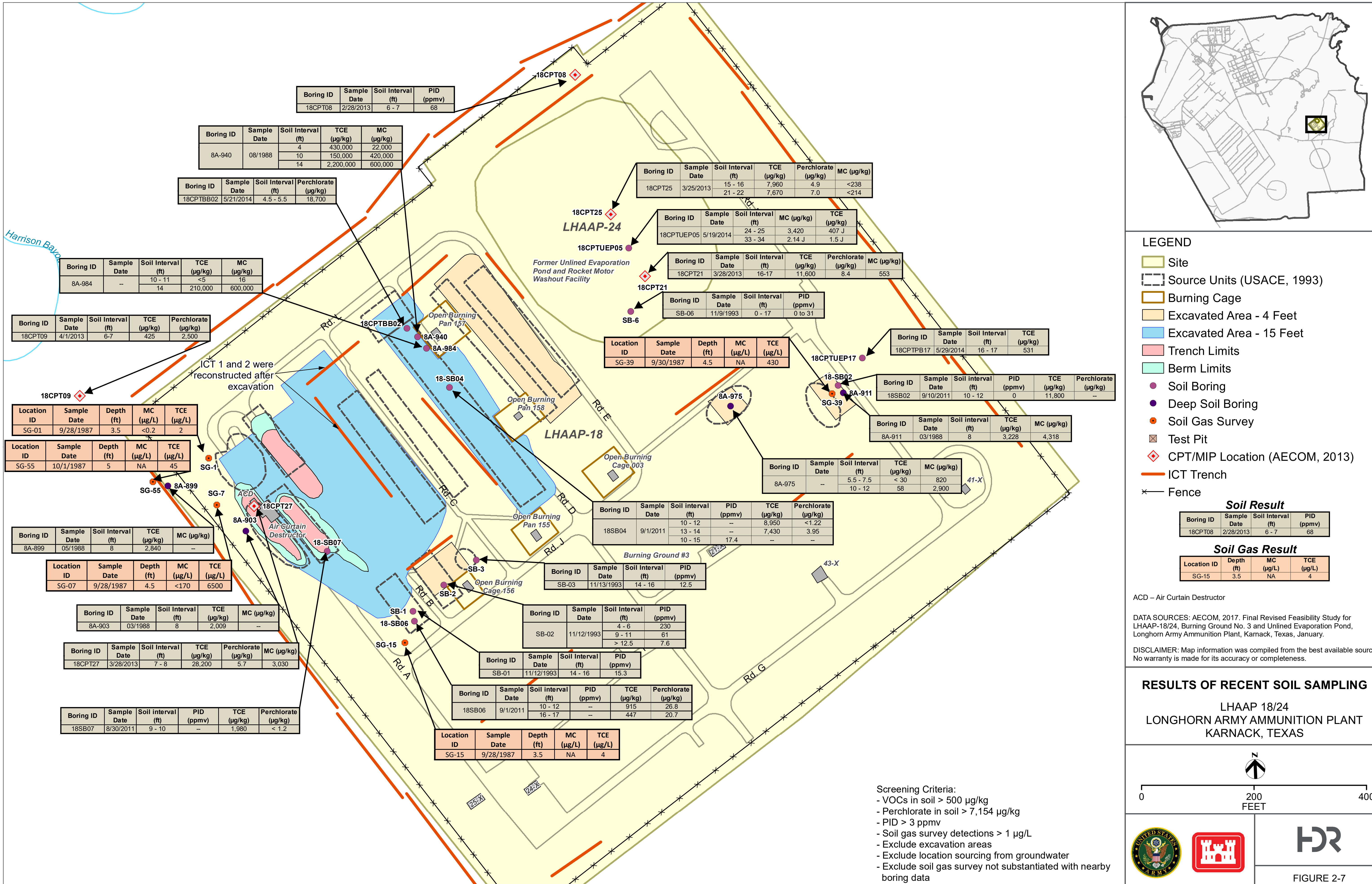
DISCLAIMER: Map information was compiled from the best available sources. No warranty is made for its accuracy or completeness.

GROUNDWATER POTENTIOMETRIC WILCOX FORMATION (JUNE 2016)
LHAAP 18/24
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

N
0 250 500
FEET

FIGURE 2-6

PATH: J:\2018\18-025_LHAAP_SITES29_47_18AND24_ROD_(WERNER)\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\LHAAP18_24\LHAAP_18_24_ROD_GWE_WILCOX_JUN_2016.MXD - USER: KLOFGREN - DATE: 12/19/2019



DATA SOURCES: AECOM, 2017. Final Revised Feasibility Study for LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas, January.

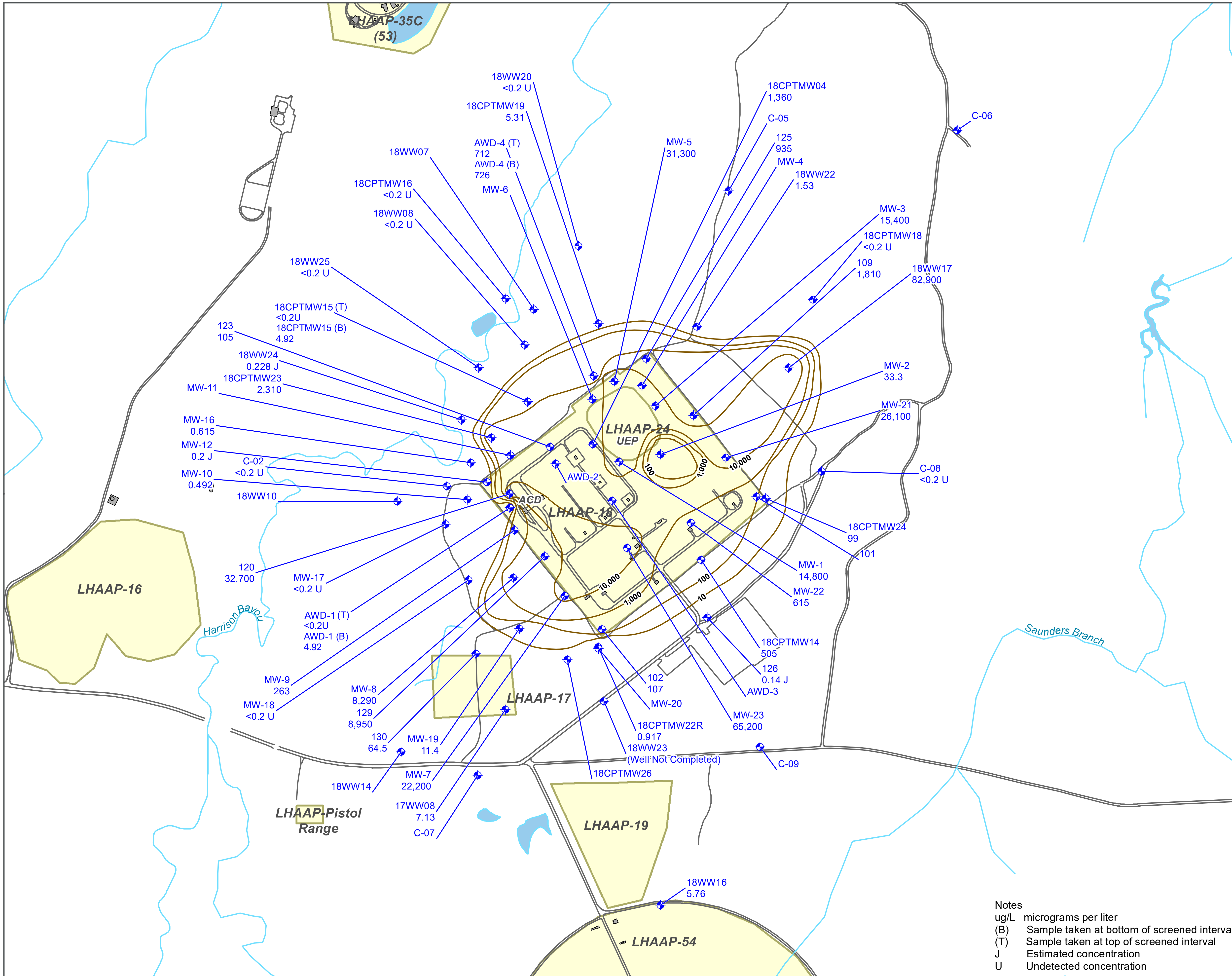
DISCLAIMER: Map information was compiled from the best available sources. No warranty is made for its accuracy or completeness.

