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

June 20, 2018

DAIM-ODB-LO

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

Re: Draft Final Remedial Action Work Plan
LHAAP-16 Landfill
Final Record of Decision September 2016
Longhorn Army Ammunition Plant, Karnack, Texas

Dear Mr. Mayer,

Two hard copies (HC) and two compact discs (CDs) for the above-referenced document are being transmitted to you for your records. The document, which addresses LHAAP-16 groundwater, includes revisions based upon your comments on the Draft received on May 23, 2018. In accordance with the 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 within this Draft Final.

The document was revised by Bhate Environmental Associates, Inc. (Bhate) 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 (letter)
P. Bruckwicki, Caddo Lake NWR, TX (1 hard copy and 1 CD)
A. Williams, USACE, Tulsa District, OK (1CD)
N. Smith, USAEC, San Antonio, TX (1CD)

K. Nemmers, Bhate, Lakewood, CO (1 hard copy and 1 CD for project files)
P. Srivastav, APTIM, Houston, TX (1 hard copy and 1 CD for project files)

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

June 20, 2018

DAIM-ODB-LO

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

Re: Draft Final Remedial Action Work Plan
LHAAP-16 Landfill
Final Record of Decision dated September 2016
Longhorn Army Ammunition Plant, Karnack, Texas

Dear Ms. Palmie,

One hard copy (HC) and one compact disc (CD) for the above-referenced document are being transmitted to you for your records. The document, which addresses LHAAP-16 groundwater, includes revisions based upon your comments on the Draft received on March 19, 2018 and your concurrence to Army responses on May 14, 2018. In accordance with the 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 within this Draft Final.

The document was revised by Bhate Environmental Associates, Inc. (Bhate) 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 (letter only):
R. Mayer, USEPA, Region 6, Dallas, TX
P. Bruckwicki, Caddo Lake NWR, TX
A. Williams, USACE, Tulsa District, OK
N. Smith, USAEC, San Antonio, TX

K. Nemmers, Bhate, Lakewood, CO (for project files)
P. Srivastav, APTIM, Houston, TX (for project files)

Response to Comments on
Draft Remedial Action Work Plan, LHAAP-16 Landfill
Longhorn Army Ammunition Plant, Karnack Texas

Document Date: 28 February 2018
Comments Date: 28 March 2018

Reviewer: Mr. Richard Mayer, U.S. Environmental Protection Agency
Respondent: Dr. Rose Zeiler, U.S. Army

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/ Paragraph	Comment	C, D, E, or X[1]	Response	A or D[2]	Comment
1	Minor Editorial Comment	Please include the following acronyms in the acronyms section: Bhate, MEGA, MATC, and O&M. Please remove ECP, HASP, MARC, O_2, and SOP since these are not used in document. Please define in the text the first use of GWTP (page 3-2), ISEB (Figure 4-1), IWWP (page 4-3), mv (page 4-12), OSWER (page 5-1), and ROI (page 4-7).	C	Concur. Text will be revised accordingly.	A	
2	Page 1-5, Section 1.5, 2nd Paragraph	The text references Figure 2-1 in regards to typical depth of water below land surface. However, EPA could not locate well 16WW24 on the figure and there was no measurement collected on well 16WW42. Please include the data to document the depth to the water below land surface. Please modify text and/or figure.	C	Concur. The reference to 16WW24 will be removed from the text. The text and figures included in Appendix A are from the approved Final RD which did not provide the water elevation readings. A reference to the Remedial Design will be added to the text.	A	
3.	Page 4-4, Monitoring Wells	More than 1 hour should be allowed for the bentonite seal to hydrate before the cement grout is used for the remaining annulus.	C	Concur. The Standard Operating Procedure in the Draft Final Installation Wide Work Plan has been revised to include an additional two hours after the final bentonite lift for the bentonite seal to hydrate before grouting begins. Also, see response to TCEQ's Comment 6.	A	

Comment No.	Section/Page/ Paragraph	Comment	C, D, E, or X[1]	Response	A or D[2]	Comment
4.	Page 4-3, Section 4.3.2	IWWP reference should be updated to draft 2018 or 2017 as shown in references.	C	Concur. The IWWP reference throughout the RAWP and in the reference section will be updated to the Final IWWP published by Bhate in 2018.	A	
5.	Table 4-9	EPA is hesitant to approve the MNA and LTM wells at this time until the pre-remedy sampling and the year 1 and 2 performance monitoring has been implemented.		Noted. The list of MNA and LTM wells in the RAWP are from the EPA and TCEQ approved Final RD, and therefore, the locations were previously approved.	A	The MNA monitoring system may need to be refined in the future per effects of the various treatments being implemented.
6.	Page 4-13, Surface Water Monitoring	Please ensure that the surface water parameters are measured using a field instrument.	C	Concur. Surface water parameters like DO, pH, ORP, temperature and conductivity will be collected using a field instrument. A new table, Table 4-10 has been added which shows the surface water monitoring plan. Also see the response to TCEQ's Comment 9.	A	Section 4.7.8 should include a sentence mentioning that field parameters will be collected in the stream with a multi-parameter meter. ***Army Response**: The following will be inserted in Section 4.7.8, as the 2nd sentence of the 2nd paragraph:* *"As part of the surface water sample collection activities, field readings (DO, pH, ORP, temperature, and conductivity) will be collected instream with a multi-parameter meter."*
7.	Figure 1-3	In the legend there is a symbol for groundwater wells. Are these considered private home/irrigation wells? Some of these are located on Longhorn. Also, the well by the fire station is not a potable water well as the faucets in the firehouse have non-potable water signs on them.	C	Concur. The wells shown on Figure 1-3 are private wells, wells used for public supply and other wells used specifically by oil and gas companies. We received a comment from TCEQ about Figure 1-3, that the water wells shown on this figure may not be useful for remediation purpose. Figure 1-3 is being revised to remove the water wells, see the response to TCEQ's Comment 11.	A	

Comment No.	Section/Page/ Paragraph	Comment	C, D, E, or X[1]	Response	A or D[2]	Comment
8.	Figures 2-1 & 2-2	Were the extraction wells running when the groundwater elevation levels were taken?		The extraction was operational at the time of the groundwater elevation readings. Section 1.5, 2nd paragraph, 2nd sentence will be revised as follows: "Shallow groundwater elevation contours based on the last comprehensive groundwater elevations collected at the site when extraction was operational in June 2016 are shown on Figure 2-1 of **Appendix A**." Section 1.5, 3rd paragraph, 3rd sentence will be revised as follows: "The intermediate groundwater elevation contours based on the last comprehensive groundwater elevations collected at the site when extraction was operational in June 2016 are shown on Figure 2-2 of **Appendix A**."	A	
9.	Table 4-1	Not all the proposed wells for this site are included in this table. Please revise accordingly.	C	Concur. Table 4-1 will be revised to include all the proposed wells.	A	
10.	Table 4-3	EPA recommends adding upper deep monitoring well 16WW20.	D	Do not concur. The Pre-Remedy Sampling table is based on the Table 4-11 of the EPA and TCEQ approved Final RD. Well 16WW20 was not included in the approved Final RD for pre-remedy sampling.	A	EPA missed that deep well planned for sampling while reviewing the document.
11.	Table 4-5	Why are the performance parameters different for well 16IW04 vs. well 16IW03?		The performance parameters are from Table 4-14 of the approved Final RD approved by TCEQ and EPA. Well 16IW04 was not selected as a well for quarterly performance monitoring.	A	

Comment No.	Section/Page/ Paragraph	Comment	C, D, E, or X[1]	Response	A or D[2]	Comment
12.	Table 4-7	EPA recommends adding well 16WW56 as a monitoring well for performance effectiveness of the Bayou Biobarrier.	D	Do not concur. The list of performance monitoring wells in the RAWP is from the approved Final RD. Well 16WW56 was added as a MNA/LTM well in the Final RD. Wells 16RW12 and 16WW40, downgradient of the Bayou Biobarrier, were selected in the approved Final RD to monitor the effectiveness of the injections.	A	
13.	General Comment	The method for analyzing for perchlorate in groundwater should be 6850. Method 314.0 does not require filtering of the groundwater samples to remove microbes (which can biodegrade the perchlorate). Also, this method historically tends to have more false positive and negative analytical results.	C	Concur. We are aware of the limited ability of Method 314.0 to provide accurate and reliable results for perchlorate. Method 6850 will be used for analysis of perchlorate samples. The tables will be revised to include Method 6850. Method 6850 is included in the IWWP, UFP-QAPP.	A	
14.	General Comment	There should be a table for surface water samples monitoring plan such as Table 4-4 as an example to follow.	C	Concur. The RAWP has been revised to include Table 4-10 which shows the surface water monitoring plan and is attached to the TCEQ's RTCs.	A	
15.	Page 4-12, Section 4.7.5	The text indicates that Figure 4-3 shows locations of wells for monitoring, but the figure is for surface water collection locations. Please revise to Figure 4-2.	C	Concur. Text will be revised to reference Figure 4-2.	A	
16.	Page 4-9: Bullets	EPA assumes that some sort of sonde for DO will be used in the collection of DO readings in the Bayou. It is assumed DO changes throughout the day within the bayou naturally (suggest conducting a 24-hour monitoring with a logger during a sunny day and night to see diurnal effects to determine a baseline). What are the criteria for changes in DO in determining if the Injectate has reached the bayou?		A handheld YSI DO meter (or equivalent) will be used to collect readings from the bayou by placing the probe directly into the bayou. Baseline DO levels in the bayou will be collected prior to the injections into the Bayou Biobarrier. At least three baseline readings will be collected throughout a working day prior to injections. Also, see response to Comment 17. The following will be added to Section 4.6.4, page 4-9, lead in paragraph above the bullets:	A	

Comment No.	Section/Page/ Paragraph	Comment	C, D, E, or X[1]	Response	A or D[2]	Comment
				"The field readings will be collected using a hand held field instrument and readings will be recorded on field forms. The probe will be placed in the bayou for a direct reading from the bayou. If the carbon source reaches the bayou, the natural organisms will utilize the carbon and will create anaerobic conditions in the water which may impact aquatic life. If any sudden decrease in DO is observed to below baseline readings or a visual change is observed in the water (murkiness) along the bayou bank, injections will be suspended. Additional monitoring and visual observations will be conducted to determine if the decrease is from injection materials or changes in the environmental conditions. If injections are suspended, corrective actions (placement of aerators and/or hay bales) will be implemented if needed. Once DO has stabilized and no visual confirmation of injection materials into the bayou is confirmed, injections will resume."		
17.	Page 4-2, Item 4	Please identify where the baseline surface water samples will be collected and what constituents/parameters will be analyzed (in regards to potential injection leakage). EPA recommends moving surface water location 16SW02 more towards the left bend in Harrison Bayou based on where TCE was found in shallow groundwater (see Appendix A, Figure 2-6 and well number 16WW40, 1060 µg/L).		Pre-remedy surface water samples will be collected from 16SW01, 16SW02, and 16SW03. Samples will be analyzed for VOCs, perchlorate and metals. Additionally, field measurements (DO, ORP, pH, temperature, and conductivity) will also be collected. The surface water sampling plan is included in a new Table 4-10 (an attachment to TCEQ's RTCs). The location for 16SW02 was established in the EPA and TCEQ approved Final RD. Text in Section 4.2.1, bullet 4 will be revised as follows: "…as indicated in **Tables 4-2** and **4-3**. Collect pre-remedy surface water samples from three	A	EPA recommended the alternate location because it was close to the location of observed seeps identified in the past at Harrison Bayou.

Comment No.	Section/Page/ Paragraph	Comment	C, D, E, or X[1]	Response	A or D[2]	Comment
				locations 16SW01, 16SW02, and 16SW03 for VOCs, perchlorate, metals, and field parameters (DO, pH, ORP, conductivity and temperature) as shown in **Table 4-10**. Additionally, baseline field readings from the bayou will be collected at locations near the Bayou Biobarrier at least three times during a work day prior to beginning injection into the Bayou Biobarrier."		
18.	Figure 4-2	Intermediate wells or potentially even deeper wells may need to be drilled on the east side of the bayou due to the intermediate zone contamination currently on the east side of the bayou at monitoring well 16WW41 at 6,650 µg/L of TCE. There is potential for additional migration to the northeast for the intermediate zone.		Noted. EPA made this similar comment during the RD review indicating that a well might be needed at some point in the future. However, at this time, no plans for an intermediate zone well on the east side of the bayou have been made until additional data is collected as part of the implementation and monitoring of the in situ bioremediation. See below for EPA's comment 17 from the review of the Remedial Design. *"EPA agrees with the additional shallow wells proposed by TCEQ shown on revised Figure 4-1. Also, EPA recognizes there may be a need for additional Intermediate groundwater monitoring wells in the future, especially in the outer eastern reaches of the plume."*	A	Evaluation of the data obtained during and after the implemented treatments should provide insight for any future actions.
19.	General Comment	When was the last time that the Upper Deep and Lower Deep groundwater monitoring wells have been sampled at the site?		The upper deep and lower deep groundwater monitoring wells were last sampled in May 2013.	A	
20.	General Comment	Please identify the monitoring wells in a Table that are above the MCL for the metal COCs for this site.	C	Concur. The metals information will be added as part of the nature and extent of contamination at the site. A new Table 1-2 (attached) will be added and a new paragraph in Section 1.4 will be added as follows: "Metals have been detected in the shallow, intermediate, upper deep, and deep wells. **Table 1-2** summarizes the wells that have had concentrations above the metal cleanup levels	A	Please provide the scheduled or projected dates for the samples on Table 1-2. ***Army Response**: The next five-year review sampling is expected to occur in 2018, and the Army will inform EPA and TCEQ approximately three weeks prior to the commencement of the*

Comment No.	Section/Page/ Paragraph	Comment	C, D, E, or X[1]	Response	A or D[2]	Comment
				indicated in **Table 1-1**. **Table 1-2** includes both the maximum concentration above the cleanup level as well as the most recent date when concentrations were above the cleanup levels. The metals are detected in a few wells and do not indicate widespread metal contamination." Additionally to address groundwater monitoring, a new section will be added as follows: "**Section 4.8 Metals Groundwater Monitoring** The selected remedy in the ROD indicates monitoring for metals will be evaluated at the first five year review to determine if any further monitoring for metals is warranted (U.S. Army 2016). **Table 1-2** provides a summary of the wells that were sampled for the metals COCs and had detected concentrations above the cleanup levels. As part of the next five year review after remedy implementation, groundwater samples will be collected. All the wells listed on **Table 1-2** will be analyzed for thallium. Selected wells listed in **Table 1-2** will be analyzed for the remaining metal COCs (chromium, arsenic, nickel and/or manganese) based on the previous results. The sampling will be conducted using low flow sampling as described in **Section 3.4** of the IWWP (Bhate 2018). The monitoring results and evaluation will be included in the next five year review report."		*groundwater sampling for metals at LHAAP-16.*
21.	General Comment	Tables 3-2, 3-4, 3-6, 3-8, 3-10, and 3-11 refer to SDC-9TM 1x1011. The meaning of 1x1011 in this context is not clear. Please clarify.		The unit for this measurement is *Dehalococcoides* organisms/liter. The units will be added to the tables.		
22.	General Comment	Please add Shaw, 2007 (Table 1-1) reference to the reference section.	C	Concur. Reference as noted on the table will be added to the reference section.		

Notes:

For an additional revision to Section 3.1.2, please see the response to TCEQ's Comment No. 3.

For an additional revision to Section 4.5.2.2, please refer to Army Comment on TCEQ's Comment No. 7.

TCEQ Comments on Draft Remedial Action Work Plan, LHAAP-16

TCEQ Project Manager: April Palmie

Document date: February 28, 2018

Comment date: March 19, 2018

Comment Ref. #	Section, Page Ref.	TCEQ Comment	C, D, E, or X[1]	Response	A or D[2]	Army Comment
1.	3.1, 3-2	In this sentence, replace "and" with "however" The Final RD specified KB-1 and an equivalent culture, SDC-9TM will be used in place of KB-1.	C	Text will be revised accordingly.		
2.	3.1.1, 3-2	First sentence, remove "(" before direct-push	C	Text will be revised accordingly.		
3.	3.1.2, 3-2	First sentence, remove ")" after EDS-ER	C	Text will be revised accordingly. Additionally the 2nd and 3rd sentences of Section 3.1.2 will be replaced with the following: "Before any of the pilot test wells are used for injections, they will be redeveloped prior to use as injection wells for Landfill Biobarrier #2, and no slug tests will be performed."		
4.	4.1.2, 4-1	Notice - TCEQ needs 30-days for UIC coordination	C	Noted.		
5.	4.0 all sections	When relevant, please reference the SOPs (especially sections in 4.3 and 4.4	C	Please refer to Response to comment 6, 7 and 9.		
6.	4.3.3, 4-4	1-hour hydration is not consistent with SOP. Please revise and reference SOP	C	Sentence beginning on the 6th line of Section 4.3.3 will be replaced as follows: "The bentonite seal will be placed in 1-foot lifts each hydrated for 30 minutes. After placement of the final bentonite lift, the		

Comment Ref. #	Section, Page Ref.	TCEQ Comment	C, D, E, or X[1]	Response	A or D[2]	Army Comment
				bentonite seal will be saturated with potable water and allowed to hydrate for an additional two hours before grouting begins (IWWP, Section 3.2 and SOP A7.3.6)".		
7.	4.4, 4-4	Reference SOPs	C	Several references will be added as follows: Section 4.1.3 first sentence will be revised as follows: " Utility location and clearance for intrusive activities will be conducted (in accordance with Section 3.1 of the IWWP) prior to drilling as follows:" Section 4.3.2 will be revised as follows: "All injection wells will be constructed of 2-inch schedule 40 polyvinyl chloride (PVC) with a 10-foot 0.010 slot PVC screen at the bottom. The wells will be screened over the target intervals as shown in Table 4-1. Injection wells (six) installed in the intermediate groundwater zone will require a minimum of 6-inch diameter Schedule 40 PVC isolation casing to approximately 35 feet. Injection wells will be constructed to the required specification for isolation casing, surface completion, prevention of commingling and confinement of undesirable groundwater to its zone of origin in accordance with Section 3.2 of the IWWP (Bhate, 2018). Please refer to Standard Operating Procedure (SOP) A7-Monitoring Well Installation in Appendix A of the IWWP for additional guidance on well installation."		

Comment Ref. #	Section, Page Ref.	TCEQ Comment	C, D, E, or X[1]	Response	A or D[2]	Army Comment
				Section 4.3.3 will have the following added at the end of the section: "...from the biobarriers for performance monitoring. Wells will be installed in accordance with Section 3.2 of the IWWP (Bhate, 2018). Please refer to Standard Operating Procedure (SOP) A7-Monitoring Well Installation in Appendix A of the IWWP for additional guidance on well installation." Section 4.3.4 will have the following added to the end of the section: "... for injection will be redeveloped. Well development will be conducted in accordance with Section 3.2.2 of the IWWP (Bhate, 2018). Please refer to SOP-A8-Monitoring Well Development for additional guidance on well development." Section 4.4 first paragraph last sentence will be replaced as follows: "Low-flow groundwater sampling will be performed in accordance with Section 3.4 of the IWWP (Bhate, 2018). Procedures for purging and sampling the wells are detailed in SOP A10-Low Stress Groundwater sampling in Appendix A of the IWWP. During the performance monitoring events, surface water samples will be collected concurrently if water is flowing in the creek. Surface water samples will be collected in accordance with Section 3.6 of the IWWP (Bhate, 2018). Please refer to SOP A11-Surface Water Sampling in Appendix A of		

Comment Ref. #	Section, Page Ref.	TCEQ Comment	C, D, E, or X[1]	Response	A or D[2]	Army Comment
				the IWWP for detailed guidance regarding surface water sampling. " Section 4.6 will have the following sentence added: "In situ injection activities will be conducted in accordance with Section 3.10 of the IWWP (Bhate, 2018). " *Note Additional Army Change:* *Additionally, text in Section 4.5.2.2 will be revised to include a top down and/or bottom up approach for injections depending on field conditions and lithology. At LHAAP-58, the amendments were injected successfully using a bottom up approach. Text in Section 4.5.2.2, first paragraph, line 2 will be revised as follows: " .. the entire target interval using a top down or bottom up approach depending on the lithology and field conditions."*		
8.	4.6.2, 4-8	Top of page, in this sentence remove "are" The injection volumes are and amendment mixture quantities (total and per point) are shown on Table 3-4.	C	Text will be revised accordingly.		
9.	4.7.8 and 4.7.9, 4-13	Reference SOPs	C	Section 4.7.8, 2nd paragraph, 2nd sentence will be revised as follows: "Surface water samples will be collected in accordance with Section 3.6 of the IWWP (Bhate, 2018). Please refer to SOP A11-Surface Water Sampling in Appendix A of the		

Comment Ref. #	Section, Page Ref.	TCEQ Comment	C, D, E, or X[1]	Response	A or D[2]	Army Comment
				IWWP for detailed guidance regarding surface water sampling." Additionally, a new Table 4-10 will be added to include the surface water monitoring plan and is attached to these response to comments (RTCs). Section 4.7.8, 2nd paragraph, 3rd line, will be revised as follows: "… these surface water samples will be analyzed for the COCs as shown in Table 4-10 and concentrations will be compared to clean up levels listed in Table 1-1."		
10.	5.1.1, 5-2	The second line of evidence sentence should reference TRRP	C	Table 1-1 establishes the cleanup levels. Section 5.1.1, last two sentences of the 2nd line of evidence bullet will be revised as follows: "…reduce COCs to the cleanup levels (Table 1-1)."		
11.	Figure 1-3	Do the private, public, and installation water wells need to be displayed on this figure? This information is helpful at remedial investigation and remedy selection phases, but not really needed for the remedial action.	C	Figure 1-3 will be revised to remove the water wells shown on the figure.		
12.	Figure 1-4	Western corner of landfill, wells 16WW05 and 06 are mislabeled. Wells 16WW44 and 45 should be added to this figure (and other relevant figures)	C	Figure 1-4 will be revised to show and label wells correctly.		

