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

April 3, 2019

DAIM-ODB-LO

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

Re: Draft Final Remedial Design and Remedial Action Work Plan, LHAAP-04 Former Pilot Wastewater Treatment Plant, Longhorn Army Ammunition Plant, Karnack, Texas, April 2019

Dear Mr. Mayer,

One hard copy and one compact disc (CD) of the above-referenced document are being transmitted to you for your records. The document includes revisions based upon the Environmental Protection Agency's (EPA) comments on the Draft version received on March 5, 2019, and Texas Commission on Environmental Quality's (TCEQ) comments received on March 12, 2019. In accordance with Federal Facility Agreement, this Draft Final will be considered Final after 30 days without further comment. Response to comments on the Draft version of the document are included with this Draft Final.

The document was prepared by Bhate Environmental Associates, Inc., (Bhate) team, on behalf of the Army as part of Bhate's Performance Based Remediation contract for the facility. I ask that Kim Nemmers, Bhate's Project Manager, be copied on any communications related to the project.

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

Copies furnished:
A. Palmie, TCEQ, Austin, TX (letter)
P. Bruckwicki, Caddo Lake NWR, TX (1 hard copy and 1 CD)
A. Williams, USACE, Tulsa District, OK (1 CD)
R. Smith, USACE, Tulsa District, OK (electronic only)
A. Maly, USAEC, San Antonio, TX (1 CD)
K. Nemmers, Bhate, Lakewood, CO (1 CD)
P. Srivastav, APTIM, Houston, TX (letter)

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

April 3, 2019

DAIM-ODB-LO

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

Re: Draft Final Remedial Design and Remedial Action Work Plan, LHAAP-04 Former Pilot Wastewater Treatment Plant, Longhorn Army Ammunition Plant, Karnack, Texas, April 2019

Dear Ms. Palmie,

One hard copy and one compact disc (CD) of the above-referenced document are being transmitted to you for your records. The document includes revisions based upon the Environmental Protection Agency's (EPA) comments on the Draft version received on March 5, 2019, and Texas Commission on Environmental Quality's (TCEQ) comments received on March 12, 2019. In accordance with Federal Facility Agreement, this Draft Final will be considered Final after 30 days without further comment. Response to comments on the Draft version of the document are included with this Draft Final.

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P. Srivastav, APTIM, Houston, TX (letter)

Response to Comments on
Draft Remedial Design / Remedial Action Work Plan
LHAAP-04 Former Pilot Wastewater Treatment Plant,
Longhorn Army Ammunition Plant, Karnack, Texas

Document Date: 20 February 2019
Comment Date: 5 March 2019

Reviewer: Mr. Richard Mayer, USEPA
Respondent: Dr. Rose Zeiler

1. Respondent Concurs (C), Does Not Concur (D), Takes Exception (E), or Delete (X)
2. Commenter Agrees (A) with response, or Does Not Agree (D) with response

Comment No.	Section, Page ref.	USEPA Comment	C, D, E, or X[1]	Response	A or D[2]
1.	Section 2.5, Page 2-5, Last Paragraph	While the Fire Station was not used as a public supply well, EPA believes that the well was originally used for drinking water (for fire station employees) for a short period but was discontinued due to bad taste. The well continued to be used for showering and washing, etc. The water from the well was also chlorinated for some time, as chlorine cylinders were eventually removed from the well house.	C	The first two sentences of the last paragraph of Section 2.5 will be revised as follows: While the Fire Station well was installed to supply industrial process water for the groundwater treatment system, it may have been used briefly for drinking water and non-potable contact use by fire station employees. The well is not currently used or planned to be used as a public supply well or drinking water source.	
2.	Figure 2-2	The potable wells labelling on this figure should be changed to non-potable to be consistent with the narrative discussion.	C	Figure 2-2 has been revised to label the three water supply wells on LHAAP as "Non-Potable Water Supply Wells"	
3.	Figure 4-1	The LUC boundary should be larger than indicated on the figure if you consider the perchlorate contamination found in 04WW05 and 04HP012.	C	The Army and USFWS will coordinate revision of the LUC boundary to reflect the plume expansion beyond the Army property line onto the refuge. The revised LUC boundary will be published in the Response Action Completion Report. The process described in Section 4.1 will be followed to implement and record the revised LUC boundary.	

Comment No.	Section, Page ref.	USEPA Comment	C, D, E, or X[1]	Response	A or D[2]
4.	Appendix A, Sample Collection Logs	Monitoring wells 04WW07 and LHSMW01 have a 0 reading [for turbidity] from the beginning to the end of the purge. Are those readings correct?	C	The turbidity readings shown on the form match the values recorded in the field. The logs for 04WW01 and 04WW10, collected on the same day immediately before and immediately after the two wells in question, both show measurable turbidity values, indicating that the meter was functioning properly.	
5.	Table 7-1	The schedule indicates that it will take one day to conduct the baseline sampling and gauging of the wells. There are 14 wells in the baseline sampling according to table 6-1. One day for sampling and gauging the wells seem rather optimistic.	C	Table 7-1 has been revised to show a 3-day duration for the baseline sampling.	

Response to Comments on
Draft Remedial Design / Remedial Action Work Plan
LHAAP-04 Former Pilot Wastewater Treatment Plant,
Longhorn Army Ammunition Plant, Karnack, Texas

Document Date: 20 February 2019
Comment Date: 12 March 2019

Reviewer: Ms. April Palmie, TCEQ
Respondent: Dr. Rose Zeiler

1. Respondent Concurs (C), Does Not Concur (D), Takes Exception (E), or Delete (X)
2. Commenter Agrees (A) with response, or Does Not Agree (D) with response

Comment No.	Section, Page ref.	TCEQ Comment	C, D, E, or X[1]	Response	A or D[2]
1.	Section 5.2.1	Suggest revisions to match LHAAP-16 RAWP page 4-1 where Permitting and Notification are separate sections. Also, TCEQ needs 30-days for UIC coordination (as indicated in the schedule).	C	The text in section 5.2 has been revised to split Permitting and Notification as requested. The 30-day UIC coordination with TCEQ is noted.	
2.	Table 2-1	Completion dates for the most recent wells are incorrect.	C	The dates for the wells have been revised on the table and on the boring logs to reflect the actual completion date for each well.	
3.	Figure 4-1	LUC boundary doesn't include the entire plume.	C	The Army and USFWS will coordinate revision of the LUC boundary to reflect the plume expansion beyond the Army property line onto the refuge. The revised LUC boundary will be published in the Response Action Completion Report. The process described in	

Comment No.	Section, Page ref.	TCEQ Comment	C, D, E, or X[1]	Response	A or D[2]
				Section 4.1 will be followed to implement and record the revised LUC boundary.	

Draft Final
Remedial Design and Remedial Action Work Plan, LHAAP-04 Former Pilot Wastewater Treatment Plant

Longhorn Army Ammunition Plant
Karnack, Texas

Prepared for U.S. Army Corps of Engineers, Tulsa District
Contracting Division
2488 East 81st Street
Tulsa, Oklahoma 74137-4290

Prepared by

bhate ENVIRONMENT & INFRASTRUCTURE

1608 13th Avenue south, Suite 300
Birmingham, Alabama 35205
1-800-806-4001 • www.bhate.com

Prepared by

APTIM

Aptim Federal Services, LLC
2500 CityWest, Suite 1700
Houston, Texas 77042

Contract No. W9128F-13-D-0012
Task Order No. W9128BV17F0150
Project No. 501032
Rev 0
April 2019

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Acronyms and Abbreviations

µg/L	micrograms per liter
APTIM	Aptim Federal Services, LLC
Bhate	Bhate Environmental Associates, Inc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
COC	constituent of concern
DAP	diammonium phosphate
DNAPL	dense non-aqueous phase liquid
DO	dissolved oxygen
DPT	direct-push technology
ECP	Environmental Condition of Property
EDS-ER™	Electron Donor Solution – Extended Release
EPA	see USEPA
EVO	emulsified vegetable oil
ft bgs	feet below ground surface
GPS	global positioning system
GWTP	groundwater treatment plant
ISB	in situ bioremediation
IWWP	Installation-Wide Work Plan
Jacobs	Jacobs Engineering Group, Inc.
LHAAP	Longhorn Army Ammunition Plant
LOE	lines of evidence
LTM	long-term monitoring
LUC	land use controls
MATOC	Multiple Award Task Order Contract
MCL	maximum contaminant level
MEGA	Multiple Environmental Government Acquisition
MMRP	Military Munitions Response Program
MOA	Memorandum of Agreement
mV	millivolts
NCP	National Contingency Plan
O&M	operation and maintenance
O_2	oxygen
ORP	oxidation-reduction potential

Acronyms and Abbreviations (continued)

PCL	Protective Concentration Level
psi	pounds per square inch
RA	remedial action
RACR	Response Action Completion Report
RA-O	Remedial Action-Operation
RAOs	remedial action objectives
RAWP	Remedial Action Work Plan
RCRA	Resource Conservation and Recovery Act
RD	remedial design
ROD	Record of Decision
ROI	radius of influence
Shaw	Shaw Environmental, Inc.
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TOC	total organic carbon
TRRP	Texas Risk Reduction Program
U.S. Army	U.S. Department of the Army
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service

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1.0 INTRODUCTION

The U.S. Army Corps of Engineers (USACE), Tulsa District, contracted Bhate Environmental, Inc. (Bhate), under the Omaha Multiple Environmental Government Acquisition (MEGA) National Small Business Multiple Award Task Order Contract (MATOC) Environmental Remediation Services with Military Munitions Response Program (MMRP), Task Order No. W9128BV17F0150 to conduct environmental restoration of LHAAP-04 at Longhorn Army Ammunition Plant (LHAAP). The Bhate Team is comprised of Bhate and Aptim Federal Services, LLC (APTIM). LHAAP is an inactive, government owned formerly contractor operated and maintained Department of Defense facility located central east Texas (Figure 1-1). This Remedial Design (RD) and Remedial Action Work Plan (RAWP) describes the basis for the design of the planned remedial action (RA) and the activities and methods planned to implement the RA to address risks associated with contaminated groundwater at LHAAP-04. This RD/RAWP has been developed to implement the selected remedy for LHAAP-04 described in the *Final Record of Decision* (ROD) for LHAAP-04 (AECOM 2016).

1.1 Organization of Work Plan

This document is composed of the following sections:

- **Section 1.0:** "Introduction" summarizes the site background, proposed remedy, and remedial action objectives (RAOs).
- **Section 2.0:** "Site Characteristics" summarizes the geology and hydrogeology of the site, as well as the nature and extent of contamination.
- **Section 3.0:** "In-Situ Bioremediation Remedial Design" describes the basis for design of the in-situ bioremediation (ISB) injections, the calculations used to determine bioremediation and bioaugmentation amendments to be used, and the proposed injection volumes. The section also described monitoring and the lines of evidence (LOE) used to evaluate the performance of the remedy.
- **Section 4.0:** "Land Use Control Remedial Design/Plan" describes the land use controls (LUCs) to be implemented to achieve the remedial objectives.
- **Section 5.0:** "In Situ Bioremediation Work Plan" describes the injection activities and methodologies to be implemented for the in-situ bioremediation component of the remedy.
- **Section 6.0:** "Post-Remedial Monitoring and Reporting" describes the remedial performance monitoring and reporting that will be performed after ISB injections.

- **Section 7.0:** "Schedule" describes the proposed implementation schedule for the RA activities.
- **Section 8.0:** "Operation and Maintenance Procedures" describe the operation and maintenance activities and other routine activities that form part of the final remedy.
- **Section 9.0:** "References" provides a list of references cited in the document.

This work plan also includes the following appendices supporting the main text.

- **Appendix A** includes the boring logs for the newly installed shallow and intermediate zone monitoring wells.
- **Appendix B** includes the calculation sheets and proposed injection volume worksheets for the ISB component of the remedy.
- **Appendix C** includes the Product Specification and Safety Data Sheets for the emulsified vegetable oil (EVO) product used in the RD calculations.
- **Appendix D** includes a blank injection log that will be used in the field to track injection volumes, flow rates and pressures.
- **Appendix E** includes the sample Annual LUC Compliance Checklist and Compliance Certification.

1.2 Site Description

LHAAP is approximately 14 miles northeast of Marshall, Texas, and approximately 40 miles west of Shreveport, Louisiana. The installation occupies approximately 1,400 of its former 8,416 acres between State Highway 43 at Karnack, Texas, and the western shore of Caddo Lake. The facility can be accessed via State Highways 43 and 134.

LHAAP-04, known as Site 04 or the former pilot wastewater treatment plant, is approximately 0.5 acres and is located in the central portion of LHAAP at the northwest corner of 6th and 60th Streets near the former fire station (**Figure 1-2**). LHAAP-04 is surrounded by light duty roads. Wastewater treatment operations began at LHAAP-04 in 1984. The demolition of the former pilot wastewater treatment facility structures, tanks, and piping, and the disposal of the associated wastes were completed in the summer of 1997 as part of the Resource Conservation and Recovery Act (RCRA) closure of the plant. Under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) program, excavation of soil impacted with mercury and perchlorate at the LHAAP-04 site was completed in 2009 along the southern edge of the slab, which formerly housed storage tanks for the former pilot wastewater treatment facility.

The U.S. Department of the Army (U.S. Army) issued the Final ROD for LHAAP-04 (AECOM 2016) in October 2016, and was signed by the Army on December 15, 2016, and the U.S. Environmental Protection Agency (USEPA) on March 30, 2017. The Texas Commission on Environmental Quality (TCEQ) issued a letter concurring with the ROD on February 7, 2017. The ROD identified perchlorate as the only constituent of concern (COC) in groundwater for LHAAP-04. The remedy selected in the ROD included in-situ bioremediation (ISB) for perchlorate concentrations in groundwater, long-term monitoring (LTM) of groundwater, and LUCs to maintain the remedy and prohibit groundwater use until COC concentrations are reduced to levels supportive of unlimited use and unrestricted exposure. The selected remedy is summarized further in **Section 1.3**.

1.3 Selected Remedy

The selected remedy was summarized in Section 1.4 of the Final ROD (AECOM 2016) as follows:

- ISB of perchlorate contaminated groundwater in an area in the vicinity of monitoring well 04WW04. Multiple injections of substrate may be needed based on effectiveness of the ISB. Bioaugmentation using appropriate microbial culture to facilitate ISB may be performed, if necessary. Prior to ISB, two shallow zone and one intermediate zone monitoring wells are planned to refine the perchlorate plume configuration.
- LTM to confirm the protection of human health and the environment by documenting the return of groundwater to the cleanup level (maximum contaminant level [MCL] or Texas Risk Reduction Program [TRRP] Tier 1 Residential Groundwater Protective Concentration Level [PCL]) through reduction of the contaminant mass, and by preventing the perchlorate-contaminated groundwater plume from migrating into surface water.
- The LUC objectives include maintaining the integrity of any current or future remedial or monitoring systems and preventing the use of groundwater contaminated above cleanup levels as a potable water source. The groundwater treatment and LTM remedial components include a groundwater monitoring system that will be used to characterize the condition of the groundwater during the period the groundwater remedy is in place until the groundwater remediation goals are achieved, and to demonstrate achievement of the groundwater remediation goals when the groundwater remedy is complete. As a part of this groundwater remedy, the Army will maintain the remedial and monitoring systems associated with the groundwater remedies until these components of the remedy are no longer needed to achieve cleanup levels, and cleanup levels have been achieved. During the period of operation of the groundwater remedy, if any of the elements of the remedial and groundwater

monitoring systems are damaged, destroyed, or become ineffective, they will be repaired or replaced with suitable components to assure that the remedial and groundwater monitoring systems are able to provide data of the quality necessary to determine the progress of and eventual completion of this component of the remedy. The actions to be taken to implement these LUC objectives and requirements will be provided through modifying the "Comprehensive Land Use Control 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 levels of COCs in surface and subsurface soil and groundwater are reduced below levels that would support unlimited use and unrestricted exposure. A LUC RD will be finalized as the land use component of the RD. Within 21 days of the issuance of the ROD, the Army will propose deadlines for completion of the RD Work Plan, RD, and RAWP. The documents will be prepared and submitted to the EPA and the TCEQ pursuant to the Federal Facility Agreement. The LUC RD will contain implementation and maintenance actions, including periodic inspections. The LTM groundwater 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.
- CERCLA five-year reviews until the levels of COCs in groundwater allow for unlimited use and unrestricted exposure.

1.4 Remedial Action Objectives

The RAOs developed for LHAAP-04 and outlined in the Final ROD (AECOM 2016) are:

- Protect human health by preventing ingestion of groundwater contaminated with perchlorate
- Return groundwater to its potential beneficial use, wherever practicable, within a reasonable time period given the particular site circumstances
- Prevent groundwater contaminated with perchlorate from migrating into nearby surface water

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

Per the ROD's RAOs, and consistent with the NCP, groundwater will be returned to its beneficial uses as drinking water. The groundwater cleanup level for perchlorate at the Site is the TRRP Tier 1 PCL for residential groundwater, 17 micrograms per liter (µg/L), and is protective of human health and the environment.

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2.0 SITE CHARACTERISTICS

2.1 Geology and Hydrogeology

LHAAP-04 is situated on the outcrop of the Wilcox Group which generally consists of a few feet of residually derived soils overlying interbedded silts and clays. Based on the site lithology, the shallow zone water bearing sand at monitoring well 04WW04 appears to be only one- to two-feet-thick, and surrounding monitoring wells mostly show clay or silt layers at the same depth.

The depth to groundwater across LHAAP varies with typical depths being 8 to 20 feet below ground surface (ft bgs) in the shallow zone. The regional groundwater flow direction beneath the facility is generally east- northeast towards Caddo Lake but varies by site location (Jacobs 2002).

As required by the Final ROD (AECOM 2016), two additional shallow groundwater monitoring wells (04WW06 and 04WW07) and one intermediate zone monitoring well (04WW08) were installed to refine the perchlorate plume configuration. The boring logs for these wells are included as **Appendix A**.

Shallow groundwater at LHAAP-04 has been assessed via twelve monitoring wells installed near LHAAP-04 to depths of approximately 20 to 25 ft bgs. An intermediate zone well (04WW08) was installed with a screened interval from 31 to 41 ft bgs and confirmed that the intermediate zone was present. Well construction information is shown on **Table 2-1**. Based on the 2018 and 2019 potentiometric surface maps (**Figure 2-1a** and **Figure 2-1b**), the groundwater flow direction in the shallow saturated zone below LHAAP-04 is to the southwest across the area of the site where perchlorate concentrations exceed the PCL. The groundwater elevations measured in January 2019 were 1 to 3 feet higher than those measured in January 2018, which is reflective of the increased recharge to the shallow aquifer from the unusually high rainfall received during 2018.

Rising head slug tests were performed on one well near LHAAP-04 to calculate hydraulic conductivity values using the Bouwer-Rice method. The hydraulic conductivity value for the shallow saturated zone was 3.5×10^{-5} centimeters per second at well LHSMW01 (Shaw 2012).

Goose Prairie Creek runs approximately 700 feet to the south of LHAAP-04 site as shown on **Figure 2-2**. Based on the network of monitoring wells located at the site, perchlorate-impacted groundwater in the shallow zone does not appear to have migrated more than 100 feet from the source area, indicating no threat to Goose Prairie Creek. Groundwater modeling also concluded there should be no impact to surface water from shallow zone groundwater

(Shaw 2007). The modeling was conservative, utilizing the highest previously detected perchlorate concentration in groundwater at the source (78,200 µg/L) that was approximately 1000 times the highest groundwater concentration measured at LHAAP-04 in 2018 (78 µg/L). Finally, perchlorate concentrations in surface water samples collected in 2010 and 2011 were less than the TRRP Tier 1 Groundwater Residential PCL (AECOM 2016).

2.2 Nature and Extent of Contamination

The former pilot wastewater treatment plant was the most likely source of contaminants being released into the environment. Since the plant has been removed and the mercury and perchlorate contaminated soil associated with leaks and/or spills from the plant was excavated in a non-time critical removal action in 2009 (Shaw 2011), there is no longer a potential soil source for releases to groundwater. The groundwater to surface water migration pathway is not complete under current conditions. Protection of surface water will be confirmed with groundwater monitoring and evaluation of plume behavior with implementation of the groundwater remedy (AECOM 2016). The only groundwater COC for LHAAP-04 identified in the Final ROD (AECOM 2016) is perchlorate.

2.2.1 2017 Monitoring Well Installation and Sampling

As required in the ROD, two additional shallow groundwater monitoring wells (04WW06 and 04WW07) and one intermediate zone monitoring well (04WW08) were installed in December 2017 (**Figure 2-3**). Ten monitoring wells at LHAAP-04 were sampled in January 2018 to determine the current plume conditions from which to plan the RD. The concentration at 04WW04 was significantly lower than the previous concentrations detected in 2011, upon which the ROD was based. The perchlorate concentration at 04WW05 also increased to above the PCL, indicating that the plume may have shifted slightly to the south and west, but the lack of monitoring locations west of 04WW05 meant the plume was not fully delineated. The January 2018 concentrations observed in the remaining wells were less than the PCL. The intermediate zone well (04WW08) contained a perchlorate concentration of 1.5 µg/L, well below the PCL and not indicative of significant vertical plume migration.

2.2.2 Supplemental Groundwater Investigation

Due to the undelineated western edge of the shallow perchlorate plume, a supplemental groundwater sampling investigation was performed in accordance with a Technical Memorandum (Bhate 2018a) that was revised and approved by EPA and TCEQ. The purpose of the investigation was to collect groundwater samples to delineate the western and southern plume boundaries. The work proposed in the Technical Memorandum included groundwater sampling at 12 direct-push technology (DPT) points in a phased manner, installation of three monitoring wells, and a round of groundwater sampling from the existing shallow wells and the three new wells. Eight initial DPT borings (04HP01 through 04HP08) were drilled in

November 2018 using a tractor mounted direct-push sampling rig. Groundwater samples were collected in accordance with the procedures outlined in the Technical Memorandum (Bhate 2018a).

The analytical results from the first eight DPT sample locations were used to select the four additional locations to be sampled. The four additional DPT borings were drilled and groundwater sampled in December 2018. One of the borings was inadvertently drilled at the wrong location, so a fifth location was drilled in the proper location. The analytical results from all 13 locations are shown on **Figure 2-3** and were used to select the locations for three new monitoring wells to be installed. The coordinates for the DPT locations shown on **Figure 2-3** were measured in the field using a Trimble handheld GPS unit and are accurate to within approximately two feet. The perchlorate concentrations detected at 04HP01 and 04HP05 confirmed that high levels of perchlorate were still present in the vicinity of the soil excavation area but had shifted slightly west from 04WW04. Non-detect results at 04HP02, 04HP03, 04HP09, 04HP10, 04HP11, and 04HP13 successfully delineated the western and southern extent of the plume.

Three 4-inch-diameter wells were installed in January 2019. One shallow monitoring well (04WW11) was installed to the west of 04HP05 to provide a downgradient clean well to bound the plume for future monitoring, while two monitoring wells (04WW09 and 04WW10) were placed adjacent to the DPT locations with the highest perchlorate concentrations detected. The well locations are shown on **Figure 2-3**.

Upon completion of the monitoring well installations, they were developed and sampled along with the nine existing shallow monitoring wells in January 2019. **Figure 2-3** shows the 2010, 2011, 2018, and 2019 perchlorate concentrations detected and shows a plume boundary based on the January 2019 analytical results. Based on the 2019 results, there is a hot spot centered along the western boundary of the soil excavation area. The concentrations are similar in magnitude to those previously detected at 04WW04 and indicate that the plume has moved slightly west from 04WW04 between 2010-2011 and 2019.

2.3 Current and Future Land Use

LHAAP is located near the unincorporated community of Karnack, Texas. Karnack is a rural community with a population of approximately 775 people. The incorporated community of Uncertain, Texas, approximate 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) with an access gate that is locked after daylight hours, which restricts public access. The fence now represents the National Wildlife Refuge boundary. The public can access most of the facility during the day with additional fencing and signage restricting access from environmental sites.

The reasonably anticipated future use of LHAAP-04 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 U.S. Fish and Wildlife Service (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-04. Presently the Caddo Lake National Wildlife Refuge occupies approximately 7,000 acres of the 8,416-acre former installation. In accordance with the National Wildlife Refuge System Administration Act of 1966 and its amendments (16 USC 668dd), the land will remain as a national wildlife refuge unless there is a change brought about by an act of Congress, or the land is part of an exchange authorized by the Secretary of the Interior. (AECOM 2016).

2.4 Current and Future Surface Water Use

There are no surface water bodies present within LHAAP-04. Surface water runoff from LHAAP-04 drains toward the southern branch of Goose Prairie Creek, located approximately 700 feet south of LHAAP-04, and which flows into Caddo Lake, a large recreational lake covering 51 square miles with a mean depth of 6 feet. The watershed of the lake encompasses approximately 2,700 square miles. Caddo Lake is used extensively for fishing and boating and provides drinking water supply to multiple cities/towns. The anticipated future uses of surface water are the same as the current uses.