RESULTS OF RECENT SOIL SAMPLING

LHAAP 18/24
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

FIGURE 2-7

PATH: J:\2018\18-025_LHAAP_SITES29_47_18AND24_ROD_(WERNER)\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\LHAAP18_24\LHAAP_18_24_ROD_SOILCONTAMINATION_REMEDIATION.MXD - USER: KLOFGREN - DATE: 12/26/2019



Notes
ug/L micrograms per liter
(B) Sample taken at bottom of screened interval
(T) Sample taken at top of screened interval
J Estimated concentration
U Undetected concentration

LEGEND

- Shallow Zone Monitoring Well with Well ID and Perchlorate Concentration in ug/L
- Perchlorate Contour (µg/L)
- Streams
- Ponded Area
- Roads
- Buildings
- Site

ACD – Air Curtain Destructor
UEP – Unlined Evaporation Pond

DATA SOURCES: AECOM, 2017. Final Revised Feasibility Study for LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas, January.

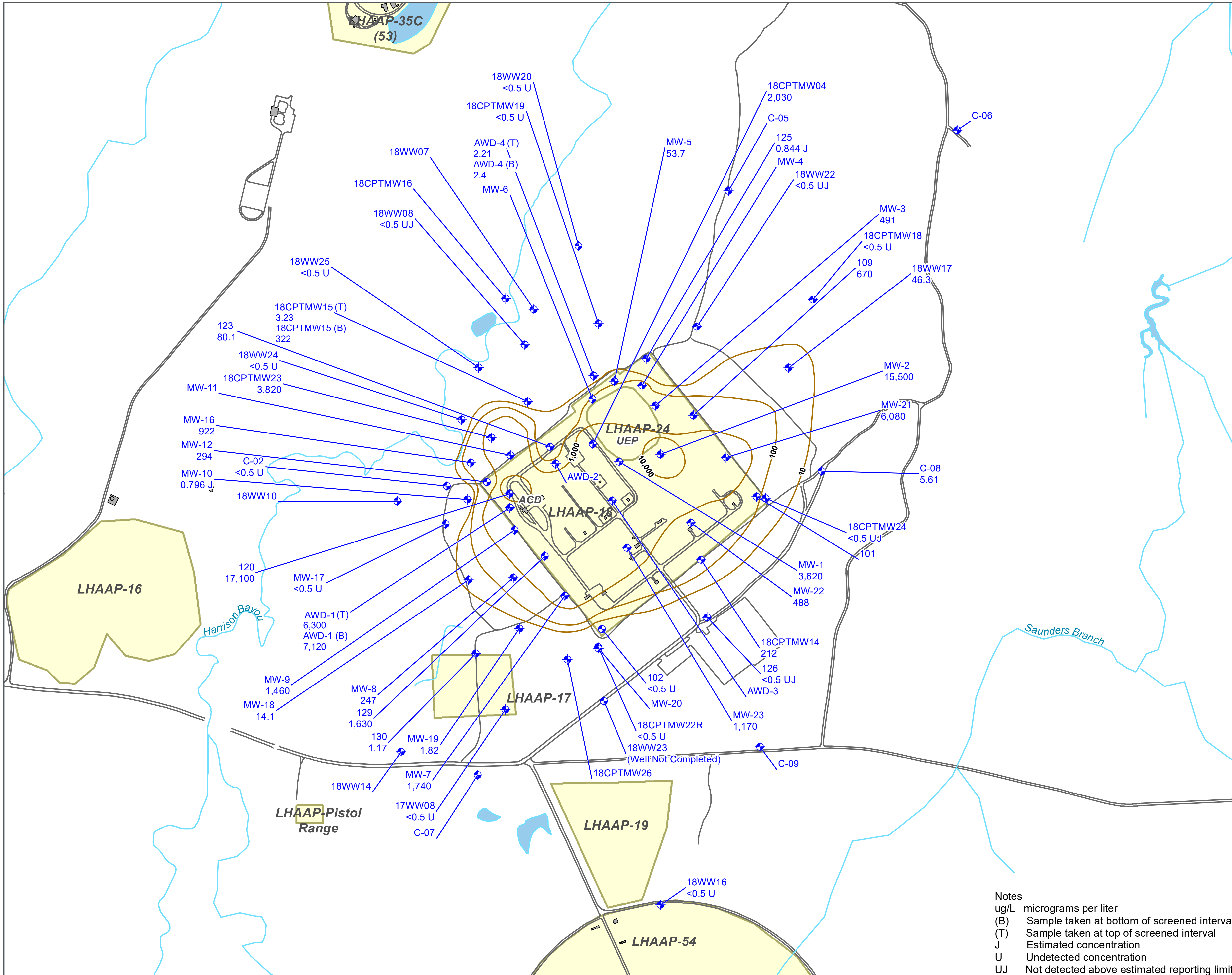
DISCLAIMER: Map information was compiled from the best available sources. No warranty is made for its accuracy or completeness.

PERCHLORATE ISOPLETH CONTOURS IN SHALLOW ZONE (JUNE 2016)
LHAAP 18/24
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

N
0 500 1,000
FEET

FIGURE 2-8

PATH: J:\2018\18-025_LHAAP_SITES29_47_18AND24_ROD_(WERNER)\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\LHAAP18_24\LHAAP_18_24_ROD_GW_PERCH_SHALLOW_2016JUN.MXD - USER: KLOFGREN - DATE: 12/19/2019



LEGEND

- Shallow Zone Monitoring Well with Well ID and Trichloroethene Concentration in ug/L
- Trichloroethene Contour (µg/L)
- Streams
- Ponded Area
- Roads
- Buildings
- Site

ACD – Air Curtain Destructor
UEP – Unlined Evaporation Pond

DATA SOURCES: AECOM, 2017. Final Revised Feasibility Study for LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas, January.

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

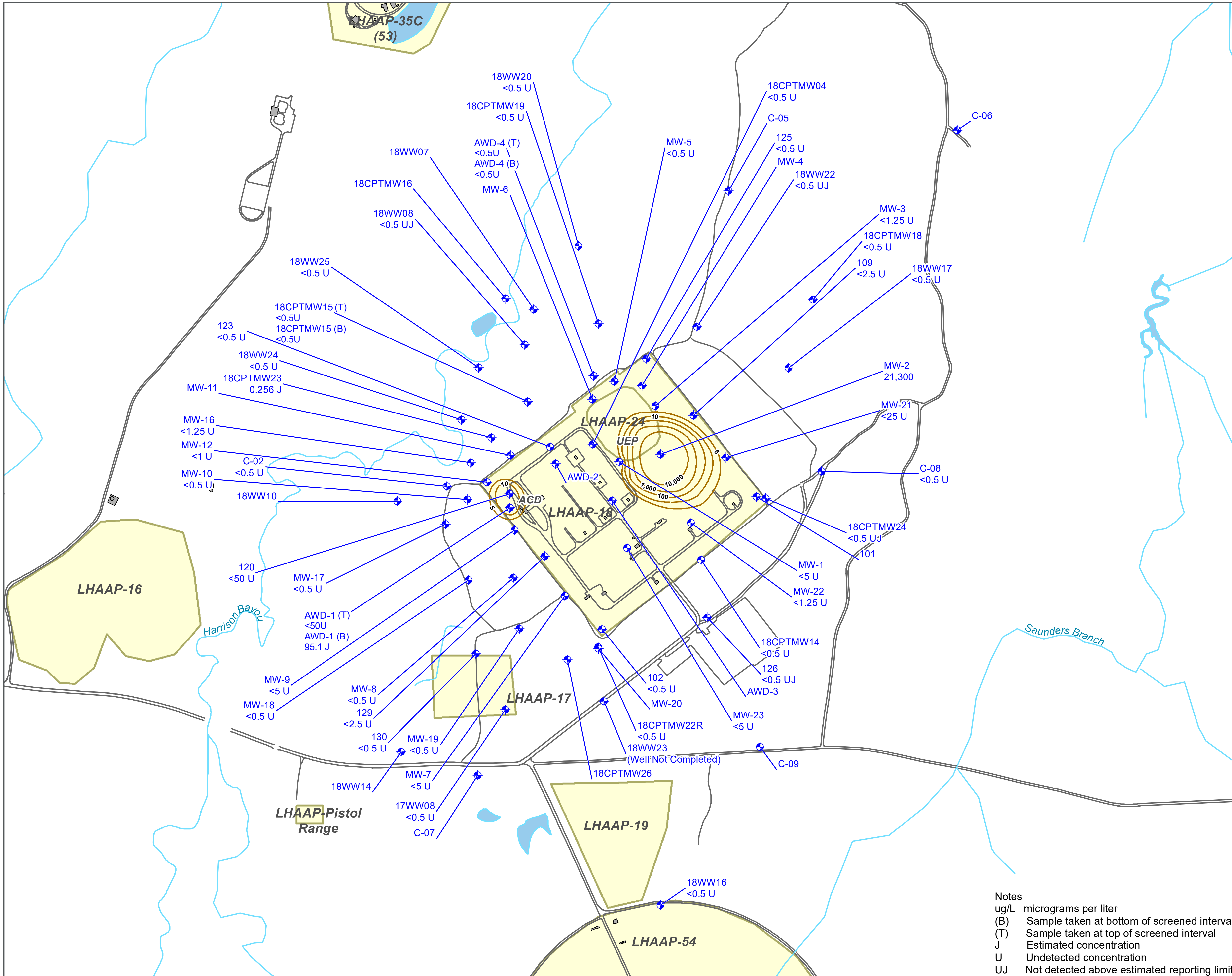
Notes
ug/L micrograms per liter
(B) Sample taken at bottom of screened interval
(T) Sample taken at top of screened interval
J Estimated concentration
U Undetected concentration
UJ Not detected above estimated reporting limit