Comment Ref. #	Section, Page Ref.	TCEQ Comment	C, D, E, or X[1]	Response	A or D[2]	Army Comment
13.	Figure 3-1	Wells 16WW44 and 45 should be added to this figure (and other relevant figures) These data points are also missing from figure: 16RW07, 16IW04, 16IW09, and 16EW08	C	Figure 3-1 will be revised to show the missing wells.		.
14.	Figure 3-3	16IW04 is mislabeled (16IW-4)	C	Figure 3-3 will be revised to correct the mislabeling.		
15.	Figure 4-2	It would be better to have all permanent wells on this figure. Would it be possible to turn on the other wells? The MNA and LTM wells could be shaded/highlighted OR the wells not being used could be faded out. It would also be helpful to have the biobarrier lines drawn for reference (without details)	C	Figure 4-2 has been revised accordingly and is attached to the RTCs.		

Included attachments to the responses:

Table 4-10
Figure 4-2

Draft Final
Remedial Action Work Plan, LHAAP-16 Landfill
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

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Contract No. W9128F-13-D-0012
Task Order No. W9128BV17F0150
Project No. 501032
Rev 0
June 2018

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Acronyms and Abbreviations

APTIM	Aptim Federal Services, LLC
bgs	below ground surface
Bhate	Bhate Environmental, Inc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
cm/sec	centimeters per second
COC	contaminants of concern
CVOC	chlorinated volatile organic compound
DCA	dichloroethane
DCE	dichloroethene
DO	dissolved oxygen
DPT	direct-push technology
EDS-ER™	electron donor solution-extended release
ERS	Environmental Remediation Services
ESD	Explanation of Significant Difference
ESTCP	Environmental Security Technology Certification Program
EVO	emulsified vegetable oil
GPS	global positioning system
GW-Ind	groundwater medium-specific concentration for industrial use
GWTP	groundwater treatment plant
IRA	interim remedial action
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
MC	methylene chloride
MEGA	Multiple Environmental Government Acquisition
mg/L	milligrams per liter
MMRP	Military Munitions and Response Program
MNA	monitored natural attenuation
mV	millivolts
O&M	operation and maintenance
OHM	OHM Remediation Services Corporation
ORP	oxidation-reduction potential

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Acronyms and Abbreviations *(continued)*

OSWER	Office of Solid Waste and Emergency Response
PoP	period of performance
PVC	polyvinyl chloride
RA	remedial action
RACR	Response Action Completion Report
RA-O	Remedial Action Operation
RAOs	remedial action objectives
RAWP	Remedial Action Work Plan
RD	remedial design
ROD	Record of Decision
ROI	radius of influence
SDC-9™	APTIM's dechlorinating culture
Shaw	Shaw Environmental & Infrastructure, Inc.
SOP	standard operating procedure
TAC	Texas Administrative Code
TCA	trichloroethane
TCE	trichloroethene
TCEQ	Texas Commission on Environmental Quality
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VC	vinyl chloride
VOC	volatile organic compound
ZVI	zero valent iron

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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 (ERS) with Military Munitions Response Program (MMRP), Task Order No. W9128BV17F0150 to conduct environmental restoration of LHAAP-16 at Longhorn Army Ammunition Plant (LHAAP). The Bhate Team is comprised of Bhate and Aptim Federal Services, LLC (APTIM). APTIM is conducting the Remedial Action (RA) for LHAAP-16. LHAAP is an inactive, government owned formerly contractor operated and maintained department of Defense facility located central east Texas (**Figure 1-1**). This work plan describes the planned (RA) to address risks associated with contaminated groundwater at the LHAAP-16 landfill. This Remedial Action Work Plan (RAWP) has been developed using the basis and details of the Remedial Design (RD) for LHAAP-16, which was approved by the regulatory agencies in January 2017 (U.S. Army 2017).

1.1 Organization of Work Plan

This work plan is composed of the following sections:

- **Section 1.0:** "Introduction" summarizes the site background, proposed remedy including the contaminants of concern (COCs) and their respective cleanup levels, the nature and extent of contamination and remedial action objectives (RAOs).
- **Section 2.0:** "Land Use Control Plan" describes the proposed scope of work including the implementation activities associated with the land use control (LUC) component of the remedy.
- **Section 3.0:** "In Situ Bioremediation (ISB)" describes the injection activities associated with enhanced in situ bioremediation component of the remedy.
- **Section 4.0:** "Field Preparation and Activities" describes the activities that will be performed prior to the start of fieldwork and the methods that will be followed to complete fieldwork.
- **Section 5.0:** "Remedy Performance Evaluation and Reporting" describes the reports that will be submitted post ISB injections.
- **Section 6.0:** "Schedule" describes the proposed implementation schedule for the RA activities.

- **Section 7.0:** "Operation and Maintenance Procedures" describe the operation and maintenance (O&M) activities and other routine activities that form part of the final remedy.
- **Section 8.0:** "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 potentiometric maps and the plume contour maps from the Final RD.
- **Appendix B** includes the sample Annual Land Use Control Compliance Certification and Documentation.
- **Appendix C** includes the Safety Data Sheets for various commercially available emulsified vegetable oil (EVO) products, APTIM's dechlorinating microbial culture (SDC-9™).
- **Appendix D** includes the procedure provided by the vendor (Redox Tech) to mix the ABC Plus amendment mixture.
- **Appendix E** includes a blank injection log that will be used in the field to track injection volumes, flow rates and pressures.
- **Appendix F** includes the landfill inspection and maintenance checklist.

1.2 Site Description

LHAAP-16 is a capped landfill covering approximately 20 acres in the south-central portion of the former LHAAP (**Figure 1-2**). Harrison Bayou is located along the northeastern edge of the site and flows into Caddo Lake, northeast of the site (**Figure 1-3**). The landfill, which covered approximately 13 acres prior to cap construction, was established in the 1940s for the disposal of solid and industrial wastes, until the 1980s, when disposal activities were terminated.

The U.S. Army and the U.S. Environmental Protection Agency (USEPA) signed a Record of Decision (ROD) and the Texas Water Commission concurred in 1995 approving an interim remedial action (IRA) for LHAAP-16 to mitigate potential risks posed by buried source material at the site. The IRA included the construction of a landfill cap, which is considered a component of the final remedy for the site. Construction of the multilayer cap was completed in 1998. The ROD also specified that the U.S. Army would be required to "perform long-term maintenance of the cap." LUCs, such as future use restrictions, would also be required.

Previous investigations identified groundwater impacted with chlorinated volatile organic compounds (CVOCs), perchlorate, and metals at LHAAP-16 (U.S. Army 2016). **Figure 1-4** shows the existing groundwater monitoring system and the approximate lateral extent of perchlorate and trichloroethene (TCE) in the Shallow Zone and Intermediate Zone groundwater, based on the last comprehensive groundwater sampling event performed in May 2013 (U.S. Army 2017). The source of this impacted groundwater is the landfill, although the metals were only detected at elevated concentrations sporadically, and do not appear to reflect widespread contamination from the landfill. A groundwater extraction system was voluntarily installed by the U.S. Army in 1996 and 1997 as a treatability study to prevent the groundwater plume from migrating to Harrison Bayou. The extraction system was shut down in August 2012 due to operational issues including damage to the power feed to the system, but operation was restored in November 2012 and the extraction system has been operational since that time.

The Final ROD for LHAAP-16 was issued in September 2016; and documents the final selected remedy for the site; including impacted groundwater (U.S. Army 2016). The Final RD was issued in January 2017; and presents the RD, inspection and maintenance requirements, and LUC requirements, associated with LHAAP-16.

1.3 Planned Remedial Action

The planned RA at LHAAP-16 is comprised of several elements as outlined in the RD (U.S. Army 2017):

- Maintenance of the existing landfill cap to preserve its integrity and minimize or prevent infiltration through the landfill.
- Installation of two biobarriers in the shallow groundwater, one located adjacent to the landfill, and the other located near Harrison Bayou.
- ISB in the most contaminated portion of the shallow and intermediate groundwater zones in conjunction with phased shut down of the existing groundwater extraction system.
- Monitored natural attenuation (MNA) of both the shallow and intermediate groundwater zones to ensure continued degradation of CVOCs, perchlorate and daughter products and that surface water in Harrison Bayou is not adversely affected by groundwater such that it fails to meet surface water standards for CVOCs, perchlorate and daughter products. MNA includes:
  - Evaluation of MNA based on performance objectives after 2 years quarterly monitoring
  - Reapplication of bio-amendments if MNA is found to be ineffective

- Long-term monitoring (LTM) semiannually for 3 years, then annually thereafter until recommended otherwise by the five-year review. LTM will not be initiated until MNA performance monitoring establishes the effectiveness of MNA.
- LUCs to prohibit access to the contaminated groundwater except for environmental monitoring and testing only.
- LUCs to preserve the integrity of the landfill cap, and to restrict intrusive activities (e.g., digging) that would degrade or alter the cap.
- LUCs to restrict land use to nonresidential.
- LUCs to maintain the integrity of any current or future remedial or monitoring systems.

1.4 Nature and Extent of Contamination

The contaminated media at LHAAP-16 includes buried source material (landfill waste under the cap) and the shallow and intermediate groundwater beneath and downgradient of the landfill. The IRA implemented in 1996 through 1998, included placement of a multilayer cap at LHAAP-16 mitigating potential risks posed by buried landfill waste. The cap prevents rainfall from infiltrating and leaching contaminants from principal threat wastes within the landfill. However, groundwater in contact with the buried waste material still provides a mechanism for transportation of COCs away from the landfill (Jacobs 2000). A groundwater extraction system was installed as a treatability study to prevent the groundwater plume from migrating to Harrison Bayou (OHM 1998).

The groundwater COCs for LHAAP-16 identified in the Final ROD (U.S. Army 2016) include CVOCs (TCE; cis-1,2-dichloroethene [DCE]; 1,1-DCE; 1,2-dichloroethane [DCA]; vinyl chloride [VC]; 1,1,2-trichloroethane [TCA], and methylene chloride [MC]), perchlorate, and metals (arsenic, chromium, manganese, nickel and thallium) in the shallow and/or intermediate groundwater. As established in the ROD, groundwater and surface water cleanup levels (U.S Army 2016) are presented in **Table 1-1**.

The isoconcentration contours for major CVOCs, and perchlorate, in Shallow Zone and Intermediate Zone groundwater based on the last comprehensive round of groundwater sampling conducted in May 2013 are included as in the Final RD (U.S. Army 2017) and are included in **Appendix A** (**Figures 2-4** through **2-7**) of this work plan. Five metals (arsenic, chromium, manganese, nickel, and thallium) had sporadic elevated detections in 2009 and were retained as COCs in shallow and/or intermediate groundwater in the Final ROD. The detected metals do not appear to be associated with widespread contamination from the landfill.

Data collected from the upper deep groundwater zone from 1998 until 2008 indicate that no COCs were reported at concentrations exceeding their respective cleanup levels (**Table 1-1**). In addition, the data collected from deep groundwater from 1997 until 2004 indicate that no COCs were reported at concentrations exceeding their respective cleanup levels (Shaw 2010).

Metals have been detected in the shallow, intermediate, upper deep, and deep wells. **Table 1-2** summarizes the wells that have had concentrations above the metal cleanup levels indicated in **Table 1-1**. **Table 1-2** includes both the maximum concentration above the cleanup level as well as the most recent date when concentrations were above the cleanup levels. The metals are detected in a few wells and do not indicate widespread metal contamination.

1.5 Geology and Hydrogeology

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

The shallow groundwater zone varies in thickness from nine to 18 feet below ground surface (bgs). Shallow groundwater elevation contours based on the last comprehensive groundwater elevations collected at the site when extraction was operational in June 2016 are shown on Figure 2-1 of **Appendix A**. Depth to groundwater in the shallow zone is approximately 4 feet to 25 feet bgs (U.S. Army 2017).

An intermediate groundwater zone containing fewer fines than the shallow zone extends from 35 to 62 feet bgs. The intermediate groundwater elevation contours based on the last comprehensive groundwater elevations collected at the site when extraction was operational in June 2016 are shown on Figure 2-2 of **Appendix A**. The upper deep groundwater zone extends from approximately 80 to 151 feet bgs. The lower deep groundwater zone extends below 220 feet bgs (U.S. Army 2017). While flow is primarily horizontal in these zones, vertical interaction between the shallow and intermediate zones is evidenced by pumping test results as well as the presence of contamination in both zones. Such interconnection is consistent with soil layers formed in fluvial depositional environments.

The groundwater flow direction is northeast toward Harrison Bayou in the shallow, intermediate and deep zones, while flow direction is southeast toward Harrison Bayou in the upper deep groundwater zone. Overall, the groundwater flow is toward Caddo Lake. The mean hydraulic conductivity value varies from 1.5×10^{-3} centimeters per second (cm/sec) in the Shallow Zone to 4.2×10^{-4} cm/sec in the Deep Zone (Jacobs 2002). Groundwater flow between the landfill and Harrison Bayou is also influenced by the presence of an extraction well system consisting of four wells in the shallow groundwater zone and four wells in the intermediate groundwater zone.

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1.6 Remedial Action Objectives

The RAOs developed for LHAAP-16 and outlined in the LHAAP-16 ROD (U.S. Army 2016) are:

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

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2.0 LAND USE CONTROL PLAN

The U.S. Army or its representative will be responsible for LUC implementation and certification, reporting and enforcement. The U.S. Army will address the LUC problems within its control that are likely to impact remedy integrity and will address problems as soon as practicable. The following section provides details for the LUC component of the RA.

2.1 Land Use Controls Implementation

The actions required to implement the land use controls (LUCs) for LHAAP-16 are described below. The first of these, the initial notice of LUCs, has been completed. A figure depicting the preliminary LUC boundaries is presented in Figure 3-1 of **Appendix A**. The following actions will be undertaken to implement the LUCs for LHAAP-16:

- Finalize the Boundaries for the LUCs as a part of the RA.
  - Revise the boundaries if necessary. The LUC boundary presented in this RAWP is subject to change, based on COC results from the two proposed wells to be installed on the east side of Harrison Bayou. The final boundaries 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 landfill LUCs (preserve the integrity of the landfill cap, and to restrict intrusive activities (e.g., digging) that would degrade or alter the cap); 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 new data has been completed and revised if necessary.
  - Survey the LUC Boundaries. The boundaries will be finalized after concurrence by USEPA and the Texas Commission on Environmental Quality (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 Texas Administrative Code (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

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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 after finalizing LUC boundary as part of the RA. 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 boundaries. The notices will be sent to federal, state, and local officials including: U.S. Senators, U.S. Congressman, State Senator, State Representative, Harrison County Judge, Harrison County Commissioner Precinct 1, City of Uncertain Mayor, and Karnack Water Supply Corporation Board Members. Notice will also be sent to the Caddo Lake National Wildlife Refuge, Manager.
- Periodically 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. The transmittal will coincide with each Five Year Review and will be documented in the report.

The elements of the LUC Plan for LHAAP-16 included in Section 5.2 and 5.3 of the Final RD will be presented in the Response Action Completion Report (RACR) as the LUC Plan. Implementation of the LUC Plan includes annual inspections which are recorded on the Annual Inspection Form included in **Appendix B**.

2.2 Comprehensive Land Use Control Management Plan

Upon finalization of this LUC RA, the amended LUC boundary map and legal description recordation will be inserted into the Comprehensive LUC Management Plan for LHAAP. The Comprehensive LUC Management Plan figure and table will be updated to reflect the inclusion of LHAAP-16.

Upon finalization of this LUC RA, the amended LUC boundary map and legal description recordation will be inserted into the Comprehensive LUC Management Plan for LHAAP. The Comprehensive LUC Management Plan figure and table will be updated to reflect the inclusion of LHAAP-16. The Comprehensive LUC Management Plan consists of LHAAP RD documents and a survey plat showing the locations where the LUC being implemented at LHAAP is applied. The purpose of this Comprehensive LUC Management Plan is to ensure the site-specific LUC is compiled into one comprehensive document for both pre-transfer use by the installation and for post-transfer use by the transferee. This document has been provided to the USEPA and the TCEQ and is accessible to the public through LHAAP's Administrative Record.

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3.0 IN SITU BIOREMEDIATION (PROPOSED REMEDIATION PLAN)

ISB will be conducted at LHAAP-16 to remediate groundwater impacted with volatile organic compounds (VOCs) and perchlorate. The injection locations at LHAAP-16 are shown in **Figure 3-1**. As described in the RD, the following ISB systems will be implemented to treat the VOC and perchlorate impacted groundwater:

- Three Landfill Biobarriers (Landfill Biobarrier #1, Landfill Biobarrier #2, Landfill Biobarrier #3 in the shallow groundwater zone adjacent to the landfill
- One Bayou Biobarrier in the shallow groundwater zone near Harrison Bayou
- A biogrid in the shallow groundwater zone and a biobarrier in the intermediate groundwater zone in the Mid Plume Area

The plume geometry and proposed injections have been developed using the basis and details of the Final RD (U.S. Army 2017). Overall, the implementation of biobarriers and biogrid will involve the injection of an electron donor and a microbial consortium capable of biodegrading primary VOCs and perchlorate.

The primary biodegradation pathway for chlorinated ethenes, such as tetrachloroethene and TCE, is reductive dechlorination, which occurs under highly reducing anaerobic conditions. During reductive dechlorination, chlorinated ethenes are used as respiratory substrates instead of oxygen by the anaerobic microorganisms that reduce these compounds to harmless by-products. Favorable aquifer conditions are established and/or maintained by adding a carbon source, such as EVO, to act as an electron donor. Details of the RA for each of the systems are described in the following sections.

3.1 Landfill Biobarriers

Three landfill biobarriers will be installed to control the migration of VOCs and perchlorate in shallow groundwater immediately downgradient of the landfill. The location of the barriers is designed to fully intercept the plume of chlorinated VOCs and perchlorate from the landfill in the shallow groundwater zone above their respective cleanup levels (**Figures 3-2**, **3-3**, and **3-4**). The substrate selected was EVO and therefore, replenishment would not be required for 3 to 5 years (U.S. Army 2017). The Safety Data Sheets for various commercial available EVO formulations are included in **Appendix C**. As specified in the RD, the specific formulation of EVO proposed for this project is electron donor solution-extended release (EDS-ER™). An equivalent EVO product will be used if EDS-ER™ becomes unavailable in the market. EDS-ER™ is a water mixable oil formulated with at least 92 percent natural seed

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oils. EDS-ER™ is provided by the vendor as a water mixable oil that contains no water, and therefore, will be mixed with water in the field. The product mixes easily with water without using high energy mixers. As specified in the Final RD, a microbial bioaugmentation culture will be used. The Final RD specified KB-1, however, an equivalent culture, SDC-9™ will be used in place of KB-1. The Safety Data Sheet for SDC-9™ is included in **Appendix C**. At the three landfill biobarriers, a conservative tracer (sodium bromide) will be used to evaluate the distribution of the substrate as part of the performance monitoring.

3.1.1 Landfill Biobarrier #1

A biobarrier will be installed by injecting an amendment mixture consisting of EDS-ER™ or an equivalent EVO product, nutrients, bioaugmentation culture, SDC-9™ (APTIM's dechlorinating culture), and sodium bromide into eighteen direct-push technology (DPT) points and one injection well, 16IW09 as shown in **Figure 3-2** and listed on **Table 3-1**. **Table 3-2** shows the volume of amendment scheduled for injection at each injection point/well. The pounds of EVO of the amendment mixture are the same as the calculation sheets provided in Final RD (U.S. Army 2017).