2.5 Current and Future Groundwater Use

Groundwater in the drinking water aquifer (250 to 430 ft bgs) under and near LHAAP is currently used as a drinking water source. The drinking water aquifer should not be confused with LHAAP "deep zone" groundwater, which extends only to a depth of approximately 151 ft bgs. The aquifer containing contaminated groundwater and the aquifer utilized for drinking water are distinct from each other with no connectivity. TCEQ identifies six active public water supply wells completed in the drinking water aquifer near LHAAP (see **Figure 2-2**). Karnack Water Supply Corporation operates two source wells servicing the town of Karnack. These wells were completed in 1905 to depths of 287 and 285 ft bgs and are located hydraulically upgradient approximately one-quarter mile northwest and one-half mile southwest of the town center, respectively. Caddo Lake Water Supply Corporation operates

three source wells located north and northwest of LHAAP that have been in use since 1905. These wells are hydraulically upgradient of LHAAP (Jacobs 2002) with completion depths of 244, 185, and 310 ft bgs. Caddo Lake State Park operates one source well located approximately 1.6 miles northwest upgradient of LHAAP. This well was installed in 1905 with a total depth of 292 feet. Due to 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. Because the extent of perchlorate contaminated groundwater is limited, it is not relevant to any of the drinking water wells.

Three water supply wells are located within the boundary of LHAAP itself (**Figure 2-2**). One well is located at the Fire Station with a total depth of 128 feet and a screened interval from 58 to 128 ft bgs; the second well is located upgradient of LHAAP-04 approximately 0.35 miles southwest of the Fire Station. The third well is located north of the USFWS administration building for Caddo Lake National Wildlife Refuge, near the main entrance to LHAAP. Two additional wells previously supplied water to the installation, but these have been plugged and abandoned. None of these three wells are currently used for drinking water at LHAAP, although they may supply water for non-potable uses.

While the Fire Station well was installed to supply industrial process water for the groundwater treatment system, it may have been used briefly for drinking water and non-potable contact use by fire station employees. The well is not currently used or planned to be used as a public supply well or drinking water source. The taps in or around the firehouse are not used for drinking water and are marked non-potable. Although the anticipated future use of the facility as a national wildlife refuge does not include the use of the groundwater at LHAAP-04 as a drinking water source, the State of Texas designates all groundwater as potential drinking water, unless otherwise classified, and consistent with 30 Texas Administrative Code (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.

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3.0 IN-SITU BIOREMEDIATION REMEDIAL DESIGN

In general, implementation of ISB will include injection of an electron donor/substrate in the subsurface. The indigenous microorganisms will grow and multiply using injected substrate as a carbon and energy source, thereby degrading perchlorate. The schematic showing the degradation pathway for perchlorate is provided below.

Perchlorate Degradation Pathway

$$\underset{\text{Perchlorate}}{ClO_4^-} \longrightarrow \underset{\text{Chlorate}}{ClO_3^-} \longrightarrow \underset{\text{Chlorite}}{ClO_2^-} \longrightarrow \underset{\text{Chloride + Oxygen}}{Cl^- + O_2}$$

ISB will be implemented at LHAAP-04 to remediate groundwater impacted with perchlorate. The ISB remedy rationale described in Section 2.12.1 of the Final ROD (AECOM 2016) was to treat the hot spot of perchlorate in the vicinity of 04WW04. The 2019 data discussed in **Section 2.2.2** indicates that the hot spot has moved slightly west from 04WW04 to the vicinity of 04WW09 and 04WW10. Accordingly, the remedy described in this section is designed to treat the hot spot with concentrations exceeding five times the 17 µg/L cleanup level (85 µg/L). The ISB system has been designed and implemented to remediate perchlorate in the groundwater down to the PCL using EVO and nutrients as the injected amendments. The EVO and nutrients will be mixed with water and injected using temporary DPT injection points within the plume area currently exceeding the PCL. The specific basis for the various design parameters selected is described in the following sections. Field implementation procedures for the ISB remedy are described in **Section 5.0**. ISB calculation sheets used to develop the RD parameters described below are provided in **Appendix B**.

3.1 Substrate Injection Strategies

The ISB substrate will be injected at approximately 25 temporary DPT locations spaced approximately 20 to 25 feet apart as shown on **Figure 3-1**. A DPT injection system will be used to inject substrate over an eight-foot treatment interval coinciding with the saturated water bearing interval at each proposed injection point. The treatment interval depth will vary depending on the lithologic information from the wells and borings nearest to each injection location. The injection interval will target the saturated sandy and silty zones above the dark gray hard clay typically encountered at approximately 18 to 22 ft bgs. The injection locations within the excavation footprint may be performed slightly deeper to minimize the potential for surfacing of injection fluids through the backfilled area.

Several direct push injection points may be manifolded for simultaneous injection to maximize delivery efficiency. The substrate will be injected at relatively low pressures (generally less than 40 pounds per square inch [psi]) to avoid development of preferential flow pathways

within the formation and/or surfacing of injection fluids. The injection pressure at each injection location will be dictated by the formation back pressure on the pumping system but will be controlled by use of pressure relief valves.

3.2 Radius of Influence and Injection Point Spacing

The low hydraulic conductivity and generally silty character of the shallow groundwater zone suggest that the radius of influence (ROI) for each DPT injection location will be low. Based on our experience at other locations on LHAAP and knowledge of the hydrogeologic conditions described in **Section 2.1**, the ROI used to calculate the number of points needed was 10 feet, and the DPT injection point spacing will be 20 to 25 feet.

3.3 Substrate Selection

EVO was selected as the substrate for ISB because of the relative ease of injection and the long lifespan of the substrate. It has previously been estimated that reducing concentrations to below the PCL using ISB at LHAAP-04 would require approximately six years (AECOM 2016). However, given the reduction in maximum concentrations at LHAAP-04 since those estimates were made, it is likely that the site will be fully remediated within the 3 to 5-year lifespan of the initial injections, and subsequent reinjections are likely to be unnecessary. The specific formulation of EVO used to develop the injection volumes for this project is Electron Donor Solution – Extended Release (EDS-ER™) available from Tersus Environmental (**Appendix C**). EDS-ER™ is a water-mixable oil formulated with 100% EVO content (no water in the emulsion). EDS-ER™ is a food-grade carbon and is made from renewable crop-based oils. The use of EDS-ER™ or equivalent is expected to be cost-effective since it would eliminate the need for continuous or more frequent injection of substrate into the subsurface.

EDS-ER™ is provided by the vendor as water-mixable oil that contains no water as shipped; therefore, it will be mixed with water in the field. Use of EDS-ER™ or an equivalent volume of a similar product will reduce the cost and environmental footprint associated with transportation of higher volumes of more dilute substrate to the site. The product mixes easily with water and does not require high energy mixers. It formulates a completely miscible product when mixed with water (it does not create emulsions or particles in water), thus preventing clogging effects when injected in groundwater. A mixing tank located adjacent to the location of the planned injection area will be used to mix the product with water. The product will be added to the tank in the volume desired, followed by pumping clean potable water into the tank to produce the mixture with the design concentration for injection. No mixers will be required due to the nature of the EDS-ER™ oil. The manufacturer's product information sheet is provided in **Appendix C**.

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The indigenous microbial types needed to degrade perchlorate are likely to be present in the existing groundwater; therefore, no bioaugmentation is anticipated to be necessary. However, nutrients in the form of diammonium phosphate (DAP) will provide essential levels of nitrogen and phosphate required for microbial activity. The nutrients will be added to each mixed batch following addition of the mix water, prior to injection.

3.4 Substrate Loading and Injection

The mass of EVO required for the shallow treatment zone shown on **Figure 3-1** was estimated based on comparison of 1) the stoichiometric demand exerted by the native (e.g., dissolved oxygen [DO], nitrate, and sulfate) and anthropogenic electron acceptors, and 2) the quantity of EVO necessary to treat the entire treatment zone when accounting for adsorption to the aquifer material. These calculations were performed using the EOS® Remediation Source Area and dense non-aqueous phase liquid (DNAPL) Design Worksheet version 2.1f dated June 18, 2008. **Appendix B** provides the input and output calculations spreadsheets. The higher of the two values is used for the planned injection quantities.

The aquifer treatment demand based on EOS's 60% carbon product is 5,107 pounds (**Appendix B**). That is equivalent to 3,064 pounds of 100% carbon EDS-ER™. The concentrated solution of EDS-ER will be diluted by mixing 15 gallons of EDS-ER™ and 6 gallons or nutrients with approximately 1,463 gallons of water to achieve the desired treatment volume for each injection point as shown on the treatment area calculation sheet in **Appendix B**. Approximately 36,945 gallons of dilute EDS-ER™ mixture will be injected into 25 injection points shown on **Figure 3-1**.

3.5 Performance Monitoring

Per the Final ROD (AECOM 2016), performance monitoring will be performed on a quarterly basis for a period of two years and will include analysis of perchlorate and geochemical parameters (sulfate, nitrate, nitrites, alkalinity). Field parameters will include DO, redox potential and ferrous ion. Performance monitoring activities are discussed in greater detail in **Section 7.2.3**. Annual reports will be prepared to document the effectiveness of the treatment. The first year annual report will include a review of the four quarters of data and provide an evaluation of the effectiveness of the selected remedy.

3.6 Long-Term Monitoring

Per the Final ROD (AECOM 2016), LTM will begin in Year 3 after treatment and will be conducted semiannually for 3 years (through Year 5), and annually thereafter. Additional details regarding LTM are provided in **Section 7.2.4**.

3.7 Remedy Evaluation and Follow-up Injections

Remedial performance will be evaluated using two primary LOEs to determine if the remedy is operating properly:

- Plume stability (i.e., plume concentrations are declining in the performance wells, and the plume is not expanding in area as demonstrated by downgradient monitoring wells)
- Reducing conditions conducive for the degradation of perchlorate are present within the treatment area

Follow-up injections may be needed if the remedy is determined to not be performing, although reinjections are not expected to be needed within the 3 to 5-year lifespan of the EVO mixture selected. Nonetheless, the decision for reapplication of organic carbon will be made based on groundwater monitoring results. Three criteria for determining the potential need to reinject are:

- Contaminant concentrations in groundwater are not trending downward at a rate indicative of achieving the cleanup level in approximately six years
- Depletion of the organic carbon to below 20 mg/L
- Oxidation-reduction potential (ORP) increases above -50 millivolts (mV)

If one or more of the criteria described above are met for two consecutive sampling events in the same sampling location, the need for additional injections in that area will be evaluated.

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4.0 LAND USE CONTROLS REMEDIAL DESIGN/PLAN

This section describes the LUC RD for LHAAP-04. In accordance with the Final ROD (AECOM 2016), the LUC RD will be finalized as the land use component of the RD.

Per the Final ROD (AECOM 2016), LUCs' performance objectives are to:

- Prohibit the use of groundwater (except for environmental testing and monitoring) as a potable water source
- Restrict land use to nonresidential
- Maintain the integrity of any current or future remedial or monitoring systems

The implementation, maintenance, and inspection requirements associated with each of the performance objectives that comprise this LUC RD are described below. The proposed actions to be taken to implement the LUC objectives during the RA phase are described in **Section 6.0**. The implementation activities, as well as ongoing maintenance, monitoring and reporting requirements will be presented in the Remedial Action Completion Report (RACR), as the final LUC RD. Upon regulatory review and concurrence with the final LUC RD, it will be included as part of the Comprehensive LUC Management Plan.

For portions of the Site subject to LUCs that are not owned by the Army, the 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 Army remains responsibility for ensuring that the remedy remains protective of human health and the environment.

4.1 LUC Implementation

The actions required to implement the LUCs for LHAAP-04 are described below. The first of these, the initial notice of LUCs, was completed on June 26, 2017. The June 26, 2017, Notice letters that were sent to relevant government officials (U.S. Army 2017) included a preliminary LUC boundary shown on **Figure 4-1**. The following actions will be undertaken to implement the LUCs for LHAAP-04:

- Finalize the boundary for the LUCs as a part of the RA.
  - Revise the boundary, if necessary, based on perchlorate results from the baseline groundwater sampling. The final boundary of the groundwater LUCs (prevent the use of groundwater contaminated above cleanup levels as a potable water source and prohibit access to the contaminated groundwater except for environmental monitoring and testing only); the remedial or monitoring system

LUCs (maintain the integrity of any current or future remedial or monitoring systems); and, the nonresidential land use LUC (restrict land use to nonresidential) will be reviewed during RA activities after an evaluation of the baseline data has been completed and revised if necessary.

  - Survey the LUC Boundaries. The boundaries will be finalized after concurrence by USEPA and TCEQ, and the LUC boundaries will be surveyed by a State-licensed surveyor. A legal description of the surveyed areas will be appended to the survey plat.

- Record the LUCs in Harrison County. The LUC plat, legal description and LUC restriction language will be recorded in the Harrison County Courthouse in accordance with TAC Title 30, §335.566.
- Notify the Texas Department of Licensing and Regulation of the groundwater LUCs. The Texas Department of Licensing and Regulation will be notified of the groundwater restrictions, which include the prohibition of water well installation for any purpose other than environmental monitoring and testing without prior approval from the Army, the USEPA, and the TCEQ. The survey plat, legal boundary and description of the groundwater restriction LUCs, in conjunction with a locator map, will be provided in hard and electronic copy.
- Provide notice of the LUCs with the revised LUC boundary.
  - Prepare the notice of the groundwater and soil (surface and subsurface) contamination and any land use restrictions referenced in the ROD. The notice will consist of a brief description of the contaminants in groundwater and soil, a written description of the LUCs and a figure depicting the revised LUC boundary.
  - Transmit the notice to federal, state, and local governments involved at this site and the owners and occupants of the properties subject to those use restrictions and LUCs within 90 days of RACR acceptance by the regulators. The notices will be sent to federal, state and local officials including: both U.S. Senators, U.S. Congressman (Texas District 1), State Senator (District 1), State Representative (District 9), Harrison County Judge, Harrison County Commissioner Precinct 1, City of Uncertain Mayor, Leigh Water Supply Corporation Board Members, Caddo Lake Water Supply Corporation Board of Directors, and the Caddo Lake National Wildlife Refuge Manager.

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4.2 Maintenance and Monitoring Requirements

The LUCs will be maintained in place as follows:

- The LUCs restricting the use of groundwater to environmental monitoring and testing only and the LUC restricting land use to nonresidential will remain in place until the levels of COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in Table 2-3 of the ROD) in surface and subsurface soil and groundwater allow for unlimited use and unrestricted exposure.
- The LUC to maintain the integrity of any current or future remedial or monitoring systems will remain in place until groundwater cleanup levels of COCs (i.e., including all hazardous substances, pollutants and contaminants found at the Site at cleanup levels as listed in Table 2-3 of the ROD) are met.

Remedial or Monitoring System LUCs include physical components that require repair and maintenance. These are described in **Section 8.0**. The RAO and Extraction System Inspection and Maintenance Checklists is provided in **Appendix E**.

The administrative maintenance required to ensure the LUCs remain in place and effective until the cleanup levels of the COCs are at levels that allow unrestricted use and unlimited exposure are:

- Annual field inspections of the site to confirm that no violations of the LUCs have occurred. Documentation of the inspection will be included in the Inspection and Maintenance Checklist (see **Appendix E**).
- Annual certifications that no LUC-restricted activities have been authorized and that site conditions and use are consistent with the LUCs. The Certification Form is presented in **Appendix E**.
- Periodic transmittal of a LUC Notice to federal, state, and local authorities and to owners and occupants of LHAAP-04. The notice will include the groundwater and soil (surface and subsurface) contamination and any land use restrictions referenced in the ROD, a written description of the LUCs and a figure depicting the LUC boundaries. The transmittal will coincide with each Five-Year Review and will be documented in the report.
- The final LUC RD appendix of the RACR will be added to the Comprehensive LUC Management Plan and the plan will be provided to the owner or occupant of LHAAP-04.

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The U.S. Army will address LUC problems within its control that are likely to impact remedy integrity and shall address problems as soon as practicable.

4.3 LUC Inspection and Monitoring

Beginning with finalization of this RD/RAWP and approval of the Inspection form and the Annual Certification Form, the U.S. Army will undertake inspections and certify continued compliance with the LUC objectives. The U.S. Army, or the transferee after transfer, will retain the LUC Inspection and Certification documents in the project files for incorporation into the five-year review reports, and these documents will be made available to USEPA and TCEQ upon request. In addition, should any violations be found during the certification, the U.S. Army will provide to USEPA and TCEQ, along with the document, a separate written explanation indicating the specific violations found and what efforts or measures have or will be taken to correct those violations. The need to continue inspections and certifications will be revisited at five-year reviews.

4.3.1 Notice of Planned Property Conveyances

Upon transfer of Army-owned property, the Army will provide written notice to the transferee of the LHAAP-04 groundwater contamination and any land use restrictions. Within 15 days of transfer, the U.S. Army will provide written notice to USEPA and TCEQ of the division of implementation, maintenance, and enforcement responsibilities unless the information has already been provided in the LUC RD. The notice will describe the mechanism by which the LUC will continue to be implemented, maintained, inspected, reported, and enforced. Upon transfer, such responsibilities may shift to the transferee via appropriate provisions placed in the Environmental Condition of Property (ECP) or other environmental document for transfer. Although the U.S. Army may transfer responsibility for various implementation actions, the U.S. Army will also retain ultimate responsibility for the remedy integrity. This means that the U.S. Army is responsible for addressing substantive violations of the LUC performance objectives that would undermine the U.S. Army's CERCLA remedy. The U.S. Army also will be responsible for incorporating RD information and outlining the transferee's LUC obligations into property transfer documentation. 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.

4.3.2 Opportunity to Review Text of Intended Land Use Controls

The U.S. Army will provide a copy of the groundwater and land use restriction notification to TCEQ for review and approval prior to its recordation in Harrison County. USEPA will also receive a copy for review. The U.S. Army will produce an ECP or other environmental document for transfer of LHAAP-04, but before executing transfer, the U.S. Army will provide USEPA and TCEQ with a copy of the ECP or other environmental document for transfer so

that they may have reasonable opportunity, before transfer, to review all LUC-related provisions.

4.3.3 Notification Should Action(s) which Interfere with Land Use Control Effectiveness be Discovered Subsequent to Conveyance

Should the U.S. Army discover after conveyance of the site any activity on the property inconsistent with the LUC performance objectives, the U.S. Army shall notify USEPA and TCEQ within 72 hours of such discovery. Consistent with **Section 4.3.5** below, the U.S. Army will then work with USEPA, TCEQ and the transferee to correct the problem(s) discovered. This reporting requirement does not preclude the U.S. Army from taking immediate action pursuant to its CERCLA authorities to prevent any perceived risk(s) to human health or the environment.

4.3.4 Land Use Control Enforcement

Should the LUC remedy reflected in this RD fail, the U.S. Army will coordinate with USEPA and TCEQ to ensure that appropriate actions are taken to reestablish its protectiveness. These actions are taken to reestablish its protectiveness. These actions may range from informal resolutions with the USFWS or its lessee, to the institution of judicial action against non-federal third parties. Alternatively, should the circumstances warrant such, the U.S. Army could choose to exercise its response authorities under CERCLA. Should the U.S. Army become aware that any future owner or user of the property has violated any LUC requirement over which a local agency may have independent jurisdiction, the U.S. Army may notify those agencies of such violation(s) and work cooperatively with them to re-achieve owner/user compliance with the LUC.

4.3.5 Modification or Termination of Land Use Controls

The LUCs shall remain in effect until such time as the U.S. Army and USEPA agree that the concentrations of perchlorate in groundwater have met cleanup levels and allow unrestricted use. When this occurs, the LUC will be terminated as needed. The decision to terminate the LUC will be documented consistent with the NCP process for post-ROD changes, potentially including an Explanation of Significant Difference or a Remedial Action Completion Report. If the property has been transferred and a determination by the U.S. Army and USEPA has been made to terminate the LUC, the U.S. Army shall provide to the owner of the property an appropriate release for recordation pertaining to the site and will also timely advise other local stakeholders of the action.

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5.0 IN-SITU BIOREMEDIATION WORK PLAN

ISB will be conducted at LHAAP-04 to remediate groundwater impacted with perchlorate. The Proposed Injection Plan for LHAAP-04 is shown on **Figure 5-1**.

The plume geometry and proposed injections have been developed using the basis and details of the RD in **Section 3.0**. The specific formulation of EVO used to develop the RD is EDS-ER™. If EDS-ER™ is not available at the time the injections are ready to proceed, an equivalent EVO product will be used, and the volumes of EVO will be adjusted if the EVO content is less than the 100% in EDS-ER™. Details of the pre-mobilization, mobilization, injection, and demobilization field activities are provided in the following sections.

5.1 ISB Injection Plan

To treat the perchlorate impacted groundwater in the shallow groundwater aquifer, a biogrid will be installed by injecting EDS-ER™ or an equivalent EVO product and nutrients, into 25 DPT points as shown in **Figure 5-1**. **Table 5-1** specifies the volume of amendment mixture to be injected at each injection point.

In order to minimize the potential for dispersion of the perchlorate plume due to injections, the outermost ring of injection locations will be injected first, beginning at the downgradient edge (injection locations 4, 8, 14, 20-25, 19, and 13), and injections will proceed counter clockwise and inward, finishing in the center of the perchlorate plume.

5.2 Pre-Mobilization Activities

5.2.1 Permitting

No permitting is required prior to the commencement of field work.

5.2.2 Notification

TCEQ and USEPA will be notified two weeks in advance of commencement of fieldwork activities.

5.2.3 Utility Clearance

Utility location and clearance for intrusive activities will be conducted prior to drilling as follows:

The site health and safety officer will:

- Prepare a map indicating the area(s) where intrusive activity is planned to occur.
- Perform the necessary reviews.

- Contact the Texas Excavation Safety System, Inc. utility notification service by calling 811 or 800 892 0123 or using their online submittal system. This notification is to be made a minimum of three working days prior to the initiation of intrusive activity (excluding Saturdays, Sundays, and holidays), but not greater than 14 days.
- Verify that all underground installations have been located, physically marked, and then noted on the map. If needed, a third-party location service will be used.
- Mark all overhead utilities with kilovolts rating on the map. It is not anticipated that the existing overhead lines will impact the proposed injection location layout.
- Notify the appropriate agencies, contracting officer's representative, and property owners (when applicable).
- Confirm that utility clearance is complete and documented.

A safety meeting shall be held, and a job safety analysis shall be completed by all personnel who are involved in the intrusive activities prior to initiating work.

5.3 Site Activities

Once the premobilization activities are completed, the field crew, DPT crew, and injection equipment will mobilize to the site to perform the following activities.

5.3.1 Baseline Sampling

Baseline samples will be collected from all of the LHAAP-04 monitoring wells prior to the implementation of injections to characterize the perchlorate concentrations and geochemical conditions in the shallow zone. As discussed in the Final ROD (AECOM 2016) the fire station well will also be sampled during the baseline to determine if additional sampling of the well will be needed during the post-injection monitoring discussed in **Section 7.0**. The baseline sampling results will be compared to sample results collected post-ISB injections. The monitoring network is discussed in **Section 7.0** and will be finalized in the RACR after the baseline sampling has been completed.

5.3.2 Injection Activities

1. Mobilize materials, equipment, mixing tanks, and labor for injections
2. Set up traffic signage and controls as needed
3. Layout injection locations and clear DPT injection points (**Section 5.5.1.1**)
4. Core concrete/asphalt at injection points, if needed, and adjust any points if obstructions are found and push rods to the desired injection interval (**Section 5.4**)

5. Setup amendment, equipment, and materials onsite
6. Begin preparing amendment solution for injection a day before planned injections. Preparation of amendment solution will be a continual activity (**Section 5.5.1.2**)
7. Inject amendments following the sequencing described above using DPT (**Section 5.1** and **5.5.2**)
8. Record injection intervals and volumes during injections (**Appendix D**)
9. Once injection is complete at a DPT injection point, abandon point (**Section 5.4**)
10. Record DPT injection point locations with global positioning system (GPS)

5.3.3 Post Injection Activities

After injections, the site will be restored as needed and the injection personnel and equipment will be demobilized. Groundwater sampling and reporting will be conducted as described in **Section 7.0**.

5.4 DPT Drilling

Drilling will utilize DPT rigs for in situ injections through a probe with a 4-foot injection screen interval. The injections will be performed over an 8-foot injection interval using a top down approach, unless the lithology and field conditions cause persistent jamming or clogging of the injection tooling; in which case a bottom up approach will be used. The injection depth intervals will be adjusted to best treat the saturated zone identified in the nearest monitoring wells or soil boring where lithology was recorded (**Table 5-1**). A total of 25 points will be installed using a DPT rig in accordance with the procedures presented in the Installation-Wide Work Plan (IWWP) (Bhate 2018b). Each DPT point will be abandoned by filling with grout after injections are completed.

5.5 ISB Injection

Placement of DPT points is shown on **Figure 5-1**. **Table 5-1** provides the number of injection points, target depths, volumes of each amendment to be prepared, and target volumes to be injected. The calculations to determine the required volumes are based on the calculation sheets provided in **Appendix B**.

5.5.1 Preparation

5.5.1.1 Location Preparation

Prior to the ISB injection, the site will be cleared of aboveground hazards. A GPS device will be used to locate each injection point. After the third-party utility locator service has marked the underground utilities (if any), the locations will be reviewed to confirm that there are no injection points that will impact any utility. Additionally, the locations will be reviewed to

determine if concrete coring is needed at a location. If the concrete is too thick to core at a location, the location will be adjusted as needed. If there are points that are affected by utility locations, the plan will be altered to relocate those points to avoid the utility, while still meeting the injection objectives. The final DPT injection point locations will be recorded with the GPS. Prior to drilling with the DPT at each point, the location will be excavated with a hand auger or post-hole digger to 5 feet to check for underground obstructions/utilities unless the location has been cleared by other means and an exemption authorized.