TRICHLOROETHENE ISOPLETH CONTOURS IN SHALLOW ZONE (JUNE 2016)
LHAAP 18/24
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

N
0 500 1,000
FEET

HDR

FIGURE 2-9



Notes
ug/L micrograms per liter
(B) Sample taken at bottom of screened interval
(T) Sample taken at top of screened interval
J Estimated concentration
U Undetected concentration
UJ Not detected above estimated reporting limit

LEGEND
- Shallow Zone Monitoring Well with Well ID and Methylene Chloride Concentration in ug/L
- Methylene Chloride Contour (µg/L)
- Streams
- Ponded Area
- Roads
- Buildings
- Site

ACD – Air Curtain Destructor
UEP – Unlined Evaporation Pond

DATA SOURCES: AECOM, 2017. Final Revised Feasibility Study for LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas, January.

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

METHYLENE CHLORIDE ISOPLETH CONTOURS IN SHALLOW ZONE (JUNE 2016)
LHAAP 18/24
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

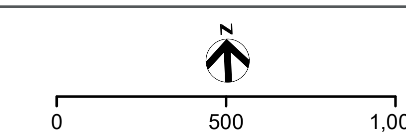
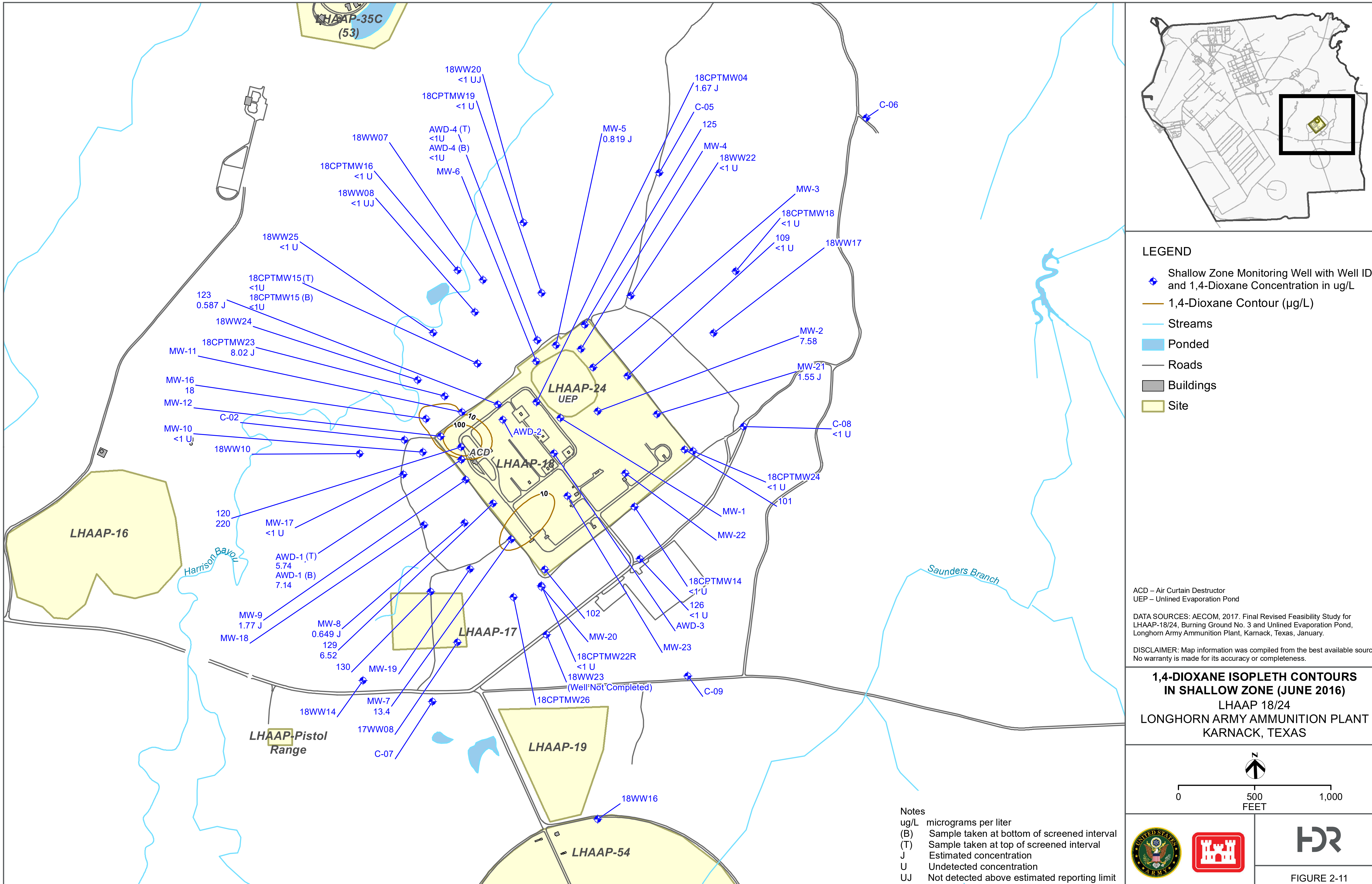


FIGURE 2-10

PATH: J:\2018\18-025_LHAAP_SITES29_47_18AND24_ROD_(WERNER)\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\LHAAP18_24\LHAAP_18_24_ROD_GW_METHCHLOR_SHALLOW_2016JUN.MXD - USER: KLOFGREN - DATE: 12/19/2019



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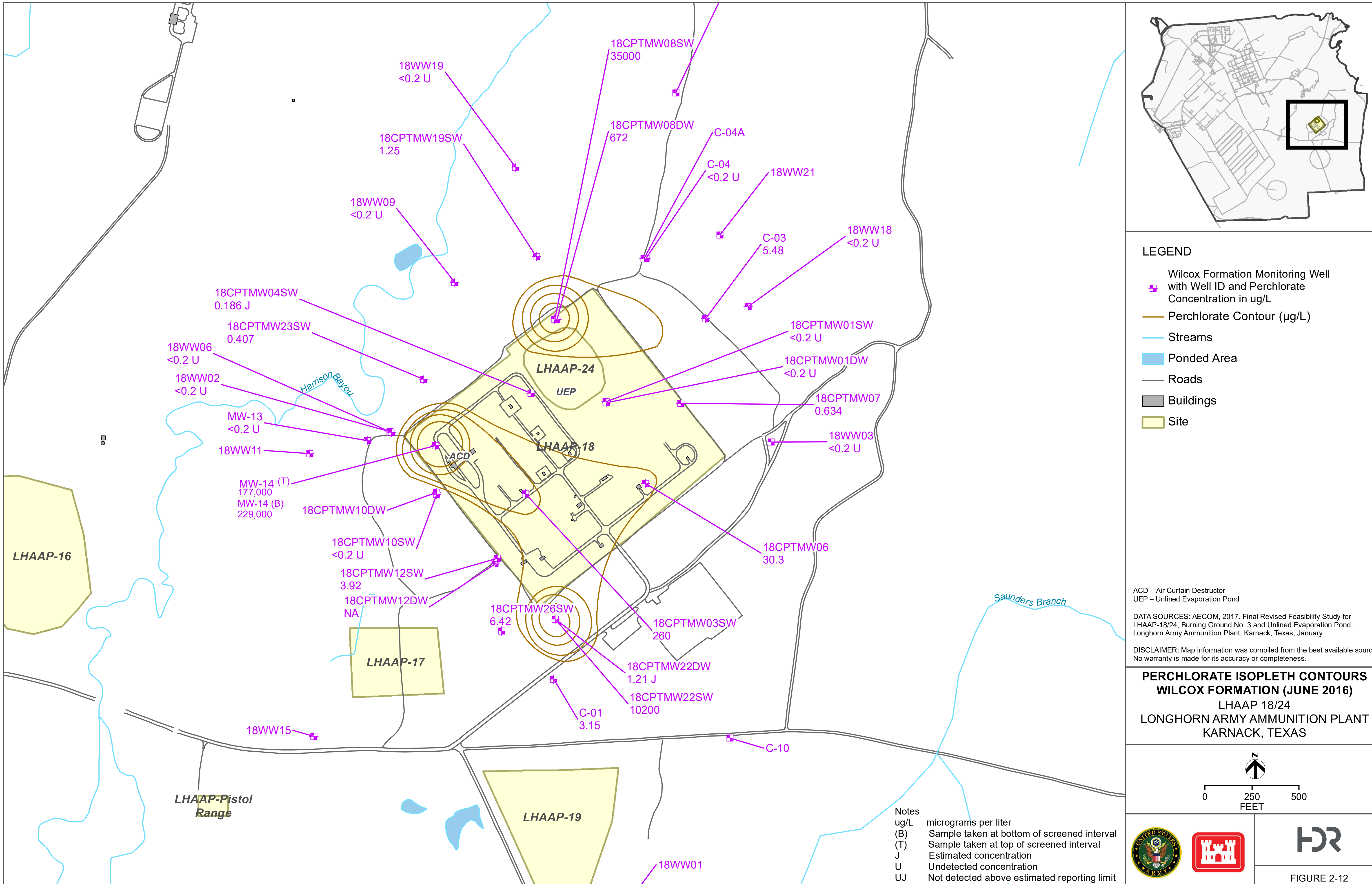