3.1.2 Landfill Biobarrier #2

Existing injection wells installed during the Environmental Security Technology Certification Program (ESTCP) study (Geosyntec 2009) will be used to inject EDS-ER™ or an equivalent EVO product, nutrients, bioaugmentation culture (SDC-9™) and sodium bromide to create Landfill Biobarrier #2. Before any of the pilot test wells are used for injections, they will be redeveloped prior to use as injection wells for Landfill Biobarrier #2, and no slug tests will be performed. Injections will be conducted in two phases. Phase 1 will use four existing injection wells for injections while extracting from five existing extraction wells to aid in the distribution of amendment crossgradient. The extracted groundwater during the first phase will accumulate in the onsite tank at LHAAP-16.

Phase 2 will use the extracted groundwater collected in the onsite tank. The extracted groundwater will be mixed with the amendment mixture and injected back into the existing five extraction wells.

The injection locations are shown on **Figure 3-3**. **Table 3-3** specifies the number of locations, and **Table 3-4** shows the planned volume of amendment mixture to be injected at every location. The pounds of EDS-ER™ of the amendment mixture are the same as the calculation sheets provided in Final RD (U.S. Army 2017).

3.1.3 Landfill Biobarrier #3

A biobarrier will be installed by injecting an amendment mixture consisting of EDS-ER™ or an equivalent EVO product, nutrients, bioaugmentation culture (SDC-9™), and sodium

bromide into seven DPT points and one injection well, 16IW10, as shown in **Figure 3-4** and listed on **Table 3-5**. **Table 3-6** provides the planned volume of amendment mixture to be injected at each injection point/well. The pounds of EVO of the amendment mixture are the same as the calculation sheets provided in Final RD (U.S. Army 2017).

3.2 Bayou Biobarrier

A biobarrier will be installed by injecting an amendment mixture consisting of ABC Plus which consists of EVO with microscale zero valent iron (ZVI), sodium bromide, and bioaugmentation culture (SDC-9™) into thirteen DPT points and one injection well, 16IW20, as shown in **Figure 3-5**. ABC Plus will consist of 3,500 pounds of EVO and 3,500 pounds of microscale ZVI. As stated in the Final RD, the ABC product will be diluted with water to form a solution of approximately 10% by weight before injection. **Table 3-7** specifies the number of locations (DPT points/injection well) that will be used to inject the amendment mixture, and **Table 3-8** provides the planned volume of amendment mixture to be injected at each injection point. The pounds of EVO and iron of the amendment mixture is the same as provided in Final RD (U.S. Army 2017). The Safety Data Sheet for ABC Plus is included in **Appendix C**.

3.3 Mid-Plume Area ISB

Injections in the Mid-Plume area include injections in the shallow and intermediate groundwater aquifers. As specified in the RD, the specific formulation of EVO proposed for this project is EDS-ER™. The Safety Data Sheets for EDS-ER™ are included in **Appendix C**.

3.3.1 Shallow Groundwater

To treat the VOC and perchlorate impacted groundwater in the shallow groundwater aquifer, a biogrid will be installed by injecting EDS-ER™ or an equivalent EVO product, nutrients, bioaugmentation culture (SDC-9™) and sodium bromide (tracer) into forty DPT points as shown in **Figure 3-6** and listed on **Table 3-9**. The Final RD also included fluorescein dye (a tracer) for this area. Only sodium bromide will be used as a tracer to indicate distribution of injected amendment. Analytical results for bromide will be used to indicate its presence. Prior to injections, the shallow zone extraction wells will be shut down. **Table 3-10** specifies the volume of amendment mixture to be injected at each injection point. The pounds of EVO of the amendment mixture are the same as provided in Final RD (U.S. Army 2017).

3.3.2 Intermediate Groundwater

To treat the intermediate groundwater zone, a biobarrier will be installed consisting of EDS-ER™ or an equivalent EVO product, nutrient, bioaugmentation culture (SDC-9™), and sodium bromide (tracer) as shown in **Figure 3-7**. The injection will occur in a phased approach. After the initial injection into the six newly installed injection wells, the four existing extraction wells will be used to recirculate the groundwater between injection wells and the

extraction wells until an increase in bromide is detected in the extraction wells. Extracted groundwater will accumulate in the onsite tank. Once bromide is detected above baseline concentrations, the extraction system will be shut down and amendment mixture will be injected into the extraction wells. **Table 3-11** specifies the volume of amendment mixture to be injected at each injection point along with the amendment mixture quantities. The pounds of EDS-ER™ of the amendment mixture are the same as provided in Final RD (U.S. Army 2017). The Safety Data Sheet for various commercial available EVO formulations is included in **Appendix C**.

3.3.3 Sequencing of Injection Areas

The RD calls for injections in the most contaminated portion of the shallow and intermediate groundwater zones in conjunction with phased shut down of the existing groundwater extraction system. Currently, active extraction is ongoing from both the shallow and intermediate groundwater in the vicinity of the mid-plume injection area. The following is the proposed sequencing of the injections and extraction:

1) Continue active extraction from the mid-plume area using the existing onsite tank.
2) Inject at Bayou Biobarrier. The Bayou Biobarrier will protect contaminants from migrating to the bayou, and injection will occur at the Bayou Biobarrier before shutting down the extraction at the Mid-Plume area to limit any additional migration to the creek from the shutdown of extraction system. Additionally, this area uses the amendment mixture using EVO and microscale ZVI, while the other areas do not use the ZVI in the mixture. While injections are ongoing at Bayou Barrier, the field technicians will build/install recirculation system for the intermediate groundwater for the Mid-Plume area.
3) Shut down extraction from the mid-plume shallow and intermediate groundwater and empty the onsite tank by transferring water to the groundwater treatment plant (GWTP) for treatment.
4) Inject into the Mid-Plume. Begin injections into the intermediate groundwater and start recirculation of intermediate groundwater using onsite tank. While recirculating in the intermediate aquifer, inject into the shallow groundwater. During injections in the shallow groundwater, the recirculation of the intermediate groundwater and amendments will be checked. Recirculation will continue in the intermediate aquifer until distribution of amendments has occurred. Once recirculation is successful in the intermediate aquifer, the accumulated water and amendments will be reinjected into the intermediate aquifer.
5) Inject at Landfill Biobarrier #1. Injections may begin at Biobarrier #1 while recirculation may be continuing in the Mid-Plume intermediate groundwater.

6) Inject at Landfill Biobarrier #2/#3. There are extraction wells at Landfill Biobarrier #2, but they are not currently connected to the existing onsite tank. The initial injections will begin at Landfill Biobarrier #3 while the piping/connections at extraction wells at Landfill Biobarrier #2 are being prepared to be connected to the mixing tank. Once the injections are complete at Biobarrier #3, the injections will be completed at Biobarrier #2. The accumulated water from extraction of the Landfill Biobarrier #2 wells will accumulate in the mixing tank until amendments are added and reinjected into the extraction wells at Landfill Biobarrier #2.

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4.0 FIELD PREPARATION AND ACTIVITIES

This section discusses the field preparation and field methods that will be utilized to complete the scope of work under the RA.

4.1 Pre-Mobilization Activities

4.1.1 Permitting

No permitting is required prior to the commencement of fieldwork.

4.1.2 Notification

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

4.1.3 Utility Clearance

Utility location and clearance for intrusive activities will be conducted (in accordance with Section 3.1 of the Installation-Wide Work Plan [IWWP]) 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. This notification is to be made a minimum of two 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.
- Notify the appropriate agencies, contracting officer's representative, and property owners (when applicable). Confirm utility clearance is complete and document.
- 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.

4.2 Site Activities

A RACR will be submitted to document site activities completed to implement the RA. Site activities in chronological order will be as follows

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4.2.1 Pre-Injection Activities

1. Install injection and monitoring wells as indicated in **Table 4-1**. Wells will be installed by a licensed Texas driller and oversight provided by an APTIM geologist.
2. Collect soil cuttings from wells in drums and sample for waste characterization.
3. Conduct slug tests for existing pilot test wells that are proposed for injections in the vicinity of Landfill Biobarrier #2, and redevelop wells if necessary.
4. Collect baseline (pre-remedy) readings and samples from existing monitoring wells as indicated in **Tables 4-2** and **4-3**. Collect pre-remedy surface water samples from three locations: 16SW01, 16SW02, and 16SW03 for VOCs, perchlorate, metals, and field parameters (dissolved oxygen [DO], pH, oxidation-reduction potential (ORP), conductivity, and temperature) as shown in **Table 4-10**. Additionally, baseline field readings from the bayou will be collected at locations near the Bayou Biobarrier at least three times during a work day prior to beginning injection into the Bayou Biobarrier. In the event that a release of amendment mixture is suspected to the surface water, a surface water sample will be collected and the results compared to the baseline surface water sample results.
5. Survey the newly installed monitoring and injection wells.
6. Dispose of soil cuttings based on waste characterization analysis.
7. Review soil boring and well completion logs from the well installation event and ones included in the Final RD.
8. Review data from new wells and adjust any amendment quantities if needed if contamination is higher than expected.

4.2.2 Injection Activities

1. Mobilize materials, equipment, mixing tanks, and labor for injections.
2. Set up traffic detouring as needed.
3. Layout of injection arrays and clear DPT injection points. Please refer to **Section 3.3.3** for the sequence of biobarriers.
4. Core concrete/asphalt at injection points, if needed, and adjust any points if obstructions are found.
5. Setup amendment, equipment, and materials onsite including materials for recirculation from Mid-Plume intermediate groundwater and Landfill Biobarrier #2 extraction.

6. Begin preparing amendment solution for injection a day before planned injections. Preparation of amendment solution will be a continual activity.
7. Inject amendments following the sequencing as outlined in **Section 3.3.3** using:
   - DPT rig to push down to required depth and inject amendment through probe rod. No soil cuttings will be generated using DPT, or
   - Injection system to inject amendment into previously installed injection/ extraction wells. Recirculate where required.
8. During injections continuously monitor for surfacing near the injection locations; for the Bayou Biobarrier, the creek will also be monitored during injections. Monitor pressure, volume, and flow into each injection point (DPT or well) by observing the gauges on the injection system. Record the injection interval during injections. Record injection information on the injection log in **Appendix E**. During active injection, the system will be continuously monitored by designated personnel.
9. Once injection is complete at a DPT injection point, abandon point.
10. Record DPT injection point locations with global positioning system (GPS).
11. Once injections and recirculation is complete, decontaminate and demobilize equipment, materials, and mixing tank.
12. Restore site and demobilize personnel.

4.2.3 Post Injection Activities

After injections, performance monitoring will be conducted followed by MNA monitoring. Landfill operations and maintenance will be ongoing.

4.3 Drilling and Well Installation

Drilling and well installation will utilize both DPT rigs and hollow stem auger rigs. DPT rigs are used for in situ injections through a probe. The hollow stem auger rigs will be used for the installation of wells. A total of nine injection wells and eighteen monitoring wells will be installed at LHAAP-16 using an auger rig rotary sonic drilling technique as shown in **Table 4-1**. All drilling and well installation activities will be supervised by a Texas-registered geologist.

4.3.1 DPT Drilling

A DPT rig will be used to install the DPT points for the biobarriers. A total of 79 points will be installed using a DPT rig between the landfill and Harrison Bayou. DPT drilling will be conducted in accordance with the procedures presented in the IWWP (Bhate 2018). Each DPT point will be abandoned by filling with grout after injections are completed.

4.3.2 Injection Wells

All injection wells will be constructed of 2-inch schedule 40 polyvinyl chloride (PVC) with a 10-foot 0.010 slot PVC screen at the bottom. The wells will be screened over the target intervals as shown in **Table 4-1**. Injection wells (six) installed in the intermediate groundwater zone will require a minimum of 6-inch diameter Schedule 40 PVC isolation casing to approximately 35 feet. Injection wells will be constructed to the required specification for isolation casing, surface completion, prevention of commingling and confinement of undesirable groundwater to its zone of origin in accordance with Section 3.2 of the IWWP (Bhate 2018). Please refer to Standard Operating Procedure (SOP) A7-Monitoring Well Installation in Appendix A of the IWWP for additional guidance on well installation. Injection wells will be installed using a hollow stem auger rig rotary sonic drilling techniques. The lithology will be logged at the proposed injection and monitoring well location.

4.3.3 Monitoring Wells

Monitoring wells will be constructed of 4-inch inside diameter schedule 40 PVC 0.01 slot well screen with a 4-inch inside diameter riser composed of schedule 40 PVC pipe. A filter pack consisting of 10/20 filter sand will be placed around the screen from the bottom of the borehole to at least 2 feet above the screen. Wells will be pre-developed by bailing and surging to aid in settling the filter pack before placing the bentonite seal. After the filter pack has been placed, a 2- to 5-foot bentonite seal will be introduced into the well above the filter pack. The bentonite seal will be placed in 1-foot lifts each hydrated for 30 minutes. After placement of the final bentonite lift, the bentonite seal will be saturated with potable water and allowed to hydrate for an additional two hours before grouting begins (IWWP, Section 3.2 and SOP A7.3.6). After the bentonite seal has hydrated, the remaining annulus will be grouted using a Type I Portland or American Petroleum Institute Class A cement/bentonite slurry.

The wells will be screened over the target intervals as shown on **Table 4-1**. Monitoring wells will be installed within and downgradient from the biobarriers for performance monitoring. Wells will be installed in accordance with Section 3.2 of the IWWP (Bhate 2018). Please refer to the SOP A7-Monitoring Well Installation in Appendix A of the IWWP for additional guidance on well installation.

4.3.4 Well Development

Each newly installed well will be developed no sooner than 24 hours following well completion. Existing wells that will be used for injection will be redeveloped. Well development will be conducted in accordance with Section 3.2.2 of the IWWP (Bhate 2018). Please refer to SOP-A8-Monitoring Well Development for additional guidance on well development.

4.4 Groundwater and Surface Water Sampling

Areas around the wells will be cleared of vegetation and biohazards to protect the field staff. Wells will be sampled prior to injections for baseline data and post injections. Low-flow groundwater sampling will be performed in accordance with Section 3.4 of the IWWP (Bhate 2018). Procedures for purging and sampling the wells are detailed in SOP A10-Low Stress Groundwater sampling in Appendix A of the IWWP. During the performance monitoring events, surface water samples will be collected concurrently if water is flowing in the creek. Surface water samples will be collected in accordance with Section 3.6 of the IWWP (Bhate 2018). Please refer to SOP A11-Surface Water Sampling in Appendix A of the IWWP for detailed guidance regarding surface water sampling.

Additional details about baseline sampling, performance sampling and surface water sampling is discussed in **Section 4.7** below.

4.5 ISB Injection

Placement of DPT points, injection wells, and existing wells for ISB is shown on **Figures 3-2** to **3-7**. **Tables 3-1** to **3-11** provide 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 the Final RD.

4.5.1 Preparation

4.5.1.1 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, APTIM will verify that there are no injection points that will impact any utility. If there are points that are affected, APTIM will alter the plan and 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, APTIM's standard procedure is to hand dig to 5 feet at each injection point to check for underground obstructions/utilities.

4.5.1.2 Amendment Preparation

The reduction of VOCs and perchlorate will be addressed by using enhancing reductive dechlorination, an anaerobic microbial process. There are various EVO formulations commercially available in the market. EDS-ER™ (or an equivalent EVO product will be used for injections along with APTIM's dechlorinating microbial consortium, SDC-9™. Additionally, the Bayou Barrier will use ABC Plus with microscale ZVI or an equivalent product.

The ISB amendments will be mixed in 20,000-gallon mixing tanks. The tanks will be located at LHAAP-16. If field conditions do not allow for placement of the tanks at LHAAP-16, the 20,000-gallon mixing tanks will be staged at the GWTP. The amendment solution will be mixed prior to the day of injection. The potable water required for mixing will be obtained from the GWTP or from an off-base fire hydrant and transported to the mixing tank in a water truck. If the 20,000-gallon tanks are staged at the GWTP, the amendment mixture will be prepared at the GWTP and transported to the site in water trucks.

Steps required for preparation of ISB (EDS-ER™ and SDC-9™) amendments are as follows:

- Approximately 24 hours prior to injection, the anaerobic solution will be prepared by adding the required volume of EDS-ER™ and dilution water (1:10 mixing ratio), nutrients, and a small volume of SDC-9™ into the mixing tank. The same amendment mixture is used for all injection areas except for the Bayou Barrier where the amendment mixture will include microscale ZVI. The microbes 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. During mixing, a conservative tracer sodium bromide (at target concentration of 500 milligrams per liter [mg/L]) will be added to the solution to evaluate the distribution of amendment during performance monitoring.
- When the solution has become anaerobic, based upon a DO meter reading of less than 1.0 mg/L, the remaining bioaugmentation culture will be added to the mixing tank and recirculated. The procedure differs from the Final RD which called for intermittent injection of anaerobic water and the microbes. Preparing the full volume of anaerobic water for injection and mixing is favorable for the microbes.
- After the anaerobic solution containing each of the amendments has been prepared, the amendments will be injected. The amendment solution will be injected into the subsurface using an injection system, as shown on **Figure 4-1**.
- The injection volume for each point at an injection area along with the associated mass and volume of amendment are provided in **Tables 3-2**, **3-4**, **3-6**, **3-8**, **3-10**, and **3-12** and are based on 92% EVO oil (EDS-ER™) by weight.

Steps required for preparation of ABC Plus amendment mixture is as follows:

The ABC product will be mixed into a slurry for injection. **Appendix D** provides details regarding the mixing preparation of the ABC Plus product. Additionally, sodium bromide (tracer) will be mixed in with the EVO at the beginning of the mixing process.

4.5.2 In Situ Injections

4.5.2.1 Injection System

An injection system will be used to allow for multiple well/DPT injections at a single time under low pressure (i.e., less than 40 pounds per square inch). 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 E**. The injection system will be connected to each well or to the DPT probe with hoses.

4.5.2.2 DPT Injection

For injection into the shallow aquifer, a DPT rig will be used to inject the amendment mixture at 2-foot intervals to cover the entire target interval using a top down or bottom up approach depending on the lithology and field conditions. An injection tool string is advanced to the top of the injection interval and the amendment is pumped through the probe rods. The cycle is repeated to provide coverage across the entire target interval.

4.5.2.3 Injection through Wells

Injection into the intermediate aquifer and Landfill Biobarrier #2 will use newly installed injection wells or existing extraction wells. The injection well screen will be installed over the target interval. The injection well screen interval may be modified during field implementation activities based on field observations including depth to groundwater. For injection using a well, the well will be fitted with an injection connection for attachment of the injection system.

Slug tests will be conducted on the pilot test wells at Landfill Biobarrier #2 to ensure they are in acceptable conditions. If the results indicate they are not, the wells will be redeveloped prior to use as injection wells.

4.5.2.4 Monitoring during Injections

During the ISB injections, possible amendment surfacing (also called daylighting) may occur at the ground surface and will be monitored. 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 or in nearby drainage features is detected, injection rates will be reduced or injections will be shut down. Bromide will be used as an indicator of distribution of the EVO (carbon). The bromide concentrations will be monitored, and an increase in bromide concentrations above the baseline results will indicate amendment distribution. Samples will be collected and analyzed for bromide to determine if there is an increase in bromide over baseline to evaluate distribution of amendment.

4.6 Injection Areas

In situ injection activities will be conducted in accordance with Section 3.10 of the IWWP (Bhate 2018).

4.6.1 Landfill Biobarrier #1 Amendment Injection

The injection will consist of delivering amendments to the subsurface using a series of eighteen DPT injection points (DPT01 through DPT18) and one injection well (16IW09). The RD proposed that the injection well would also serve as a groundwater monitoring location within the biobarrier. A spacing of 15 feet between injection locations was selected based on the rationale and injection radius of influence (ROI) presented in Section 4.1.2 of the Final ROD.

The target injection intervals are shown on **Table 3-1**. The injection locations are shown on **Figure 3-2**. The injection volumes and amendment mixture quantities (total and per point) are shown on **Table 3-2**.

4.6.2 Landfill Biobarrier #2 Amendment Injection

Existing injection wells and extraction wells installed as part of the ESTCP study (Geosyntec 2009) will be used to deliver the amendments. The injections will be conducted in two phases in the vicinity of Landfill Biobarrier #2. The injection locations are shown on **Figure 3-2**. The screen intervals of the existing wells are included on **Table 3-3**. The injection volumes and amendment mixture quantities (total and per point) are shown on **Table 3-4**.