5.5.1.2 Amendment Preparation

There are various EVO formulations commercially available in the market. EDS-ER™ or an equivalent product will be used for injections. The ISB amendments will be mixed in 2,000 to 4,000-gallon mixing tanks. The tanks will be located at LHAAP-04 adjacent to the injection area. The amendment solution will be mixed prior to the day of injection. The potable water required for mixing will be obtained from the groundwater treatment plant (GWTP) or from an off-base fire hydrant and transported to the mixing tank in a water truck.

Steps required for preparation of ISB amendments are as follows:

- Approximately 24 hours prior to injection, the anaerobic solution will be prepared by adding the required volume of EVO, dilution water, and nutrients into the mixing tank. The same EVO amendment mixture is used for all injection locations. Microbes in the water will grow on a small amount of the carbon, and during respiration, they will use the available oxygen in the mixing tank, creating an anaerobic medium.
- When the solution has become anaerobic, based upon a DO meter reading of less than 1.0 milligrams per liter, the amendments will be injected. The amendment solution will be injected into the subsurface using an injection system, as shown on **Figure 5-2**.
- The injection volume for each point at an injection area along with the associated mass and volume of amendment are provided in **Table 5-1** and are based on 100% EVO oil by weight.

5.5.2 In Situ Injections

5.5.2.1 Injection System

An injection system will be used to allow for multiple DPT injections at a single time under low pressure (i.e., less than 40 psi). The injection system will include volume and pressure gauges, so amendment volume can be recorded for each injection location. The total volumes per well, injection pressures and gallon per minute will be tracked on paper and electronically

using the Injection Log in **Appendix D**. The injection system will be connected to each DPT probe using hoses as shown in the schematic on **Figure 5-2**.

5.5.2.2 Monitoring During Injections

During the ISB injections, possible amendment surfacing (also called daylighting) may occur at the ground surface and will be monitored visually. Injection pressures will also be monitored since sudden reductions may be an indication of amendment loss into subsurface, possibly from fracturing induced by the injection or from a high-permeability zone. If daylighting on the surface is observed, injection rates will be reduced. If the reduction in pressure does not eliminate the daylighting, injections will be shut down and the remaining injection volume will be divided among the nearest injection locations to ensure the full design volume is injected in the area. If daylighting into a surface water feature is observed, the injection at that location will cease and necessary measure to capture the fluid released and to maintain the DO levels in the surface water will be implemented, if necessary. The remaining volume will be distributed to the other nearby injection locations. Total organic carbon (TOC) will be monitored in the performance wells during the injections using field methods and approximately 1 week after the completion of injections at an offsite laboratory as an indicator of distribution of the EVO (carbon). TOC will be used as an indicator of amendment distribution in the performance monitoring wells within the injection area (04WW04 and 04WW05).

5.5.3 Remediation Derived Waste Management

Remediation derived waste include the following:

- Groundwater generated from purging of wells prior to sampling
- Decontamination fluids
- Disposable protective clothing and supplies

Wastewater generated from equipment decontamination, well development, groundwater sampling, or other investigative and remedial activities will be stored in 55-gallon drums and transported to the GWTP at LHAAP-18/24 as specified in Section 3.8.2 of the IWWP (Bhate 2018b).

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6.0 POST-REMEDIAL MONITORING AND REPORTING

6.1 Monitoring Network

The monitoring network for the baseline sampling will include all of the LHAAP-04 monitoring wells and the fire station well. A subset of these wells will be selected in the RACR based on the results of the baseline sampling to be used to evaluate the performance of the LHAAP-04 remedy. Performance wells within the treatment area and at impacted locations near the treatment area will be analyzed for perchlorate and TOC, as well as geochemical parameters (sulfate, nitrate, nitrites, and alkalinity) and field parameters (DO, ORP, and ferrous iron). Perimeter wells surrounding the plume area will be used to evaluate plume stability and will be analyzed for perchlorate, DO, and ORP. The preliminary monitoring network wells are shown on **Figure 6-1** but may change based on the results of the baseline sampling.

6.2 Groundwater Sampling

Groundwater sampling events performed for LHAAP-04 will consist of:

- A baseline monitoring event conducted no more than 30 days prior to the initiation of ISB injections
- Performance monitoring that will be conducted quarterly for two years and used to evaluate the performance of the RA
- LTM monitoring that will be conducted semiannually in years 3 through 5 and annually thereafter until the groundwater perchlorate concentrations are below the PCL or the Army and regulators agree that less frequent sampling schedule is more appropriate

Areas around the wells will be cleared of vegetation and biohazards prior to each sampling event to protect the field staff. Low-flow groundwater sampling will be performed in accordance with Section 3.5 of the IWWP. Validated data packages will be provided at the monthly managers meeting as they become available.

6.2.1 Baseline Sampling

All of the LHAAP-04 monitoring wells along with the fire station well will be analyzed for the parameters shown on **Table 6-1** prior to initiating injections to allow establishment of baseline conditions against which the remedial performance can be evaluated.

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6.2.2 Evaluation of Injection Effectiveness

Groundwater samples will be collected for TOC analysis from the performance monitoring wells approximately one week after completion of the injections to evaluate effectiveness of the ISB injections.

6.2.3 Performance Monitoring Year 1 and Year 2

Wells included in **Tables 6-1** (as modified in the RACR**)** will be used to monitor the performance of ISB injections and the long-term stability of the plume. The process of biodegradation results in depletion of DO and ORP. Performance monitoring will be conducted to evaluate change in geochemical conditions and perchlorate concentrations and LTM monitoring will be conducted to verify that the plume extent is stable or shrinking. For the first two years post-injection the wells will be analyzed quarterly, with results provided in the monthly manager's meetings and summarized more fully in the Annual Remedial Action-Operation (RA-O) reports described in **Section 6.4**. The number of LTM wells may be reduced based on the RA-O monitoring results and recommendations made in RA-O Reports.

6.2.4 Long-Term Monitoring Years 3 through 5

After two years of quarterly performance monitoring, the monitoring will shift to semiannual LTM monitoring, and the analyte list for the performance wells will be reduced to perchlorate, TOC, and field parameters (DO and ORP). The number of LTM wells may be reduced based on the RA-O monitoring results and recommendations made in RA-O Reports. Monitoring will be discontinued with regulator concurrence after perchlorate concentrations in all wells drop below the PCL. The need for any additional LTM will be discussed in the next Five-Year Review.

6.2.5 Long-Term Monitoring Beyond Year 5

LTM will continue annually after Year 5, if needed, using a monitoring network and analyte list established in the Year 5 RA-O Report based on the ongoing monitoring data.

6.3 Response Action Completion Report

A RACR will be submitted upon implementation of the ISB injection and LUC work plans to document activities performed to complete the RA. Performance monitoring and LTM monitoring results will be included in RA-O Reports.

6.4 Annual RA-O Reports

An Annual RA-O Report will be prepared at the end of each year post-injection to present groundwater monitoring results. The Year 1 and Year 2 Annual RA-O Reports will include an evaluation of the effectiveness of treatment for LHAAP-04. Wells within the plume areas will be evaluated for effectiveness of treatment and wells surrounding the plume will be used to

evaluate plume stability. The report will provide recommendations if possible for reducing the number of monitoring wells to be included in the monitoring program and/or frequency of monitoring events. The Annual RA-O Report will also include the annual LUC inspection, and monitoring system operation and maintenance (O&M) discussion.

6.4.1 Remedy Evaluation

Remedial performance will be evaluated using two primary LOEs to determine if the remedy is operating properly:

- Plume stability (i.e., plume concentrations are declining in the performance wells, and the plume is not expanding in area as demonstrated by downgradient monitoring wells)
- Reducing conditions conducive for the degradation of perchlorate are present within the treatment area

Follow-up injections (**Section 6.5**) may be needed if the remedy is determined to not be performing, although reinjections are not expected to be needed within the 3 to 5-year lifespan of the EVO mixture selected. Nonetheless, the decision for reapplication of organic carbon will be made based on groundwater monitoring results.

6.5 Follow-up Injection Criteria

Three criteria for determining the potential need to reinject are:

- Contaminant concentrations in groundwater are not trending downward at a rate indicative of achieving the cleanup level in approximately 6 years
- Depletion of the organic carbon to below 20 mg/L
- ORP increases above -50 mV

If one or more of the criteria described above are met for two consecutive sampling events in the same sampling location, the need for additional injections in that area will be evaluated.

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7.0 SCHEDULE

Table 7-1 shows the estimated duration for each major site activity and timeline. Weather and unknown site conditions could affect this schedule.

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8.0 OPERATION AND MAINTENANCE PROCEDURES

Some components of the final remedy at LHAAP-04 require O&M and those O&M activities are described in this section, along with other routine maintenance activities. The remedy components that require O&M are maintenance of the groundwater monitoring system (this would include all wells that serve some purpose) and maintenance of the LUCs. These activities will be conducted annually unless recommended otherwise during a five-year review. An RA-O Inspection and Maintenance Checklist is presented in **Appendix E**.

8.1 Maintenance of the Current or Future Groundwater Monitoring System

The groundwater monitoring system is comprised of a network of monitoring wells used to implement ISB, monitor progress of the remedial activities, and determine the magnitude and extent of COCs. This system of wells will be inspected and maintained as part of the annual inspection and maintenance program. The monitoring wells will be inspected for the integrity of the pad, bollards, surface casing, and well markings, the presence and accumulation of silt in the well screen, the presence and integrity of a locking mechanism, positive drainage around the well pad, the presence of encroaching vegetation, such as tree roots and weeds, and the presence of biological hazards, such as ant mounds and bee nests. Maintenance activities will be performed as needed and could include replacement of the pads and well markings, resurfacing/painting the well casing and bollards, and redevelopment of the wells. Photo documentation of well conditions will be collected during inspection and maintenance activities. The annual inspection and maintenance activities will be documented in the Annual RA-O reports.

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9.0 REFERENCES

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Tables

Table 2-1
Monitoring Well Completion Summary

Well ID	Zone	Completion Date	Northing [a]	Easting [a]	Ground Surface Elevation (ft amsl) [b,c]	Top of Casing Elevation (ft amsl) [b]	Well Depth (ft bgs) [c]	Top of Screen (ft bgs) [c]	Bottom of Screen (ft bgs) [c]	Well Construction
04WW01	Shallow	29-Nov-00	6958971.173	3305911.786	208.78	212.51	24	13	23	4" SS
04WW02	Shallow	29-Nov-00	6959284.718	3305973.89	212.80	216.70	23	13	23	4" SS
04WW03	Shallow	29-Nov-00	6959561.995	3306189.503	212.38	215.93	25	13	23	4" SS
04WW04	Shallow	18-Aug-10	6959126.04	3305944.13	211.30	214.10	27	8	18	2" PVC
04WW05	Shallow	18-Aug-10	6959066.75	3305863.17	211.00	213.70	26.5	16	26	2" PVC
04WW06	Shallow	12-Dec-17	6859225.38	3305871.99	212.52	215.63	25	15	25	4" PVC
04WW07	Shallow	12-Dec-17	6859038.63	3306006.11	211.66	214.64	20	10	20	4" PVC
04WW08	Intermediate	14-Dec-17	6959148.15	3305963.41	212.07	214.82	41	31	41	10" PVC Surface Casing to 23', 4" PVC well
04WW09	Shallow	15-Jan-19	6959090.67	3305897.71	211.47	214.61	20	10	20	4" PVC
04WW10	Shallow	15-Jan-19	6959041.73	3305928.94	210.40	213.67	19	9	19	4" PVC
04WW11	Shallow	16-Jan-19	6959032.36	3305839.02	209.31	212.01	15.5	5.5	15.5	4" PVC
LHSMW02	Shallow	20-Aug-94	6959133.73	3305705.23	213.75	215.43	16	5.5	15.5	4" PVC riser, 316 SS screen
LHSMW01	Shallow	19-Aug-94	6959159.79	3306087.69	211.19	214.43	16	4.5	14.5	4" PVC riser, 316 SS screen

Notes:

[a] Northing and Easting Coordinates are Texas State Plane Coordinate System, North Central Zone (4202), 1983 North American Datum (NAD 83).

[b] Survey elevations are North American Vertical Datum of 1988 (NAVD 88).

[c] The ground surface elevation is measured at the soil surface adjacent to the well pad.

ID - identification

ft amsl - feet above mean sea level

ft bgs - feet below ground surface

PVC - polyvinyl chloride

SS - stainless steel

Table 5-1
Injection Locations and Amendment Volumes

DPT Location	Amendment Volume per Location			Nearest Monitoring Well	DPT Injection Depths (ft bgs)
	Gallons of EVO (EDS-ER or Equivalent)	Gallons of Nutrients (DAP)	Gallons of Water		
04DPT03, -06, and -07	15	6	1,463	04WW05	12 - 20
04DPT01, -02, -04, and -05	15	6	1,463	04WW09	6 - 14
04DPT08, -09, -10, -11, -12, -13, -14, -17, -18, -19, -20, -24, and -25	15	6	1,463	04WW10	7 - 15
04DPT15, -16, -21, -22, and -23	15	6	1,463	04WW07	7 - 15

Notes:

ft bgs - feet below ground surface

DAP - Diammonium phosphate

DPT - direct-push technology

evo - emulsified vegetable oil

Table 6-1
Proposed Monitoring Network Locations and Analyses

Monitoring Location	Primary Rationale for Well Selection	Proposed Analyses																				
		Baseline								1 Week Post Injection [a]	Performance – Years 1 and 2 (Quarterly)								LTM – Years 3 thru 5 (Semiannual)				
		Perchlorate (314.0)	DO (field reading)	ORP (field reading)	pH (field reading)	Ferrous Iron (field reading)	Alkalinity (2320B)	Anions [b] (E300.0)	TOC (SW9060)	TOC (SW9060)	Perchlorate (314.0)	DO (field reading)	ORP (field reading)	pH (field reading)	Ferrous Iron (field reading)	Alkalinity (2320B)	Anions [b] (E300.0)	TOC (SW9060)	Perchlorate (314.0)	DO (field reading)	ORP (field reading)	pH (field reading)	TOC (SW9060)
04WW05	Performance data within the treatment zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
04WW07	Performance data within the treatment zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
04WW09	Performance data within the treatment zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
04WW10	Performance data within the treatment zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
04WW01	Downgradient well for measuring plume stability	✓	✓	✓	✓						✓	✓	✓	✓					✓	✓	✓	✓	
04WW04	Upgradient well for measuring plume stability	✓	✓	✓	✓						✓	✓	✓	✓					✓	✓	✓	✓	
04WW06	Upgradient well for measuring plume stability	✓	✓	✓	✓						✓	✓	✓	✓					✓	✓	✓	✓	
04WW11	Downgradient well for measuring plume stability	✓	✓	✓	✓						✓	✓	✓	✓					✓	✓	✓	✓	
LHSMW01	Crossgradient well for measuring plume stability	✓	✓	✓	✓						✓	✓	✓	✓					✓	✓	✓	✓	
LHSMW02	Crossgradient well	✓	✓	✓	✓						The need for continued sampling of these wells will be determined based on the results of the baseline sampling.												
04WW02	Upgradient well	✓	✓	✓	✓																		
04WW03	Upgradient well	✓	✓	✓	✓																		
04WW08	Intermediate Zone well	✓	✓	✓	✓																		
Fire Station Well	Downgradient well	✓	✓	✓	✓																		

Notes:

[a] To be conducted approximately 7 days after the completion of substrate injection. A second sample will be collected between 30 and 45 days if the results from the first event were inconclusive.

[b] Anions include nitrate, nitrites, and sulfate.

✓ Indicates that sample will be collected and analyzed for the listed analyte.

Table 7-1
Schedule for Major Site Activities

Activities	Duration
Provide Injection Information to State	30
Baseline Sampling and Gauging	3
Utility Clearance	1
Mobilization / Site Set-up for Injections	1
Clear Injection Locations	2
Conduct Injection	9
Demobilization	1
Total Number of Days	47

Figures

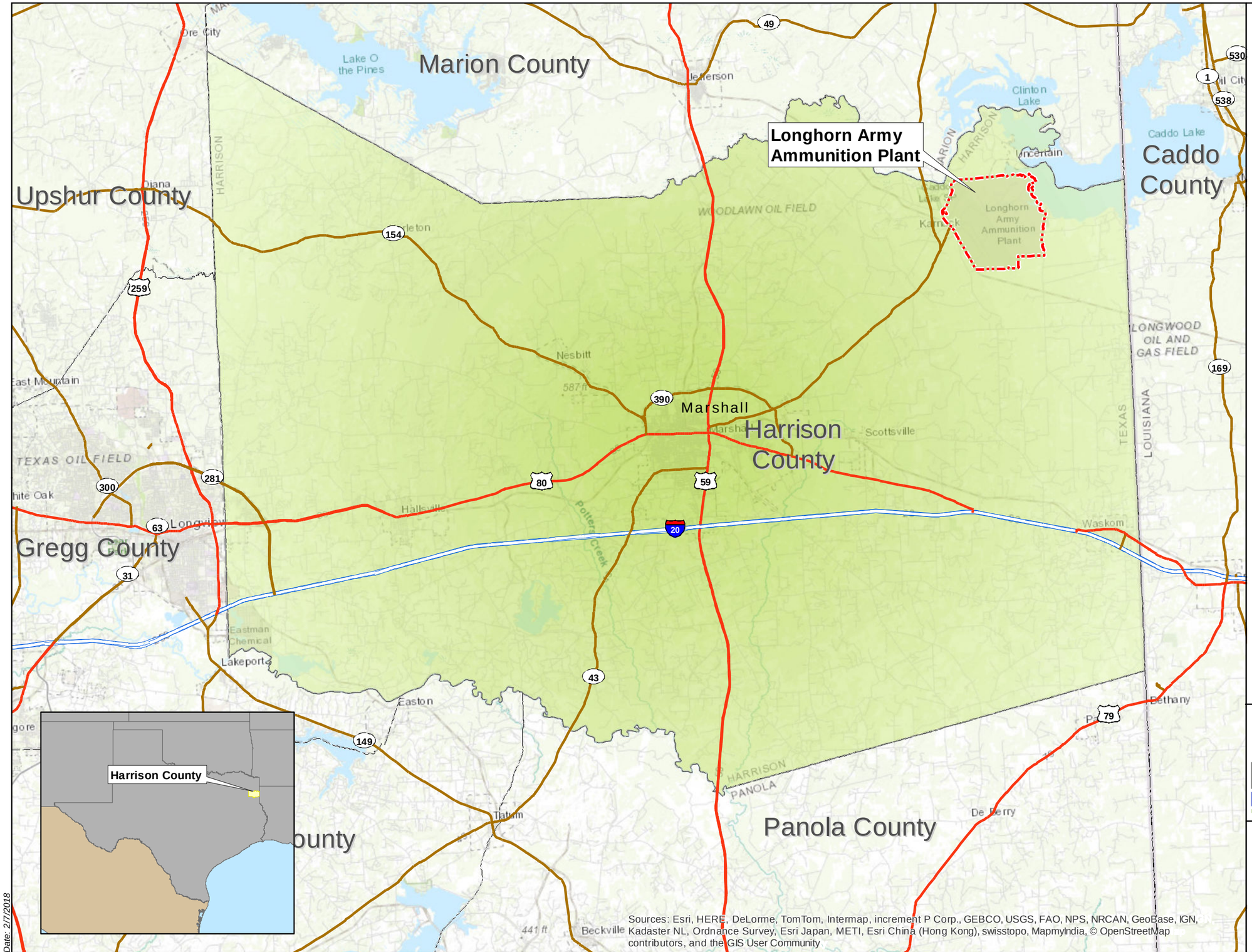

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Figure 1-1

LHAAP Location Map
LHAAP-04
Remedial Design/Remedial Action Work Plan
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 2/7/2018

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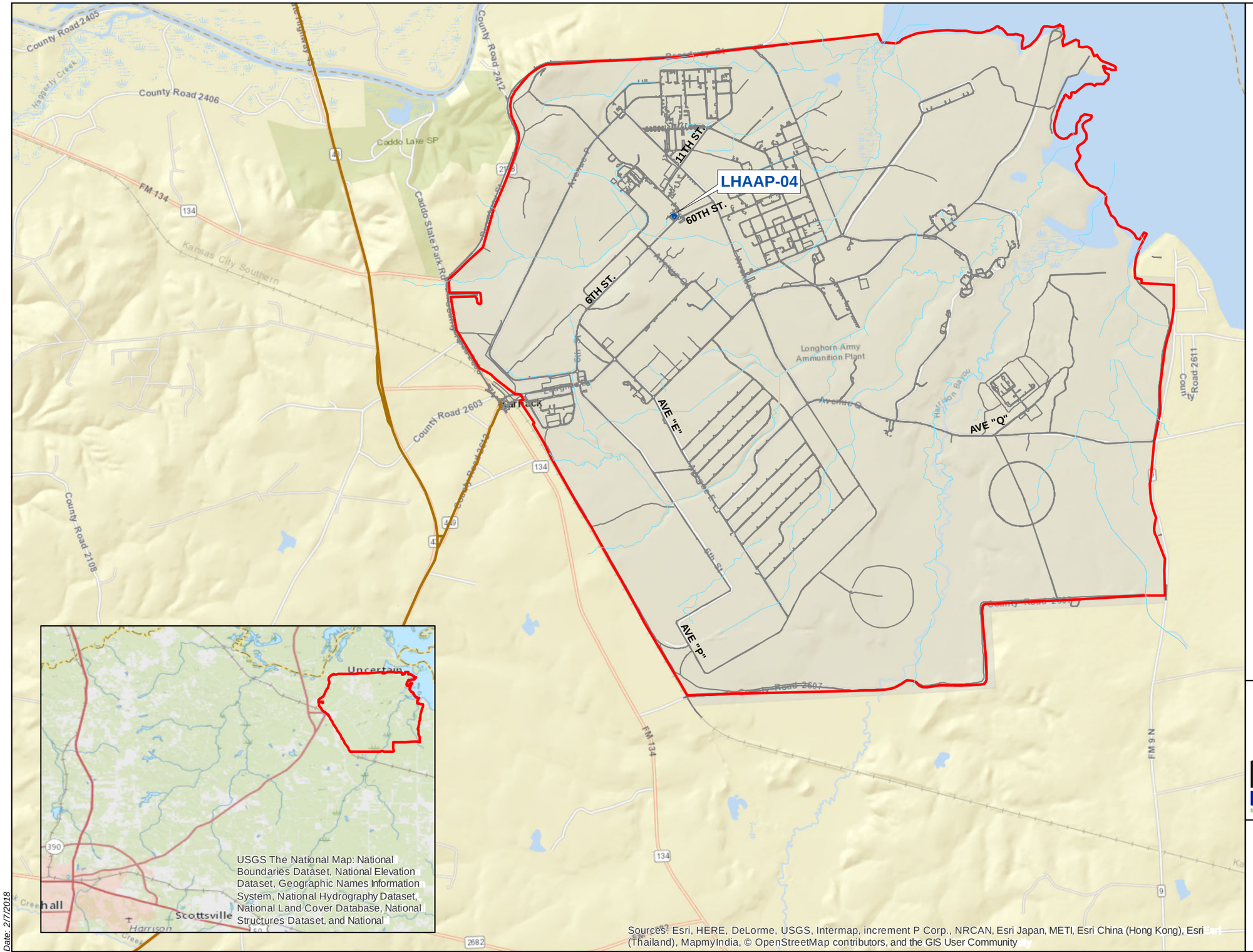

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Figure 1-2

LHAAP Site Location Map
LHAAP-04
Remedial Design/Remedial Action Work Plan
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 2/7/2018

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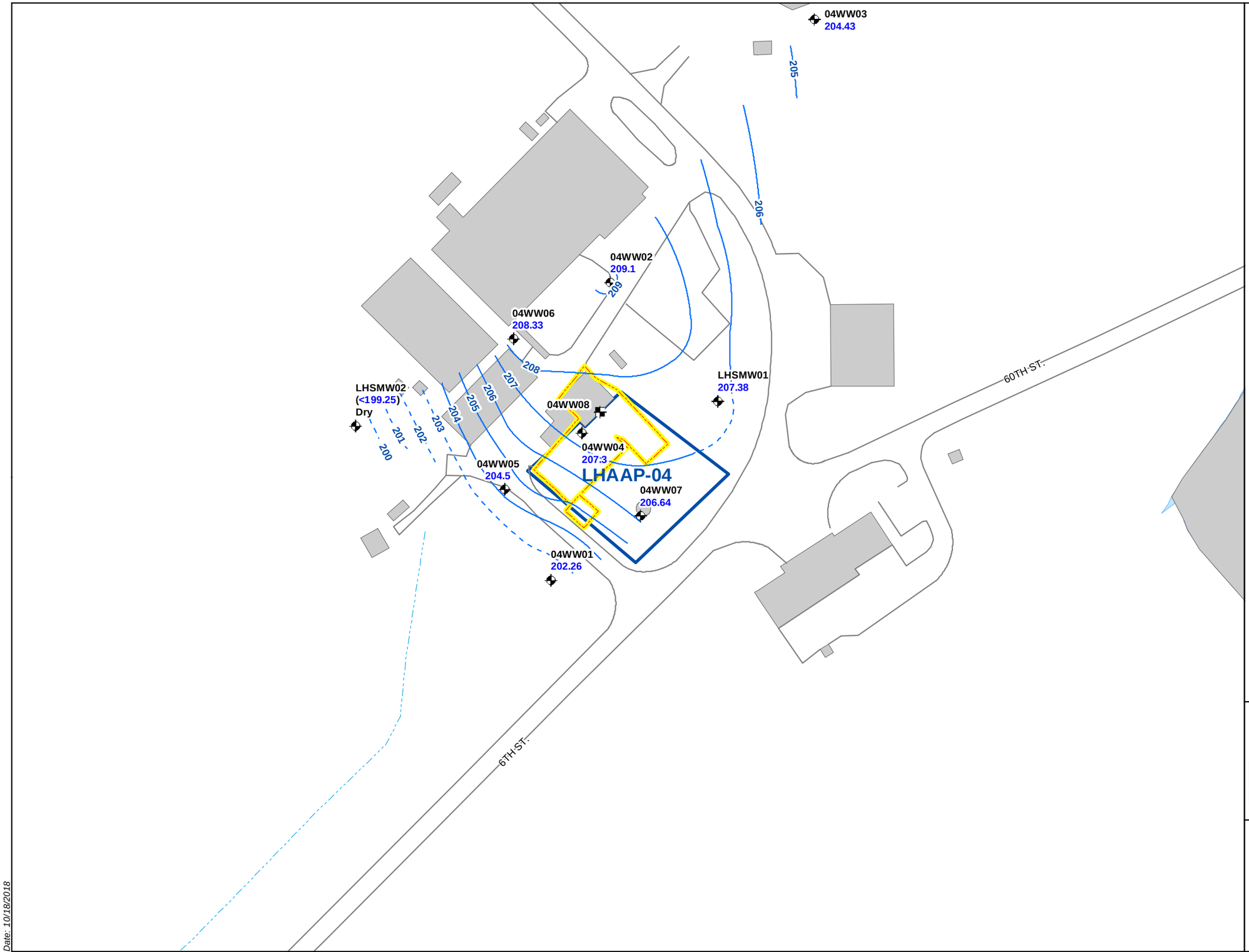