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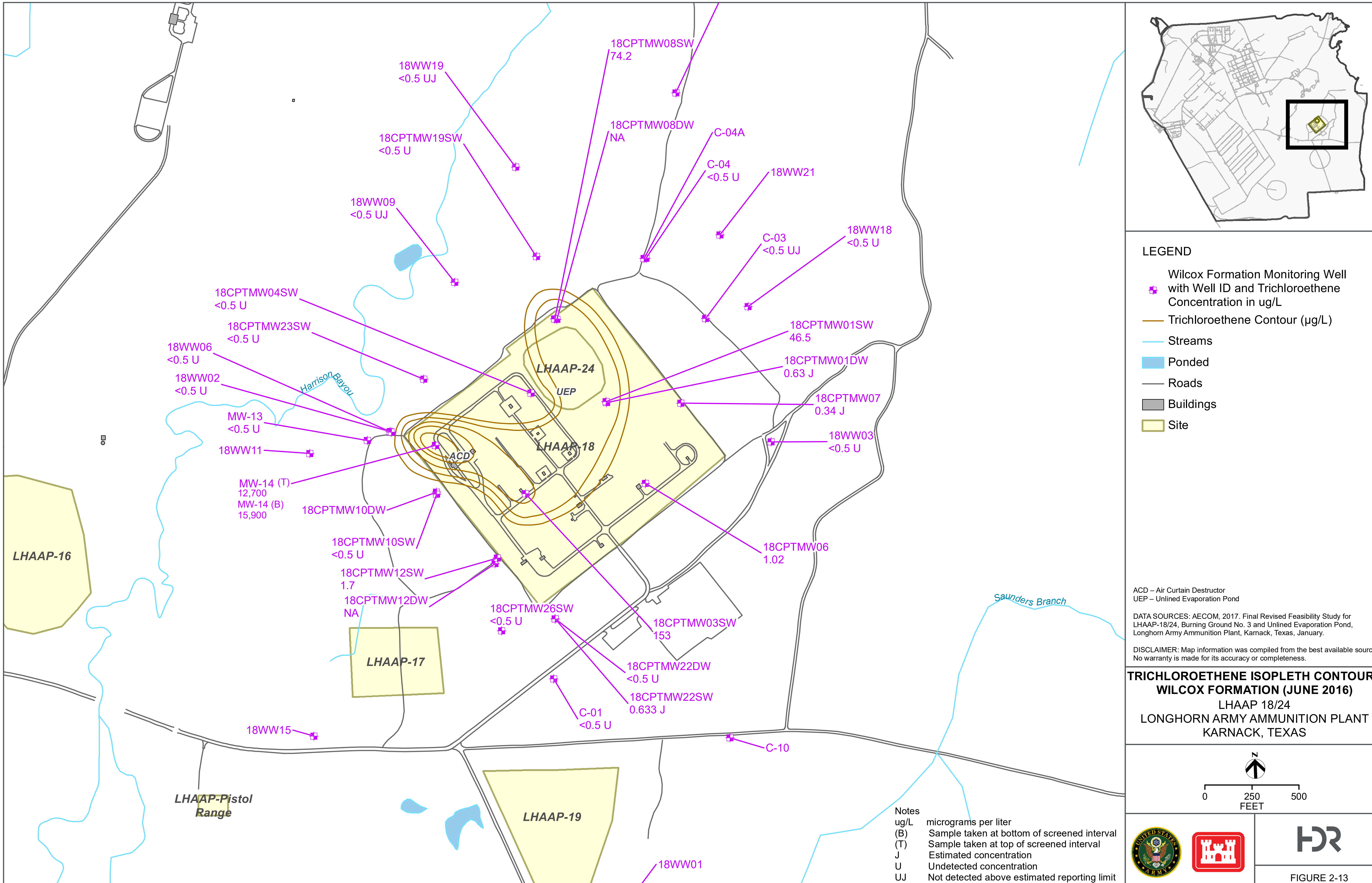
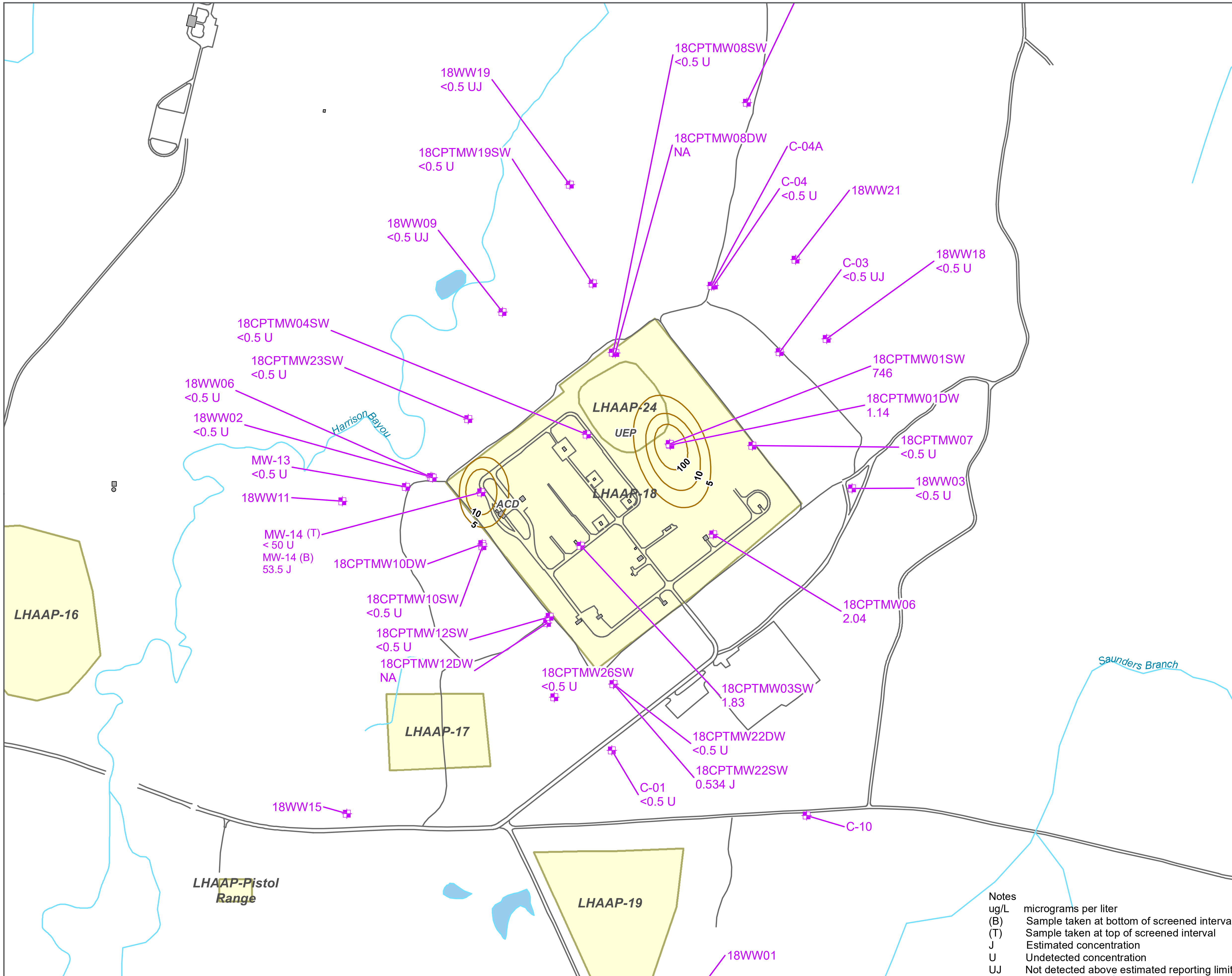