Phase 1 will involve injecting into injection wells 16IW01, 16IW03, 16IW05, and 16IW07 as groundwater is extracted from extraction wells 16EW11, 16EW12B, 16EW13, 16EW14B, and 16EW15 to enhance distribution of the amendment mixture cross gradient. Pumps and piping are not currently installed and will be temporarily installed for extraction. The extracted groundwater will accumulate into the empty mixing tank. Once the planned amendment volume has been injected, a sample of the extracted groundwater will be collected from each extraction well and tested for bromide. If bromide concentration is more than the baseline concentration, extraction will end. If bromide concentrations are not detected above baseline levels, extraction of groundwater will continue until a higher concentration of bromide is detected in the extraction wells. The extraction wells will be turned off once bromide is detected above baseline concentrations. If additional extraction occurs, it is likely that the accumulated water volume may be more than is needed for the amendment mixture for Phase 2. If this occurs, once the accumulated groundwater is more than 3,500 gallons, the excess water will be reinjected into the injection wells while extraction continues.

During Phase 2 of the injections, the extraction wells will be shutdown. The water accumulated from Phase I of injections will be used to make the amendment mixture for Phase 2. One part of the concentrated EVO solution will be mixed with 10 parts of extracted groundwater and

injected into extraction wells 16EW11, 16EW12B, 16EW13, 16EW14B, and 16EW15. The injection volumes and amendment mixture quantities (total and per point) are shown on **Table 3-4**.

4.6.3 Landfill Biobarrier #3 Amendment Injection

The injection will consist of delivering amendments to the subsurface using series of seven injection points using DPT (DPT19 through DPT25) and one injection well (16IW10). A spacing of 15 feet between injection locations was selected based on the rationale and injection ROI presented in Section 4.1.2 of the Final ROD. The RD proposed that the injection well would also serve as a groundwater monitoring location within the biobarrier.

The injection locations are shown on **Figure 3-4**. The target injection intervals for the DPT locations are shown on **Table 3-5**. The injection volumes and amendment mixture quantities (total and per point) are shown on **Table 3-6** for the injection points and well.

4.6.4 Bayou Biobarrier Amendment Injection

The injection will consist of delivering amendments to the subsurface using a series of thirteen DPT locations (DPT-26 through DPT-35, and DPT-37 through DPT-39) and one injection well (16IW20) to inject the amendment mixture. The injection well will also serve as a groundwater monitoring location within the biobarrier along with 16RW11. The amendment mixture will comprise of a ABC Plus (EVO and microscale ZVI), SDC-9™ and sodium bromide (tracer). A slower rate of injection will be used to reduce chances of surfacing and reaching the creek. 16WW40 and 16WW56 will be used as injection control wells and will be visually monitored hourly during injections to determine if EVO reaches the well. The well should be outside the ROI. However, if EVO reaches the well, then the flow rate and volume will be reduced to ensure that a buffer zone is maintained at the creek and the injection pattern for other points will be modified to move the points away from the creek. Injections will be conducted during weekdays (and not on weekends) in order to facilitate visits by the Army and regulatory personnel for observation.

The field readings will be collected using a hand held field instrument and readings will be recorded on field forms. The probe will be placed in the bayou for a direct reading from the bayou. If the carbon source reaches the bayou, the natural organisms will utilize the carbon and will create anaerobic conditions in the water which may impact aquatic life. If any sudden decrease in DO is observed to below baseline readings or a visual change is observed in the water (murkiness) along the bayou bank, injections will be suspended. Additional monitoring and visual observations will be conducted to determine if the decrease is from injection materials or changes in the environmental conditions. If injections are suspended, corrective actions (placement of aerators and/or hay bales) will be implemented if needed. Once DO has stabilized and no visual confirmation of injection materials into the bayou is confirmed,

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injections will resume. During and after the injection, the surface water of Bayou will be monitored for DO. The following monitoring frequency will be conducted along the Bayou:

- Hourly visual and DO inspection along the Bayou during injections within 50 feet of any subsurface drainage feature
- Daily visual and DO inspection during weekdays for one week after injections
- Daily visual and DO inspections during weekend if more than 1 inch of rain is recorded within a week after the injections
- Visual and DO inspections every other day after the first significant rain (3 inches or more within a seven day period) for two weeks

During the injections, parameters will be monitored and recorded by APTIM personnel to ensure consistency. During injections, possible amendment surfacing (also known as daylighting) may occur at the ground surface or in the surface water at the Bayou and will be monitored. If daylighting on the surface or in Bayou is detected, injection rates will be reduced, or injections will be shutdown. If a spill is observed along the Bayou, amendments will be isolated using sand bags and hay bales and the affected materials will be collected and disposed. A solar powered aerator will be available for use, if needed, to aerate and reoxygenate impacted surface water. The target injection intervals are shown on **Table 3-7**. The injection locations are shown on **Figure 3-5**. The injection volumes and amendment mixture quantities (total and per point) are shown on **Table 3-8**.

4.6.5 Mid Plume Area (Shallow Groundwater Zone) Amendment Injection

The extraction wells (16EW01, 16EW02, 16EW03, and 16EW04) will be shut down prior to injections. The injection will consist of delivering amendments to the subsurface using a series of forty DPT locations (DPT-40 through DPT-79). An attempt will be made to inject into alternate points simultaneously to eliminate potential surfacing. The target DPT injection intervals are shown on **Table 3-9**. The injection volume and amendment mixture quantities (total and per point) are shown on **Table 3-10**.

The well locations are shown on **Figure 3-6**.

4.6.6 Mid Plume Area (Intermediate Groundwater Zone) Amendment Injection

Two new injection wells will be installed between pairs of existing extraction wells 16EW05 and 16EW06, 16EW06 and 16EW07, and 16EW07 and 16EW08 for a total of six new injection wells in the intermediate zone to recirculate groundwater between the injection and extraction wells. The proposed well locations are shown on **Figure 3-7**. The existing extraction wells will

be used as injection wells once the recirculation is terminated. The injection volume and amendment mixture quantities (total and per point) are shown on **Table 3-11**.

To distribute the amendments along the linear biobarrier between the injection wells, and to minimize mounding and/or surfacing, a sequence of recirculation will be used as follows:

- Check bromide before injecting and twice a week from active extraction wells. Once an increase in bromide is observed in an individual extraction well, the extraction is shut down from that well.
- Inject all the amendment mixture into each injection well (16IW25 to 16IW30).
- Start extraction at extraction wells 16EW05 and 16EW07 into the onsite tank and recirculate back into injection wells 16IW25, 16IW26, 16IW27, 16IW28, 16IW29, and 16IW30. Continue recirculation for 3 days unless an increase in bromide is observed above baseline levels in 16EW05 and 16EW07, and the extraction would stop.
- After 3 days, switch extraction to extraction wells 16EW06 and 16EW08 to the onsite tank and recirculate back into injection wells 16IW26, 16IW27, 16IW28, 16IW29, and 16IW30. Continue recirculation for 3 days unless an increase in bromide is observed above the baseline levels in 16EW05 and 16EW07, and the extraction would stop.
- After extracting for 3 days at 16EW06 and 16EW08, switch back to 16EW05 and 16EW07. Keep rotating extraction from wells until bromide is above baseline in all extraction wells.
- The extraction wells are estimated to be on for 2 to 3 weeks.
- After extraction has shut down in all extraction wells, the EVO amendment mixture will be injected into the existing extraction wells.

4.7 Performance Monitoring

APTIM will collect performance samples to evaluate the effectiveness of the ISB injections as indicated in **Tables 4-4** through **4-8**.

4.7.1 Baseline Sampling

Baseline samples will be collected prior to the implementation of injections to characterize the CVOC and perchlorate concentrations and geochemical conditions in the Shallow and Intermediate Zone. The wells selected include wells inside and outside of the plumes and wells located upgradient, within and downgradient of the ISB areas. The baseline sampling results will be compared to sample results collected post ISB injections. The wells that will be sampled during the baseline sampling event are included in **Table 4-2** and **4-3**.

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4.7.2 Evaluation of Design Effectiveness

Groundwater data will be collected within the first two months of remedy implementation to evaluate effectiveness of injections. Two sets of groundwater samples will be collected before the first quarterly performance monitoring event. The performance monitoring plan for Landfill Biobarrier #1, Landfill Biobarrier #2, Landfill Biobarrier #3, Bayou Biobarrier and Mid-Plume are presented in **Tables 4-4**, **4-5**, **4-6**, **4-7**, and **4-8**, respectively.

4.7.3 Performance Monitoring Year 1 and Year 2

Wells included in **Tables 4-4** to **4-8** will be used to monitor the performance of ISB injections in each area. The *Dehalococcoides* are expected to break down the chlorinated ethenes to harmless byproducts like ethene and ethane. This process of biodegradation results in depletion of DO and lowering of ORP. Performance monitoring will be conducted to evaluate change in geochemical conditions, VOCs, and perchlorate concentrations, due to biodegradation reactions. Additionally bromide will also be analyzed to evaluate the distribution of amendments after injections. The performance monitoring plan for Landfill Biobarrier #1, Landfill Biobarrier #2, Landfill Biobarrier #3, Bayou Biobarrier, and Mid-Plume are presented in **Tables 4-4**, **4-5**, **4-6**, **4-7**, and **4-8**. These tables also present the rationale for selection of each monitoring location. Any recommendations to reduce the frequency and/ or drop analytical parameters or wells from the sampling list will be made in the Annual Remedial Action Operation (RA-O) Report. Additionally, results will be evaluated to determine if reinjections are needed.

4.7.4 Follow-up Injections in Biobarriers

As specified in the ROD, follow up injections for the biobarriers will be implemented based on the groundwater monitoring results. Though the EVO is specified to last for 3 to 5 years, the decision to reinject will be based on the following criteria:

- Depletion of total organic carbon to below 20 mg/L.
- ORP increase above -50 millivolts (mV).
- Contaminant concentrations in groundwater performance wells for the landfill biobarriers and in surface water for the Bayou Biobarrier remain above cleanup standards.
- If these conditions occur, reinjections will be conducted only in specific areas that meet the above criteria. The wells used to determine the follow-up injection, in the previously injected biobarriers, are indicated as wells for “performance data within the biobarrier” in **Tables 4-4** through **4-7**.

4.7.5 MNA Evaluation

After two years of quarterly performance monitoring, the performance of MNA will be evaluated. The wells selected for performance monitoring for MNA evaluation for shallow and intermediate groundwater plumes are included in **Table 4-9** and in **Figure 4-2**. The analysis for the samples is also included on **Table 4-9**. The performance evaluation for MNA will be based on eight quarters of data combined with historical data to evaluate the effectiveness of biogeochemical reactions in reducing contaminant concentrations. Per the Final ROD (U.S. Army 2016), the evaluation of MNA after two years will be based on the following:

- Plume stability (i.e., plume concentrations are reducing in majority of the performance wells, and the plume is not expanding in area as demonstrated with compliance wells).
- MNA potential based on evaluation of biodegradation screening scores using USEPA guidance.
- MNA process evaluation, based on an attenuation rate calculated with empirical performance monitoring data, and MNA process demonstration based on the presence of daughter products and bacterial culture counts.

4.7.6 Contingency Action for MNA Areas

A contingency remedy will be implemented for MNA areas outside the active remediation areas if the above criteria (stated in **Section 4.7.5**) are not met. A contingency remedy involving the application of bioamendments to address the ineffective aspects of MNA will be conducted. The area and elements of contingency remedy will be selected based on the entire data set available. If the contingency remedy is required, it will be documented in an Explanation of Significant Difference (ESD).

4.7.7 Long-Term Monitoring Year 3 to Next Five Year Review

LTM will be initiated if MNA is found to be effective based on the first two years of performance monitoring. Per the Final ROD, LTM will be implemented at a semiannual frequency for three years, and then annually until the next five-year review. The wells selected and planned analysis is included in **Table 4-9** and will be modified based on the review of first two years of data.

4.7.8 Surface Water Monitoring

Surface water monitoring will be conducted during performance events to ensure that concentrations do not exceed surface water standards for contaminants. The surface water sampling events will be conducted along with the groundwater sampling events for performance monitoring. If surface water samples could not be collected from Harrison Bayou during quarterly sampling events due to a dry event, samples will be collected outside the

routine quarterly sampling events following significant rain events. An attempt will be made to collect four surface water samples every monitoring year.

Surface water samples will be collected at three locations: upgradient, downgradient and immediately adjacent to LHAAP-16 (**Figure 4-3**). As part of the surface water sample collection activities, field readings (DO, pH, ORP, temperature and conductivity) will be collected instream with a multi-parameter meter. Surface water samples will be collected in accordance with Section 3.6 of the IWWP (Bhate 2018). Please refer to SOP A11-Surface Water Sampling in Appendix A of the IWWP for detailed guidance regarding surface water sampling. These surface water samples will be analyzed for the COCs as shown in **Table 4-10** and concentrations will be compared to clean-up levels listed in **Table 1-1**. Surface water conditions will be noted and photos documented during the groundwater sampling event, and when surface water samples are collected.

4.7.9 Remediation Derived Waste Management

Remediation derived waste include the following:

- Drill cuttings from injection and monitoring wells
- Groundwater generated from development of new wells
- Groundwater generated from purging of wells prior to sampling
- Decontamination fluids
- Disposable protective clothing and supplies

Drill cuttings will be placed in 55-gallon drums or high-density polyethylene lined roll off containers. Composite samples will be collected and analyzed for waste characterization prior to proper handling and disposition. All handling of drill cuttings will be performed in accordance with Section 3.8.1 of the IWWP.

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.

4.8 Metals Groundwater Monitoring

The selected remedy in the ROD indicates monitoring for metals will be evaluated at the first five year review to determine if any further monitoring for metals is warranted (U.S. Army 2016). **Table 1-2** provides a summary of the wells that were sampled for the metals COCs and had detected concentrations above the cleanup levels. As part of the next five year review after remedy implementation, groundwater samples will be collected. All the wells listed on **Table 1-2** will be analyzed for thallium. Selected wells listed in **Table 1-2** will be analyzed

for the remaining metal COCs (chromium, arsenic, nickel and/or manganese) based on the previous results. The sampling will be conducted using low flow sampling as described in Section 3.4 of the IWWP (Bhate 2018). The monitoring results and evaluation will be included in the next five year review report.

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5.0 REMEDY PERFORMANCE EVALUATION AND REPORTING

A RACR will be submitted to document site activities completed to implement the RA. Performance monitoring results will be included in the Year 1 and Year 2 Annual RA-O Reports. The Year 1 and Year 2 Annual RA-O Reports will include an MNA evaluation of the groundwater COCs for LHAAP-16. After the first two years, if MNA is found to be effective, an Operating Properly and Successfully Report will be prepared. RA-O sampling will continue at a semiannual frequency through the remainder of the period of performance (PoP) and the results will be documented in Annual RA-O Reports.

5.1 Annual RA-O Reports

An Annual RA-O Report will be prepared at the end of each year to present groundwater monitoring results. Wells within the plume areas will be evaluated for MNA performance. 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 landfill O&M, annual LUC inspection, and well system O&M.

5.1.1 MNA Evaluation

A technical evaluation of natural attenuation potential will be performed at the end of the first year and second year of groundwater monitoring. The USEPA guidance, Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater (USEPA 1998), will be used as guidance for the natural attenuation evaluation. The USEPA guidance specifies a tiered approach of recommended lines of evidence (LOE) required for demonstrating that MNA is an effective remedy.

There are three LOE according to the USEPA guidance document based on the Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-17 (USEPA 1999), which are described as follows:

- **First Line of Evidence.** Observed reduction in contaminant mass and concentration. Relies on use of historical groundwater data that demonstrate a clear trend of stable decreasing concentrations over time at appropriate monitoring or sampling points.
- **Second Line of Evidence.** Identified and Quantified Natural Attenuation Processes. Uses geochemical indicators to document certain geochemical signatures or “footprints” in the groundwater that demonstrate (indirectly) the type of natural attenuation process(es) occurring at the site, and the rate at which such processes will

reduce COCs to the cleanup levels (**Table 1-1**), or groundwater medium-specific concentration for industrial use (GW-Ind) levels, established by TCEQ.

- **Third Line of Evidence.** Microcosm Studies. Most often consists of predictive modeling studies and other laboratory/field studies that demonstrate the occurrence of natural attenuation process(es) at the site and its ability to degrade the COC.

5.2 Contingency Action for MNA Areas

Per the ROD, a contingency remedy would be implemented if the above criteria (**Section 5.1.1**) were not met for the passive MNA areas (i.e., MNA areas outside the active remediation areas). The contingency remedy includes additional injections to enhance MNA. If a contingency remedy is needed, details of additional injections will be documented in an ESD.

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6.0 SCHEDULE

Table 6-1 shows the estimated duration for each major site activity and timeline. Weather and unknown site conditions could affect this schedule.

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7.0 OPERATION AND MAINTENANCE PROCEDURES

Some components of the final remedy at LHAAP-16 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 existing landfill cap, which includes signage; and maintenance of the current or future groundwater monitoring system (this would include all wells that serve some purpose, including bioremediation, MNA, background, water levels, and cap performance). Other routine maintenance activities include maintenance and repair of site access features, such as roads, gates, and fencing, as needed. These activities will be conducted annually unless recommended otherwise during a five-year review.

7.1 Maintenance of the Existing Landfill Cap

As discussed previously, a multilayer cap was constructed at LHAAP-16 landfill from 1996 through 1998 as part of an early IRA (under CERCLA) in accordance with the interim ROD signed in 1995. Per the 1995 IRA ROD and 2016 Final ROD, this cap includes the following layers: foundation soil layer, sodium bentonite geocomposite liner, geomembrane, 18-inch fill soil layer, 6-inch top soil, and perimeter berms and drainage swales. Please refer to **Appendix A** for a figure of the Landfill Cap.

Per the selected remedy documented in the 2016 Final ROD, the existing cap will continue to be monitored, maintained, and repaired, as necessary, to preserve its long-term effectiveness. This includes inspection of the landfill cap to check for erosion, settlement, and deep-rooted vegetation, and implementation of necessary repairs. Per the 1995 IRA ROD and 2016 Final ROD, the substantive post-closure requirements at 40 CFR Sections 264.228 (b)(1), (3), and (4); 264.310 (b); and 30 TAC 335.174 are ARARs for landfill cap maintenance and monitoring. The substantive requirements of these post-closure ARARs relevant to LHAAP-16 include the following:

- Maintain the integrity and effectiveness of the final cover, including making repairs to the cap as necessary to correct the effects of settling, subsidence, erosion, or other events (e.g. deep-rooted vegetation and burrowing animals).
- Maintain and monitor the ground-water monitoring system.
- Prevent run-on and run-off from eroding or otherwise damaging the final cover.

In order to comply with above requirements, annual inspections will be conducted for the different components of the landfill cap. Inspections will include examining each component of the cap to determine maintenance needs. The area will be checked for proper signage to

ensure that required signs are posted and are legible. If missing or no longer legible, the signs will be replaced.

An RAO Inspection and Maintenance Checklist is presented in **Appendix F**.

7.2 Vegetative Cover Maintenance

Vegetative cover is intended to reduce erosion caused by wind or water. Vegetation will be visually inspected annually, or as needed, following major events including a seismic event greater than a magnitude of 4 on the Richter scale, wildfires, or floods that may affect the integrity of the cover system, for overall health and continuous coverage. Bare spots where the topsoil is exposed, and/or areas of the cap where vegetation is dead or stressed to the point it no longer adequately inhibits erosion will be re-seeded, as appropriate. Unwanted vegetation (e.g., plants with potentially deep root systems such as trees) that has the potential to compromise the integrity of the cap will be removed.

7.3 Erosion and Settlement Inspection and Maintenance

The landfill cap will be inspected annually, for erosion and settlement, or as needed following major events including a seismic event greater than a magnitude of 4 on the Richter scale, wildfires, or floods that may affect the integrity of the cover system. If evidence of significant erosion, settlement, or deterioration, such as gullies, linear crevasses, washouts, rills, or settlement depressions, are observed, the need for cap repair will be evaluated. Settlement can cause cracks, differential displacement, or zones of depression that disrupt the intended flow of storm water over the cover. If repairs are determined to be needed, they will be performed to preserve the integrity of the cap and may include filling and covering the erosion and settlement features with material of similar composition to the existing topsoil. Replacement topsoil will be compacted to restore the cap to the specified grade.

7.4 Drainage System Inspection and Maintenance

The drainage system consisting of graded drainage swales will be visually inspected annually, or as needed, following major events including a seismic event greater than a magnitude of 4 on the Richter scale, wildfires, or floods that may affect the integrity of the cover system, for overgrown vegetation, debris and silt, and erosion of banks and slopes. Areas of the drainage system where vegetation is overgrown to the point that it interferes with drainage off the cover, or where silt and/or debris have accumulated, will be maintained by removing the overgrowth, and/or accumulated sediment/debris from the drainage swale. Also, areas with bank and slope erosion will be restored by removing eroded soil, adding new soil, compacting in 6-inch lifts, and adding vegetation for slope stability. If further stabilization is required, riprap can be placed along the bank slope.