Shallow Monitoring Well

Intermediate Monitoring Well

Groundwater Contour (Dashed where inferred based on bottom of screen elevation in LHSMW02)

Stream

Limits of Excavation at Surface (*Source: LHAAP-04 Final Completion Report, Shaw, 2011*)

Road

Building

Site Boundary

Lakes

N

0 50 100 Feet

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Figure 2-1a

Potentiometric Map (January 2018)
LHAAP-04

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 10/18/2018

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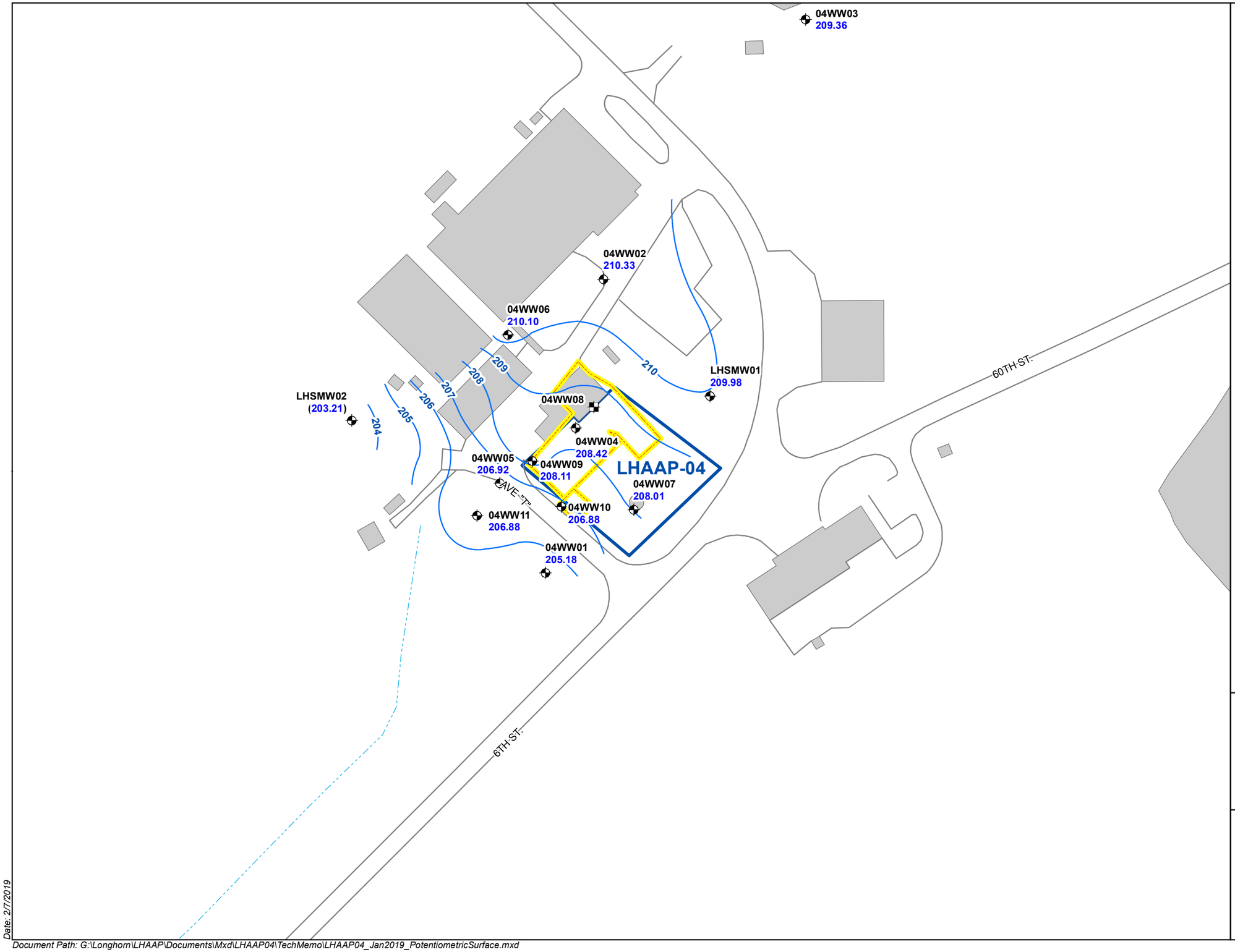

Shallow Monitoring Well

Intermediate Monitoring Well

Groundwater Contour

Stream

Limits of Excavation at Surface (*Source: LHAAP-04 Final Completion Report, Shaw, 2011*)

Road

Building

Site Boundary

N

0 50 100 Feet

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Figure 2-1b

Potentiometric Map (January 2019)
LHAAP-04

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 2/7/2019

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP04\TechMemo\LHAAP04_Jan2019_PotentiometricSurface.mxd

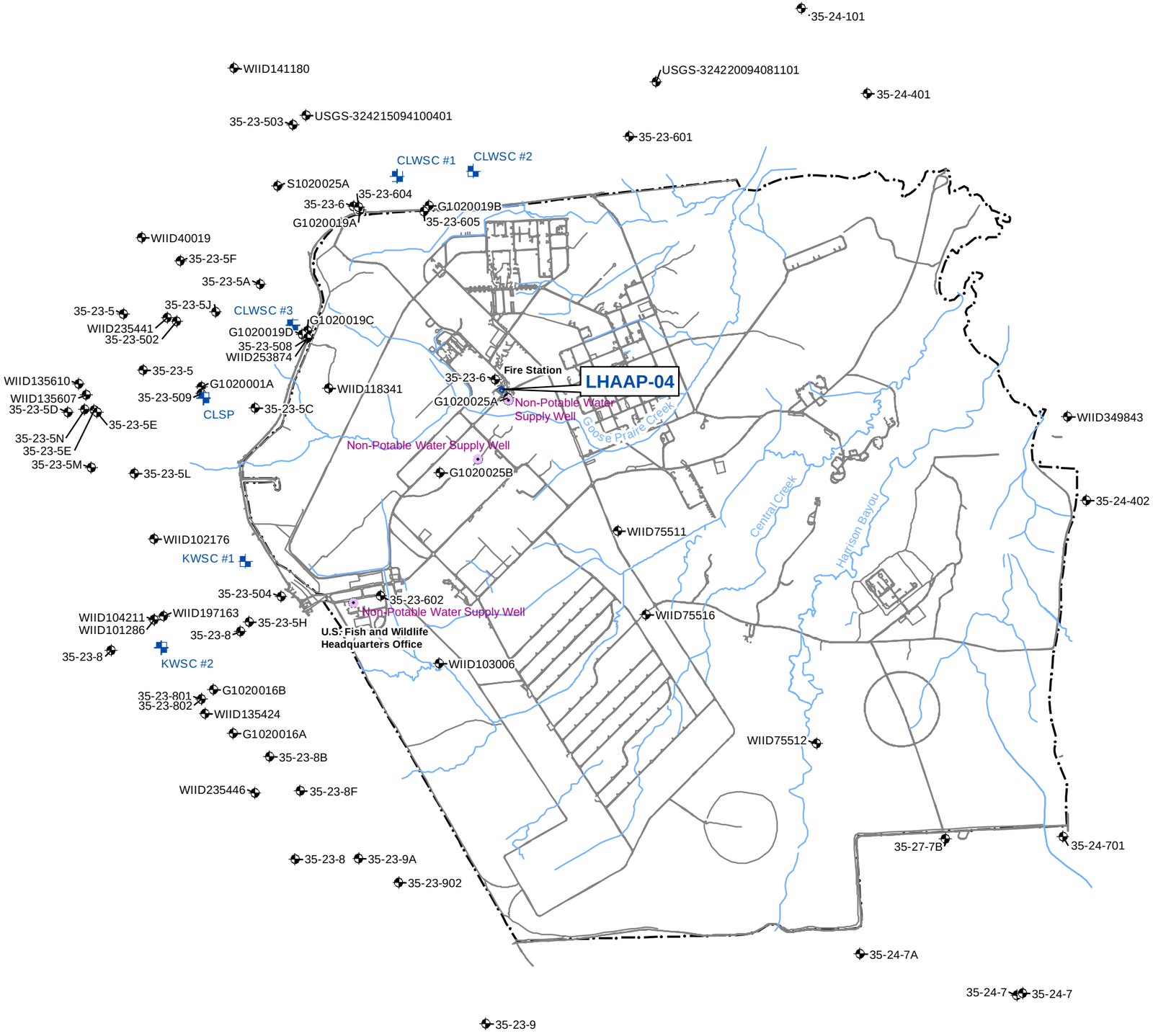

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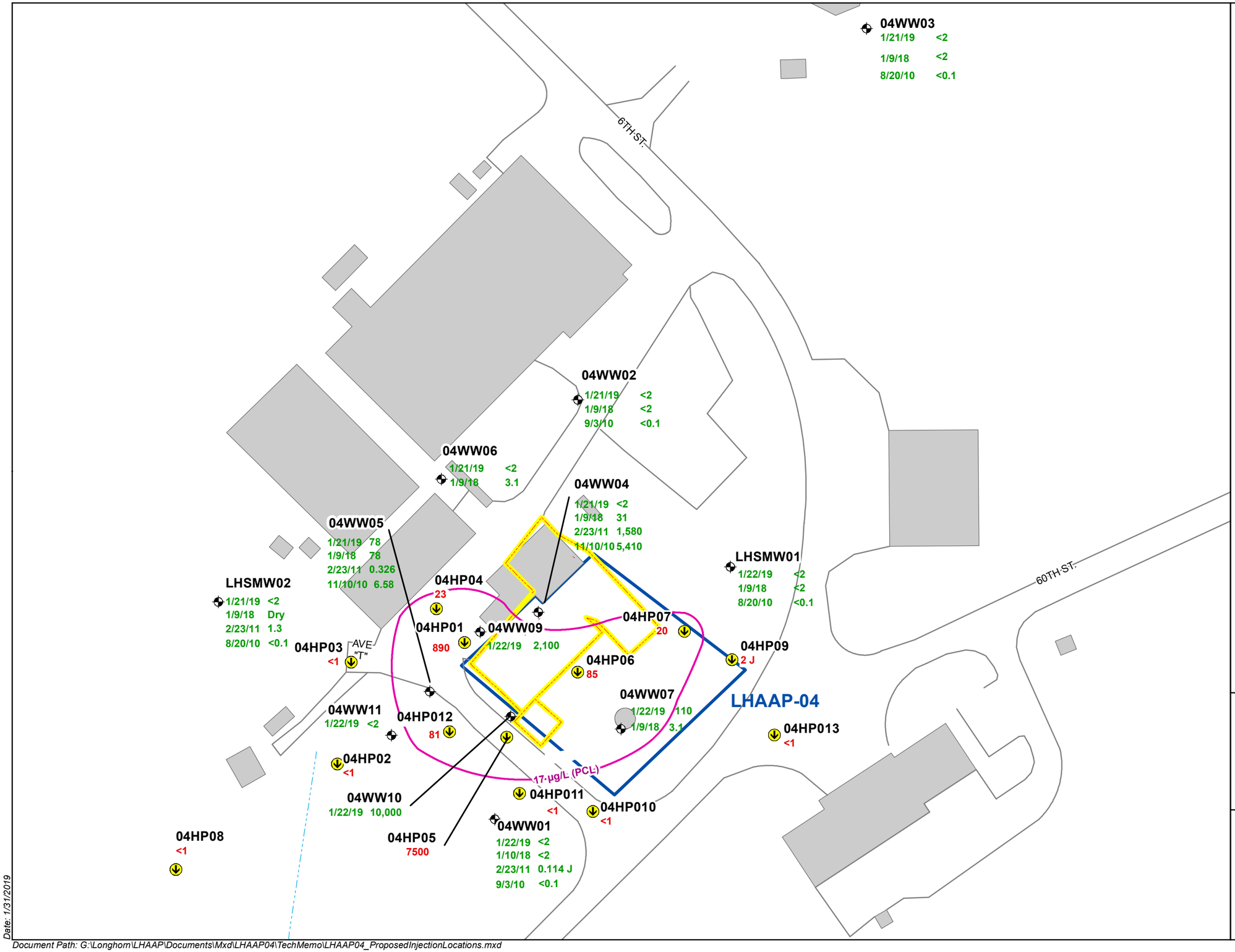
Figure 2-2

Site Vicinity Map
LHAAP-04
Remedial Design/Remedial Action Work Plan
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 2/7/2018

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP04\RD_RAWP\Fig1-3_SiteVicinityMap.mxd



Note:
1. Perchlorate concentrations reported in micrograms per liter (µg/L).
2. Plume boundaries based on most recent results available at each well (2018-2019).
3. PCL - Texas Risk Reduction Program Protective Concentration Level for Residential Groundwater
4. 85 = Hydropunch November-December 2018 data
110 = 2010, 2011, 2018, and 2019 monitoring well data

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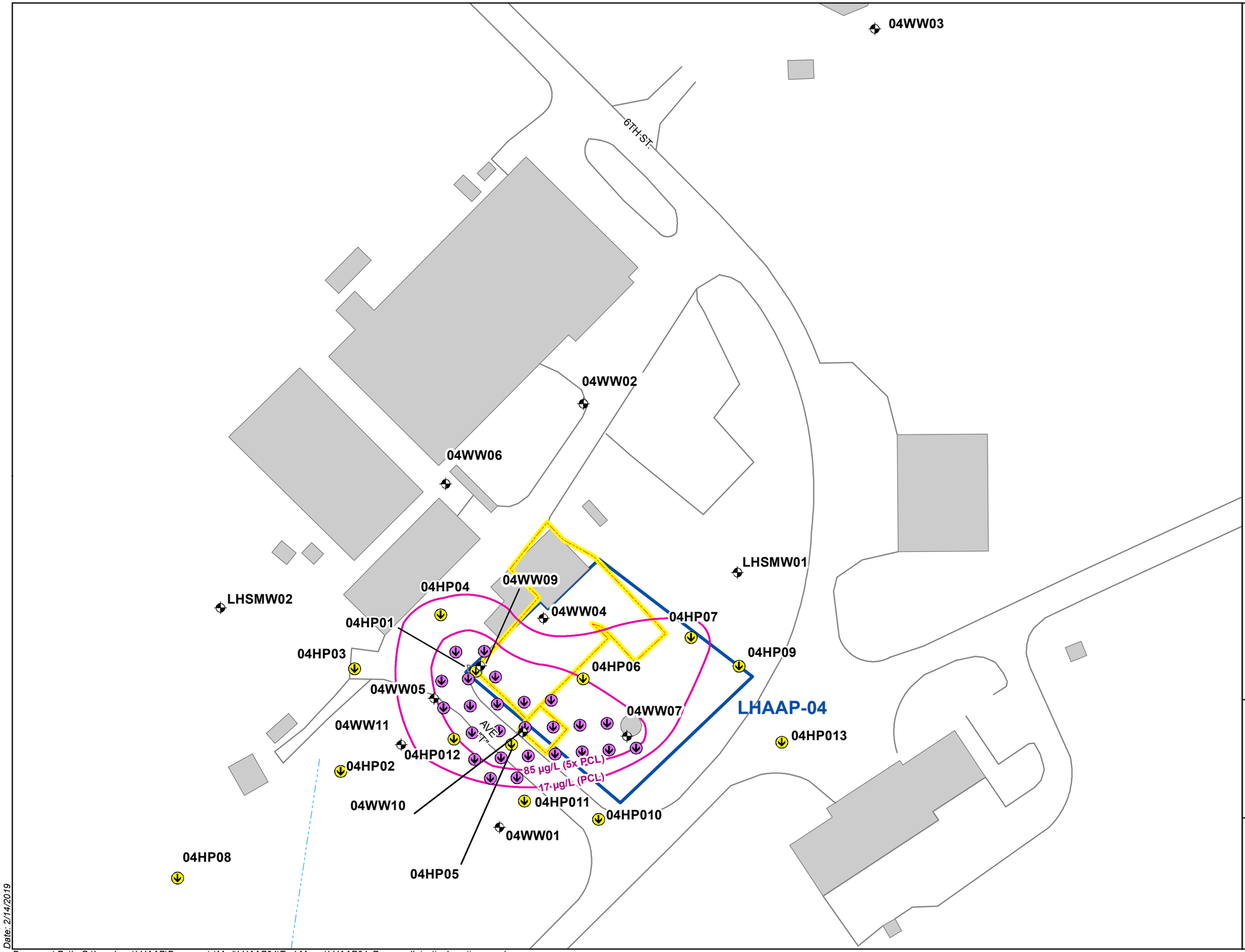
Figure 2-3

Perchlorate Concentrations in Shallow Groundwater at LHAAP-04

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 1/31/2019

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP04\TechMemo\LHAAP04_ProposedInjectionLocations.mxd



- Shallow Monitoring Well
- Proposed Injection Location
- Hydropunch Location
- Perchlorate Plume
- Stream
- Limits of Excavation at Surface (*Source: LHAAP-04 Final Completion Report, Shaw, 2011*)
- Road
- Building
- Site Boundary

Note:
1. Plume boundaries based on most recent results available at each well (2018).
2. PCL - Texas Risk Reduction Program Protective Concentration Level for Residential Groundwater
3. The injection pattern generally targets the area within the 85 µg/L contour, but has been shifted to the southwest to account for potential future migration.

N

0 50 100 Feet

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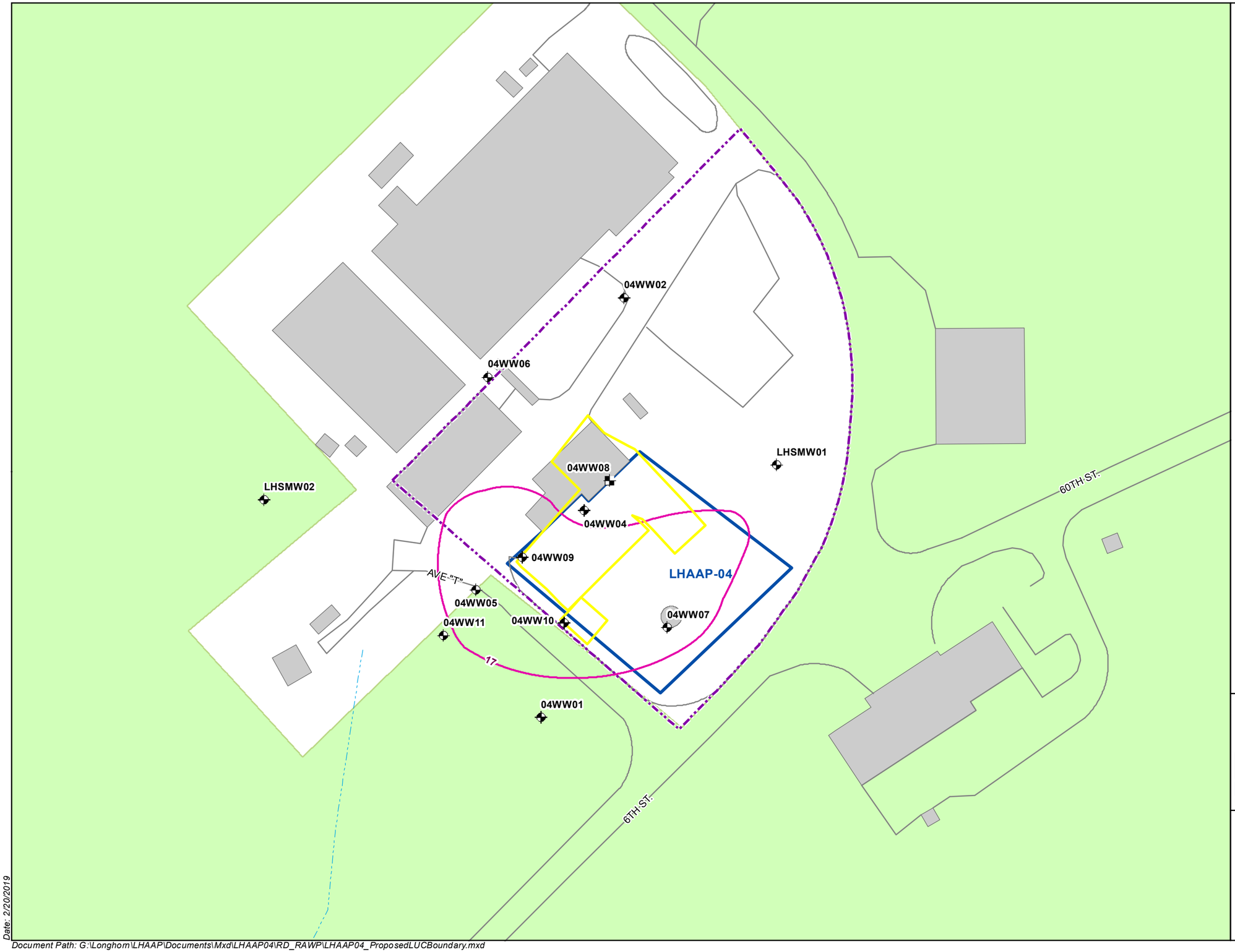
Figure 3-1

Proposed Injection Locations at LHAAP-04

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 2/14/2019

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP04\TechMemo\LHAAP04_ProposedInjectionLocations.mxd



Shallow Monitoring Well
Intermediate Monitoring Well
Limits of Excavation
Perchlorate Plume Extent (PCL - 17 µg/L)
Stream
Road
Preliminary LUC Boundary
Building
Site Boundary
National Wildlife Refuge

N

0 35 70 Feet

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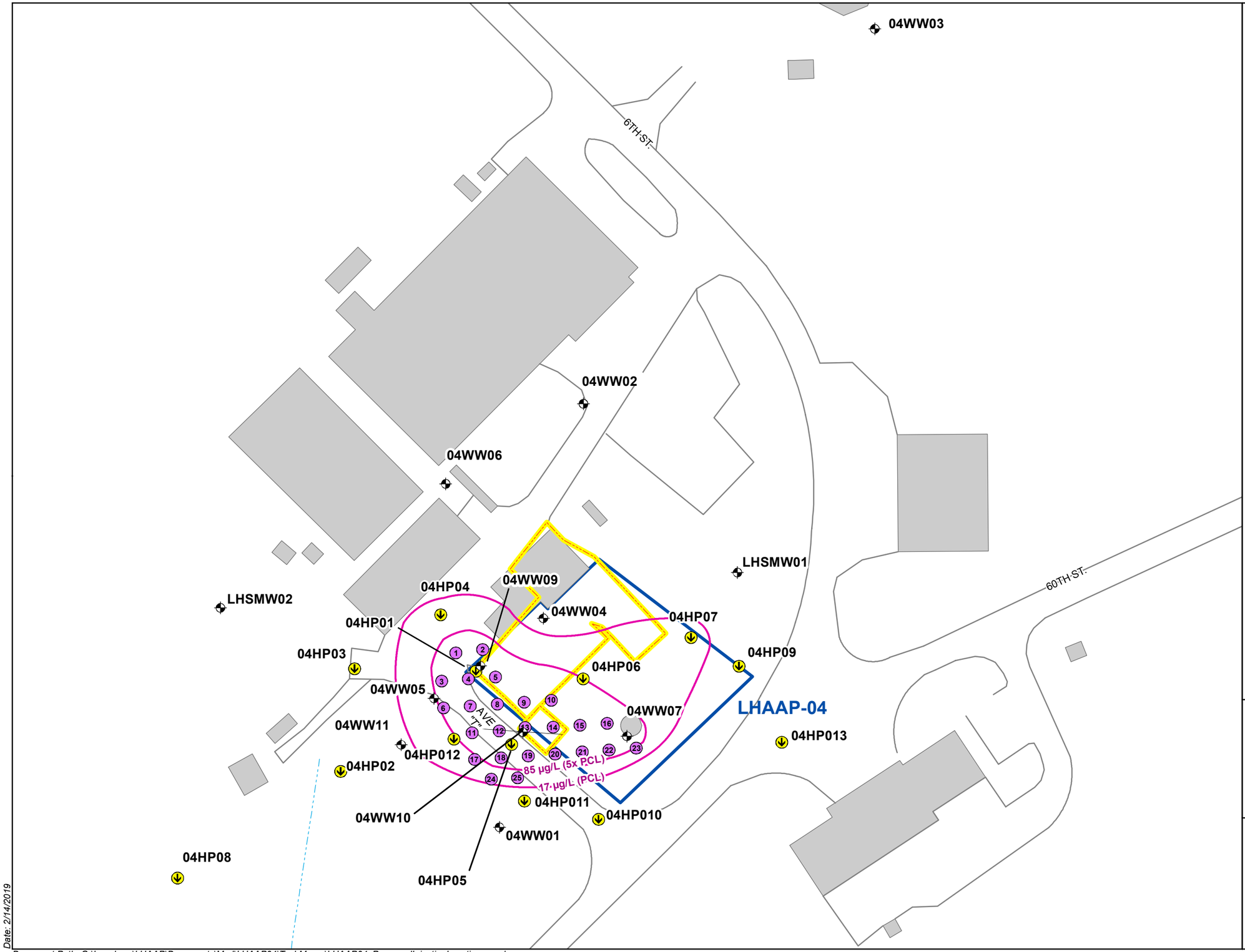
Figure 4-1

Preliminary LUC Boundary
LHAAP-04
Remedial Design/Remedial Action Work Plan
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 2/20/2019

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP04\RD_RAWP\LHAAP04_ProposedLUCBoundary.mxd



- Shallow Monitoring Well
- Proposed Injection Location
- Hydropunch Location
- Perchlorate Plume
- Stream
- Limits of Excavation at Surface (*Source: LHAAP-04 Final Completion Report, Shaw, 2011*)
- Road
- Building
- Site Boundary

Note:
1. Plume boundaries based on most recent results available at each well (2018).
2. PCL - Texas Risk Reduction Program Protective Concentration Level for Residential Groundwater
3. The injection pattern generally targets the area within the 85 µg/L contour, but has been shifted to the southwest to account for potential future migration.