TRICHLOROETHENE ISOPLETH CONTOURS WILCOX FORMATION (JUNE 2016)
LHAAP 18/24
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

FIGURE 2-13

PATH: J:\2018\18-025_LHAAP_SITES29_47_18AND24_ROD_(WERNER)\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\LHAAP18_24\LHAAP_18_24_ROD_GW_TCE_WILCOX_JUN_2016.MXD - USER: KLOFGREN - DATE: 12/19/2019



LEGEND

- Wilcox Formation Monitoring Well with Well ID and Methylene Chloride Concentration in ug/L
- Methylene Chloride Contour (µg/L)
- Streams
- Ponded Area
- Roads
- Buildings
- Site

ACD – Air Curtain Destructor
UEP – Unlined Evaporation Pond

DATA SOURCES: AECOM, 2017. Final Revised Feasibility Study for LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas, January.

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

Notes

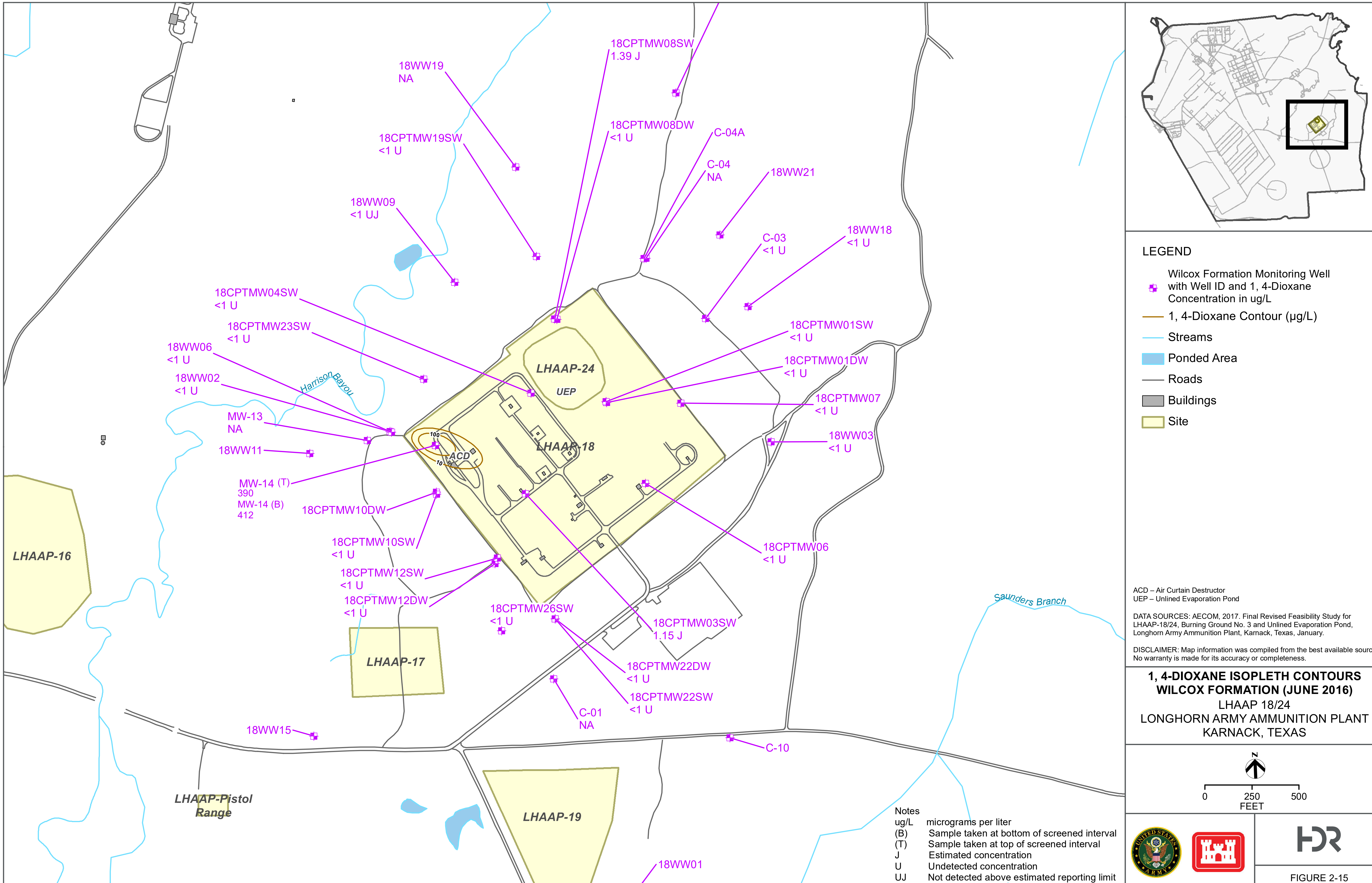
ug/L	micrograms per liter
(B)	Sample taken at bottom of screened interval
(T)	Sample taken at top of screened interval
J	Estimated concentration
U	Undetected concentration
UJ	Not detected above estimated reporting limit

METHYLENE CHLORIDE ISOPLETH CONTOURS WILCOX FORMATION (JUNE 2016)

LHAAP 18/24
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

FIGURE 2-14

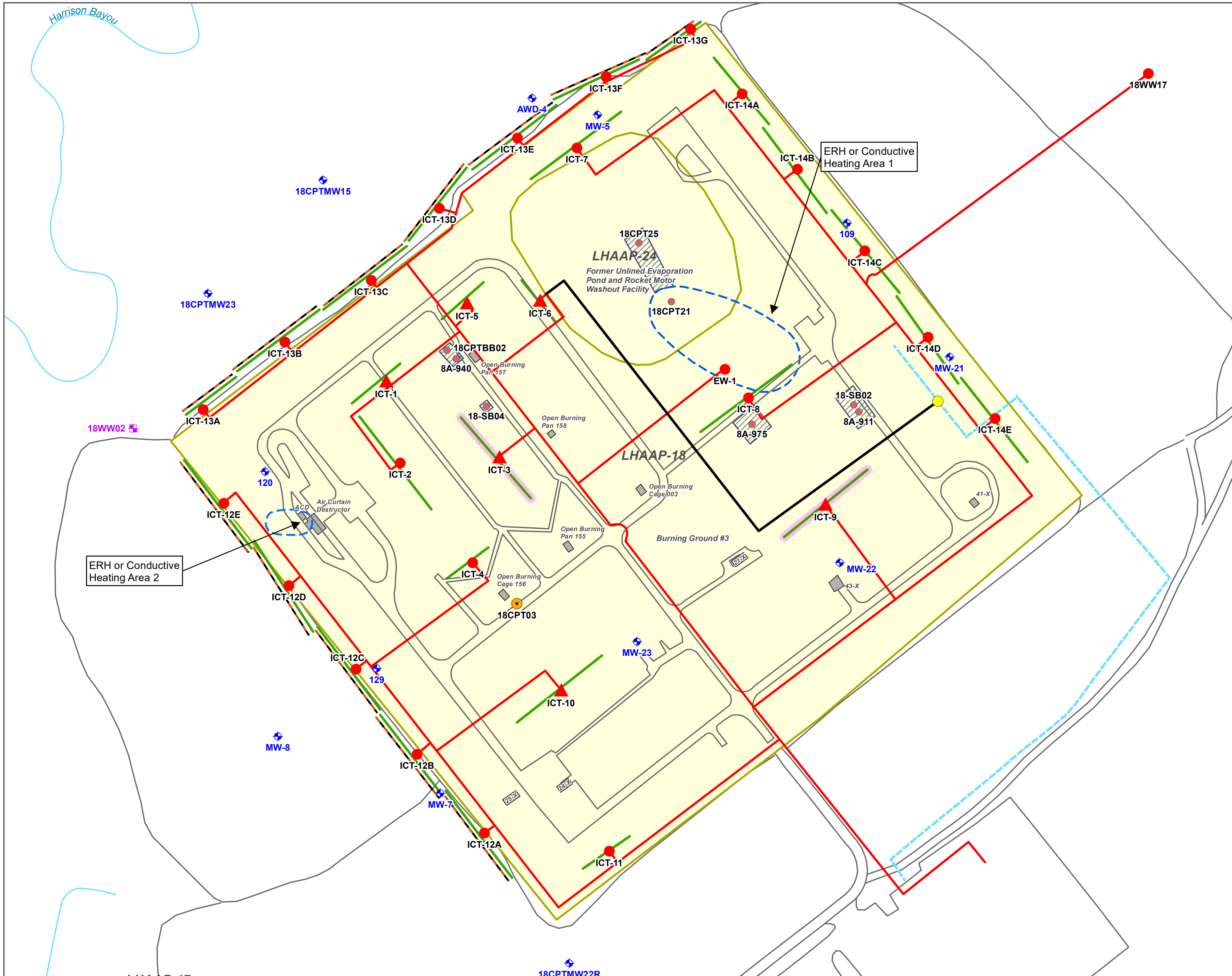
PATH: J:\2018\18-025_LHAAP_SITES29_47_18AND24_ROD_(WERNER)\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\LHAAP18_24\LHAAP_18_24_ROD_GW_METHCHLOR_WILCOX_JUN_2016.MXD - USER: KLOFGREN - DATE: 12/19/2019