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7.5 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, evaluate the performance of the cap, 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 discussed for the landfill cap. 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, 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 condition will be collected during inspection and maintenance activities. The annual inspection and maintenance activities will be documented in the Annual RA-O reports.

7.6 Maintenance of Site Access Features

LHAAP-16 is accessed by roads and through gates in a perimeter fence. The roads, perimeter fence, and gates will be visually inspected annually, or as needed, to ensure that the roads remain accessible and the perimeter fence and gates are intact and undamaged. Maintenance will be conducted as needed.

Any fence posts that are not securely anchored in the ground and/or metallic parts that are excessively corroded will be repaired or replaced. If evidence of unauthorized entry through, over, or under the fence is observed, these sections of the fence will be reinforced.

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Tables

Table 1-1
Groundwater and Surface Water Cleanup Levels, LHAAP-16

COC	Cleanup Level (µg/L)
	MCL
Trichloroethene	5
cis-1,2-dichlorethene	70
1,1-dichloroethene	7
1,2-dichloroethane	5
Vinyl Chloride	2
1,1,2-trichloroethane	5
Methylene Chloride	5
Chromium	100
Arsenic	10
Thallium	2
	TRRP Tier 1 Groundwater Residential PCLs
Nickel	490
Perchlorate	17
Manganese	1,100 [a]

Notes:

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

µg/L - micrograms per liter

COC - contaminant of concern

MCL - maximum contaminant level

PCL - Texas Risk Reduction Program (TRRP) Tier 1 Groundwater Residential Protective Concentration Level.

UTL - upper tolerance limit

Table 1-2

LHAAP-16 Wells with Metal Concentrations above Cleanup Levels

	Maximums					Most Recent Results				
	Arsenic	Chromium	Manganese [a]	Nickel	Thallium	Arsenic	Chromium	Manganese [a]	Nickel	Thallium [b]
Cleanup Levels	10	100	1100/7820	490	2	10	100	1100/7820	490	2
Shallow Wells										
16WW12	–	1820 (10/97)	–	816 (02/04)	footnote b	–	107 (03/09)	–	–	footnote b
16WW14	–	3090 (10/97)	–	1630 (10/97)	footnote b	–	143 (03/09)	–	–	footnote b
16WW16	–	465 (12/04)	*2090 (12/04)*	–	footnote b	–	–	*2090 (12/04)*	–	footnote b
16WW22	–	3860 (12/04)	–	690 (12/04)	footnote b	–	–	–	690 (12/04)	footnote b
16WW24	–	5220 (10/97)	*6020 (12/04)*	751 (10/97)	17.3 J (03/03)	–	830 (3/09)	*6020 (12/04)*	–	17.3 J (03/03)
16WW26	11 (10/97)	114 (10/97)	*2350 (02/04)*	–	11.9 J (12/04)	–	–	*2070 (12/04)*	–	11.9 J (12/04)
16WW30	–	–	*1640 (02/04)*	–	19.1 J (03/03)	–	–	*1510 (12/04)*	–	19.1 J (03/03)
16WW32	–	1260 (12/04)	–	–	footnote b	–	–	–	–	footnote b
16WW34	14 (10/97)	32400 (03/09)	–	1780 (02/04)	footnote b	–	32400 (03/09)	–	985 (12/04)	footnote b
16WW36	–	–	*5330 (02/04)*	–	6.19 J (3/03)	–	–	*5310 (12/04)*	–	6.19 J (3/03)
16WW38	–	783 (02/04)	–	976 (02/04)	footnote b	–	671 (03/09)	–	–	footnote b
16WW39	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
16WW40	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
16WW42	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
16WW43	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
16WW44	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
16WW46	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Intermediate Wells										
16WW06	–	–	*1770 (02/04)*	–	footnote b	–	–	–	–	footnote b
16WW13	–	–	29800 (10/97)	–	11.1 J (03/03)	–	–	*3760 (03/09)*	–	11.1 J (03/03)
16WW23	–	133 (03/03)	15700 (03/09)	720 (03/03)	40.3 (03/03)	–	–	15700 (03/09)	–	40.3 (03/03)
16WW25	105 (3/09)	–	9300 (02/04)	–	43.7 (03/03)	105 (03/09)	–	*7190 (03/09)*	–	43.7 (03/03)
16WW27	–	113 (03/03)	*4250 (02/04)*	–	17.6 J (03/03)	–	–	*3550 (02/04)*	–	17.6 J (03/03)
16WW28	–	–	*1510 (02/04)*	–	9.53 J (03/03)	–	–	*1380 (12/04)*	–	9.53 J (03/03)
16WW29	–	–	*1770 (02/04)*	–	24.5 (03/03)	–	–	*1710 (12/04)*	–	13.2 J (12/04)
16WW31	–	122 (12/04)	–	–	footnote b	–	122 (12/04)	--	–	footnote b
16WW33	–	1750 (12/04)	*5080 (10/97)*	887 (03/03)	footnote b	–	–	*1760 (12/04)*	–	footnote b
16WW35	123 (03/09)	–	9700 (03/09)	–	90.5 (03/03)	123 (03/09)	–	9700 (03/09)	–	90.5 (03/03)
16WW37	–	251 (10/97)	*5700 (10/97)*	–	footnote b	–	–	*4700 (12/04)*	–	footnote b
16WW41	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Upper Deep Wells										
16WW19	–	–	–	–	24.2 (03/03)	–	–	–	–	24.2 (03/03)
16WW20	23 (10/97)	129 (10/97)	–	–	footnote b	–	–	–	–	footnote b
16WW21	–	391 (03/03)	–	–	footnote b	–	–	–	–	footnote b
Lower Deep Wells										
16WW15	20 J (06/95)	–	–	–	14.8 (03/03)	–	–	–	–	14.8 (03/03)
16WW17	–	–	–	–	6.62 J (03/03)	–	–	–	–	6.62 J (03/03)
16WW18	–	–	–	–	6.11 J (03/03)	–	–	–	–	6.11 J (03/03)

Notes:

All Concentrations in micrograms per liter (µg/L)

Numbers in parenthesis are month and date of the maximum concentration or most recent sample

– concentration below the Cleanup Levels

[a] *Italic values* are above the TCEQ Protective Concentration Limit of 1100 µg/L but below background of 7820 µg/L.

[b] Thallium was not detected; however, the detection limits were above the cleanup level.

µg/L - micrograms per liter

J - estimated value

NS - not sampled

Table 3-1
Injection Depths and Monitoring Well Screen Intervals – Landfill Biobarrier #1

Well or DPT ID	Existing/Proposed	Primary Purpose		DPT Injection Depths/ Screen Intervals (feet bgs) [a]
		Substrate Injection	Performance Monitoring	
DPT-01 – DPT-07	Proposed	✓		15 – 21
DPT-08 – DPT-12	Proposed	✓		13 – 18
DPT-13 – DPT-18	Proposed	✓		5 – 18
16IW09	Proposed	✓		13 – 18
16RW01	Proposed		✓	15 – 21
16RW02	Proposed		✓	13 – 18
16RW03	Proposed		✓	13 – 18
16RW04	Proposed		✓	15 – 21
16RW05	Proposed		✓	13 – 18
16WW26	Existing		✓	13 – 18
16WW42	Existing		✓	2 – 12

Notes:

Wells 16WW26 and 16WW42 used to estimate injection depths. Please refer to Appendix C of the Final RD for the well logs.

[a] DPT Injection depths and monitoring well screen intervals may be modified based on field observations including depth of clay layer separating shallow and intermediate groundwater zones and depth to groundwater.

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

bgs - below ground surface

DPT - direct-push technology

ID - identification

Table 3-2
ISB Parameters, Landfill Biobarrier #1, LHAAP-16

Landfill Biobarrier #1

EDS-ER™ Biobarrier Volume Requirements per Well

	Wells	Treatment Thickness	Injection Interval (feet bgs)	Total Feet	EDS-ER™ (pounds)	EDS-ER™ (gallons)	SDC-9™ (gallons)	SDC-9™ (liters)	Sodium bromide (pounds)	Water (gallons)	EDS-ER™ per Well (pounds)	EDS-ER™ per Well (gallons)	SDC-9™ / Well (liters)	SDC-9™ / Well (gallons)	Sodium bromide per well (pounds)	Water per Well (gallons)	Total Volume per Well (gallons)
DPT 01-07	7	6	15-21	42	1411	204	0.44	1.68	8.51	1837	202	29	0.2	0.1	1.2	262	291.58
DPT 08-12	5	5	13-18	25	840	122	0.26	1.00	5.07	1093	168	24	0.2	0.1	1.0	219	242.99
DPT 13-18	6	13	5-18	78	2621	379	0.82	3.12	15.81	3411	437	63	0.5	0.1	2.6	568	631.76
16IW09	1	5	13-18	5	168	24	0.05	0.20	1.01	219	168	24	0.2	0.1	1.0	219	242.99
Totals	19			150		729	1.59	6.00	30.41	6,559							

Biobarrier EDS-ER™ Volume Requirements

Total EDS-ER required	5,041	pounds
Total EDS-ER required	729	gallons
SDC-9™ 1×10^{11} (DHC/liter)	2	gallons
SDC-9™ 1×10^{11} (DHC/liter)	6	liters
Total water volume	6,559	gallons
EDS-ER™ Requirement	34	pounds/foot
EDS-ER™ Requirement	5	gallons/foot
SDC-9™ requirement 1×10^{11} (DHC/liter)	0.01	gallons/foot
Water Requirement	44	gallons/foot
Sodium bromide	0.20	pounds/foot
Total volume	7,290	gallons
Total volume	49	gallons/foot
Amount of Sodium bromide needed	14	kilos

Notes:

Refer to Table 3-1 for injection intervals

bgs - below ground surface

DHC- dehalococcoides

DPT - direct-push technology

EDS-ER - Electron Donor Solution-Extended Release

EVO - emulsified vegetable oil

ft - feet

ISB - in situ bioremediation

SDC-9™ - APTIM's (Aptim Federal Services, LLC) dechlorinating culture

Table 3-3
Screen Intervals of Injection/Monitoring Wells – Landfill Biobarrier #2

Well ID	Existing/Proposed	Primary Purpose		Injection/Screen Intervals (feet bgs) [a]
		Substrate Injection	Performance Monitoring	
16EW11	Existing	✓		15.2 – 24.8
16EW12B	Existing	✓		13 – 28
16EW13	Existing	✓		15 – 24.6
16EW14B	Existing	✓		14 – 29
16EW15	Existing	✓		13.9 – 23.5
16IW01	Existing	✓		15 – 25
16IW03	Existing	✓		15 – 25
16IW05	Existing	✓		15 – 25
16IW07	Existing	✓		14 – 24
16PM02	Existing		✓	15.1 – 24.8
16PM03	Existing		✓	15 – 24.5
16PM04	Existing		✓	15.1 – 24.8
16PM14	Existing		✓	15.2 – 24.8
16PM06	Existing		✓	14.9 – 24.6
16PM09	Existing		✓	14.1 – 23.8

Notes:

Wells 16EW11 through 16EW15 used to estimate injection depths. Well logs are included in Appendix C of the Final RD.

[a] Injection / monitoring well screen intervals may be modified during field implementation activities based on field observations including depth clay layer separating shallow and intermediate groundwater zones and depth to groundwater.

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

bgs - below ground surface

ID - identification

Table 3-4
ISB Parameters, Landfill Biobarrier #2, LHAAP-16 (Phase I and Phase 2 Injections)

Site Parameters	Units	LHAAP-16	
Amendment Volume Requirements		Phase I	Phase 2
EDS-ER™	pounds	1797	1,797
EDS-ER™	gallons	260	260
SDC-9™ 1×10^{11} (DHC/liter)	Liters	2	2
SDC-9™ 1×10^{11} (DHC/liter)	gallons	0.5	0.5
Water	gallons	2339	2,339
Sodium Bromide	kilo	5	5
Volumes per Point			
EDS-ER™	gallons	65	52
SDC-9™ 1×10^{11} (DHC/liter)	Liters	0.5	0.4
SDC-9™ 1×10^{11}(DHC/liter)	gallons	0.13	0.11
Water	gallons	585	468
Injection Parameters			
Injection Spacing	feet	15	15
Target Depth	ft bgs	Refer to Table 3-3 for depths of existing IW & EW	Refer to Table 3-3 for depths of existing IW & EW
Thickness	feet	10	10
Total Volume per Point	gallons	650	520
Injection Rate	gpm	4	4
Injection Pressure (not to exceed)	psi	40	40
Time per Point	hours	2.7	2.2
Simultaneous Points	points	3	3
Hours of Injection per day	hours	8	8
Maximum Volume that can injected per day	gallons	5760	5,760
Points to be Completed (existing IWs and EWs)	points	4	5
Days of Injection	days	0.5	0.5

Notes:

Phase I of injections include injecting amendment into 16IW01, 16IW03, 16IW05 and 16IW07

Phase 2 of injections include injecting amendment into 16EW11, 16EW12B, 16EW13, 16EW14B and 16EW15

DHC - dehalococcoides

EDS-ER™ - Electron donor Substrate - Extended Release

EW - extraction well

ft bgs - feet below ground surface

gpm - gallons per minute

ISB - in situ bioremediation

IW - injection well

psi - pounds per square inch

SDC-9™ - APTIM's (Aptim Federal Services, LLC) dechlorinating culture

Table 3-5
Injection Depths and Monitoring Well Screen Intervals – Landfill Biobarrier #3

Well or DPT ID	Existing/Proposed	Primary Purpose		DPT Injection Depths/Screen Intervals (feet bgs) [a]
		Substrate Injection	Performance Monitoring	
DPT-19 – DPT-22	Proposed	✓		17 – 27
DPT-23 – DPT-25	Proposed	✓		15 – 25
16IW10	Proposed	✓		15 – 25
16RW06	Proposed		✓	17 – 27
16RW07	Proposed		✓	15 – 25
16RW08	Proposed		✓	15 – 25
16RW09	Proposed		✓	17 – 27
16RW10	Proposed		✓	15 – 25

Notes:

Wells 16WW14 used to estimate injection depths. The well log for 16WW14 is included in Appendix C of the Final RD.

[a] DPT Injection depths and monitoring well screen intervals may be modified based on field observations including depth of clay layer separating shallow and intermediate groundwater zones and depth to groundwater.

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

bgs - below ground surface

DPT - direct-push technology

ID - identification

Table 3-6
ISB Parameters, Landfill Biobarrier # 3, LHAAP-16

Site Parameters	Units	LHAAP-16
Amendment Volume Requirements		
EDS-ER™	pounds	2,333
EDS-ER™	gallons	337
SDC-9™ 1×10^{11}(DHC/liter)	Liters	3
SDC-9™ 1×10^{11}(DHC/liter)	gallons	1
Water	gallons	3,032
Sodium Bromide Required	kilo	6
Volumes per Point		
EDS-ER™	gallons	42
SDC-9™ 1×10^{11}(DHC/liter)	liters	0.38
SDC-9™ 1×10^{11}(DHC/liter)	gallons	0.10
Water	gallons	379
Injection Parameters		
Injection Spacing	feet	15
Target Depth	ft bgs	17-27; 15-25
Thickness	feet	10
Total Volume per Point	gallons	421
Injection Rate	gpm	4
Injection Pressure (not to exceed)	psi	40
Time per Point	hours	2
Simultaneous Points	points	3
Hours of Injection per day	hours	8
Maximum volume that can be injected per day	gallons	5,760
Points to be Completed (existing IWs and DPT)	points	8
Days of Injection	days	0.59

Notes:

DHC- dehalococcoides

DPT - direct-push technology

ft bgs - feet below ground surface

gpm - gallons per minute

ISB - in situ bioremediation

IW - injection well

psi - pounds per square inch

SDC-9™ - APTIM's (Aptim Federal Services, LLC) dechlorinating culture

Table 3-7
Injection Depths and Monitoring Well Screening Intervals – Bayou Biobarrier

Well or DPT ID	Existing/Proposed	Primary Purpose		DPT Injection Depths/Screen Intervals (feet bgs) [a]
		Substrate Injection	Performance Monitoring	
DPT-26 – DPT-31	Proposed	✓		22 – 32
DPT-32 – DPT-35	Proposed	✓		18 – 28
DPT-37 – DPT-39	Proposed	✓		14 – 24
16IW20	Proposed	✓		14 – 24
16WW22	Existing		✓	21 – 31
16RW11	Proposed		✓	14 – 24
16RW12	Proposed		✓	22 – 32
16WW39	Existing		✓	N/A
16WW12	Existing		✓	14 – 24

Notes:

Wells 16WW12 and 16WW22 used to estimate injection depths.Well logs for 16WW12 and 16WW22 in Appendix C of the Final RD.

[a] DPT Injection depths and monitoring well screen intervals may be modified based on field observations including depth of clay layer separating shallow and intermediate groundwater zones and depth to groundwater.

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

bgs - below ground surface

DPT - direct-push technology

ID - identification

N/A - not available

Table 3-8
ISB Parameters, Bayou Biobarrier, LHAAP-16

Site Parameters	Units	LHAAP-16
Amendment Volume Requirements		
ABC Plus (includes both EVO and ZVI) [a]	pounds	7,000
SDC-9™ 1×10^{11} (DHC/liter)	Liters	5
Volume of product with water	gallons	3,800
Sodium bromide required	kilo	7
Volumes per Point		
Product with water	gallons	271
SDC-9™ 1×10^{11} (DHC/liter)	liters	0.36
SDC-9™ 1×10^{11} (DHC/liter)	gallons	0.10
Injection Parameters		
Injection Spacing	feet	15
Target Depth	ft bgs	Refer to Table 3-7 for target depths
Thickness	feet	10
Total Volume per Point	gallons	271
Injection Rate	gpm	4
Injection Pressure (not to exceed)	psi	40
Time per Point	hours	2
Simultaneous Points	points	3
Hours of Injection per day	hours	8
Maximum volume that can be injected per day	gallons	5,760
Points to be Completed (proposed 1 IW & 13 DPT)	points	14
Days of Injection	days	0.66

Notes:

[a] Includes 3,500 pounds of ABC and 3,500 pounds of ZVI)

ABC is the EVP product supplied by Redox Tech

DHC- dehalococcoides

DPT - direct-push technology

EVO - emulsified vegetable oil

ft bgs - feet below ground surface

gpm - gallons per minute

ISB - in situ bioremediation

IW - injection well

psi - pounds per square inch

SDC-9™ - APTIM's (Aptim Federal Services, LLC) dechlorinating culture

ZVI - zero valent iron

Table 3-9
Screen Intervals of Injection/Extraction Wells – Mid-Plume ISB

Well ID	Existing/ Proposed	Purpose		Screen Intervals (feet bgs) [b]
		Substrate Emplacement [a]	Performance Monitoring	
Shallow Groundwater Zone				
DPT-40 – DPT-79	Proposed	✓		14 – 36
16EW01	Existing		✓	31.2 – 36.2
16EW02	Existing		✓	21.5 – 26.5
16EW03	Existing		✓	13 – 18
16EW04	Existing		✓	14 – 19
16WW48	Proposed		✓	25 – 35
16WW39	Existing		✓	N/A
16WW30	Existing		✓	25 – 35
Intermediate Groundwater Zone				
16EW05	Existing	✓	✓	47 – 52
16EW06	Existing	✓	✓	50 – 55
16EW07	Existing	✓	✓	41 – 46
16EW08	Existing	✓	✓	34 – 39
16IW25	Proposed	✓		40 – 55
16IW26	Proposed	✓		40 – 55
16IW27	Proposed	✓		40 – 55
16IW28	Proposed	✓		35 – 50
16IW29	Proposed	✓		35 – 50
16IW30	Proposed	✓		35 – 50
16WW49	Proposed		✓	45 – 55
16WW51	Proposed		✓	35 – 45

Notes:

[a] Wells 16EW01 through 16EW04 in the Shallow Zone and wells 16EW05 through 16EW08 in the Intermediate Zone used to estimate injection depths. Well logs are included in Appendix C of the Final RD.

[b] Injection/monitoring well screen intervals may be modified during field implementation activities based on field observations including depth clay layer separating shallow and intermediate groundwater zones and depth to groundwater.