N

0 50 100 Feet

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Figure 5-1

Injection Plan
LHAAP-04

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 2/14/2019

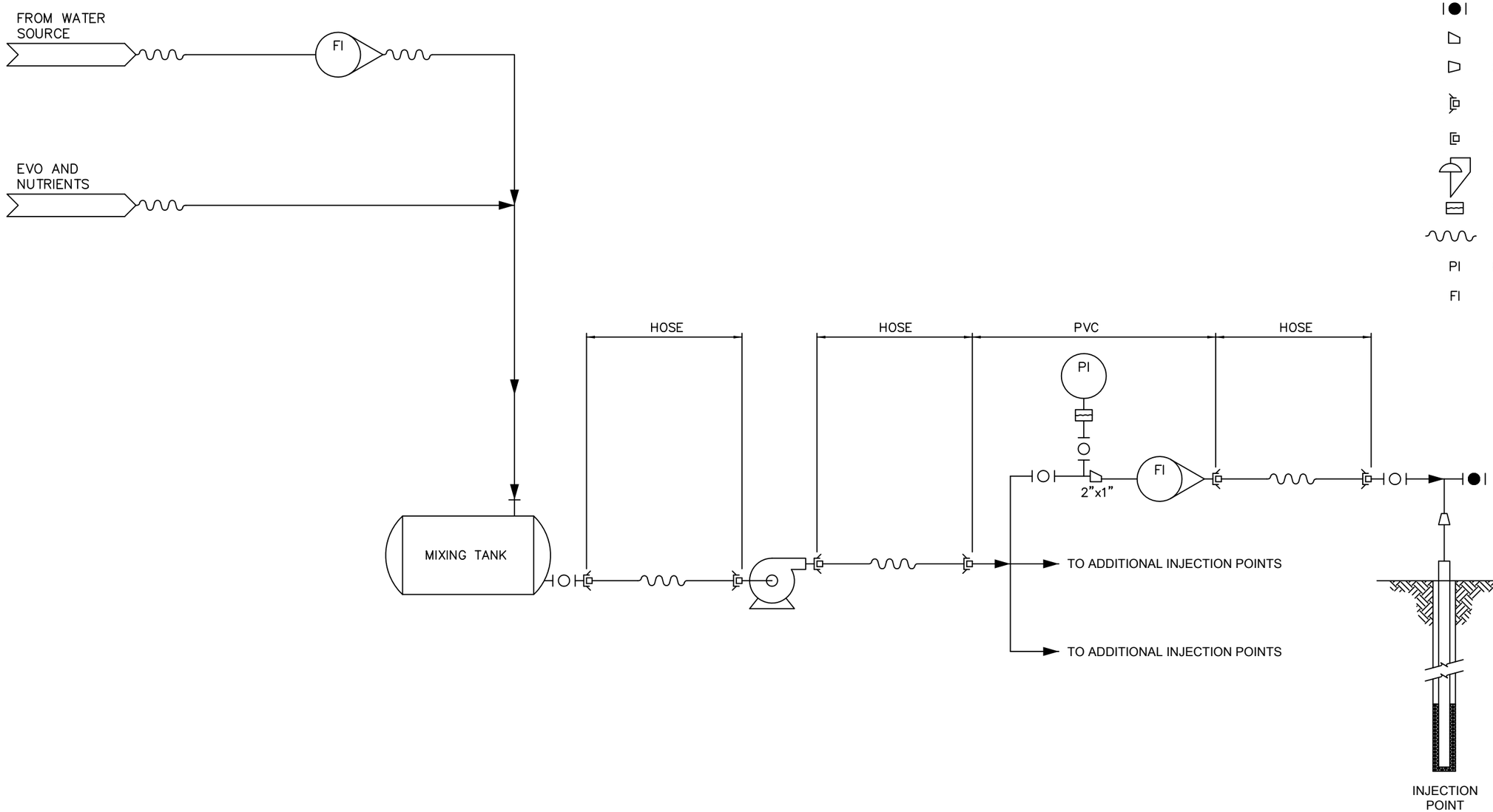
Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP04\TechMemo\LHAAP04_ProposedInjectionLocations.mxd

NOTE:

1. EVO – EMULSIFIED VEGETABLE OIL.

LEGEND:

- BALL VALVE (OPEN)
- BALL VALVE (CLOSED)
- ECCENTRIC REDUCER
- CONCENTRIC REDUCER
- CAMLOCK QUICK DISCONNECT
- BALL LOCK QUICK DISCONNECT
- PNEUMATIC ACTUATOR
- SEAL
- FLEXHOSE
- PI PRESSURE INDICATOR
- FI FLOW INDICATOR



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TULSA, OKLAHOMA

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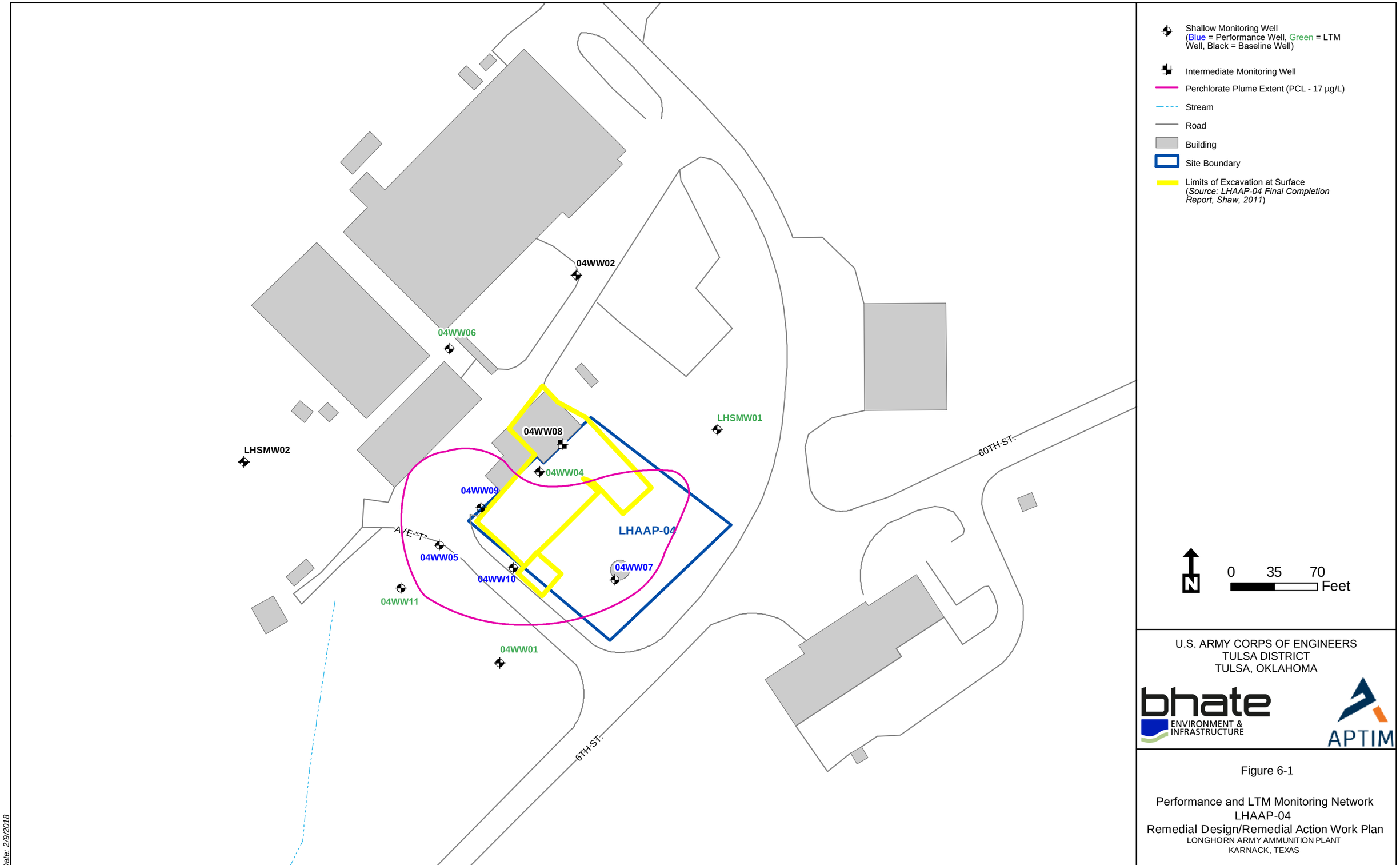
APTIM

Figure 5-2
ISB DPT Injection System
LHAAP-04
Remedial Design/Remedial Action Work Plan
Longhorn Army Ammunition Plant
Karnack, Texas

G:\Ft_Gillem\GIS_Documents\Output\FTG_07\FTG07_Treatment_System_Diagrams\FTG07_ISEB-DPT Injection System.ai



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APTIM

Figure 6-1

Performance and LTM Monitoring Network
LHAAP-04
Remedial Design/Remedial Action Work Plan
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 2/9/2018

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP04\RD_RAWP\LHAAP04_ProposedLUCBoundary.mxd

Appendix A

Boring Logs and Monitoring Well Construction Forms for Newly Installed Monitoring Wells

Drilling Log

Soil Boring **04HP01**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *18.0 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *6.0 ft.* Static *NA* Diameter *2 in.*

Screen: Dia *NA* Length *NA* Type/Size *NA*

Casing: Dia *NA* Length *NA* Type *NA*

Fill Material *Granular Bentonite* Rig/Core *Kubota Geoprobe*

Drill Co. *Best Drilling* Method *Direct Push (0-18')*

Driller *Ramon Gutierrez* Log By *Wesley Garcia* Date *11/27/18* Driller # *NA*

Checked By *Bill Foss* License No. *TX290*

COMMENTS
Hydropunch to 15.5'. Collect 04HP01-181127@1330.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0				CL	**SANDY CLAY**; red (2.5YR 4/6), firm, moist, some silt, trace roots.
4				CL	**SILTY CLAY**; reddish gray (5YR 5/2), stiff, damp, trace sand, trace brown mottling.
6 ▽				SM	**SILTY SAND**; red (10R 4/6), loose to firm, saturated, trace clay.
8				CL	**SILTY CLAY**; light brown and gray (7.5YR 6/3), stiff, damp, trace sand, trace calcareous nodules.
12				ML	**SANDY SILT**; red (10R 5/6), loose, wet, trace clay.
				CL	**SILTY CLAY**; light brown (7.5YR 6/4), stiff, dry to damp, trace sand.
14				ML	**CLAYEY SILT**; yellowish brown (10YR 5/4), soft, wet, some sand.
16				CL	**SILTY CLAY**; SAA, soft to firm, moist, trace sand.
18				CL	**SANDY CLAY**; mottled dark grayish brown (10YR 2/2 and 4/2), hard, dry, some silt.
20					**END OF BORING AT 18 FEET.**

Drilling Log

Soil Boring **04HP02**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *14.0 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *8.0 ft.* Static *NA* Diameter *2 in.*

Screen: Dia *NA* Length *NA* Type/Size *NA*

Casing: Dia *NA* Length *NA* Type *NA*

Fill Material *Granular Bentonite* Rig/Core *Kubota Geoprobe*

Drill Co. *Best Drilling* Method *Direct Push (0-14')*

Driller *Ramon Gutierrez* Log By *Wesley Garcia* Date *11/28/18* Driller # *NA*

Checked By *Bill Foss* License No. *TX290*

COMMENTS
Hydropunch to 12'.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0					
0				CL	**SILTY CLAY**; brown (10YR 4/3), soft, wet, some sand, some roots.
4				CL	**SANDY CLAY**; light yellowish brown (10YR 6/4), firm, moist, trace silt.
6				CL	**SILTY CLAY**; dark yellowish brown (10YR 4/6), stiff, moist, trace roots, trace ferrous iron (Fe) nodules.
8 ▽				SC	**CLAYEY SAND**; pale brown (10YR 7/3), loose, saturated, trace silt.
10				CL	**SANDY CLAY**; yellowish brown (10YR 5/8), firm to stiff, moist, trace silt, trace Fe staining.
12				CL	**SAA**; dark grayish brown (10YR 4/2); stiff, wet, trace silt, laminar appearance.
14					**END OF BORING AT 14 FEET.**
16					
18					
20					

Drilling Log

Soil Boring **04HP03**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *18.0 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *7.5 ft.* Static *NA* Diameter *2 in.*

Screen: Dia *NA* Length *NA* Type/Size *NA*

Casing: Dia *NA* Length *NA* Type *NA*

Fill Material *Granular Bentonite* Rig/Core *Kubota Geoprobe*

Drill Co. *Best Drilling* Method *Direct Push (0-18')*

Driller *Ramon Gutierrez* Log By *Wesley Garcia* Date *11/28/18* Driller # *NA*

Checked By *Bill Foss* License No. *TX290*

COMMENTS
Hydropunch to 17.5'.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0					Topsoil
2				CL	**SANDY CLAY**;brown (7.5YR 5/3), firm, moist, small gravel and roots present.
4				SC	**CLAYEY SAND**; gray (7.5YR 6/1), loose to medium dense, moist to wet, trace Fe staining, trace roots.
6					
▽					
8				CL	**SILTY CLAY**; light gray (7.5YR 7/1), firm to stiff, damp, trace Fe staining.
10				CL	**SANDY CLAY**; strong brown (7.5YR 5/6), firm, moist, trace silt.
12				CL	**SILTY CLAY**; yellowish brown (10YR 5/4), soft, moist, trace sand.
14				CL	**SANDY CLAY**; very dark brown (10YR 2/2), mottled with gray, firm, moist. **SAA**; color change to grayish brown (10YR 5/2).
16				CL	**SILTY CLAY**; dark grayish brown (10YR 4/2), stiff, damp, laminar appearance, trace sand.
18					**END OF BORING AT 18 FEET.**
20					

Drilling Log

Soil Boring **04HP04**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *20.0 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *7.0 ft.* Static *NA* Diameter *2 in.*

Screen: Dia *1 in.* Length *10 ft.* Type/Size *Sch. 40 PVC/0.010 in.*

Casing: Dia *1 in.* Length *5 ft.* Type *Sch. 40 PVC*

Fill Material *Granular Bentonite* Rig/Core *Kubota Geoprobe*

Drill Co. *Best Drilling* Method *Direct Push (0-20')*

Driller *Ramon Gutierrez* Log By *Wesley Garcia* Date *11/27/18* Driller # *NA*

Checked By *Bill Foss* License No. *TX290*

COMMENTS
Hydropunch to 17.1'. PVC screen set 5-15'.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0				CL	**SANDY CLAY**; brown (10YR 5/3), firm, moist, trace roots, trace silt.
2					
				SC	**CLAYEY SAND**; dark grayish brown (10YR 4/2), dense, damp, trace gravel.
4				CL	**SANDY CLAY**; light gray (10YR 7/1), firm, moist, trace Fe staining, moisture increasing with depth, saturated at 7 feet.
6					
▽					
8				CL	**SILTY CLAY**; grayish brown (10YR 5/2), firm, wet, trace sand.
10					**SAA**; color change to gray (10YR 501), moisture change to damp.
12				ML	**SANDY SILT**; pale brown (10YR 6/3), stiff, moist to wet, some clay.
14					**SAA**; color change to yellowish brown (10YR 5/6), density change to firm.
				CL	**SANDY CLAY**; light gray (10YR 7/2), stiff to hard, damp, trace gravel.
16				CL	**SILTY CLAY**; brownish yellow (10YR 6/6), firm, moist, trace sand.
18				CL	**SANDY CLAY**;dark gray (10yr 4/1), hard, damp, laminar appearance and crumbly texture.
20					**END OF BORING AT 20 FEET.**

Drilling Log

Soil Boring **04HP05**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *20.0 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *8.0 ft.* Static *NA* Diameter *2 in.*

Screen: Dia *1 in.* Length *10 ft.* Type/Size *Sch. 40 PVC/0.010 in.*

Casing: Dia *1 in.* Length *5 ft.* Type *Sch. 40 PVC*

Fill Material *Granular Bentonite* Rig/Core *Kubota Geoprobe*

Drill Co. *Best Drilling* Method *Direct Push (0-20')*

Driller *Ramon Gutierrez* Log By *Wesley Garcia* Date *11/27/18* Driller # *NA*

Checked By *Bill Foss* License No. *TX290*

COMMENTS
Hydropunch to 15'. PVC screen set to 5-15'.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0					Asphalt & Gravel
2				CL	**SILTY CLAY**; yellowish brown (10YR 5/6), soft to firm, moist, trace sand.
4					**SAA**; gray (10YR 6/1), firm, damp, trace Fe staining.
6					
8 ▽				SC	**CLAYEY SAND**; dark brown (10YR 3/3), firm, moist to wet, trace silt, trace Fe staining.
10				CL	**SILTY CLAY**; gray (10YR 5/1) with yellowish brown (10YR 5/6) mottles, firm to stiff, moist, trace sandy lenses.
12				CL	**SANDY CLAY**; yellowish brown (10YR 5/4), firm to stiff, moist to damp, silt increasing with depth, color changing to gray (10YR 5/1) with depth.
14					
16					**SAA**; dark gray (10YR 4/1), hard, damp, laminar appearance, blocky texture.
18					
20					**END OF BORING AT 20 FEET.**

Drilling Log

Soil Boring **04HP06**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *16.0 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *7.0 ft.* Static *NA* Diameter *2 in.*

Screen: Dia *1 in.* Length *10 ft.* Type/Size *Sch. 40 PVC/0.010 in.*

Casing: Dia *1 in.* Length *4 ft.* Type *Sch. 40 PVC*

Fill Material *Granular Bentonite* Rig/Core *Kubota Geoprobe*

Drill Co. *Best Drilling* Method *Direct Push (0-16')*

Driller *Ramon Gutierrez* Log By *Wesley Garcia* Date *11/27/18* Driller # *NA*

Checked By *Bill Foss* License No. *TX290*

COMMENTS
Hydropunch to 14'. PVC screen set to 4-14'.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0				CL	Sandy Clay FILL
2					
4				CL	**SILTY CLAY**; dark grayish brown (10YR 4/2), firm, moist, trace sand, trace roots.
6					**SAA**; yellowish brown (10YR 5/4), soft, moist, trace sand, trace plastic debris (possibly fill). **SAA**; light gray (10YR 7/1), firm, wet at 7 feet, trace Fe staining, trace sand.
8				CL	**SANDY CLAY**; light gray (10YR 7/1), firm, wet, trace silt.
10					
12				CL	**SILTY CLAY**; light gray (10YR 7/1), soft, wet, some sand. **SAA**; light gray (10YR 6/1), stiff, moist, trace sand
14				CL	**SANDY CLAY**; dark gray (10YR 4/1), stiff to hard, damp, laminar appearance.
16					**END OF BORING AT 16 FEET.**
18					
20					

Drilling Log

Soil Boring **04HP07**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *20.0 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *12.0 ft.* Static *NA* Diameter *2 in.*

Screen: Dia *NA* Length *NA* Type/Size *NA*

Casing: Dia *NA* Length *NA* Type *NA*

Fill Material *Granular Bentonite* Rig/Core *Kubota Geoprobe*

Drill Co. *Best Drilling* Method *Direct Push (0-20')*

Driller *Ramon Gutierrez* Log By *Wesley Garcia* Date *11/28/18* Driller # *NA*

Checked By *Bill Foss* License No. *TX290*

COMMENTS
Hydropunch to 17'.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0					Topsoil (Sandy Clay)
2				CL	**SANDY CLAY**; dark yellowish brown (10YR 4/4), soft to firm, moist, trace silt.
4					
6				CL	**SILTY CLAY**; yellowish brown (10YR 5/6), firm, damp, some Fe staining and calcareous nodules.
8				CL	**SANDY CLAY**; gray (10YR 6/1), stiff to hard, damp, trace Fe staining, trace silt.
10					
12 ▽				SC	**CLAYEY SAND**; light yellowish brown (10YR 6/4), loose to medium dense, wet, trace silt.
14				CL	**SANDY CLAY**; light gray (10YR 7/1), stiff, moist, trace silt.
16				CL	**SILTY CLAY**; pale brown (10YR 7/4), mottled with gray, stiff, moist, trace Fe staining.
18				CL	**SANDY CLAY**; grayish brown (10YR 5/2), grading to black at bottom (10YR 2/1), stiff, damp, laminar appearance.
20					**END OF BORING AT 20 FEET.**

Drilling Log

Soil Boring **04HP08**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *20.0 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *10.0 ft.* Static *NA* Diameter *2 in.*

Screen: Dia *1 in.* Length *10 ft.* Type/Size *Sch. 40 PVC/0.010 in.*

Casing: Dia *1 in.* Length *6 ft.* Type *Sch. 40 PVC*

Fill Material *Granular Bentonite* Rig/Core *Kubota Geoprobe*

Drill Co. *Best Drilling* Method *Direct Push (0-20')*

Driller *Ramon Gutierrez* Log By *Wesley Garcia* Date *11/28/18* Driller # *NA*

Checked By *Bill Foss* License No. *TX290*

COMMENTS
Hydropunch to 16'. PVC screen set to 6-16'.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0				CL	**SANDY CLAY**; yellowish brown (10YR 5/4), soft, moist, trace roots, trace silt.
2					
4					**SAA**; very pale brown (10YR 8/2), firm, damp, trace Fe staining, trace calcareous nodules.
6					
8					
10 ▽				SC	**CLAYEY SAND**; very pale brown (10YR 8/2), loose, saturated, trace silt.
12					
14				CL	**SILTY CLAY**; very pale brown (10YR 8/2), stiff, moist, trace sand.
16				CL	**SANDY CLAY**; grayish brown (10YR 5/2), soft, moist, trace silt.
18					**SAA**; dark gray (10YR 4/1), hard, damp, laminar appearance.
20					**END OF BORING AT 20 FEET.**

Drilling Log

Soil Boring **04HP09**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *19.0 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *8.0 ft.* Static *NA* Diameter *2 in.*

Screen: Dia *NA* Length *NA* Type/Size *NA*

Casing: Dia *NA* Length *NA* Type *NA*

Fill Material *Granular Bentonite* Rig/Core *Kubota Geoprobe*

Drill Co. *Best Drilling* Method *Direct Push (0-19')*

Driller *Ramon Gutierrez* Log By *Wesley Garcia* Date *12/13/18* Driller # *NA*

Checked By *Bill Foss* License No. *TX290*

COMMENTS
Hydropunch to 16.5'.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0					Topsoil (Sandy Clay)
2				CL	**SANDY CLAY**; yellowish brown (10YR 5/4), firm, moist, trace Fe staining.
4					**SAA**; light gray (10YR 7/1), firm, damp, trace Fe staining, trace silt, trace calcareous nodules.
6					
8 ▽				SC	**CLAYEY SAND**; dark gray (10YR 4/1), loose to medium dense, wet, density increasing with depth.
10					
12				CL	**SANDY CLAY**; brownish yellow (10YR 6/8), firm, moist, trace silt.
14				CL	**SILTY CLAY**; yellowish brown (10YR 5/8), soft, wet, sandy lenses, density increasing with depth.
16				CL	**SANDY CLAY**; dark grayish brown (10YR 4/2), firm, moist.
18					**SAA**; very dark gray (10YR 3/1), stiff, damp, laminar appearance.
20					**END OF BORING AT 19 FEET.**

Drilling Log

Soil Boring **04HP10**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *19.0 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *8.0 ft.* Static *NA* Diameter *2 in.*