1, 4-DIOXANE ISOPLETH CONTOURS WILCOX FORMATION (JUNE 2016)
LHAAP 18/24
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\LHAAP18_24\LHAAP_18_24_ROD_GW_DIOXANE_WILCOX_JUN_2016.MXD - USER: KLOFGREN - DATE: 12/19/2019



LEGEND

- Extraction Location
- Currently Deactivated Sump
- Injection Point (discontinued)
- Soil Boring
- Shallow Zone Monitoring Well
- Wilcox Formation Monitoring Well
- Soil Boring - May 2013
- Injection Line Tie In Point
- ICT Location
- HDPE Liner Installed on the Outside of the ICT
- Extraction Pipeline
- Irrigation Pipeline
- Road
- Stream
- Site
- Former Building or Concrete Slab

Alternative 5 Activities

- Reactivate Sump - Enhanced Groundwater Extraction
- DNAPL Removal Area - Thermal Treatment
- Excavation Area up to 12 Feet Below Ground Surface

ACD – Air Curtain Destructor

DATA SOURCES: AECOM, 2017. Final Revised Feasibility Study for LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas, January.

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

THERMAL TREATMENT (ERH OR CONDUCTIVE HEATING) AREAS, ENHANCED GROUNDWATER EXTRACTION LOCATIONS AND AREAS OF SOIL EXCAVATION

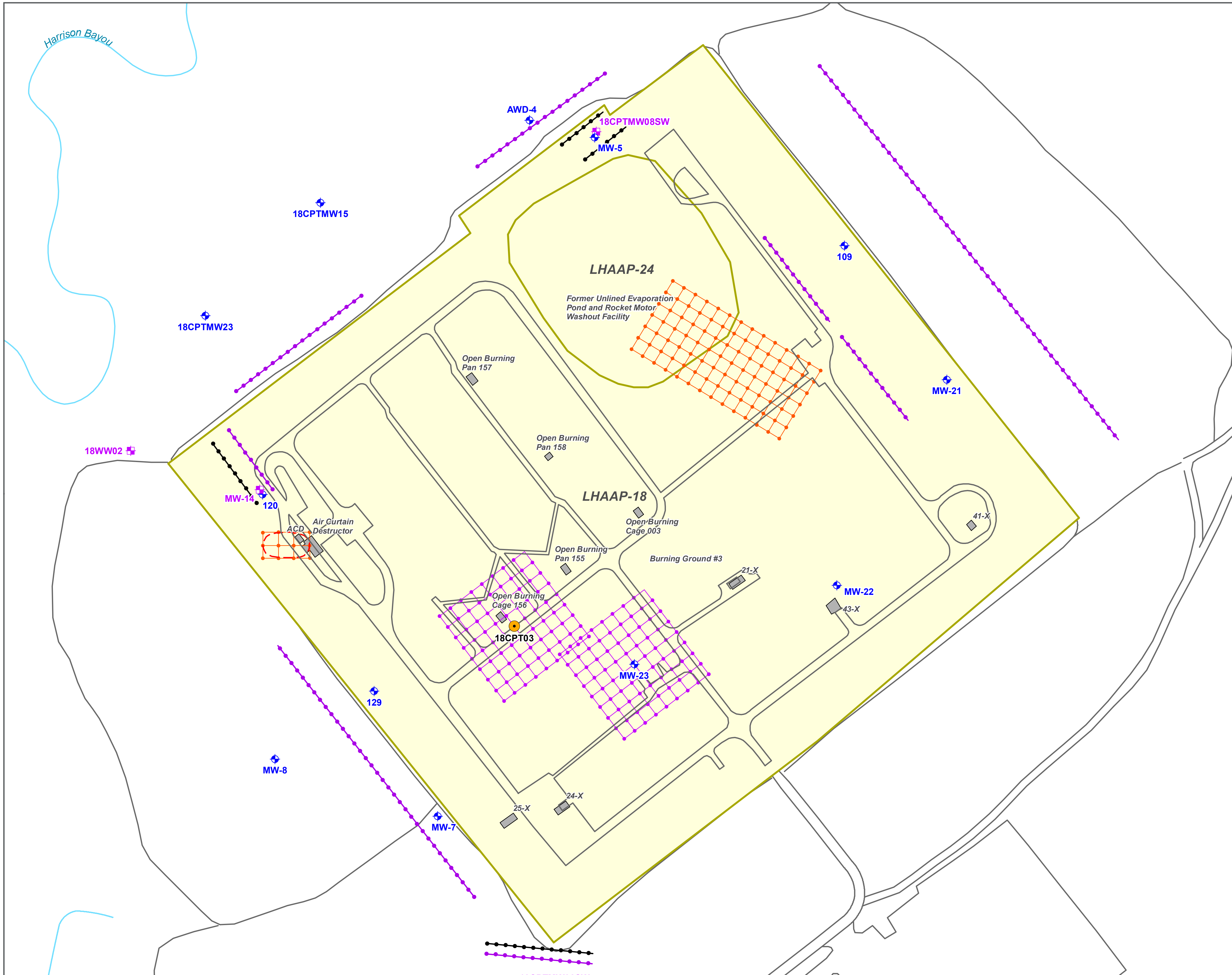
LHAAP 18/24
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

N

0 250 500
FEET

FIGURE 2-16

PATH: J:\2018\18-025_LHAAP_SITES29_47_18AND24_ROD_(WERNER)\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\LHAAP18_24\LHAAP_18_24_ROD_GW_EXTRACTION_LOCATIONS.MXD - USER: KLOFGREN - DATE: 12/26/2019



LEGEND

- Road
- Stream
- Site
- Former Building or Concrete Slab
- Shallow Zone Monitoring Well
- Wilcox Formation Monitoring Well
- Soil Boring - May 2013

Alternative 5 Activities

- Shallow Zone ISB
- Wilcox ISB
- Shallow Zone ISB Grid
- Shallow Zone ISB Grid after DNAPL Removal

Notes

ISB In-Situ Bioremediation

Barriers, grids and other remedy component features shown in this figure were used to facilitate comparison of alternatives including costs. The locations, number and layout may change during Remedial Design phase.

ACD – Air Curtain Destructor

DATA SOURCES: AECOM, 2017. Final Revised Feasibility Study for LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas, January.