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

bgs - below ground surface

DPT - direct-push technology

ID - identification

ISB - in situ bioremediation

N/A - not available

Table 3-10
ISB Parameters, Mid Plume (Shallow Zone), LHAAP-16

Site Parameters	Units	LHAAP-16
Amendment Volume Requirements		
EDS-ER™	pounds	28,414
EDS-ER™	gallons	4,107
SDC-9™ 1×10^{11} (DHC/liter)	Liters	201
SDC-9™ 1×10^{11} (DHC/liter)	gallons	53
Water	gallons	36,910
Sodium Bromide Required	kilo	78
Volumes per Point		
EDS-ER™	gallons	103
SDC-9™ 1×10^{11} (DHC/liter)	liters	5
SDC-9™ 1×10^{11} (DHC/liter)	gallons	1.33
Water	gallons	923
Injection Parameters		
Injection Spacing	feet	15
Target Depth	ft bgs	14-36
Thickness	feet	22
Total Volume per Point	gallons	1,027
Injection Rate	gpm	4
Injection Pressure (not to exceed)	psi	40
Time per Point	hours	5
Simultaneous Points	points	3
Hours of Injection per day	hours	8
Gallons per day	gallons	5,760
Points to be Completed (DPT points)	points	40
Days of Injection	days	7.13

Notes:

DHC- dehalococcoides

DPT - direct-push technology

EDS-ER™ - Electron Donor Substrate - Extended Release

ft bgs - feet below ground surface

gpm - gallons per minute

ISB - in situ bioremediation

psi - pounds per square inch

SDC-9™ - APTIM's (Aptim Federal Services, LLC) dechlorinating culture

Table 3-11
ISB Parameters, Mid Plume (Intermediate Zone), LHAAP-16

Site Parameters	Units	LHAAP-16
Amendment Volume Requirements		
EDS-ER™	pounds	16,565
EDS-ER™	gallons	2,394
SDC-9™ 1×10^{11} (DHC/liter)	Liters	67
SDC-9™ 1×10^{11} (DHC/liter)	gallons	18
Water	gallons	21,528
Sodium Bromide Required	kilo	45
Volumes per Point		
Emulsified Vegetable Oil	gallons	239
SDC-9™ 1×10^{11} (DHC/liter)	Liters	7
SDC-9™ 1×10^{11} (DHC/liter)	gallons	2
Water	gallons	2,153
Injection Parameters		
Injection Spacing	feet	15
Target Depth	ft bgs	Please refer to Table 3-9 for target depths
Thickness	feet	5 and 15
Total Volume per Point	gallons	2,394
Injection Rate	gpm	4
Injection Pressure (not to exceed)	psi	40
Time per Point	hours	10
Simultaneous Points	points	3
Hours of Injection per day	hours	8
Gallons per day	gallons	5,760
Points to be Completed (4 existing EWs and 6 new IWs)	points	10
Days of Injection	days	4.16

Notes:

DHC- dehalococcoides

DPT - direct-push technology

EW - extraction well

ft bgs - feet below ground surface

gpm - gallons per minute

ISB - in situ bioremediation

IW - injection well

psi - pounds per square inch

SDC-9™ - APTIM's (Aptim Federal Services, LLC) dechlorinating culture

Table 4-1
Proposed Injection and Monitoring Wells, LHAAP-16

Well ID	Injections	Performance Monitoring	Screen Intervals	Shallow/ Intermediate Zone
16RW01		✓	15-21	Shallow
16RW02		✓	13-18	Shallow
16RW03		✓	13-18	Shallow
16RW04		✓	15-21	Shallow
16RW05		✓	13-18	Shallow
16IW09	✓		13-18	Shallow
16RW06		✓	17-27	Shallow
16RW07		✓	15-25	Shallow
16RW08		✓	15-25	Shallow
16RW09		✓	17-27	Shallow
16RW10		✓	15-25	Shallow
16IW10	✓	✓	15-25	Shallow
16WW55		✓	17-27	Shalllow
16RW11		✓	14-24	Shallow
16RW12		✓	22-32	Shallow
16WW56		✓	22-32	Shallow
16WW57		✓	14-24	Shallow
16WW58		✓	10-20	Shallow
16IW20	✓		14-24	Shallow
16WW48		✓	25-35	Shallow
16IW25	✓		40-55	Intermediate
16IW26	✓		40-55	Intermediate
16IW27	✓		40-55	Intermediate
16IW28	✓		35-50	Intermediate
16IW29	✓		35-50	Intermediate
16IW30	✓		35-50	Intermediate
16WW49		✓	45-55	Intermediate
16WW51		✓	35-45	Intermediate

Table 4-2
Pre-Remedy Sampling Plan in the Shallow Zone, LHAAP-16

Monitoring Locations	ISB Area	Proposed Analyses								
		VOCs [a] (SW8260B)	Perchlorate (6850)	Anions [b] (E300.0)	Dissolved Gases [c] (RSK-175)	Alkalinity (2320B)	TOC (SW9060)	DHC (qPCR)	Bromide (E300.0)	Field Parameters [d]
16WW26	Downgradient to Landfill Biobarrier #1	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW42	Downgradient to Landfill Biobarrier #1	✓	✓						✓	✓
16WW44	Background	✓	✓							✓
16WW38	Upgradient to Landfill Biobarrier #2	✓	✓							✓
16WW16	Upgradient to Landfill Biobarrier #2	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW36	Downgradient to Landfill Biobarrier #2	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW14	Upgradient to Landfill Biobarrier #3	✓	✓							✓
16WW55	Proposed Well Downgradient to Landfill Biobarrier #3	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW12	Upgradient to Bayou Biobarrier	✓	✓						✓	✓
16WW40	Downgradient to Bayou Biobarrier	✓	✓						✓	✓
16WW22	Upgradient to Bayou Biobarrier	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW56	Proposed Well and Downgradient to Bayou Biobarrier	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW57	Proposed Well and Across Bayou Biobarrier	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW58	Proposed Well and Across Bayou Biobarrier	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW30	Downgradient of Mid-Plume	✓	✓						✓	✓
16WW48	Proposed Well and Downgradient of Mid-Plume ISB Area	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW39	Downgradient of Mid-Plume ISB Area	✓	✓						✓	✓
16WW46	Downgradient Outside of Contaminated Area	✓	✓							✓
16WW32	Cross-gradient Outside of Containment Area	✓	✓							✓
16WW34	Cross-gradient Outside of Containment Area	✓	✓							✓
16WW24	Cross-gradient to South of Plume	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW43	Cross-gradient to South of Plume	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 4-2
Pre-Remedy Sampling Plan in the Shallow Zone, LHAAP-16

Monitoring Locations	ISB Area	Proposed Analyses								
		VOCs [a] (SW8260B)	Perchlorate (6850)	Anions [b] (E300.0)	Dissolved Gases [c] (RSK-175)	Alkalinity (2320B)	TOC (SW9060)	DHC (qPCR)	Bromide (E300.0)	Field Parameters [d]
16WW21	Downgradient of Mid-Plume ISB Area	✓	✓						✓	✓
16EW02	Inside Mid-Plume ISB Area	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes:

This schedule assumes sampling of the extraction wells will be continued annually until the remedy is implemented; therefore, only 16EW02 will be sampled during pre-remedy monitoring.

[a] VOCs include TCE; cis-1,2-DCE; 1,1-DCE; 1,2-DCA; 1,1,2-TCA; VC; and methylene chloride.

[b] Anions include nitrate and sulfate.

[c] Dissolved gasses include ethene, ethane, and methane.

[d] Field Parameters include dissolved oxygen, oxidation reduction potential, and pH.

[e] Upper deep monitoring well

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

DHC - Dehalococcoides (microbial analysis)

TOC - total organic carbon

VOCs - volatile organic compounds

Table 4-3
Pre-Remedy Sampling Plan in the Intermediate Zone, LHAAP-16

Monitoring Locations	ISB Area	Proposed Analyses								
		VOCs [a] (SW8260B)	Perchlorate (6850)	Anions [b] (E300.0)	Dissolved Gases [c] (RSK-175)	Alkalinity (2320B)	TOC (SW9060)	DHC (qPCR)	Bromide (E300.0)	Field Parameters [d]
16WW45	Background	✓	✓							✓
16WW37	Downgradient of Landfill / Upgradient of Landfill Biobarrier #2	✓	✓							✓
16WW35	Upgradient of Mid-Plume ISB Area / Downgradient of Landfill Biobarrier #2	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW25	Upgradient of Mid-Plume ISB Area / Downgradient of Landfill Biobarrier #1	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW13	Downgradient of Landfill	✓	✓						✓	✓
16WW23	Downgradient of Landfill	✓	✓							✓
16WW27	Downgradient Outside of Contaminated Area	✓	✓							✓
16WW29	Downgradient of Mid-Plume ISB Area	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW41	Downgradient of Mid- Plume ISB Area	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW31	Cross-gradient Outside of Containment Area	✓	✓							✓
16WW33	Cross-gradient Outside of Containment Area	✓	✓							✓
16WW21[e]	Downgradient of Mid-Plume ISB Area	✓	✓							✓
16WW49	Proposed Well and Downgradient of Mid-Plume ISB Area	✓	✓						✓	✓
16WW51	Proposed Well and Downgradient of Mid-Plume ISB Area	✓	✓						✓	✓
16EW06	Inside Mid-Plume ISB Area	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes:

This schedule assumes sampling of the extraction wells will be continued annually until the remedy is implemented; therefore, only 16EW06 will be sampled during pre-remedy monitoring.

[a] VOCs include TCE; cis-1,2-DCE; 1,1-DCE; 1,2-DCA; 1,1,2-TCA; VC; and methylene chloride.

[b] Anions include nitrate and sulfate.

[c] Dissolved gasses include ethene, ethane, and methane.

[d] Field parameters include dissolved oxygen, oxidation reduction potential, and pH.

[e] Upper deep monitoring well

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

DHC - Dehalococcoides (microbial analysis)

TOC - total organic carbon

VOCs - volatile organic compounds

Table 4-4
ISB Performance Monitoring Plan (Years 1 and 2) – Landfill Biobarrier #1

Monitoring Locations	Primary Rationale for Well Selection	Year 1 (Quarterly)																	Year 2 (Quarterly)											
		DO (field reading)	ORP (field reading)	pH (field reading)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs [c] (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions [b] (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	DHC (qPCR)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs [c] (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions [b] (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	Bromide (E300.0)	TOC (SW9060)
16RW03	Performance data within the biobarrier	✓	✓	✓	✓	✓																									
16IW09	Performance data within the biobarrier	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
16RW01	Upgradient well for monitoring influent concentrations	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	✓							
16RW02	Upgradient well for monitoring influent concentrations	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	✓							
16RW04	Downgradient well to monitor effluent concentrations and biobarrier effectiveness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓							
16RW05	Downgradient well to monitor effluent concentrations and biobarrier effectiveness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓							
16WW26	Downgradient well to monitor effluent concentrations and biobarrier effectiveness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓
16WW42	Downgradient well to monitor effluent concentrations and biobarrier effectiveness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓

Notes:

[a] To be conducted within 15 to 30 days of the completion of substrate injection. A second event will be collected between 45 and 60 days if the results from the first event were inconclusive.

[b] Anions include nitrate and sulfate.

[c] VOCs include TCE; cis-1,2-DCE; 1,1-DCE; 1,2-DCA; 1,1,2-TCA; VC; and methylene chloride.

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

ISB - in-situ bioremediation

Table 4-5
ISB Performance Monitoring Plan (Years 1 and 2) – Landfill Biobarrier #2

Monitoring Locations	Primary Rationale for Well Selection	Year 1 (Quarterly)																	Year 2 (Quarterly)												
		DO (field reading)	ORP (field reading)	pH (field reading)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs [c] (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions [b] (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	DHC (qPCR)	Bromide (E300)	TOC (SW9060)	Perchlorate (6850)	VOCs [c] (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions [b] (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	Bromide (E300.0)	TOC (SW9060)
16IW03	Performance data within the biobarrier	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
16IW04	Performance data within the biobarrier	✓	✓	✓	✓	✓																									
16PM02	Upgradient well for monitoring influent concentrations	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	✓							
16PM03	Upgradient well for monitoring influent concentrations	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	✓							
16PM06	Downgradient well to monitor effluent concentrations and biobarrier effectiveness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓							
16PM09	Downgradient well to monitor effluent concentrations and biobarrier effectiveness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	✓							
16PM14	Downgradient well to monitor effluent concentrations and biobarrier effectiveness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓							
16WW36	Downgradient well to monitor effluent concentrations and biobarrier effectiveness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓

Notes:

[a] To be conducted within 15 to 30 days of the completion of substrate injection. A second event will be collected between 45 and 60 days if the results from the first event were inconclusive.

[b] Anions include nitrate and sulfate.

[c] VOCs include trichloroethene (TCE); cis-1,2-dichloroethene (DCE); 1,1-DCE; 1,2-dichloroethane (DCA); 1,1,2-trichloroethane (TCA); Vinyl Chloride (VC); and methylene chloride.

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

ISB - in-situ bioremediation

Table 4-6
ISB Performance Monitoring Plan (Years 1 and 2) – Landfill Biobarrier #3

Monitoring Locations	Primary Rationale for Well Selection	Year 1 (Quarterly)																	Year 2 (Quarterly)											
		DO (field reading)	ORP (field reading)	pH (field reading)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs [c] (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions [b] (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	DHC (qPCR)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs [c] (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions [b] (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	Bromide (E300.0)	TOC (SW9060)
16RW08	Performance data within the biobarrier	✓	✓	✓	✓	✓																									
16IW10	Performance data within the biobarrier	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
16RW06	Upgradient well for monitoring influent concentrations	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	✓							
16RW07	Upgradient well for monitoring influent concentrations	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	✓							
16RW09	Downgradient well to monitor effluent concentrations and biobarrier effectiveness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓
16RW10	Downgradient well to monitor effluent concentrations and biobarrier effectiveness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓

Notes:

[a] To be conducted within 15 to 30 days of the completion of substrate injection. A second event will be collected between 45 and 60 days if the results from the first event were inconclusive.

[b] Anions include nitrate and sulfate.

[c] VOCs include trichloroethene (TCE); cis-1,2-dichloroethene (DCE); 1,1-DCE; 1,2-dichloroethane (DCA); 1,1,2-trichloroethane (TCA); Vinyl Chloride (VC); and methylene chloride.

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

ISB - in-situ bioremediation

Table 4-7
ISB Performance Monitoring Plan (Years 1 and 2) – Bayou Biobarrier

Monitoring Locations	Primary Rationale for Well Selection	Year 1 (Quarterly)																	Year 2 (Quarterly)												
		DO (field reading)	ORP (field reading)	pH (field reading)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs [c] (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions [b] (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	DHC (qPCR)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs [c] (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions [b] (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	Bromide (E300.0)	TOC (SW9060)
16RW11	Performance data within the biobarrier	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	✓							
16IW20	Performance data within the biobarrier	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
16RW12	Performance data downgradient of biobarrier	✓	✓	✓	✓	✓																									
16WW39	Upgradient well for monitoring influent concentrations	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	✓							
16WW12	Upgradient well to monitor effluent concentrations and biobarrier effectiveness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓							
16WW22	Upgradient well to monitor effluent concentrations and biobarrier effectiveness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓							
16WW40	Downgradient well to monitor effluent concentrations and biobarrier effectiveness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓

Notes:

[a] To be conducted within 15 to 30 days of the completion of substrate injection. A second event will be collected between 45 and 60 days if the results from the first event were inconclusive.

[b] Anions include nitrate and sulfate.

[c] VOCs include trichloroethene (TCE); cis-1,2-dichloroethene (DCE); 1,1-DCE; 1,2-dichloroethane (DCA); 1,1,2-trichloroethane (TCA); Vinyl Chloride (VC); and methylene chloride.

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

ISB - in-situ bioremediation

Table 4-8
ISB Performance Monitoring Plan (Years 1 and 2) – Mid-Plume ISB

Monitoring Locations	Primary Rationale for Well Selection	Year 1 (Quarterly)																Year 2 (Quarterly)											
		DO (field reading)	ORP (field reading)	pH (field reading)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs [c] (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions [b] (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	DHC (qPCR)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs [c] (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions [b] (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	Bromide (E300.0)	TOC (SW9060)
16EW01	Performance data for injection ISB area - Shallow Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
16EW02	Performance data for injection ISB area - Shallow Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							
16EW03	Performance data for injection ISB area - Shallow Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
16EW04	Performance data for injection ISB area - Shallow Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	✓							
16EW05	Performance Data for Injection Well – Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
16EW06	Performance data for injection well - Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
16EW07	Performance data for injection well - Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	✓							
16EW08	Performance data for injection well - Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓							
16WW48	Performance data for downgradient - Shallow Zone (proposed)						✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW30	Performance data for downgradient - Shallow Zone						✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓							
16WW39	Performance data for downgradient - Shallow Zone						✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓							
16WW29	Performance data for downgradient well - Intermediate Zone						✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓							
16WW49	Performance data for downgradient well - Intermediate Zone (proposed)						✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓							
16WW51	Performance data for downgradient well - Intermediate Zone (proposed)						✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓							
16WW21	Performance data for downgradient well in Upper Deep Zone						✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓							

Notes:

[a] To be conducted within 15 to 30 days of the completion of substrate injection. A second event will be collected between 45 and 60 days if the results from the first event were inconclusive.

[b] Anions include nitrate and sulfate.

[c] VOCs include trichloroethene (TCE); cis-1,2-dichloroethene (DCE); 1,1-DCE; 1,2-dichloroethane (DCA); 1,1,2-trichloroethane (TCA); Vinyl Chloride (VC); and methylene chloride.

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

ISB - in-situ bioremediation

Table 4-9
MNA and LTM Performance Monitoring Plan – LHAAP-16

Monitoring Locations	Groundwater Zone	Proposed Analyses								
		VOCs [a] (SW8260B)	Perchlorate (6850)	Anions [b] (E300.0)	Dissolved Gases [c] (RSK-175)	Alkalinity (2320B)	TOC (SW9060)	DHC (qPCR)	Bromide (E300.0)	Field Parameters [d]
16WW44	Shallow	✓	✓							✓
16WW38	Shallow	✓	✓							✓
16WW16	Shallow	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW14	Shallow	✓	✓							✓
16WW36	Shallow	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW26	Shallow	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW42	Shallow	✓	✓							✓
16WW43	Shallow	✓	✓							✓
16WW30	Shallow	✓	✓							✓
16WW40	Shallow	✓	✓							✓
16WW22	Shallow	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW46	Shallow	✓	✓							✓
16WW32	Shallow	✓	✓							✓
16WW34	Shallow	✓	✓							✓
16WW24	Shallow	✓	✓							✓
16WW48	Shallow	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW39	Shallow	✓	✓							✓
16WW55	Shallow	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW56	Shallow	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW57	Shallow	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW58	Shallow	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW37	Intermediate	✓	✓							✓
16WW35	Intermediate	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW13	Intermediate	✓	✓							✓
16WW23	Intermediate	✓	✓							✓
16WW25	Intermediate	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW27	Intermediate	✓	✓							✓
16WW29	Intermediate	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW41	Intermediate	✓	✓	✓	✓	✓	✓	✓	✓	✓
16WW31	Intermediate	✓	✓							✓
16WW33	Intermediate	✓	✓							✓
16WW49	Intermediate	✓	✓							✓
16WW51	Intermediate	✓	✓							✓
16WW21	Upper Deep	✓	✓							✓

Notes:

This schedule assumes sampling of the extraction wells will be continued annualy until the remedy is implemented; therefore, only 16EW02 will be sampled during baseline monitoring.

[a] VOCs include trichloroethene (TCE); cis-1,2-dichloroethene (DCE); 1,1-DCE; 1,2-dichloroethane (DCA); 1,1,2-trichloroethane (TCA); Vinyl Chloride (VC); and methylene chloride.

[b] Anions include nitrate and sulfate.

[c] Dissolved gasses include ethene, ethane, and methane.

[d] Field Parameters include dissolved oxygen, oxidation reduction potential, and pH.

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

DHC - Dehalococcoides (microbial analysis)

LTM - long-term monitoring

TOC - total organic carbon

VOCs - volatile organic compounds

Table 4-10
Surface Water Sampling Plan, LHAAP-16

Monitoring Locations	Proposed Analyses			
	VOCs [a] (SW8260B)	Perchlorate (6850)	Metals (/6020A/7471B)	Field Parameters [b]
16SW01	✓	✓	✓	✓
16SW02	✓	✓	✓	✓
16SW03	✓	✓	✓	✓

Notes:

Surface water samples will be collected from the above locations as part of the pre-remedy sampling event and quarterly performance monitoring events

[a] VOCs include trichloroethene (TCE); cis-1,2-dichloroethene (DCE); 1,1-DCE; 1,2-dichloroethane (DCA); 1,1,2-trichloroethane (TCA); Vinyl Chloride (VC); and methylene chloride.

[b] Metals include arsenic, chromium, manganese, nickel and thallium.

[c] Field Parameters include dissolved oxygen, oxidation reduction potential, conductivity, temperature and pH.