Screen: Dia *NA* Length *NA* Type/Size *NA*

Casing: Dia *NA* Length *NA* Type *NA*

Fill Material *Granular Bentonite* Rig/Core *Kubota Geoprobe*

Drill Co. *Best Drilling* Method *Direct Push (0-19')*

Driller *Ramon Gutierrez* Log By *Wesley Garcia* Date *12/13/18* Driller # *NA*

Checked By *Bill Foss* License No. *TX290*

COMMENTS
Hydropunch to 15'.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0					Topsoil (Sandy Clay)
4				SC	**CLAYEY SAND**; brownish yellow (10YR 6/6), loose, moist, trace silt, trace roots.
6				CL	**SANDY CLAY**; light gray (10YR 7/1), firm, damp, trace calcareous nodules.
8 ▽				SC	**CLAYEY SAND**; brownish yellow (10YR 6/6), loose, saturated, trace calcareous nodules.
10				CL	**SANDY CLAY**; light gray (10YR 7/1), firm, moist, trace Fe staining.
12				SC	**CLAYEY SAND**; yellowish brown (10YR 5/6), medium dense, saturated, trace silt.
16				CL	**SANDY CLAY**; gray (10YR 5/1), firm, damp, trace silt.
18					**SAA**; dark gray (10YR 4/1), stiff, damp, laminar appearance.
20					**END OF BORING AT 19 FEET.**

Drilling Log

Soil Boring **04HP11**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *18.5 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *7.0 ft.* Static *NA* Diameter *2 in.*

Screen: Dia *NA* Length *NA* Type/Size *NA*

Casing: Dia *NA* Length *NA* Type *NA*

Fill Material *Granular Bentonite* Rig/Core *Kubota Geoprobe*

Drill Co. *Best Drilling* Method *Direct Push (0-18.5')*

Driller *Ramon Gutierrez* Log By *Wesley Garcia* Date *12/13/18* Driller # *NA*

Checked By *Bill Foss* License No. *TX290*

COMMENTS
Hydropunch to 15.5'.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0					Topsoil (Sandy Clay)
2				CL	**SANDY CLAY**; yellowish brown (10YR 5/4), soft, moist, trace silt, trace roots.
4					**SAA**; color change to very pale brown (10YR 8/3).
6					**SANDY CLAY**; light gray (7/1), with yellowish brown (10YR 5/8) mottles, firm, damp, trace silt.
▽ 8				SC	**CLAYEY SAND**; pale brown (10YR 6/3), loose, saturated, decreased sand with depth, medium dense at 8 feet.
10					
12				CL	**SANDY CLAY**; gray (10YR 6/1), firm to stiff, moist, silt increasing with depth.
14				CL	**SILTY CLAY**; yellowish brown (10YR 5/4), stiff, damp, trace sand.
16				CL	**SANDY CLAY**; very dark gray (10YR 3/1) with gray (10YR 5/1) laminations, hard, damp.
18					**END OF BORING AT 18.5 FEET.**
20					

Drilling Log

Soil Boring **04HP12**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *19.0 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *9.0 ft.* Static *NA* Diameter *2 in.*

Screen: Dia *NA* Length *NA* Type/Size *NA*

Casing: Dia *NA* Length *NA* Type *NA*

Fill Material *Granular Bentonite* Rig/Core *Kubota Geoprobe*

Drill Co. *Best Drilling* Method *Direct Push (0-19')*

Driller *Ramon Gutierrez* Log By *Wesley Garcia* Date *12/13/18* Driller # *NA*

Checked By *Bill Foss* License No. *TX290*

COMMENTS
Hydropunch to 16.5'.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0					
					Topsoil (Sandy Clay)
2				CL	**SANDY CLAY**; yellow (10YR 7/6), firm, moist, trace small gravel.
4					**SAA**; yellowish brown (10YR 5/6), firm, damp, trace silt.
6					**SAA**; yellow (10YR 7/6), firm, damp, trace silt, trace Fe staining, trace calcareous nodules.
8					**SILTY CLAY**; interbedded brownish yellow (10YR 6/8) and light gray (10YR 7/1) layers, firm, wet at 9 feet, trace sand.
▽					
10					
12				SC	**CLAYEY SAND**; yellowish brown (10YR 5/6), loose, saturated, trace silt.
14				CL	**SILTY CLAY**; brownish yellow (10YR 6/6), stiff, moist, trace sand.
16				CL	**SANDY CLAY**; grayish brown (10YR 5/2) to gray (10YR 5/1), hard, damp, laminar appearance.
18					
20					**END OF BORING AT 19 FEET.**

Drilling Log

Soil Boring **04HP13**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *18.0 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *12.0 ft.* Static *NA* Diameter *2 in.*

Screen: Dia *NA* Length *NA* Type/Size *NA*

Casing: Dia *NA* Length *NA* Type *NA*

Fill Material *Granular Bentonite* Rig/Core *Kubota Geoprobe*

Drill Co. *Best Drilling* Method *Direct Push (0-18')*

Driller *Ramon Gutierrez* Log By *Wesley Garcia* Date *12/13/18* Driller # *NA*

Checked By *Bill Foss* License No. *TX290*

COMMENTS
Hydropunch to 16'.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0					Topsoil (Sandy Clay)
2				CL	**SANDY CLAY**; yellowish brown (10YR 5/8), firm, moist, some mottling with light brownish gray (10YR 6/2).
				CL	**SILTY CLAY**; very dark gray (10YR 3/1), firm, damp, trace sand.
4				CL	**SANDY CLAY**; very pale brown (10YR 8/4), stiff, damp, trace calcareous nodules.
6				CL	**SILTY CLAY**; gray (5/1) with many calcareous nodules (10YR 8/1), stiff, damp, some Fe staining.
8					
10					
12 ▽				SC	**CLAYEY SAND**; gray (10YR 6/1), loose, saturated, color grading to very pale brown (10YR 7/3) with depth, clay content increasing with depth.
14					
16				CL	**SANDY CLAY**; white to light gray (10YR 8/1 and 7/2), stiff, damp, slight laminar appearance.
18					**END OF BORING AT 18 FEET.**
20					

Drilling Log

Monitoring Well **04WW06**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *25.0 ft.* North *6959225.38 ft.* East *3305871.99 ft.*

Top of Casing *NA* Water Level Initial ▽ *10.5 ft.* Static *NA* Diameter *10.25 in.*

Screen: Dia *4 in.* Length *10 ft.* Type/Size *Sch. 40 PVC/0.010 in.*

Casing: Dia *4 in.* Length *15 ft.* Type *Sch. 40 PVC*

Fill Material *20/40 Sand; bentonite chips, grout* Rig/Core *CME 75 Mobile Rig*

Drill Co. *Best Drilling* Method *Hand auger (0-5'); hollow stem auger (5-25')*

Driller *Sonny Tobola* Log By *D. Rowan* Date *12/12/17* Driller # *3026*

Checked By *Bill Foss* License No. *TX290*

COMMENTS

4" PVC 0.010" slot screen set from 15-25'. 4" PVC casing 0-15'. 20/40 Sand at 12-25'. Bentonite at 10-12'. Grout 0-10'.

NOTE: First 48" using post hole digger for utility cleance, then probe to 60", boring drilled using ~10.25" diameter hollow stem augers, logged from split spoon at 2.5' intervals.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0				CL	**SANDY CLAY**; topsoil, some red silty clay.
2				CL	**SILTY CLAY**; gray, firm to soft, moist, mottled orange Fe staining, slight plasticity, platy layers.
4				CL	**SANDY CLAY**; tan, moist, soft, mottled orange Fe staining, few calciite nodules, few intermittent pebbles.
6				CL	**SILTY CLAY**; dark gray to black, very moist, lessening of sand concentration, orange Fe staining. **SAA**; color change to light gray, orange Fe staining.
8					**SAA**; color change to gray, moist to very moist, interbedded sand lenses, few calcite nodules.
10 ▽				CL	**SANDY CLAY**; tan, interbedded gray clay lenses, very moist, slightly mottled orange Fe staining.sand.
12				CL	**SILTY CLAY**; light gray, interbedded sand lenses, moist to damp, firm to soft, plastic when wet. Same as above with the addition of interbedded orange Fe staining.
14					
16					
18					Same as above with the addition of interbedded black Fe staining.
20					**SILTY CLAY**; dark gray to black, interbedded tan sand, firm, damp
22					Same as above without sand.
24					
26					**END OF BORING AT 25 FEET.**

Drilling Log

Monitoring Well **04WW07**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *20.0 ft.* North *6959038.63 ft.* East *3306006.11 ft.*

Top of Casing *NA* Water Level Initial *NA* Static *NA* Diameter *10.25 in.*

Screen: Dia *4 in.* Length *10 ft.* Type/Size *Sch. 40 PVC/0.010 in.*

Casing: Dia *4 in.* Length *10 ft.* Type *Sch. 40 PVC*

Fill Material *20/40 Sand; bentonite chips, grout* Rig/Core *CME 75 Mobile Rig*

Drill Co. *Best Drilling* Method *Hand auger (0-5'); hollow stem auger (5-20')*

Driller *Sonny Tobola* Log By *D. Rowan* Date *12/12/17* Driller # *3026*

Checked By *Bill Foss* License No. *TX290*

COMMENTS

4" PVC screen set from 10-20'. 4" PVC casing 0-10'. 20/40 Sand at 7-20'. Bentonite from 5-7'. Grout 0-5'.

NOTE: First 48" using post hole digger for utility cleance, then probe to 60", boring drilled using ~10.25" diameter hollow stem augers, logged from split spoon at 2.5' intervals.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0					
					Topsoil
2				CL	**SILTY CLAY**; tan to gray with interbedded sand lenses, orange Fe staining with black Fe Mn or organic nodules, moist with area of very moist.
					Same as above with increase in Fe staining, higher concentration of sand in bottom 1.5'.
4					
					SILTY CLAY; firm, moist, plastic, mottled orange Fe staining, lessening silt concentration with depth, loss of sand.
6					
					Same as above with some interbedded sand lenses.
8					
10					Same as above with lessening Fe staining.
12					**SILTY CLAY**; light gray to black with mottled orange Fe staining nodules, trace sand/silica throughout, firm to soft, moist to damp, little to no plasticity even when wet.
14					Same as above with black Fe Mn or organic nodules at 17', darkening of color at 16'.
16					
18				CL	**CLAY**; black, dry, few nodules of orange Fe staining.
				CL	**SILTY CLAY**; black, dry, firm, very dense.
20					**END OF BORING AT 20 FEET.**

Drilling Log

Monitoring Well **04WW08**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *45.0 ft.* North *6959148.15 ft.* East *3305963.41 ft.*

Top of Casing *NA* Water Level Initial ▽ *32.5 ft.* Static *NA* Diameter *10.25 in.*

Screen: Dia *4 in.* Length *10 ft.* Type/Size *Sch. 40 PVC/0.010 in.*

Casing: Dia *4 in.* Length *35 ft.* Type *Sch. 40 PVC*

Fill Material *20/40 Sand; bentonite chips, grout* Rig/Core *CME 75 Mobile Rig*

Drill Co. *Best Drilling* Method *Hollow stem auger (0-45')*

Driller *Sonny Tobola* Log By *D. Rowan* Date *12/14/17* Driller # *3026*

Checked By *Bill Foss* License No. *TX290*

COMMENTS

Top 12' most likely backfill from excavation as noted on 04WW04 boring log.

12" PVC surface casing set in shallow zone from 0-23' on 12/12/2017. 4" PVC screen set from 31 to 41'. 20/40 Sand from 29-45'. Bentonite from 27-29'. Grout from 0-27'.

Hole diameter 0-23' is 14; from 23-45' hole diameter is 10.25'.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0				CL	**SANDY CLAY**; topsoil, some silt, some red silty clay.
2				ML	**SANDY SILT**; gray, clayey, increasing clay concentration and decreasing sand with depth.
4					
6				CL	**SANDY CLAY**; red, firm, moist, with depth there is increasing moisture content as well as decreasing sand concentration.
8				CL	**SILTY CLAY**; red, soft, moist to very moist, trace orange Fe staining with some nodules of black Fe Mn or organics.
10					
12					**SILTY CLAY**; native gray, damp, trace sand, mottled orange Fe staining with interbedded black nodules of Fe Mn or organics. **SAA**; color change to gray, very firm, sheeted, plastic when wet, trace interbedded sand.
14					
16					Same as above with increasing trace of sand starting at 16', some orange Fe staining.
18				CL	**CLAY**; light gray to dark gray with silt and trace sand, firm, moist, plastic when wet.
20					

Continued Next Page

Drilling Log

Monitoring Well **04WW08**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
					Continued
22				CL	Same as above with some orange Fe staining.
24					
26				CL	**SILTY CLAY**; medium to dark gray, very firm, dense, dry, interbedded black organic nodules, increase in moisture to a moist consistency around 28.5' through rest of core, transition to light gray color at 29'.
28					
30				CL	**CLAY**; dark gray, moist, some orange Fe staining, firm to soft, plastic when wet. **SAA**; color change to black, with silt, dry, firm.
32 ▽					NO RECOVERY
34					
36				CL	**SILTY CLAY**; dark gray to black, from top to bottom saturated to moist, firm to stiff, slight plasticity.
38					
40				ML	**CLAYEY SILT**; light gray, clayey, damp, sheeted, firm to soft, no plasticity.
42					
44					
46					**END OF BORING AT 45 FEET.**
48					

Drilling Log

Monitoring Well **04WW09**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *20.0 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *7.0 ft.* Static *NA* Diameter *10.25 in.*

Screen: Dia *4 in.* Length *10 ft.* Type/Size *Sch. 40 PVC/0.010 in.*

Casing: Dia *4 in.* Length *10 ft.* Type *Sch. 40 PVC*

Fill Material *20/40 Sand; bentonite chips, grout* Rig/Core *CME 55*

Drill Co. *ETTL* Method *Hand auger (0-5'); hollow stem auger (5-20')*

Driller *Rich Herman* Log By *Wesley Garcia* Date *1/15/19* Driller # *59385M*

Checked By *Bill Foss* License No. *TX290*

COMMENTS

4" PVC well set at 20' with 10' of 0.010" slot screen. Filter pack 20/40 Sand at 8-20'. Bentonite chips 6-8' in 12" lifts, hydrated between lifts. Grout 0-5' placed 1/16/2019.

Depth (ft.)	Well Completion	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0						Hand augered for utility clearance. See 04HP01 log for lithology.
4					CL	**SILTY CLAY**; reddish gray (5YR 5/2), stiff, damp, trace sand and roots (FILL).
6					SM	**SILTY SAND**; red (10R 4/6), loose to firm, saturated, trace clay.
8					CL	**SILTY CLAY**; light brown (7.5YR 6/3) and gray (7.5YR 6/1), stiff, damp, trace sand, trace calcareous nodules.
12					SM	**SANDY SILT** interbedded with **SILTY CLAY**; red (10R 5/6) and light brown (7.5YR 6/4), silt lenses loose and wet, clay is firm and moist, trace sand.
14					CL	**SILTY CLAY**; yellowish brown (10YR 5/4), soft to firm, wet to moist, trace sand.
18					CL	**SANDY CLAY**; light brownish gray (10YR 6/2) to very dark brown (10YR 2/2), hard dry, some silt.
20						**END OF BORING AT 20 FEET.**

Drilling Log

Monitoring Well **04WW10**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *19.0 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *8.0 ft.* Static *NA* Diameter *10.25 in.*

Screen: Dia *4 in.* Length *10 ft.* Type/Size *Sch. 40 PVC/0.010 in.*

Casing: Dia *4 in.* Length *9 ft.* Type *Sch. 40 PVC*

Fill Material *20/40 Sand; bentonite chips, grout* Rig/Core *CME 55*

Drill Co. *ETTL* Method *Hand auger (0-5'); hollow stem auger (5-19')*

Driller *Rich Herman* Log By *Wesley Garcia* Date *1/15/19* Driller # *59385M*

Checked By *Bill Foss* License No. *TX290*

COMMENTS

4" PVC well set at 19' with 10' of 0.010" slot screen. Filter pack 20/40 Sand at 7-19'. Bentonite chips 5-7' in 12" lifts, hydrated between lifts. Grout 0-5' placed 1/16/2019.

Depth (ft.)	Well Completion	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0						Hand augered for utility clearance. See 04HP05 log for lithology.
6					CL	**SILTY CLAY**; gray (10YR 6/1), firm, damp, trace Fe staining.
8 ▽					SC	**CLAYEY SAND**; dark brown (10YR 3/3), medium dense, moist to wet at 8 feet, trace silt, trace Fe staining.
10					CL	**SILTY CLAY**; gray (10YR 5/1) with yellowish brown (10YR 5/6) mottles, firm to stiff, moist, trace sandy lenses.
12					CL	**SANDY CLAY**; yellowish brown (10YR 5/4), firm to stiff, moist to damp, silt increasing with depth, color change fades to gray (10YR 5/1) with depth.
16						**SAA**; dark gray (10YR 4/1), hard, damp, laminar appearance, blocky texture.
20						**END OF BORING AT 19 FEET.**

Drilling Log

Monitoring Well **04WW11**

Project *Longhorn Army Ammunition Plant* Owner *USACE*

Location *LHAAP-04* Proj. No. *501032*

Surface Elev. *NA* Total Hole Depth *15.5 ft.* North _____ East _____

Top of Casing *NA* Water Level Initial ▽ *7.0 ft.* Static *NA* Diameter *10.25 in.*

Screen: Dia *4 in.* Length *10 ft.* Type/Size *Sch. 40 PVC/0.010 in.*

Casing: Dia *4 in.* Length *5.5 ft.* Type *Sch. 40 PVC*

Fill Material *20/40 Sand; bentonite chips, grout* Rig/Core *CME 55*

Drill Co. *ETTL* Method *Hand auger (0-5'); hollow stem auger (5-15.5')*

Driller *Rich Herman* Log By *Wesley Garcia* Date *1/16/19* Driller # *59385M*

Checked By *Bill Foss* License No. *TX290*

COMMENTS

Auger refusal at 11'. Used mud bit inside auger to break through cemented layer. 4" PV well set at 15.5' with 10' of 0.010" slot screen. Filter pack of 20/40 Sand at 4.5-15.5'. Bentonite chips 2.5-4.5' in in 12" lifts, hydrated between lifts. Grout 0-2.5' placed2 hours after bentonite hydration.

Depth (ft.)	Well Completion	PID (ppm)	Sample ID % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0						Hand augered for utility clearance. Lithology not recorded.
6					CL	**SILTY CLAY**; dark yellowish brown (10YR 4/6), stiff, moist, roots, trace Fe staining.
8					SC	**CLAYEY SAND**; pale brown (10YR 5/6), loose, saturated, trace silt.
10					CL	**SANDY CLAY**; yellowish brown (10YR 5/6), stiff, moist, silt, trace Fe staining.
12						**Cemented SILTSTONE**; very dark gray (10YR 3/1), dry.
14					CL	**SANDY CLAY**; very dark gray (10YR 3/1), hard, dry, lighter gray laminations.
16						**END OF BORING AT 15.5 FEET.**
18						
20						

Sample Collection Log

Project Name: **Longhorn AAP**

Location ID: **04WW01**

Project No: **501032**

Sampler(s): **Scott Beesinger**

FIELD CONDITIONS

Cloudy

SAMPLING INFORMATION

Sample No: 04WW01-190122

DATE/TIME: 1/22/2019 / 12:30

Pump Inlet Depth (ft): 22.00

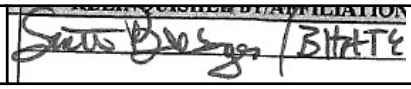
Sampling Method: Bladder Pump

Sample Purpose: REG

Sample Matrix: GW

Sample Notes:

Chain of Custody	COC Notes	Analysis Group	Analytic Method
ALSHT-012219	None	PERCHLORATE	6850

Sampler:		Scott Beesinger	
QC'ed By:		William A. Foss	2/12/2019

WELL AND PURGING INFORMATION

Measuring Point : Top of Casing

Casing ID (in.): 4

Depth to Water - Initial (DTWi) (ft) 7.33

Measured Depth of Well (ft): 27.28

Screen Interval (ft): 17.00 - 27.00

Pump Start Time: 1/22/2019 / 12:00

Purging Method/Equipment: Low Flow

Purge Start Date/Time: 1/22/2019 / 12:00

Purge End Date/Time: 1/22/2019 / 12:30

PID Reading: N/A

Sample Collection Log

APTIM

Location ID: 04WW01		Sample No: 04WW01-190122								
Date of Reading	**Time of Reading**	**Purge Rate**	**Total Purge**	**DTW**	**Cond.**	**Temp.**	**pH**	**Turbidity**	**ORP**	**DO**
		(ml/min)	**(L)**	**(ft)**	**(mS/cm)**	**(°C)**		**(NTU)**	**(mV)**	**(mg/L)**
	Purge Stabilization Criteria	-	-	Drawdown limit 0.3 ft	±10%		±0.1 units	No criteria		± 10% or 0.2 mg/L
1/22/2019	12:05	100	0.50	7.41	3.13	16.26	6.83	22.0	319	0.80
1/22/2019	12:10	100	1.0	7.46	3.10	16.36	6.41	14.6	324	0.39
1/22/2019	12:15	100	1.5	7.50	3.10	16.36	6.20	11.8	326	0.16
1/22/2019	12:20	100	2.0	7.53	3.10	16.37	6.19	11.5	326	0.15
1/22/2019	12:25	100	2.5	7.55	3.10	16.38	6.18	11.1	327	0.16
1/22/2019	12:30	100	3.0	7.56	3.10	16.39	6.17	10.9	327	0.15

Sample Collection Log

APTIM

Project Name: **Longhorn AAP**

Location ID: **04WW02**

Project No: **501032**

Sampler(s): **Scott Beesinger**

FIELD CONDITIONS

Clear

SAMPLING INFORMATION

Sample No: 04WW02-190121

DATE/TIME: 1/21/2019 / 09:55

Pump Inlet Depth (ft): 21.00

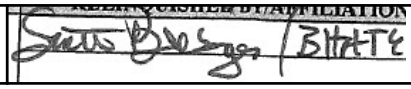
Sampling Method: Bladder Pump

Sample Purpose: REG

Sample Matrix: GW

Sample Notes:

Chain of Custody	COC Notes	Analysis Group	Analytic Method
ALSHT-012119	None	PERCHLORATE	6850

Sampler:		Scott Beesinger	
QC'ed By:		William A. Foss	2/12/2019

WELL AND PURGING INFORMATION

Measuring Point : Top of Casing

Purging Method/Equipment: Low Flow

Casing ID (in.): 4"

Purge Start Date/Time: 1/21/2019 / 09:25

Depth to Water - Initial (DTWi) (ft) 6.47

Purge End Date/Time: 1/21/2019 / 09:55

Measured Depth of Well (ft): 26.73

PID Reading: N/A

Screen Interval (ft): 16.00 - 26.00

Pump Start Time: 1/21/2019 / 09:25

Sample Collection Log

APTIM

Location ID: 04WW02		Sample No: 04WW02-190121								
Date of Reading	**Time of Reading**	**Purge Rate**	**Total Purge**	**DTW**	**Cond.**	**Temp.**	**pH**	**Turbidity**	**ORP**	**DO**
		(ml/min)	**(L)**	**(ft)**	**(mS/cm)**	**(°C)**		**(NTU)**	**(mV)**	**(mg/L)**
	Purge Stabilization Criteria	-	-	Drawdown limit 0.3 ft	±10%		±0.1 units	No criteria		± 10% or 0.2 mg/L
1/21/2019	09:30	100	0.50	6.52	0.446	16.22	6.94	55.60	250	0.85
1/21/2019	09:35	100	1.0	6.58	0.435	16.70	6.62	20.0	230	0.63
1/21/2019	09:40	100	1.50	6.62	0.433	16.91	6.43	8.30	224	0.58
1/21/2019	09:45	100	2.0	6.65	0.432	16.99	6.42	6.0	223	0.57
1/21/2019	09:50	100	2.5	6.67	0.432	17.06	6.41	5.7	222	0.57
1/21/2019	09:55	100	3.0	6.69	0.432	17.13	6.40	4.50	221	0.56

Sample Collection Log

APTIM

Project Name: **Longhorn AAP**

Location ID: **04WW03**

Project No: **501032**

Sampler(s): **Scott Beesinger**

FIELD CONDITIONS

Clear

SAMPLING INFORMATION

Sample No: 04WW03-190121

DATE/TIME: 1/21/2019 / 09:00

Pump Inlet Depth (ft): 21.00

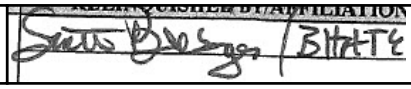
Sampling Method: Bladder Pump

Sample Purpose: REG

Sample Matrix: GW

Sample Notes:

Chain of Custody	COC Notes	Analysis Group	Analytic Method
ALSHT-012119	None	PERCHLORATE	6850

Sampler:		Scott Beesinger	
QC'ed By:		William A. Foss	2/12/2019

WELL AND PURGING INFORMATION

Measuring Point : Top of Casing

Casing ID (in.): 4"