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

ENHANCED IN-SITU BIOREMEDIATION LOCATIONS

LHAAP 18/24

LONGHORN ARMY AMMUNITION PLANT

KARNACK, TEXAS

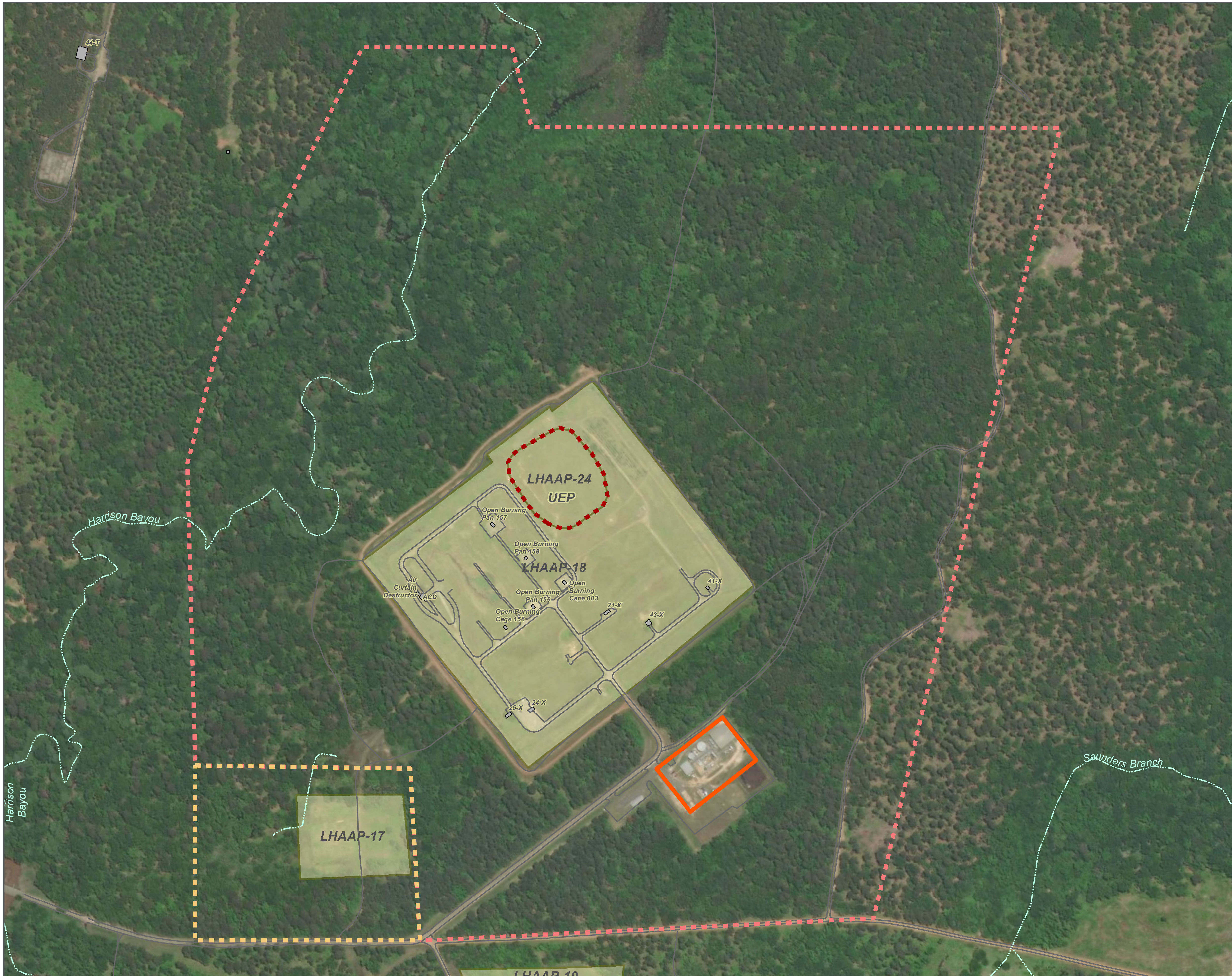
N

0 250 500

FEET

FIGURE 2-17

PATH: J:\2018\18-025_LHAAP_SITES29_47_18AND24_ROD_(WERNER)\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\LHAAP18_24\LHAAP_18_24_ROD_EISB_LOCATIONS.MXD - USER: KLOFGREN - DATE: 12/26/2019



LEGEND

Preliminary Land Use Control Boundary

- LUC 17
- LUC 18
- LUC 24 (UEP)
- GWTP – Groundwater Treatment Plant
- Roads
- Streams
- Buildings
- Site

ACD – Air Curtain Destructor, UEP – Unlined Evaporation Pond

DATA SOURCES: AECOM, 2017. Final Revised Feasibility Study for LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas, January.

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

PRELIMINARY LAND USE CONTROL BOUNDARY

LHAAP 18/24

LONGHORN ARMY AMMUNITION PLANT

KARNACK, TEXAS

N

0 250 500

FEET

FIGURE 2-18

PATH: J:\2018\18-025_LHAAP_SITES29_47_18AND24_ROD_(WERNER)\7.2_WORK_IN_PROGRESS\MAP_DOCS\DRAFT\LHAAP18_24\LHAAP_18_24_ROD_LUC.MXD - USER: KLOFGREN - DATE: 12/26/2019

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-18/24 as presented in the PP. 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. One public comment period and public meeting were held for the LHAAP-18/24 PP. Responsiveness summaries for the meeting are provided below.

The U.S. Army, USEPA, and TCEQ provide information regarding LHAAP-18/24 through a public meeting, the Administrative Record for the facility, and an announcement published in the Shreveport Times and Marshall News Messenger newspapers. **Section 2.3** discusses community participation on LHAAP-18/24, including the dates for the public comment period, the date, location, and time of the public meeting, and the location of the Administrative Record. The following documents related to community involvement were added to the Administrative Record for the comment period and public meeting:

- Transcript of the public meeting held on April 25, 2019;
- Presentation slides from the April 25, 2019 public meeting;
- Written questions and comments from the public during the public comment period, and the U.S. Army response to those comments, presented in this ROD; and

Stakeholder Issues and Lead Agency Responses

This section responds to significant issues raised by stakeholders including comments received from the public and community groups in written and verbal form. Verbal comments and questions were discussed and addressed during the public meeting on April 25, 2019 and are summarized below. Responses to written comments are presented following the verbal comments.

2019 Proposed Plan Verbal Comments

Question/Comment: Looking at the figure against the wall that shows the plumes in the Shallow Zone it also shows an area for monitored natural attenuation. But all the plumes are not covered by that MNA area. Could you explain why?

Response: *The reason that all of the wells within the plumes aren't part of the MNA area is because they are upgradient of where the contamination is. So, historically, those concentrations haven't been increasing because the primary flow direction is towards the bayou. The gray area represents the area where we will be monitoring for concentrations to be dropping over time demonstrating that natural attenuation is occurring. But some of those upgradient wells may be part of the sampling program and be monitored for natural attenuation parameters also. A lot of this is decided in the remedial design phase, so this is the '10,000-foot look' at what the remediation alternative is, and then you really get into the details during the remedial design phase.*

Question/Comment: I have a question about where you intend to use EISB. You said that was inside and outside the containment area, but on your maps it seems to me the locations are all inside the containment area.

Response: *There are lines shown outside the containment area that represent linear ISB injection locations. Again, this is the conceptual design, so the actual locations may shift during the remedial design to better address the contamination.*

Question/Comment: When I evaluate these kind of plans, there are three questions I try to answer. First is, have all the contaminants been identified; the second is, has the extent of contamination been determined--that's both horizontally and vertically--and, finally, if the proposed plan is implemented, is it likely to clean up contaminants in a reasonable amount of time. And my initial answers to all three of those questions is yes. I think that you've identified all the contaminants; you've identified the extent; and as far as the cleanup plan working, I am concerned mostly with DNAPL, because we all -- for those of you who have been involved, you know that DNAPLs are probably the most difficult thing to clean up that we deal with. And this technology that you plan to use is new to me; but I've done a little research on it, and I went looking for examples where the technology didn't work, but I was unable to find an example where it didn't work. It might be out there; but in all the cases I've looked at, have worked, so I think it's quite promising. I do have one criticism, though, and that has to do with metals. You've mentioned the fact that metals are present in groundwater, including arsenic and chromium; but nowhere in any of the documents I've looked at does the Army explicitly say "This is how we're going to clean up the metals", or do they say, alternatively, "We don't need to clean up the metals”. I think that we need more explanation of what you intend to do, if anything, about the metals. Other than that it’s a good and reasonable plan.

Response: *Thank you.* The metals will be addressed through monitoring over time and will be evaluated at five year reviews. If any further action is required to demonstrate protectiveness, that also will be addressed during the five year review.

<u>2019 Proposed Plan Written Comments</u>

Question/Comment: DNAPLs are the most difficult contaminants to remove from an aquifer. The thermal technology that the Army is proposing to use is probably the most effective means of cleaning up DNAPL that is available.

Response: *No response required.*

Question/Comment: Groundwater at the site is contaminated with metals (see tables 1 and 2). However, the Army has not clearly stated what, if anything, it intends to do about the metals. The Army should either 1) develop a plan that clearly states how it intends to clean up metals, or 2) explain why the cleanup is unnecessary.