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

VOCs - volatile organic compounds

Table 6-1
Schedule for Major Site Activities

Activities	Duration
Submit Injection Information to State	30
Utility Clearance	1
Clear Injection / New Well Locations	3
Install Injection Wells and Monitoring Wells	10
Develop Wells/slug test	4
Baseline Sampling and Gauging	13
Mobilization / Site Set-up for Injections	3
Conduct Injection	25
Demobilization	1
Total No. of days	90

Notes:

Sampling will occur on a quarterly basis for 2 years.

Figures

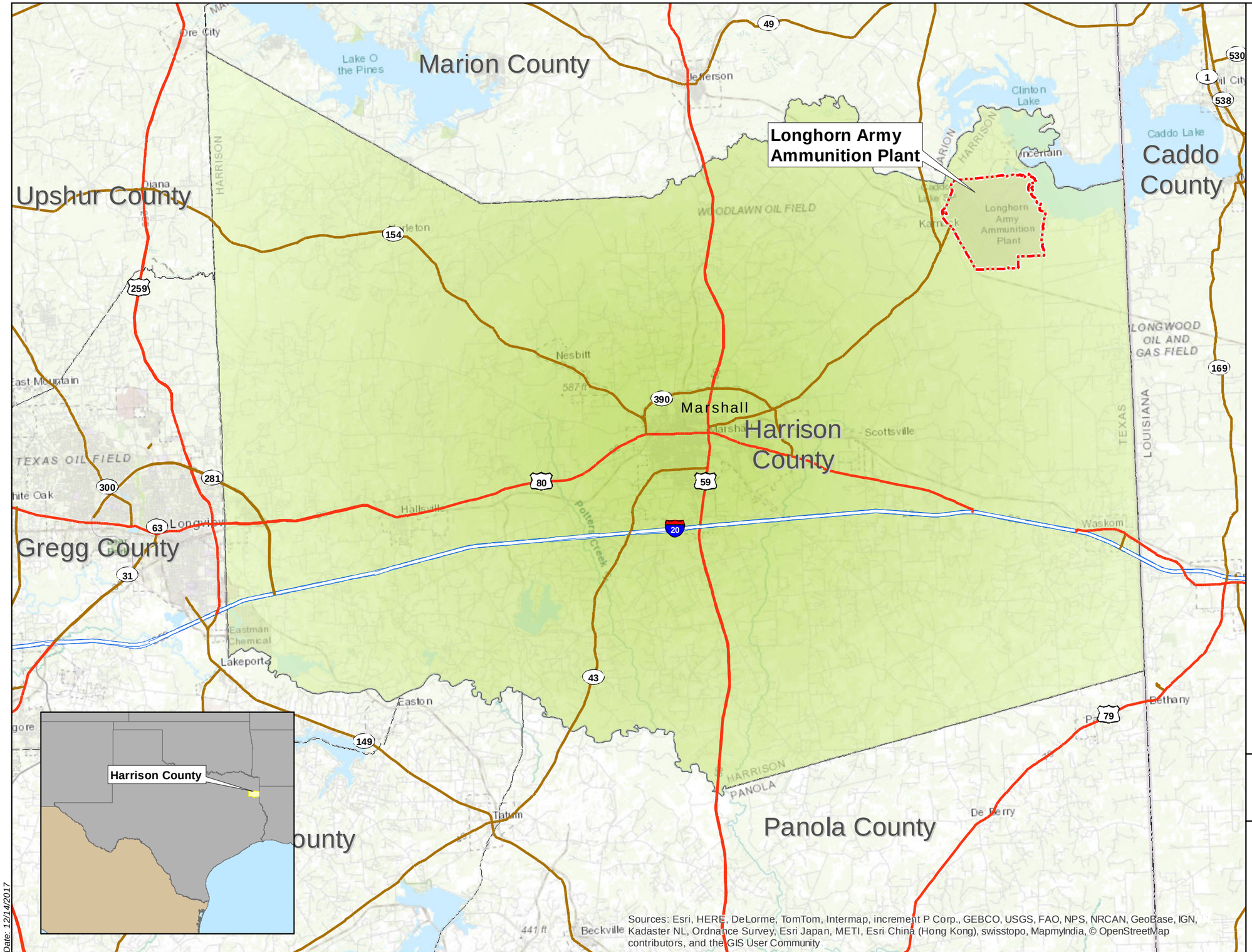

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Figure 1-1

LHAAP Location Map
LHAAP-16 RAWP

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 12/14/2017

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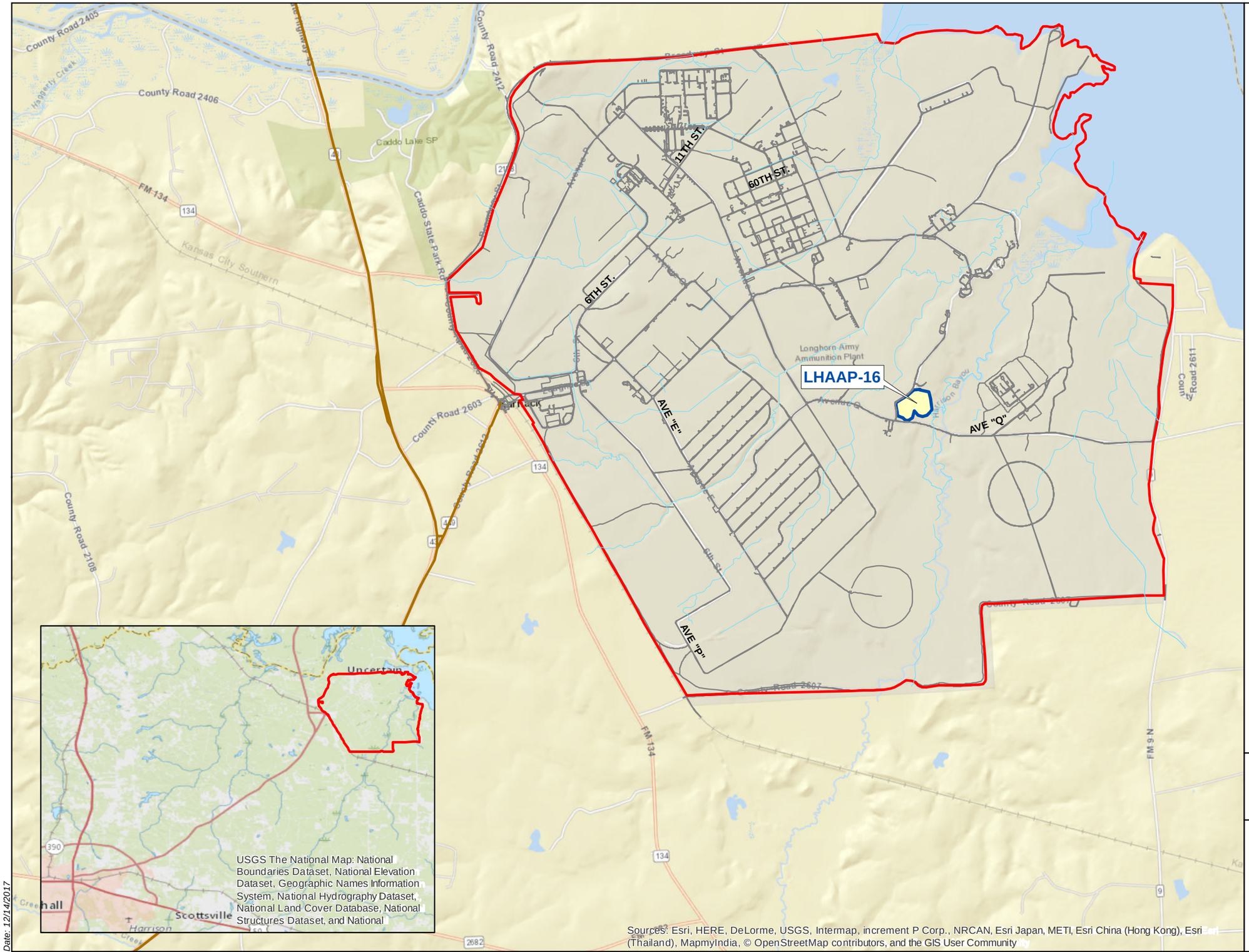

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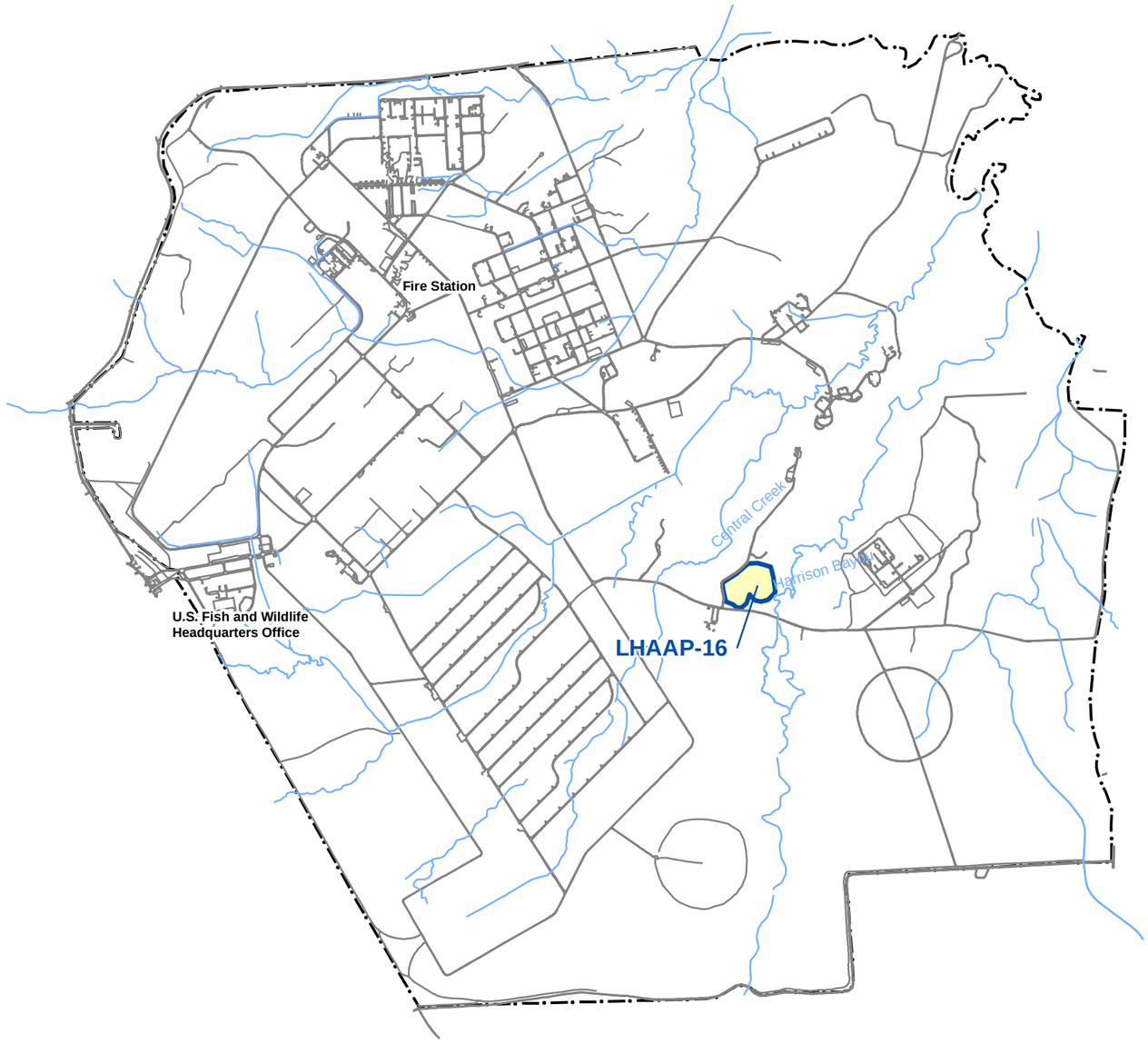
Figure 1-2

LHAAP Site Location Map
LHAAP-16 RAWP

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 12/14/2017

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP16\RAWP\Fig1-2_LHAAP_SiteLocationMap.mxd



Stream
Road
LHAAP Boundary
LHAAP-16 Site Boundary

N

0 1,500 3,000
Feet

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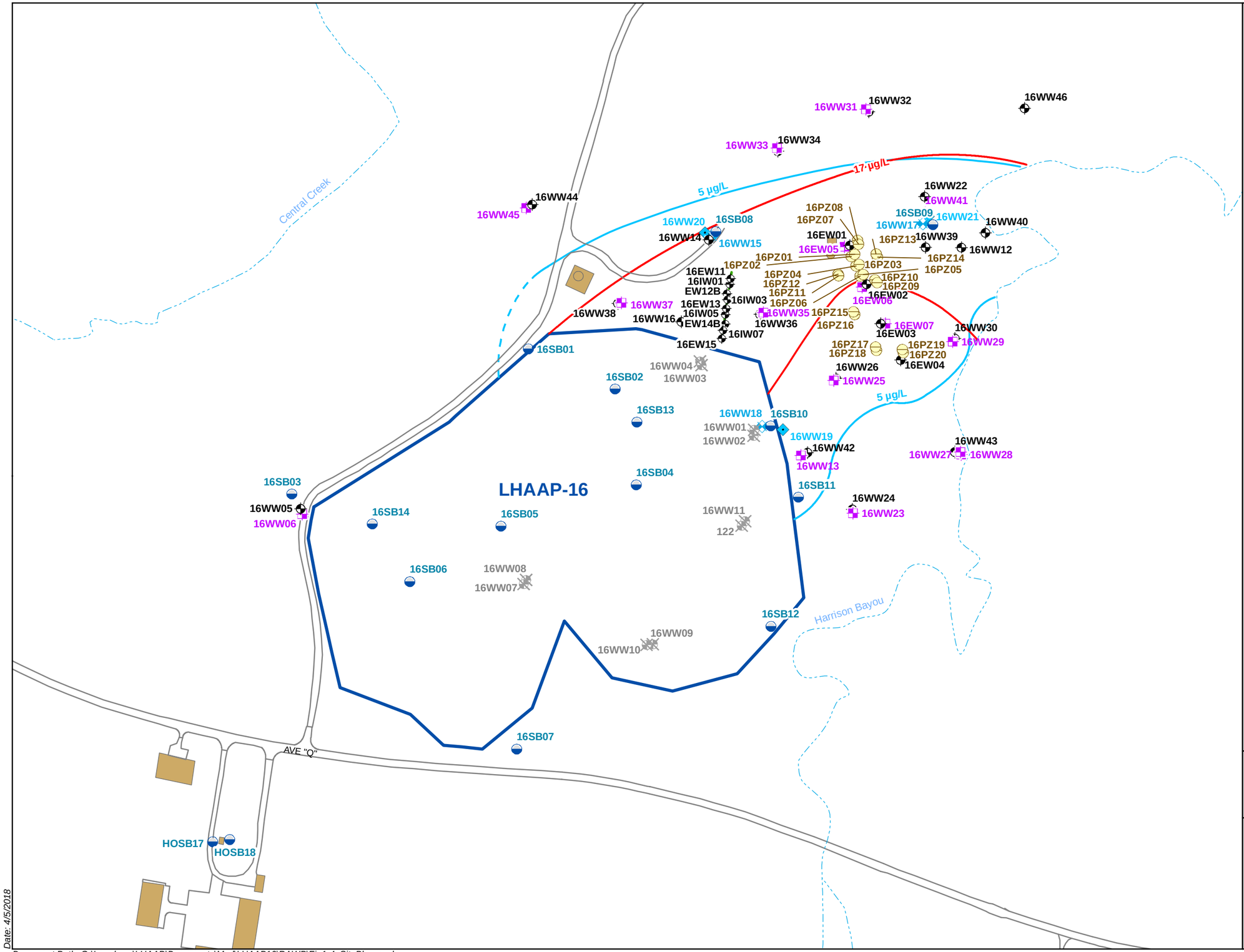
Figure 1-3

Site Vicinity Map
LHAAP-16 RAWP

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 6/19/2018

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP16\RAWP\Fig1-3_SiteVicinityMap.mxd



Date: 4/5/2018

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Figure 1-4

LHAAP-16 Site Plan
LHAAP-16 RAWP

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

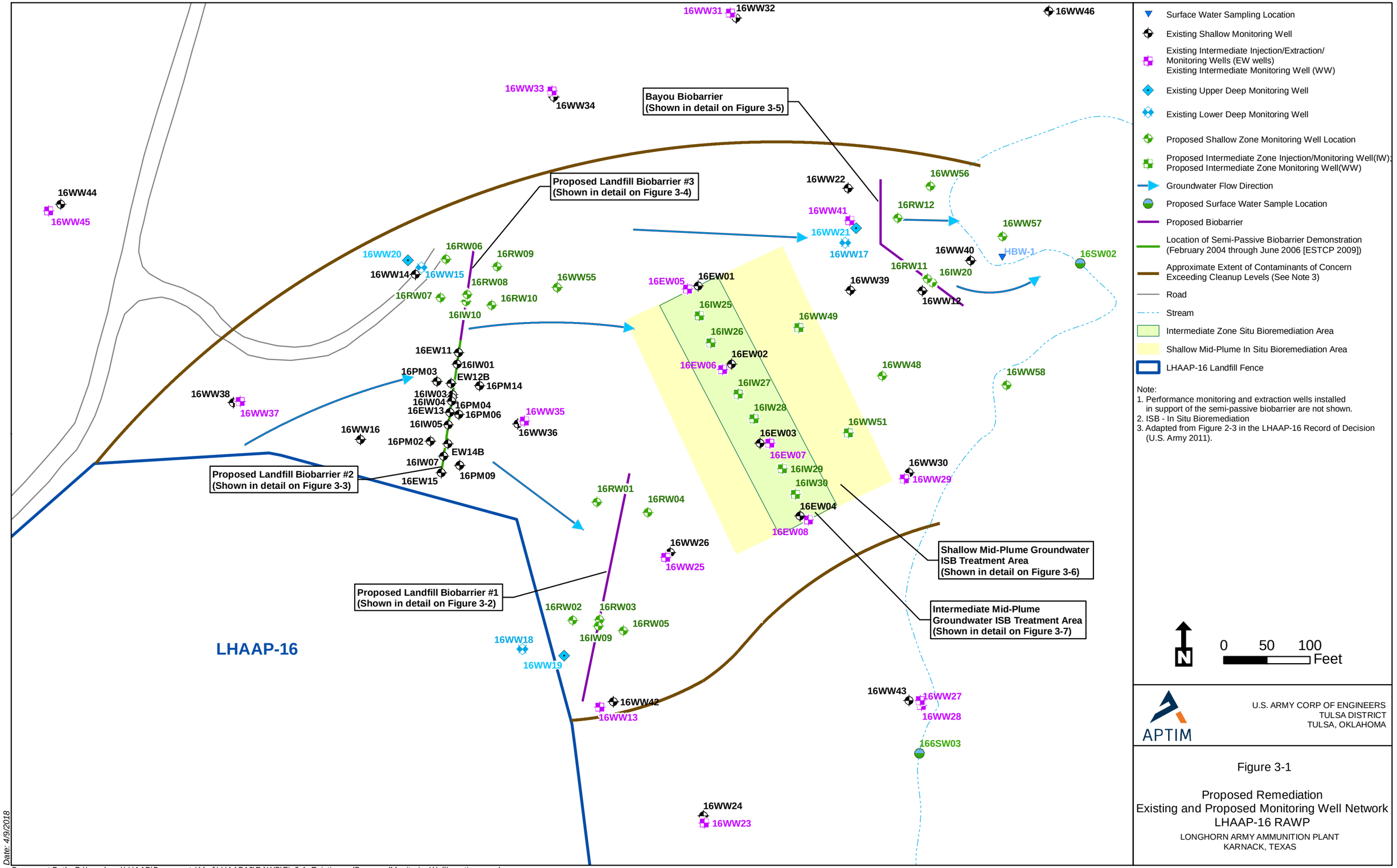

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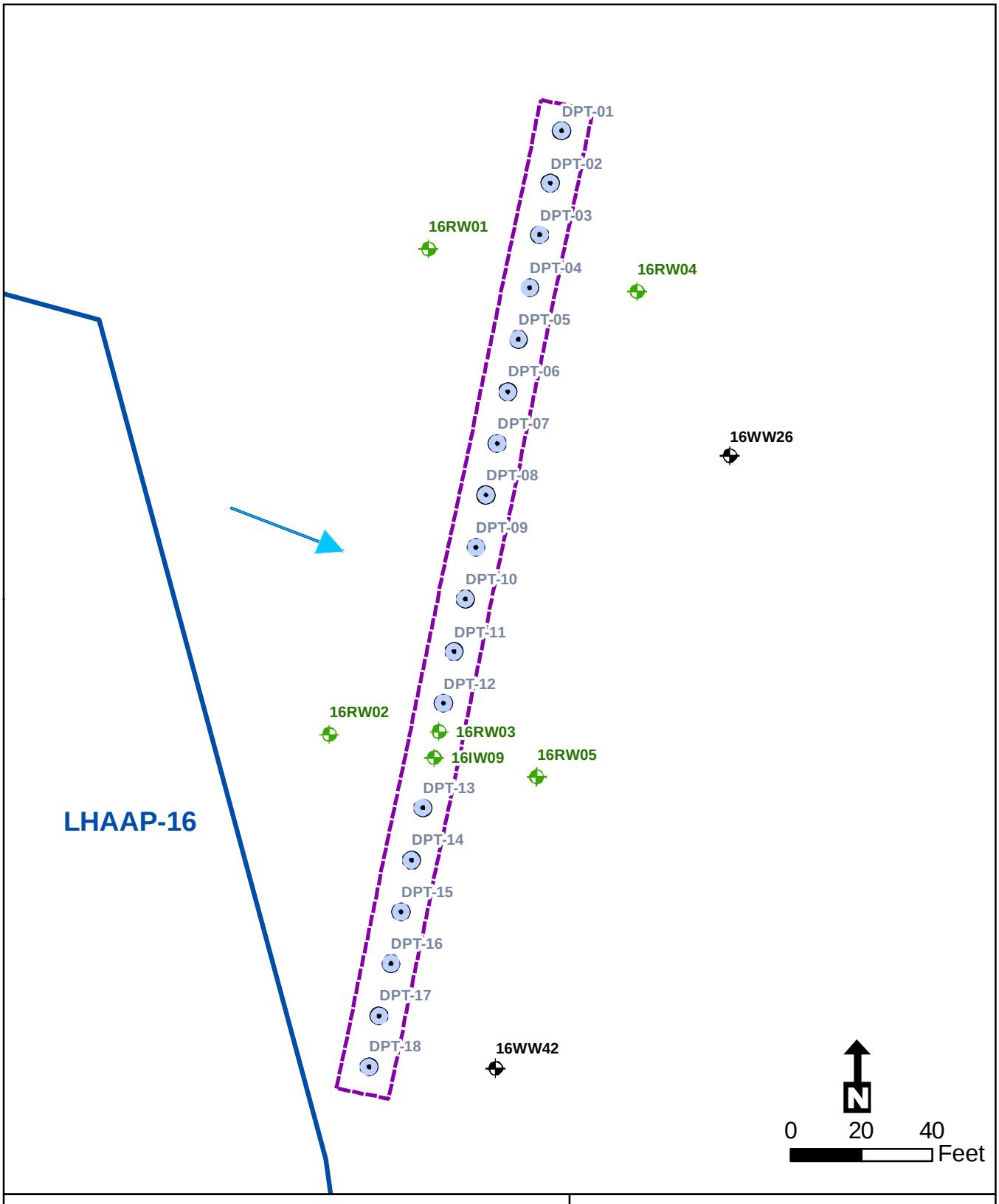
Figure 3-1