Depth to Water - Initial (DTWi) (ft) 6.57

Measured Depth of Well (ft): 26.88

Screen Interval (ft): 16.00 - 26.00

Pump Start Time: 1/21/2019 / 08:30

Purging Method/Equipment: Low Flow

Purge Start Date/Time: 1/21/2019 / 08:30

Purge End Date/Time: 1/21/2019 / 09:00

PID Reading: N/A

APTIM

Sample Collection Log

Location ID: 04WW03				Sample No: 04WW03-190121						
Date of Reading	**Time of Reading**	**Purge Rate**	**Total Purge**	**DTW**	**Cond.**	**Temp.**	**pH**	**Turbidity**	**ORP**	**DO**
		(ml/min)	**(L)**	**(ft)**	**(mS/cm)**	**(°C)**		**(NTU)**	**(mV)**	**(mg/L)**
	Purge Stabilization Criteria	-	-	Drawdown limit 0.3 ft	±10%		±0.1 units	No criteria		± 10% or 0.2 mg/L
1/21/2019	08:35	100	0.50	6.63	1.17	12.15	7.33	29.5	299	3.68
1/21/2019	08:40	100	1.0	6.69	1.13	12.67	7.05	7.5	260	3.25
1/21/2019	08:45	100	1.5	6.73	1.13	12.95	7.04	3.9	256	3.19
1/21/2019	08:50	100	2.0	1.76	1.12	13.04	7.03	2.6	255	3.17
1/21/2019	08:55	100	2.5	6.78	1.12	13.12	7.03	2.0	254	3.15
1/21/2019	09:00	100	3.0	6.79	1.12	13.18	7.03	1.3	254	3.14

Sample Collection Log

APTIM

Project Name: **Longhorn AAP**

Project No: **501032**

Location ID: **04WW04**

Sampler(s): **Scott Beesinger**

FIELD CONDITIONS

Clear

SAMPLING INFORMATION

Sample No: 04WW04-190121

DATE/TIME: 1/21/2019 / 12:30

Pump Inlet Depth (ft): 16.00

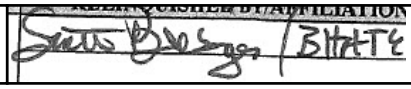
Sampling Method: Bladder Pump

Sample Purpose: REG

Sample Matrix: GW

Sample Notes:

Chain of Custody	COC Notes	Analysis Group	Analytic Method
ALSHT-012119	None	PERCHLORATE	6850

Sampler:		Scott Beesinger	
QC'ed By:		William A. Foss	2/12/2019

WELL AND PURGING INFORMATION

Measuring Point : Top of Casing

Casing ID (in.): 2

Depth to Water - Initial (DTWi) (ft) 5.68

Measured Depth of Well (ft): 21.6

Screen Interval (ft): 11.00 - 21.00

Pump Start Time: 1/21/2019 / 12:00

Purging Method/Equipment: Bladder Pump

Purge Start Date/Time: 1/21/2019 / 12:00

Purge End Date/Time: 1/21/2019 / 12:30

PID Reading: N/A

Sample Collection Log

APTIM

Location ID: 04WW04		Sample No: 04WW04-190121								
Date of Reading	**Time of Reading**	**Purge Rate**	**Total Purge**	**DTW**	**Cond.**	**Temp.**	**pH**	**Turbidity**	**ORP**	**DO**
		(ml/min)	**(L)**	**(ft)**	**(mS/cm)**	**(°C)**		**(NTU)**	**(mV)**	**(mg/L)**
	Purge Stabilization Criteria	-	-	Drawdown limit 0.3 ft	±10%		±0.1 units	No criteria		± 10% or 0.2 mg/L
1/21/2019	12:05	100	0.5	5.75	0.418	15.34	6.20	110	24	0.78
1/21/2019	12:10	100	1.0	5.81	0.419	16.30	6.33	93	2	0.39
1/21/2019	12:15	100	1.5	5.85	0.425	16.67	6.33	88.9	-6	0.15
1/21/2019	12:20	100	2.0	5.88	0.425	16.74	6.33	88.5	-7.0	0.15
1/21/2019	12:25	100	2.5	5.90	0.426	16.85	6.33	88.1	-8.0	0.16
1/21/2019	12:30	100	3.0	5.91	0.426	16.95	6.33	87.7	-8	0.15

Sample Collection Log

APTIM

Project Name: **Longhorn AAP**

Project No: **501032**

Location ID: **04WW05**

Sampler(s): **Scott Beesinger**

FIELD CONDITIONS

SAMPLING INFORMATION

Sample No: 04WW05-190121

DATE/TIME: 1/21/2019 / 13:20

Pump Inlet Depth (ft): 24.00

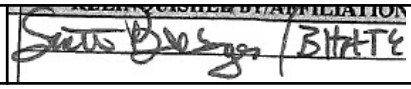
Sampling Method: Bladder Pump

Sample Purpose: REG

Sample Matrix: GW

Sample Notes:

Chain of Custody	COC Notes	Analysis Group	Analytic Method
ALSHT-012119	None	PERCHLORATE	6850

Sampler:		Scott Beesinger	
QC'ed By:		William A. Foss	2/12/2019

WELL AND PURGING INFORMATION

Measuring Point : Top of Casing

Casing ID (in.): 2

Depth to Water - Initial (DTWi) (ft) 6.78

Measured Depth of Well (ft): 29.63

Screen Interval (ft): 19.00 - 29.00

Pump Start Time: 1/21/2019 / 12:50

Purging Method/Equipment: Bladder Pump

Purge Start Date/Time: 1/21/2019 / 12:50

Purge End Date/Time: 1/21/2019 / 13:20

PID Reading: N/A

Sample Collection Log

APTIM

Location ID: 04WW05		Sample No: 04WW05-190121								
Date of Reading	**Time of Reading**	**Purge Rate**	**Total Purge**	**DTW**	**Cond.**	**Temp.**	**pH**	**Turbidity**	**ORP**	**DO**
		(ml/min)	**(L)**	**(ft)**	**(mS/cm)**	**(°C)**		**(NTU)**	**(mV)**	**(mg/L)**
	Purge Stabilization Criteria	-	-	Drawdown limit 0.3 ft	±10%		±0.1 units	No criteria		± 10% or 0.2 mg/L
1/21/2019	12:55	100	0.50	6.85	0.577	16.93	6.43	39.3	73	2.12
1/21/2019	13:00	100	1.0	6.90	0.583	17.30	6.34	35.6	130	1.79
1/21/2019	13:05	100	1.5	6.94	0.583	17.57	6.27	33.5	160	1.65
1/21/2019	13:10	100	2.0	6.97	0.584	17.65	6.26	33.1	161	1.64
1/21/2019	13:15	100	2.5	6.99	0.584	17.70	6.26	32.8	162.0	1.63
1/21/2019	13:20	100	3.0	7.0	0.584	17.73	6.25	32.6	163	1.62

Sample Collection Log

APTIM

Project Name: **Longhorn AAP**

Project No: **501032**

Location ID: **04WW06**

Sampler(s): **Scott Beesinger**

FIELD CONDITIONS

Clear

SAMPLING INFORMATION

Sample No: 04WW06-190121

DATE/TIME: 1/21/2019 / 10:50

Pump Inlet Depth (ft): 23.00

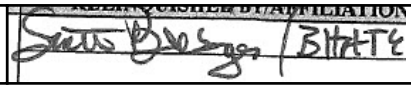
Sampling Method: Bladder Pump

Sample Purpose: REG

Sample Matrix: GW

Sample Notes:

Chain of Custody	COC Notes	Analysis Group	Analytic Method
ALSHT-012119	None	PERCHLORATE	6850

Sampler:		Scott Beesinger	
QC'ed By:		William A. Foss	2/12/2019

WELL AND PURGING INFORMATION

Measuring Point : Top of Casing

Casing ID (in.): 4

Depth to Water - Initial (DTWi) (ft) 5.53

Measured Depth of Well (ft): 28.14

Screen Interval (ft): 18.00 - 28.00

Pump Start Time: 1/21/2019 / 10:20

Purging Method/Equipment: Low Flow

Purge Start Date/Time: 1/21/2019 / 10:20

Purge End Date/Time: 1/21/2019 / 10:50

PID Reading: N/A

Sample Collection Log

APTIM

Location ID: 04WW06		Sample No: 04WW06-190121								
Date of Reading	**Time of Reading**	**Purge Rate**	**Total Purge**	**DTW**	**Cond.**	**Temp.**	**pH**	**Turbidity**	**ORP**	**DO**
		(ml/min)	**(L)**	**(ft)**	**(mS/cm)**	**(°C)**		**(NTU)**	**(mV)**	**(mg/L)**
	Purge Stabilization Criteria	-	-	Drawdown limit 0.3 ft	±10%		±0.1 units	No criteria		± 10% or 0.2 mg/L
1/21/2019	10:25	100	0.50	5.60	1.33	15.57	6.83	2.0	266	3.19
1/21/2019	10:30	100	1.0	5.65	1.36	15.98	6.80	1.9	263	3.0
1/21/2019	10:35	100	1.50	5.69	1.36	16.02	6.76	1.8	263	2.88
1/21/2019	10:40	100	2.0	5.72	1.37	16.10	6.75	2.0	264	2.85
1/21/2019	10:45	100	2.5	5.74	1.37	16.16	6.75	2.3	263	2.83
1/21/2019	10:50	100	3.0	5.75	1.37	16.20	6.75	2.1	264	2.82

Sample Collection Log

APTIM

Project Name: **Longhorn AAP**

Project No: **501032**

Location ID: **04WW07**

Sampler(s): **Scott Beesinger**

FIELD CONDITIONS

Cloudy

SAMPLING INFORMATION

Sample No: 04WW07-190122

DATE/TIME: 1/22/2019 / 11:40

Pump Inlet Depth (ft): 17.50

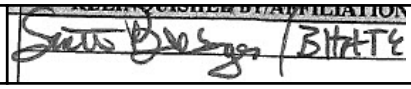
Sampling Method: Bladder Pump

Sample Purpose: REG

Sample Matrix: GW

Sample Notes:

Chain of Custody	COC Notes	Analysis Group	Analytic Method
ALSHT-012219	None	PERCHLORATE	6850

Sampler:		Scott Beesinger	
QC'ed By:		William A. Foss	2/12/2019

WELL AND PURGING INFORMATION

Measuring Point : Top of Casing

Casing ID (in.): 4

Depth to Water - Initial (DTWi) (ft) 6.63

Measured Depth of Well (ft): 22.7

Screen Interval (ft): 12.50 - 22.50

Pump Start Time: 1/22/2019 / 11:10

Purging Method/Equipment: Low Flow

Purge Start Date/Time: 1/22/2019 / 11:10

Purge End Date/Time: 1/22/2019 / 11:40

PID Reading: N/A

Sample Collection Log

APTIM

Location ID: 04WW07		Sample No: 04WW07-190122								
Date of Reading	**Time of Reading**	**Purge Rate**	**Total Purge**	**DTW**	**Cond.**	**Temp.**	**pH**	**Turbidity**	**ORP**	**DO**
		(ml/min)	**(L)**	**(ft)**	**(mS/cm)**	**(°C)**		**(NTU)**	**(mV)**	**(mg/L)**
	Purge Stabilization Criteria	-	-	Drawdown limit 0.3 ft	±10%		±0.1 units	No criteria		± 10% or 0.2 mg/L
1/22/2019	11:15	100	0.5	6.70	5.55	16.29	6.43	0.0	344	2.12
1/22/2019	11:20	100	1.0	6.75	4.30	16.72	6.34	0.0	341	1.94
1/22/2019	11:25	100	1.50	6.79	4.19	16.79	6.25	0.0	338	1.88
1/22/2019	11:30	100	2.0	6.81	4.18	16.86	6.24	0.0	337	1.86
1/22/2019	11:35	100	2.5	6.83	4.18	16.94	6.23	0.0	336	1.84
1/22/2019	11:40	100	3.0	6.84	4.17	17.0	6.22	0.0	336	1.83

Sample Collection Log

APTIM

Project Name: **Longhorn AAP**

Location ID: **04WW09**

Project No: **501032**

Sampler(s): **Scott Beesinger**

FIELD CONDITIONS

Cloudy

SAMPLING INFORMATION

Sample No: 04WW09-190122

DATE/TIME: 1/22/2019 / 09:05

Pump Inlet Depth (ft): 18.00

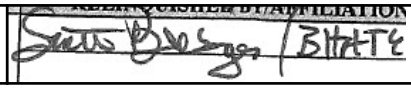
Sampling Method: Bladder Pump

Sample Purpose: REG

Sample Matrix: GW

Sample Notes: 04WW09-190122-FD Also Collected

Chain of Custody	COC Notes	Analysis Group	Analytic Method
ALSHT-012219	None	PERCHLORATE	6850

Sampler:		Scott Beesinger	
QC'ed By:		William A. Foss	2/12/2019

WELL AND PURGING INFORMATION

Measuring Point : Top of Casing

Purging Method/Equipment: Low Flow

Casing ID (in.): 4

Purge Start Date/Time: 1/22/2019 / 08:35

Depth to Water - Initial (DTWi) (ft) 6.5

Purge End Date/Time: 1/22/2019 / 09:05

Measured Depth of Well (ft): 23.53

PID Reading: N/A

Screen Interval (ft): 13.00 - 23.00

Pump Start Time: 1/22/2019 / 08:35

APTIM

Sample Collection Log

Location ID: 04WW09		Sample No: 04WW09-190122								
Date of Reading	**Time of Reading**	**Purge Rate**	**Total Purge**	**DTW**	**Cond.**	**Temp.**	**pH**	**Turbidity**	**ORP**	**DO**
		(ml/min)	**(L)**	**(ft)**	**(mS/cm)**	**(°C)**		**(NTU)**	**(mV)**	**(mg/L)**
	Purge Stabilization Criteria	-	-	Drawdown limit 0.3 ft	±10%		±0.1 units	No criteria		± 10% or 0.2 mg/L
1/22/2019	08:40	100	0.50	6.58	0.561	16.65	6.40	49.4	327	6.51
1/22/2019	08:45	100	1.0	6.64	0.563	17.40	6.10	17.8	327	6.05
1/22/2019	08:50	100	1.5	6.68	0.563	17.60	6.03	7.30	327	5.85
1/22/2019	08:55	100	2.0	6.71	0.562	17.68	6.02	5.9	327	5.83
1/22/2019	09:00	100	2.5	6.73	0.562	17.75	6.02	4.5	326	5.80
1/22/2019	09:05	100	3.0	6.74	0.562	17.81	6.02	3.2	326	5.78

Sample Collection Log

APTIM

Project Name: **Longhorn AAP**

Project No: **501032**

Location ID: **04WW10**

Sampler(s): **Scott Beesinger**

FIELD CONDITIONS

Cloudy

SAMPLING INFORMATION

Sample No: 04WW10-190122

DATE/TIME: 1/22/2019 / 09:55

Pump Inlet Depth (ft): 17.00

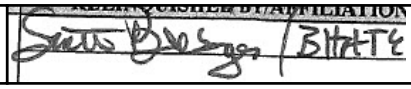
Sampling Method: Bladder Pump

Sample Purpose: REG

Sample Matrix: GW

Sample Notes:

Chain of Custody	COC Notes	Analysis Group	Analytic Method
ALSHT-012219	None	PERCHLORATE	6850

Sampler:		Scott Beesinger	
QC'ed By:		William A. Foss	2/12/2019

WELL AND PURGING INFORMATION

Measuring Point : Top of Casing

Casing ID (in.): 4

Depth to Water - Initial (DTWi) (ft) 6.79

Measured Depth of Well (ft): 22.53

Screen Interval (ft): 12.00 - 22.00

Pump Start Time: 1/22/2019 / 09:25

Purging Method/Equipment: Low Flow

Purge Start Date/Time: 1/22/2019 / 09:25

Purge End Date/Time: 1/22/2019 / 09:55

PID Reading: N/A

Sample Collection Log

APTIM

Location ID: 04WW10		Sample No: 04WW10-190122								
Date of Reading	**Time of Reading**	**Purge Rate**	**Total Purge**	**DTW**	**Cond.**	**Temp.**	**pH**	**Turbidity**	**ORP**	**DO**
		(ml/min)	**(L)**	**(ft)**	**(mS/cm)**	**(°C)**		**(NTU)**	**(mV)**	**(mg/L)**
	Purge Stabilization Criteria	-	-	Drawdown limit 0.3 ft	±10%		±0.1 units	No criteria		± 10% or 0.2 mg/L
1/22/2019	09:30	100	0.50	6.87	1.12	15.48	6.27	7.50	325	4.14
1/22/2019	09:35	100	1.0	6.93	1.17	15.55	6.0	4.6	327	3.78
1/22/2019	09:40	100	1.5	6.98	1.17	15.56	5.66	4.1	331	3.65
1/22/2019	09:45	100	2.0	7.01	1.17	15.56	5.64	3.7	332	3.63
1/22/2019	09:50	100	2.5	7.03	1.17	15.57	5.63	3.2	332	3.61
1/22/2019	09:55	100	3.0	7.04	1.17	15.58	5.62	2.7	333	3.59

Sample Collection Log

APTIM

Project Name: **Longhorn AAP**

Location ID: **04WW11**

Project No: **501032**

Sampler(s): **Scott Beesinger**

FIELD CONDITIONS

Cloudy

SAMPLING INFORMATION

Sample No: 04WW11-190122

DATE/TIME: 1/22/2019 / 08:20

Pump Inlet Depth (ft): 13.50

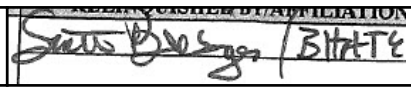
Sampling Method: Bladder Pump

Sample Purpose: REG

Sample Matrix: GW

Sample Notes:

Chain of Custody	COC Notes	Analysis Group	Analytic Method
ALSHT-012219	None	PERCHLORATE	6850

Sampler:		Scott Beesinger	
QC'ed By:		William A. Foss	2/12/2019

WELL AND PURGING INFORMATION

Measuring Point : Top of Casing

Purging Method/Equipment: Low Flow

Casing ID (in.): 4

Purge Start Date/Time: 1/22/2019 / 07:50

Depth to Water - Initial (DTWi) (ft) 5.13

Purge End Date/Time: 1/22/2019 / 08:20

Measured Depth of Well (ft): 18.53

PID Reading: N/A

Screen Interval (ft): 8.5 - 18.5

Pump Start Time: 1/22/2019 / 07:50

APTIM

Sample Collection Log

Location ID: 04WW11				Sample No: 04WW11-190122						
Date of Reading	**Time of Reading**	**Purge Rate**	**Total Purge**	**DTW**	**Cond.**	**Temp.**	**pH**	**Turbidity**	**ORP**	**DO**
		(ml/min)	**(L)**	**(ft)**	**(mS/cm)**	**(°C)**		**(NTU)**	**(mV)**	**(mg/L)**
	Purge Stabilization Criteria	-	-	Drawdown limit 0.3 ft	±10%		±0.1 units	No criteria		± 10% or 0.2 mg/L
1/22/2019	07:55	100	0.50	5.20	0.747	13.60	6.13	11.6	334	2.24
1/22/2019	08:00	100	1.0	5.26	0.723	13.55	6.63	7.1	332	1.87
1/22/2019	08:05	100	1.5	5.30	0.717	13.57	6.91	6.2	325	1.62
1/22/2019	08:10	100	2.0	5.33	0.716	13.59	6.93	5.7	324	1.60
1/22/2019	08:15	100	2.5	5.35	0.716	13.60	6.94	5.3	323	1.58
1/22/2019	08:20	100	3.0	5.36	0.716	13.62	6.95	4.8	323	1.57

Sample Collection Log

APTIM

Project Name: **Longhorn AAP**

Location ID: **LHSMW01**

Project No: **501032**

Sampler(s): **Scott Beesinger**

FIELD CONDITIONS

Cloudy

SAMPLING INFORMATION

Sample No: LHSMW01-190122

DATE/TIME: 1/22/2019 / 10:50

Pump Inlet Depth (ft): 12.50

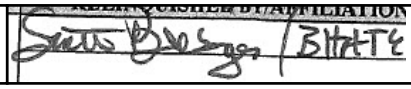
Sampling Method: Bladder Pump

Sample Purpose: REG

Sample Matrix: GW

Sample Notes: LHSMW01-190122-MS/MSD Also Collected

Chain of Custody	COC Notes	Analysis Group	Analytic Method
ALSHT-012219	None	PERCHLORATE	6850

Sampler:		Scott Beesinger	
QC'ed By:		William A. Foss	2/12/2019

WELL AND PURGING INFORMATION

Measuring Point : Top of Casing

Purging Method/Equipment: Low Flow

Casing ID (in.): 4

Purge Start Date/Time: 1/22/2019 / 10:20

Depth to Water - Initial (DTWi) (ft) 4.45

Purge End Date/Time: 1/22/2019 / 10:50

Measured Depth of Well (ft): 18.03

PID Reading: N/A

Screen Interval (ft): 7.50 - 17.50

Pump Start Time: 1/22/2019 / 10:20

Sample Collection Log

APTIM

Location ID: LHSMW01		Sample No: LHSMW01-190122								
Date of Reading	**Time of Reading**	**Purge Rate**	**Total Purge**	**DTW**	**Cond.**	**Temp.**	**pH**	**Turbidity**	**ORP**	**DO**
		(ml/min)	**(L)**	**(ft)**	**(mS/cm)**	**(°C)**		**(NTU)**	**(mV)**	**(mg/L)**
	Purge Stabilization Criteria	-	-	Drawdown limit 0.3 ft	±10%		±0.1 units	No criteria		± 10% or 0.2 mg/L
1/22/2019	10:25	100	0.50	4.52	3.19	15.01	5.87	0.0	335	1.09
1/22/2019	10:30	100	1.0	4.57	2.98	15.16	5.50	0.0	348	0.40
1/22/2019	10:35	100	1.50	4.60	2.95	15.15	5.37	0.0	362	0.18
1/22/2019	10:40	100	2.0	4.62	2.95	15.14	5.36	0.0	363	0.18
1/22/2019	10:45	100	2.50	4.63	2.94	15.13	5.35	0.0	364	0.17
1/22/2019	10:50	100	3.0	4.63	2.94	15.13	5.34	0.0	365	0.17

Sample Collection Log

APTIM

Project Name: **Longhorn AAP**

Location ID: **LHSMW02**

Project No: **501032**

Sampler(s): **Scott Beesinger**

FIELD CONDITIONS

Sunny

SAMPLING INFORMATION

Sample No: LHSMW02-190121

DATE/TIME: 1/21/2019 / 11:40

Pump Inlet Depth (ft): 13.50

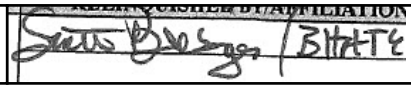
Sampling Method: Bladder Pump

Sample Purpose: REG

Sample Matrix: GW

Sample Notes:

Chain of Custody	COC Notes	Analysis Group	Analytic Method
ALSHT-012119	None	PERCHLORATE	6850

Sampler:		Scott Beesinger	
QC'ed By:		William A. Foss	2/12/2019

WELL AND PURGING INFORMATION

Measuring Point : Top of Casing

Purging Method/Equipment: Low Flow

Casing ID (in.): 4

Purge Start Date/Time: 1/21/2019 / 11:10

Depth to Water - Initial (DTWi) (ft) 12.22

Purge End Date/Time: 1/21/2019 / 11:40

Measured Depth of Well (ft): 19.08

PID Reading: N/A

Screen Interval (ft): 8.50 - 18.50

Pump Start Time: 1/21/2019 / 11:10

Sample Collection Log

APTIM

Location ID: LHSMW02				Sample No: LHSMW02-190121						
Date of Reading	**Time of Reading**	**Purge Rate**	**Total Purge**	**DTW**	**Cond.**	**Temp.**	**pH**	**Turbidity**	**ORP**	**DO**
		(ml/min)	**(L)**	**(ft)**	**(mS/cm)**	**(°C)**		**(NTU)**	**(mV)**	**(mg/L)**
	Purge Stabilization Criteria	-	-	Drawdown limit 0.3 ft	±10%		±0.1 units	No criteria		± 10% or 0.2 mg/L
1/21/2019	11:15	100	0.5	12.30	0.307	13.48	6.87	39.9	276	3.45
1/21/2019	11:20	100	1.0	12.36	0.287	14.10	6.28	36.8	292	3.38
1/21/2019	11:25	100	1.5	12.39	0.279	14.14	6.12	31.7	297	3.30
1/21/2019	11:30	100	2.0	12.42	0.278	14.17	6.11	31.2	298	3.28
1/21/2019	11:35	100	2.5	12.44	0.278	14.20	6.10	30.9	299	3.27
1/21/2019	11:40	100	3.0	1246	0.278	14.24	6.09	30.5	299	3.26

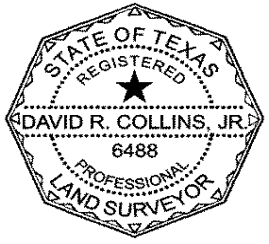
LONGHORN ARMY AMMUNITION PLANT (LHAAP) - KARNACK, TEXAS

PREPARED FOR APTIM Federal Services, LLC.