Response: *Isolated detections of metals in the shallow zone at concentrations exceeding the MCLs/PCLs occur across the site, but without the clear plume patterns exhibited by VOCs. The major metals in the Shallow Zone are arsenic, barium, and chromium. The other metals (cobalt and nickel) are not detected consistently. In the Wilcox Formation, sporadic detections of arsenic above the MCL were reported in three wells. Groundwater monitoring will be conducted to evaluate metals and the need to continue monitoring for metals will be evaluated at five year intervals. In addition,* *the LUCs that will be put in place will prevent human exposure to unacceptable metals concentrations.*

Question/Comment: There are three areas in the Wilcox Formation where the vertical extent of groundwater contamination has not been determined. The first is in the north central portion of the site, at well 18CPTMW01DW. Methylene chloride concentrations at this well exceed the drinking water standard. The second is along the northern boundary of the site, at well 18CPTMW08DW. Perchlorate concentrations at this well exceed the drinking water standard. The third is in the western corner of the site, at well M-14. Perchlorate, solvents (e.g., methylene chloride, TCE), and 1,4-dioxane concentrations exceed the drinking water standards.

The Army should install additional wells in these areas to determine the vertical extent of contamination.

Response: To clarify, the vertical extent of all wells outside the contained area has been determined. However, the three wells identified are inside the contained area. Well 18CPTMW01DW has been below MCL for methylene chloride in 2016 and 2018 sampling events and will continue to be monitored to ensure vertical extent is defined. While 18CPWMW08DW has remained above the PCL for perchlorate and MW-14 has remained above the cleanup standards for perchlorate, MC and TCE and 1,4-dioxane during 2016 and 2018 sampling events, it is anticipated that the RD will include ISB treatment for these two sections of the site. The Army intends to implement the active remediation in these areas prior to considering installing any deeper wells to avoid creating a potential conduit for downward migration.

Question/Comment: With regard to 18/24, we heard the contractor, HDR, state that the vertical extent was known. Can they please tell us which wells were used to determine the vertical extent and the accompanying analysis of those wells over time?

Response: *The statement made during the presentation should have been limited to the areas outside the contained area. The vertical extent is not defined at two of the locations cited in the previous comment. See previous response.*

Question/Comment: The Army claims that the In-situ Thermal Treatment system will remove 99.9% of the DNAPL at site 18/24. However, the Army does not provide a reference to information that supports this claim. The Army should state where the information can be found.

Response: *The estimate for removal efficiency was obtained from Vendor-supplied information for thermal treatment technologies. Additional information regarding performance of thermal technologies is available at: https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Persistent-Contamination/ER-200314/ER-200314-TR.*

Question/Comment: The Army estimates that cleanup will be completed in 20 years. However, the Army does not provide a reference to the calculations that support this estimate. The Army should state where the calculations can be found.

Response: *The cleanup duration is described in the January 2017 Revised Feasibility Study Report – LHAAP-18/24. The cleanup duration is based on the Natural Attenuation Evaluation included in Appendix A of the FS.*

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Appendix A

Public Notice Affidavits

THE MARSHALL NEWS MESSENGER

The Marshall News Messenger
309 E Austin
Marshall, TX 75670

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

04/03/19

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 # 640129, was published in said newspaper on April 3, 2019, 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 April, 2019.

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

ad id: 640129

PUBLIC NOTICE

THE UNITED STATES ARMY INVITES PUBLIC COMMENT ON THE PROPOSED PLAN FOR THE FINAL REMEDY FOR ENVIRONMENTAL SITE LHAAP-18/24, BURNING GROUND No. 3 AND UNLINED EVAPORATION POND, LONGHORN ARMY AMMUNITION PLANT, TEXAS

PUBLIC MEETING ON APRIL 25, 2019
AT THE KARNACK COMMUNITY CENTER, KARNACK, TX

The U.S. Army is the lead agency for environmental response actions at Longhorn Army Ammunition Plant (LHAAP). 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 Proposed Plan for site LHAAP-18/24, Burning Ground No. 3 and Unlined Evaporation Pond. Although the Proposed Plan identifies the preferred final remedy for the site, the U.S. Army welcomes the public's review and comment. Beginning on April 2, 2019, copies of the Proposed Plan and supporting documentation will be available for public review at the Marshall Public Library, 300 S. Alamo, Marshall, Texas, 75670 and on the LHAAP website at http://www.longhornaap.com/LHAAP-18-24. The public comment period is April 2, 2019 through May 2, 2019. The public meeting will be held on Thursday, April 25, 2019 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 Proposed Plan will be recorded by a court reporter during the public meeting. Written comments will be accepted throughout the public comment period.

LHAAP is an inactive, government-owned, formerly contractor-operated industrial facility located in central-east Texas in the northeastern corner of Harrison County. The former installation occupied 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-18/24, known as the Burning Ground No. 3 (18) and Unlined Evaporation Pond (UEP) (24), is a 34.5 acre fenced, cleared area (containment area) located in the southeastern section of LHAAP. The area was used for the treatment, storage, and disposal of solid and liquid explosive, pyrotechnic, and combustible solvent waste by open burning/open detonation, incineration, evaporation, and burial. LHAAP-18 Burning Ground No. 3 operated between 1955 and 1998 and LHAAP- 24 UEP was used to collect water from the washout of rocket motor casings and process waste sumps from 1963 to 1984.

The Proposed Plan for LHAAP-18/24 addresses potential risks associated with exposure to contaminated soil and groundwater in both the shallow zone and Wilcox formation and also prevents contaminated groundwater from migrating and impacting surface water at unacceptable levels. The full list of alternatives evaluated is: 1) no action; 2) enhanced groundwater extraction and ex-situ treatment, and land use controls (LUCs) in the shallow zone and Wilcox formation, enhanced in-situ bioremediation (EISB) inside & outside the containment area in the shallow zone and Wilcox formation, unsaturated soil excavation and off-site disposal; 3) groundwater extraction and treatment, monitored natural attenuation (MNA) outside the containment area in the shallow zone and Wilcox formation, LUCs in the shallow zone and Wilcox formation, and containment; 4) enhanced groundwater extraction and treatment, LUCs in the shallow zone and Wilcox formation, EISB inside & outside the containment area in the shallow zone and Wilcox formation, unsaturated soil excavation and off-site disposal, and surfactant enhanced dense non-aqueous phase liquid (DNAPL) removal; 5) enhanced groundwater extraction and treatment, LUCs in the shallow zone and Wilcox formation, EISB inside & outside the containment area in the shallow zone and Wilcox formation, unsaturated soil excavation and off-site disposal, and thermal DNAPL removal; and 6) enhanced groundwater extraction and treatment, LUCs in the shallow zone and Wilcox formation, EISB inside & outside the containment area in the shallow zone and Wilcox formation, unsaturated soil excavation and off-site disposal, and enhanced DNAPL remediation using zero-valent iron (ZVI). Based on available information, the preferred remedy is Alternative 5, which would remove contaminated soil from LHAAP-18/24 with off-site disposal; reduce groundwater contamination in the shallow zone and Wilcox formation through extraction and treatment and EISB, employ thermal DNAPL removal, and ongoing LUCs to assure protection of human health and the environment. Through the use of treatment technologies, Alternative 5 will permanently reduce the toxicity, mobility, and volume of source materials that constitute the principal threat wastes at the site.

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.

The Times

State of Louisiana
Parish of Caddo

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______________, personally known to me who being duly sworn, deposes and says that he/she is the LEGAL CLERK, for The Times, and that the attached advertisement published entitled:

PUBLIC NOTICE THE UNITED STATES ARMY INVITES PUBLIC COMMENT ON THE PROPOSED PLAN FOR THE FINAL REMEDY FOR ENVIRONMENTAL SITE LHAAP-18/24, BURNING GROUND NO. 3

Notice published in the Times on 04/05/19

(Signed)______________

______________ 9/5/2019

Notary Public. State of Wisconsin. County of Brown

8-25-23

My commission expires

SHELLY HORA
Notary Public
State of Wisconsin

PUBLIC NOTICE THE UNITED STATES ARMY INVITES PUBLIC COMMENT ON THE PROPOSED PLAN FOR THE FINAL REMEDY FOR ENVIRONMENTAL SITE LHAAP-18/24, BURNING GROUND NO. 3 AND UNLINED EVAPORATION POND, LONGHORN ARMY AMMUNITION PLANT, TEXAS PUBLIC MEETING ON APRIL 25, 2019 AT THE KARNACK COMMUNITY CENTER, KARNACK, TX

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The Times
April 5, 2019

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