2500 CityWest Blvd, Suite 1700

Houston, Texas 77042

	TEXAS STATE PLANE COORDINATE SYSTEM NORTH CENTRAL ZONE (4202), 1983 NORTH AMERICAN DATUM			
MONITORING WELL	NORTHING	EASTING	NAVD 88 ELEVATION	
	TOP OF CASING	TOP OF CASING	TOP OF CASING	GROUND
04WW06	6959225.38	3305871.99	215.63	212.52
04WW07	6959038.63	3306006.11	214.64	211.66
04WW08	6959148.15	3305963.41	214.82	212.07
04WW09	6959090.67	3305897.71	214.61	211.47
04WW10	6959041.73	3305928.94	213.67	210.40
04WW11	6959032.36	3305839.02	212.01	209.31
17WW19	6952718.36	3315313.67	180.08	176.63
17PZ01	6952783.40	3315662.50	177.22	174.14
17PZ02	6952764.55	3315647.64	177.75	174.57
17PZ03	6952773.35	3115739.59	177.76	174.69
17WW20	6952980.24	3315580.24	180.02	177.13
FLOWLINE CREEK 1	6958236.20	3307772.02	198.47 TOP BANK	191.49 FLOWLINE
FLOWLINE CREEK 2	6958026.38	3308220.92	196.62 TOP BANK	189.16 FLOWLINE



DAVID R. COLLINS, JR. R.P.L.S.#6488

SURVEY DATE: FEBRUARY 1, 2019

Appendix B

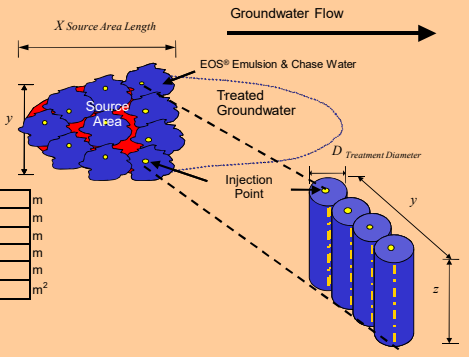
ISB Design Calculation Sheets

EOS® SOURCE AREA & DNAPL DESIGN WORKSHEET

U.S. Version 2.1f, Rev. Date: June 18, 2008
www.EOSRemediation.com

Help

Site Name:	Longhorn AAP	LHAAP04
Location:	Karnack, TX	
Project No.:	501032	



Step 1: Select a Substrate from the EOS® Family of Bioremediation Products

Substrate Selected (pick from drop down list): EOS® 598B42 (Preferred for Chlorinateds)
For Product Literature Click Here

Step 2: EOS® Consumption During Contaminant Biodegradation / Biotransformation

Section A: Source Area Dimensions

Length of treatment area parallel to groundwater flow, "x"	105	ft	32.0	m
Width of treatment area perpendicular to groundwater flow, "y"	105	ft	32.0	m
Minimum depth to contamination	12	ft	3.7	m
Maximum depth of contamination	20	ft	6.1	m
Treatment thickness, "z"	8	ft	2.4	m
Treatment zone cross-sectional area, A = y * z	840	ft²	78.0	m²

Section B: Groundwater Flow Rate / Site Data

Soil Characteristics

Nominal Soil Type (pick from drop down list)	Silty Sand			
Total Porosity (accept default or enter *n*)	0.30	(decimal)		
Effective Porosity (accept default or enter n_e)	0.28	(decimal)		
Soil bulk density; (1-n)*2.65 g/cc (accept calculated or enter dry bulk density)	1.86	g/cc	116	lbs / ft³
Fraction of organic carbon: foc	0.0050	range: 0.0001 to 0.01		

Hydraulic Characteristics

Hydraulic Conductivity (accept default or enter *K*)	0.099	ft/day	3.5E-05	cm/sec
Hydraulic Gradient (accept default or enter *i*)	0.028	ft/ft		

Note: Since the hydraulic gradient ($i = dh/dx$) is negative, we ask you to enter $-i$ in the EOS® Design Tool so that you can enter a positive number for convenience.

Non-reactive Transport Velocity, $V_x = -(K \times i) / n_e$	LESS THAN	0.01	ft/day	LESS THAN	0.003 m/day
Groundwater flow rate through treatment zone, $Q = -KiA$		17.42	gallons/day	LESS THAN	66.60 L/day

Section C: Calculated Contact Length

Contact time (τ) between oil and contaminants (accept default or enter τ)		60	typical values 60 to 180 days, see comment	
Calculated Contact Length (x) $= \tau * V_x$	Suggested Minimum	5.0	ft	1.5 m

Treatment zone volume	88,200	ft³	2,498	m³
Treatment zone groundwater volume (volume * porosity)	197,921	gallons	749,264	L

Section D: Design Lifespan For One Application

	5	year(s)	typical values 5 to 10 years
Estimated total groundwater volume treated over design life	229,707	gallons	870,811 L

Section E: Electron Acceptors

Dissolved Phase Electron Donor Demand

Inputs	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e⁻ equiv./ mole	Stoichiometry *Contaminant/ H_2 (wt/wt H_2)*	Hydrogen Demand ($g\ H_2$)
Dissolved Oxygen (DO)	0 to 8	3.59	32.0	4	7.94	393.8783374
Nitrate Nitrogen (NO_3^- - N)	1 to 10	10	62.0	5	12.30	707.7589029
Sulfate (SO_4^{2-})	10 to 500	20	96.1	8	11.91	1461.940169
Tetrachloroethene (PCE), C_2Cl_4			165.8	8	20.57	
Trichloroethene (TCE), C_2HCl_3			131.4	6	21.73	
cis-1,2-dichloroethene (c-DCE), $C_2H_2Cl_2$			96.9	4	24.05	
Vinyl Chloride (VC), C_2H_3Cl			62.5	2	31.00	
Carbon tetrachloride, CCl_4			153.8	8	19.08	
Chloroform, $CHCl_3$			119.4	6	19.74	
sym- tetrachloroethane, $C_2H_2Cl_4$			167.8	8	20.82	
1,1,1-Trichloroethane (TCA), CH_3CCl_3			133.4	6	22.06	
1,1-Dichloroethane (DCA), CH_2CHCl_2			99.0	4	24.55	
Chloroethane, C_2H_5Cl			64.9	2	32.18	
Perchlorate, ClO_4^-		10	99.4	8	12.33	706.1846342
Hexavalent Chromium, Cr[VI]			52.0	3	17.20	
User added						
User added						
User added						

Sorbed Phase Electron Donor Demand

The concentration of the sorbed contaminant can be estimated by: $C_{SOIL} = K_{OC} \times f_{oc} \times C_{WATER}$

Where: K_{oc} is partition coefficient with respect to organic carbon.
f_{oc} (fraction organic carbon) is the mass of organic matter in soil divided by the total mass of soil
C_{WATER} is the concentration of the contaminant in the groundwater

Default values for Koc taken from: US EPA, Superfund Section, APPENDIX K, Soil Organic Carbon (Koc) / Water (Kow) Partition Coefficients (Average Value Used)

Inputs Adjust *Koc* as necessary to provide site specific estimates or enter sediment concentration (C_{SOIL})	K_{oc} (L/kg)	C_{SOIL} (mg/Kg)	Mass (g)	Hydrogen Demand ($g\ H_2$)
Tetrachloroethene (PCE), C_2Cl_4	272			
Trichloroethene (TCE), C_2HCl_3	97			
cis-1,2-dichloroethene (c-DCE), $C_2H_2Cl_2$	38			
Vinyl Chloride (VC), C_2H_3Cl	241			
Carbon tetrachloride, CCl_4	158			
Chloroform, $CHCl_3$	53			
sym- tetrachloroethane, $C_2H_2Cl_4$	79			
1,1,1-Trichloroethane (TCA), CH_3CCl_3	139			
1,1-Dichloroethane (DCA), CH_2CHCl_2	54			
User added				
User added				
User added				

Section F: Additional Hydrogen Demand and Carbon Losses

Generation (Potential Amount Formed)	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e⁻ equiv./ mole	Stoichiometry *Contaminant / H_2*	Hydrogen Demand ($g\ H_2$)	DOC Released *(moles)*
Estimated Amount of $Fe2^+$ Formed	10 to 100	50	55.8	1	55.41	785.8272003	
Estimated Amount of Manganese (Mn^{2+}) Formed		5	54.9	2	27.25	159.760166	
Estimated Amount of CH_4 Formed	5 to 20	10	16.0	8	1.99	4376.798773	
Target Amount of DOC to Release	60 to 100	100	12.0				7250.11

Design Safety Factor: 2.0 typical values 1 to 3

Calculations assume:
1.) all reactions go to completion during passage through emulsified edible oil treated zone; and,
2.) perfect reaction stoichiometry.

EOS® Requirement Calculations Based on Hydrogen Demand and Carbon Losses

Stoichiometric Hydrogen Demand	37.9	pounds
DOC Released	827.8	pounds

EOS® Requirement Based on Hydrogen Demand and Carbon Loss
1,000 lbs

Step 3: EOS® Requirement Based on Attachment by Aquifer Material

Soil Characteristics

Effective treatment thickness, "z_e" (typically less than 40%)	0.25	
For Additional Information on Effective Thickness, Click Here		
Weight of sediment to be treated	2,553,475	lbs
Adsorptive Capacity of Soil (accept default or enter site specific value)	0.0020	lbs EOS® / lbs sediment

EOS® Attachment by Aquifer Material[1]
- Fine sand with some clay 0.001 to 0.002 lbs EOS® / lbs soil
- Sand with higher silt/clay content 0.002 to 0.004 lbs EOS® / lbs soil

[1]Default values provided based on laboratory studies completed by NCSU
For Additional Data, Click Here

EOS® Requirement Based on Oil Entrapment by Aquifer Material
5,107 lbs

Summary – How much EOS® do you need?

Suggested Quantity of EOS® for Your Project: 13 drums

Nutrient Dosing Calculation Sheet

Site Name: Longhorn AAP
Location: LHAAP-04
Project No.: 501032

Carbon content of soybean oil

Major component is linoleic acid				
$CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7\ CO_2CH_3$, or $C_{19}H_{34}O_2$				
Formula weight:	294.48	grams per mole		
Carbon content:	77.42%			

Carbon content of 93% soybean oil EVO

Density of EVO	8.10	pounds/gallon		
Mass of EVO	3,065	pounds		
Mass of EVO	1,390	killograms		
Volume of EVO	378	gallons		
55 gal drum of EVO	6.88	drums		
Grade of EVO	100%			
Mass of carbon	1,076.42	killograms		
Mass of carbon	2,368.13	pounds		

Nutrient demand based on 100C:10N:1P ratio

Carbon	2,368	pounds		
Nitrogen	237	pounds		
Phosphate	24	pounds		

Nutrient source required

DAP	**1,116**	lbs		

N & P content of nutrient sources

Diamoium Phosphate (DAP) solid (16-46-10)

	molecular wt.	atoms	total wt.	%
Nitrogen	14.0067	2	28.0134	21.21328922
Hydrogen	1.0079	9	9.0711	6.869136479
Phospate	30.9738	1	30.9738	23.45506713
Oxygen	15.9994	4	63.9976	48.46250717
		Total	**132.1**	**100**

100lbs of DAP =21.2 lbs of N

4.71 lbs DAP for 1 lb N

Accelerite®, liquid (JRW Bioremeiation)

5 gallons accelerite for 5.25 drums EVO

0.95238 gal accelrite/drum EVO

9.2 lbs accelerite/gal

LHAAP-04 Treatment Area Calculation Worksheet

Site Parameters	units	LHAAP 04
Target Width	feet	105
Target Length	feet	105
Treatment Interval	feet	8
Target Area Volume	cubic feet	88,200
Effective Porosity		0.28
Target Area Water Volume	cubic feet	24,696
Target Area Water Volume	gallons	184,726
Injection Radius of Influence	feet	10
Target Injection Volume (20%)	gallons	36,945
Amendment Volume Requirements		
Emulsified Vegetable Oil	pounds	3,065
Emulsified Vegetable Oil	gallons	367
Emulsified Vegetable Oil	drums	7
Nutrients (DAP)	pounds	1,116
Water	gallons	36,578
Volumes per Point		
Emulsified Vegetable Oil	gallons	15
Nutrients (DAP)	gallons	6
Water	gallons	1,463
Injection Parameters		
Injection Spacing	feet	20
Target Depth	ft bgs	20-Dec
Thickness	feet	8
Total Volume per Point	gallons	1,478
Volume per foot		185
Injection Rate	gpm	3
Injection Pressure (not to exceed)	psi	40
Time per Point	hours	9
Simultaneous Points	points	3
Hours of Injection per day	hours	8
Gallons per day	gallons	4,320
Points to be Completed (Injection Wells)	points	25
Days of Injection	days	9

Notes:
ft bgs - Feet below ground surface.
psi - Pound per square inch.
gpm - Gallons per minute.

Appendix C

Product Specification and Safety Data Sheets

Tech Brief

Enhanced Anaerobic Bioremediation

Tersus Environmental
For every zone of your plume, we've got you covered!

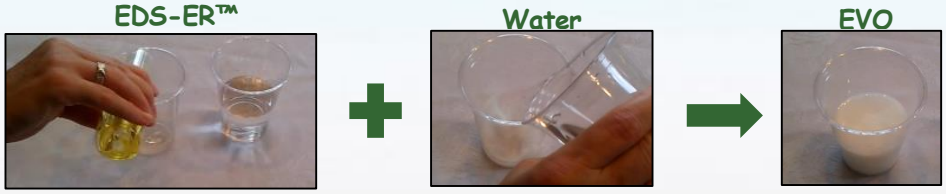
EDS-ER™

Electron Donor Solution – Extended Release

As delivered, the physical state of *EDS-ER*™ (electron donor solution – extended release) by Tersus Environmental is significantly different than standard emulsified vegetable oil (EVO) products. Whereas other EVO products are concentrated emulsions containing water, *EDS-ER*™ is a water-mixable oil; it contains no water. Thus, the costs for shipping EDS-ER are about 50% less than conventional products.

At room temperature, *EDS-ER*™ is a liquid material with an appearance and viscosity roughly equivalent to vegetable oil. Unlike common EVO products, *EDS-ER*™ will not separate, will not freeze, and has a shelf life of 2 years without spoilage.

Tersus Environmental is proud to announce that *EDS-ER*™ does NOT contain ethoxylated surfactants. As you may know, many environmental remediation injectates, such as emulsified vegetable oils use biodegradable non-ionic surfactants. Unfortunately, ethoxylation, the manufacturing process that creates these surfactants (e.g., polysorbates) often results in these products containing 1,4-dioxane.



Purpose

EDS-ER™ is a simple, safe, low-cost solution for the bioremediation of halogenated compounds (e.g., PCE, TCE, DCE, VC, TCA, CT, etc.), perchlorate, explosives such as aromatic nitrates, energetic munitions residuals, nitrates, acids, radionuclides, select oxidized heavy metals, and other contaminants.

Benefits

- 100% fermentable and contains no water
- Because the product is completely water mixable, the number of necessary injection points for low permeability structures decreases
- Easily mixes with water, simplifying field operations
- Controlled release of electron donors for up to five years
- Food-grade carbon source
- Low total dissolved solids to comply with secondary water quality requirements for amendments with low salt content
- Conforms to EPA's EPP (Environmentally Preferable Purchasing) and USDA biobased criteria
- Neutral pH when mixed with water
- Clean, low-cost, non-disruptive application (e.g., direct-push, wells and excavations)
- Lowers transportation costs when compared to other electron donors
- Over two years shelf life
- Freezing Point is -4 °F (-20 °C)

Field Application Design

EDS-ER™ applications are easily tailored to meet site-specific conditions. Typical configurations consist of grid and barrier patterns and application in excavations or trenches. The product's low viscosity allows subsurface distribution through direct-push injection points, hollow-stem augers or pumped through existing wells.

Packaging Options

- 55-gallon poly drums
- 275-gallon IBC containers
- 3,000 - 5,000 gallon tankers

tersusenv.com • tersusenv.fr • tersusenv.es
919.453.5577 • info@tersusenv.com

Rev: 2/11/2015

Electron Donor Solution

Section 1: Chemical Product and Company Identification

Product Name: Electron Donor Solution Extended Release
Catalog Codes: EDS-ER
CAS#: 8001-22-7
TSCA: TSCA 8(b) inventory: Soybean oil
HMIS Code: H F R P: 10 0 A
Trade Name and Synonyms: EDS-ER
Chemical Family: Glyceride Oils

Contact Information:
Tersus Environmental, LLC
109 E. 17th Street, Suite #3880
Cheyenne, WY 82001
Ph: 307.638.2822 • info@tersusenv.com
www.tersusenv.com
For emergency assistance, call: 919.638.7892

Section 2: Composition and Information on Ingredients

COMPONANT	CAS #	OSHA TWA	OSHA STEL	ACGIH TWA	ACGIH STEL
Soybean Oil	8001-22-7	---	10 mg/m^3	---	---
Vegetable Oil Derived Fatty Acid Esters	Confidential	---	---	---	---

HAZARDOUS INGREDIENTS: NONE AS DEFINED UNDER THE U.S. OSHA HAZARD COMMUNICATION STANDARD (29 CFR 1910.1200) OR THE CANADIAN HAZARDOUS PRODUCTS. ACT S.C. 1987, C.30 (PART 1).

THE PRECISE COMPOSITION OF THIS PRODUCT IS PROPRIETARY INFORMATION. A MORE COMPLETE DISCLOSURE WILL BE PROVIDED TO A PHYSICIAN IN THE EVENT OF A MEDICAL EMERGENCY.

SARA HAZARD: NONE NOTED (SECTION 311/312) TITLE III SECTION 313 - NOT LISTED
All components of this product are listed on the TSCA registry.

Section 3: Physical/Chemical Characteristics

BOILING RANGE: Not applicable VAPOR DENSITY: Exceeds 1.0

SPECIFIC GRAVITY (H20=1.0): 0.92 - 0.925 VAPOR PRESSURE: Not applicable

PERCENT VOLATILE BY VOLUME: 0%SOLUBILITY IN WATER: Miscible

EVAPORATION RATE: Not applicable
APPEARANCE AND ODOR: A pale yellow, oily liquid - only a faint odor.
WEIGHT PER GALLON: 7.7 lbs. at 60F.

Section 4: Fire and Explosion Data

FLAMMABILITY CLASSIFICATION: Combustible Liquid - Class IIIB.
FLASHPOINT: Greater than 550 F (288 C).
METHOD USED: Tag Closed Cup.
EXTINGUISHING MEDIA: CO2, dry chemical, foam, sand.
SPECIAL FIREFIGHTING PROCEDURES: Avoid use of water as it may spread fire by dispersing oil. Use water to keep fire-exposed containers cool. Water spray may be used to flush spills away from fire.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Rags soaked with any oil or solvent can present a fire hazard and should always be stored in UL Listed or Factory Mutual approved, covered containers. Improperly stored rags can create conditions that lead to oxidation. Oxidation, under certain conditions can lead to spontaneous combustion.

Section 5: Reactivity Data

STABILITY: Generally stable. Spontaneous combustion can occur. See Unusual Fire and Explosion Procedures, Section IV.

CONDITIONS TO AVOID: High surface area exposure to oxygen can result in polymerization and release of heat.

INCOMPATABILITY (MATERIALS TO AVOID): Avoid contact with strong oxidizing agents.

HAZARDOUS DECOMPOSITIONS OR BY-PRODUCTS: Decomposition may produce carbon dioxide and carbon monoxide.

HAZARDOUS POLYMERIZATION: Will not occur.

Section 6: Health Hazard Data

THRESHHOLD LIMIT VALUE: As a liquid - none. As oil mist - 10 mg/m3 total particulate.

INHALATION HEALTH RISKS AND SYMPTOMS OF EXPOSURE: Excessive inhalation of oil mist may affect the respiratory system. Oil mist is classified as a nuisance particulate by ACGIH.

SKIN ABSORPTION HEALTH RISKS AND SYMPTOMS OF EXPOSURE: Not classified as a primary skin irritant or corrosive material. Sensitive individuals may experience dermatitis after long exposure of oil on skin.

HEALTH HAZARDS (ACUTE AND CHRONIC): Acute: none observed by inhalation. Chronic: none reported.

EMERGENCY AND FIRST AID PROCEDURES FOR:

SKIN CONTACT: May be removed from skin by washing with soap and warm water.

EYE CONTACT: Immediately flush eyes with plenty of cool water for at least 15 minutes. Do NOT let victim rub eyes.

INHALATION: Immediately remove exposed individual to fresh air source. If victim has stopped breathing give artificial respiration, get medical attention immediately.

Section 7: Precautions for Safe Handling and Use

ENVIRONMENTAL PRECAUTIONS: Where large spills are possible, a comprehensive spill response plan should be developed and implemented.

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Wear appropriate respiratory protection and protective clothing as described in section VIII. Depending on quantity of spill: (a) Small spill - add solid adsorbent, shovel into disposable container and wash the area. Clean area with detergent. (b) Large spill - Squeegee or pump into holding container. Clean area with detergent. In the event of an uncontrolled release of this material, the user should determine if this release is reportable under applicable laws and regulations.

WASTE DISPOSAL METHOD: All recovered material should be packaged, labeled, transported, and disposed or reclaimed in accordance with local, state, and federal regulations and good engineering practices.

Section 8: Control Measures

RESPIRATORY PROTECTION: Not normally needed. A qualified health specialist should evaluate whether there is a need for respiratory protection under specific conditions.

VENTILATION: Handle in the presence of adequate ventilation. Intermittent clean air exchanges recommended, but not required.

PROTECTIVE GLOVES: Not normally needed. However, protective clothing is always recommended when handling chemicals.

EYE PROTECTION: Eye protection is always recommended when handling chemicals. Wear safety glasses meeting the specifications established in ANSI Standard Z87.1.

Section 9: Special Precautions

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Store away from flame, fire, and excessive heat.

Section 10: Disposal Considerations

General Information: Do not discharge into drains, watercourses or onto the ground. Discharge, treatment, or disposal may be subject to national, state, or local laws. Empty containers may contain product residues.

Disposal Methods: No specific disposal method required.

Container: Since emptied containers retain product residue, follow label warnings even after container is emptied.

Section 11: Transportation Information

DOT Not regulated.
TDG Not regulated.
IATA Not regulated.
IMDG Not regulated.

Section 12: Other Information

Hazard Ratings

	Health Hazard	Fire Hazard	Instability	Special Hazard
NFPA	1	1	0	NONE

Hazard rating: 0 - Minimal; 1 - Slight; 2 - Moderate; 3 - Serious; 4 - Severe
NFPA Label colored diamond code: Blue - Health; Red - Flammability; Yellow - Instability; White - Special Hazards

	Health Hazard	Flammability	Physical Hazard	Personal Protection
HMIS	1	1	0	--

Hazard rating: 0 - Minimal; 1 - Slight; 2 - Moderate; 3 - Serious; 4 - Severe
HMIS Label colored bar code: Blue - Health; Red - Flammability; Orange - Physical Hazards; White - Special

Section 13: Disclaimer and/or Comments

We suggest that containers be either professionally reconditioned for re-use by certified firms or properly disposed of by certified firms to help reduce the possibility of an accident. Disposal of containers should be in accordance with applicable federal, state and local laws and regulations. "Empty" drums should not be given to individuals.

The conditions of handling, storage, use and disposal of the product are beyond our control and may be beyond our knowledge. For this and other reasons, we do not assume responsibility and expressly disclaim liability for loss, damage or expense arising out of or in any way connected with the handling, storage, use or disposal of the product.

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Tersus Environmental be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if Tersus Environmental has been advised of the possibility of such damages.

Appendix D

Daily ISB Injection Log

APTIM

Drilling Company: ____________________ Area: __________ Injection Oversight: ____________________

Oversight Company: Aptim Federal Services, LLC Injection Operator: ____________________

Injection Point	Date	Pressure (psi)	Total Volume (gal)	Flow Rate (gpm)	Start	End	Comments
LHAAP-04							
Total Volume 0							

Contract No. W9128F-13-D-0012, Task Order No. W9128BV17F0150 • Draft Final • Rev 0 • April 2019

Appendix E

LUC Inspection and Maintenance Checklist and Compliance Certification

Annual Land Use Control Compliance Certification Form

In accordance with the Remedial Design dated _____ for LHAAP-04 an inspection of the site was conducted by _____ [indicate transferee] on _____.

The land use control mechanisms are:

- Groundwater restrictions - prohibit access to the contaminated groundwater except for environmental monitoring and testing only until cleanup goals are met;
- Land use restrictions - restrict land use to nonresidential;
- Integrity of remedial and monitoring systems - maintain the integrity of any current or future remedial or monitoring systems until cleanup goals are met.

No unauthorized activities or uses have occurred. Compliance with land use controls and restrictions is as follows:

- No use of groundwater (other than environmental testing and monitoring), installation of new groundwater wells, or tampering with existing monitoring wells;
- No land use other than nonresidential; and
- No activities that would compromise the integrity of the remedial or monitoring systems.

I, the undersigned, do document that the inspection was conducted as indicated above, and that the above information is true and correct to the best of my knowledge, information, and belief.

Date: _____

Name/Title: _____

Signature: _____

Annual compliance certification forms shall be completed no later than March 1 of each year for the previous calendar year, retained in the file and provided to Army, EPA and TCEQ upon request.

RAO Inspection and Maintenance Checklist

General Information	
Project Name	RAO Inspection and Maintenance, LHAAP-04 Longhorn Army Ammunition Plant, Karnack, TX
Contractor	
Inspector's Name	
Inspector's Title	
Inspector's Signature	
Inspector's Contact Number	
Inspection Date	
Type of Inspection	☐ Quarterly ☐ Semiannual ☐ Annual ☐ Prior to forecast rain ☐ After a rain event ☐ Other ----------

A. Groundwater Monitoring Wells						
D.1	Are the installed groundwater monitoring wells in poor condition?					
D.2	Is the well cleared of vegetation and accessible?					
D.3	Any other relevant observations?					
D.4	Are there any significant cracks present?					
D.5	Are there any damaged areas?					