Proposed Remediation
Existing and Proposed Monitoring Well Network
LHAAP-16 RAWP

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 4/9/2018

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP16\RAWP\Fig3-1_ExistingandProposedMonitoringWellLocations.mxd



Proposed Well Location

Existing Well Location

Proposed Direct Push Injection Point

Groundwater Flow Direction Without Extraction (Shallow Zone)

Target In-Situ Reaction Zone Based on Design Radius of Influence

LHAAP-16 Landfill Fence

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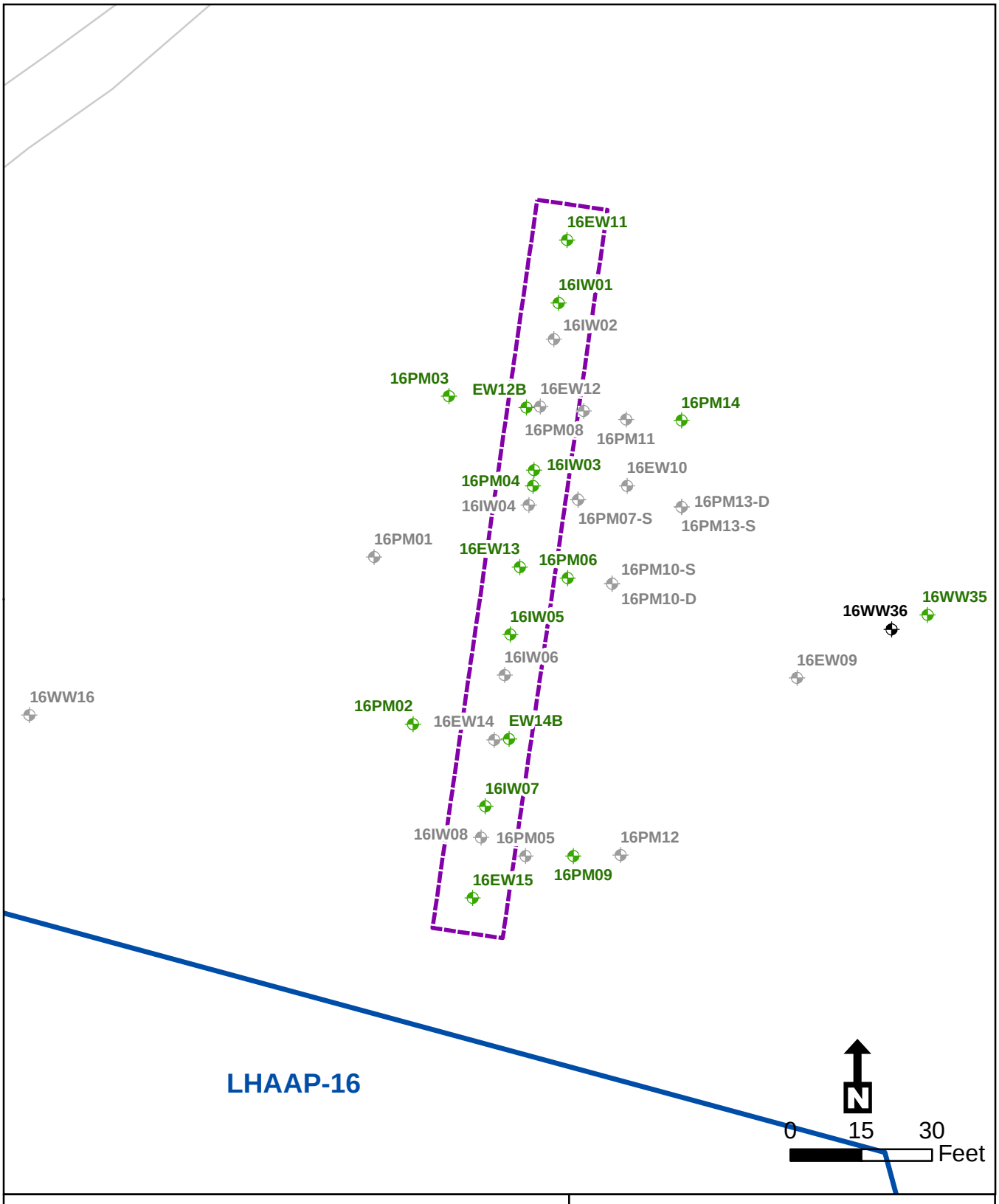
Figure 3-2

Landfill Biobarrier #1
Proposed Remediation
LHAAP-16 RAWP

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 12/14/2017

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP16\RAWP\Fig3-2_Landfill_Biobarrier_1_Prop_Rem.mxd



Existing Monitored Natural Attenuation Performance Monitoring Well

Existing In-Situ Bioremediation Injection/ Extraction/Performance Monitoring Well

Other Existing Monitoring Well

Target In-Situ Reaction Zone Based on Design Radius of Influence

LHAAP-16 Landfill Fence

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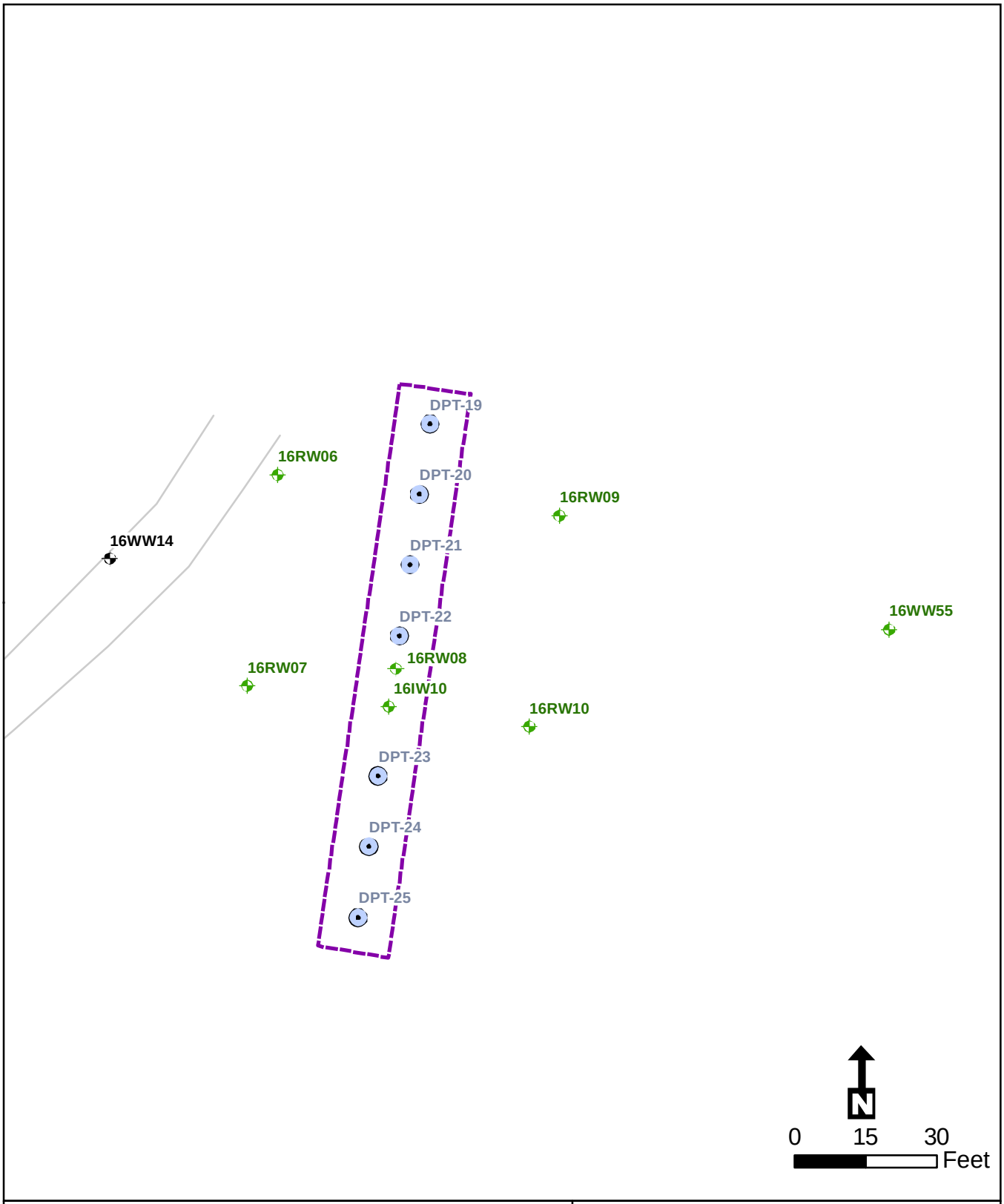
Figure 3-3

Landfill Biobarrier #2
Proposed Remediation
LHAAP-16 RAWP

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 3/26/2018

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP16\RAWP\Fig3-3_Landfill_Biobarrier_2_Prop_Rem.mxd



Existing Monitored Natural Attenuation Performance Monitoring Well

Proposed Shallow Well Location
IW - Injection Well Location
RW - Recovery Well Location

Proposed Direct Push Injection Point

Target In-Situ Reaction Zone Based on Design Radius of Influence

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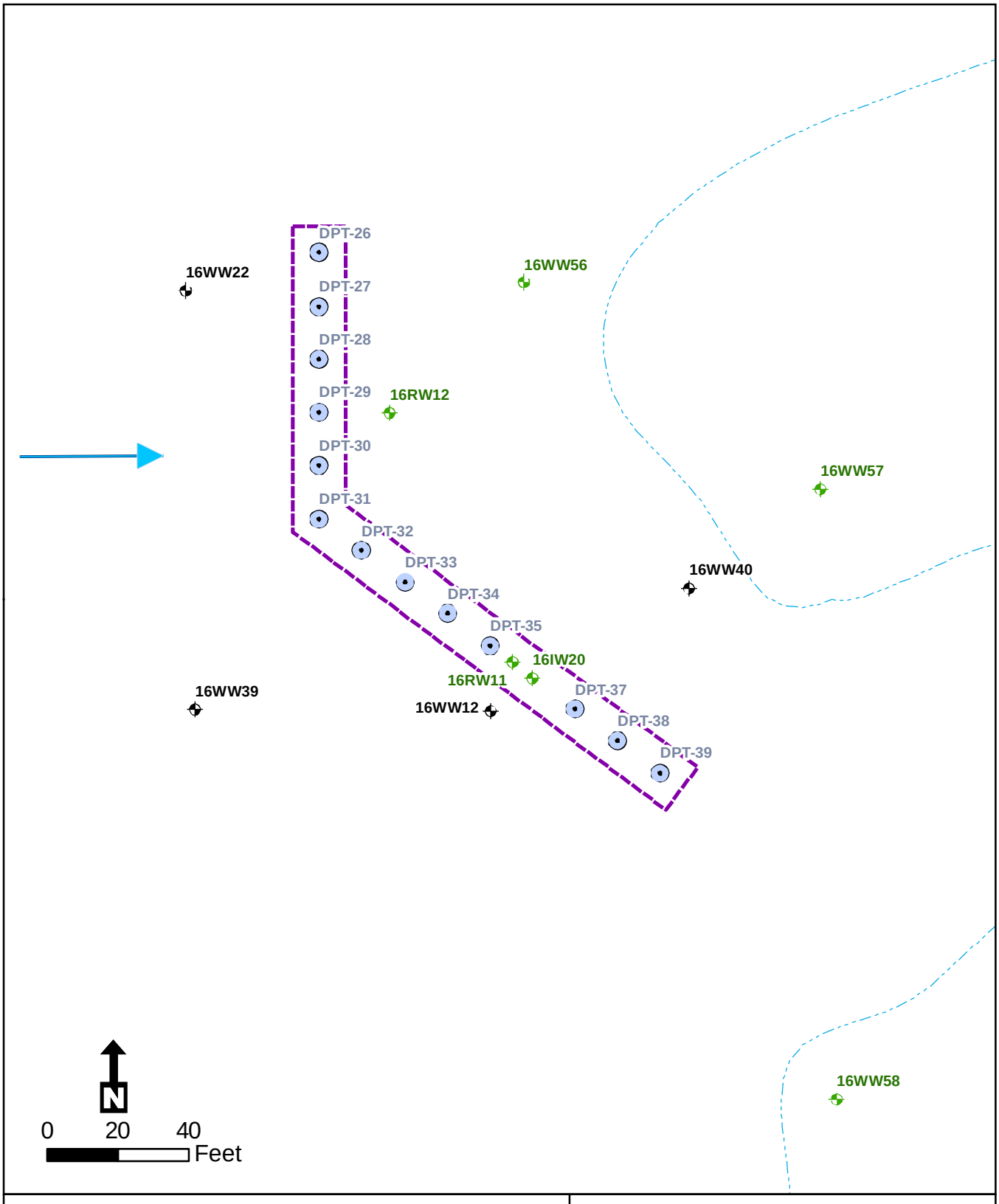
Figure 3-4

Landfill Biobarrier #3
Proposed Remediation
LHAAP-16 RAWP

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 12/14/2017

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP16\RAWP\Fig3-4_Landfill_Biobarrier_3_Prop_Rem.mxd



Proposed Direct Push Injection Point

Existing Monitored Natural Attenuation Performance Monitoring Well

Proposed Shallow Well Location
IW = Injection Well
RW = Recovery Well Location

Groundwater Flow Direction Without Extraction (Shallow Zone)

Target In-Situ Reaction Zone Based on Design Radius of Influence

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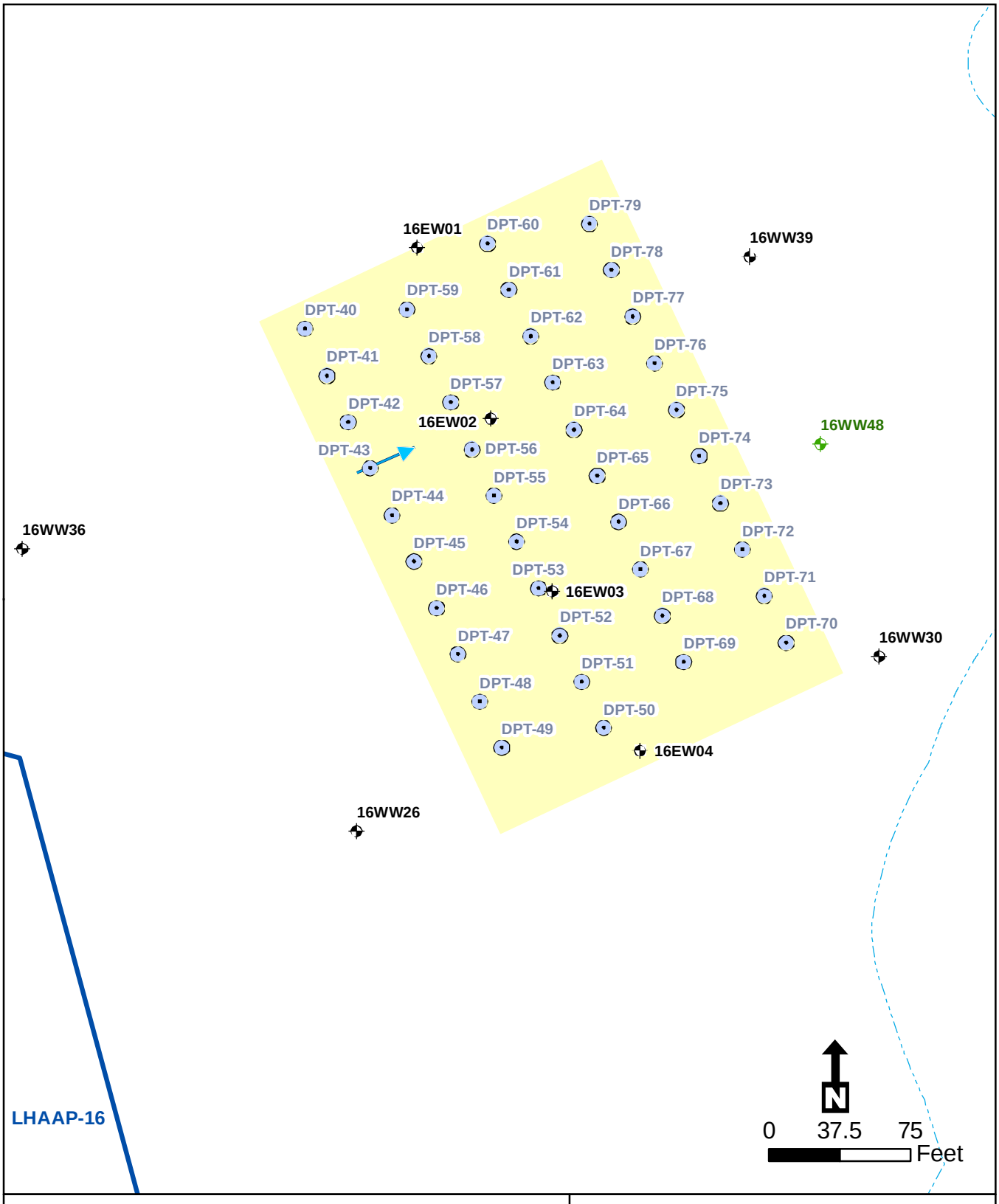
Figure 3-5

Bayou Biobarrier
Proposed Remediation
LHAAP-16 RAWP

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 12/14/2017

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP16\RAWP\Fig3-5_Landfill_Biobarrier_Bayou_Prop_Rem.mxd



Existing Shallow Monitoring Well (WW) or Extraction Well (EW) Location

Proposed Direct Push Injection Point

Prroposed Shallow Monitoring Well Location

Stream

Groundwater Flow Direction Without Extraction (Shallow Zone)

Shallow In Situ Bioremediation Area

LHAAP-16 Landfill Fence

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Figure 3-6

Mid Plume Shallow Groundwater Zone
Proposed Remediation
LHAAP-16 RAWP

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 12/14/2017

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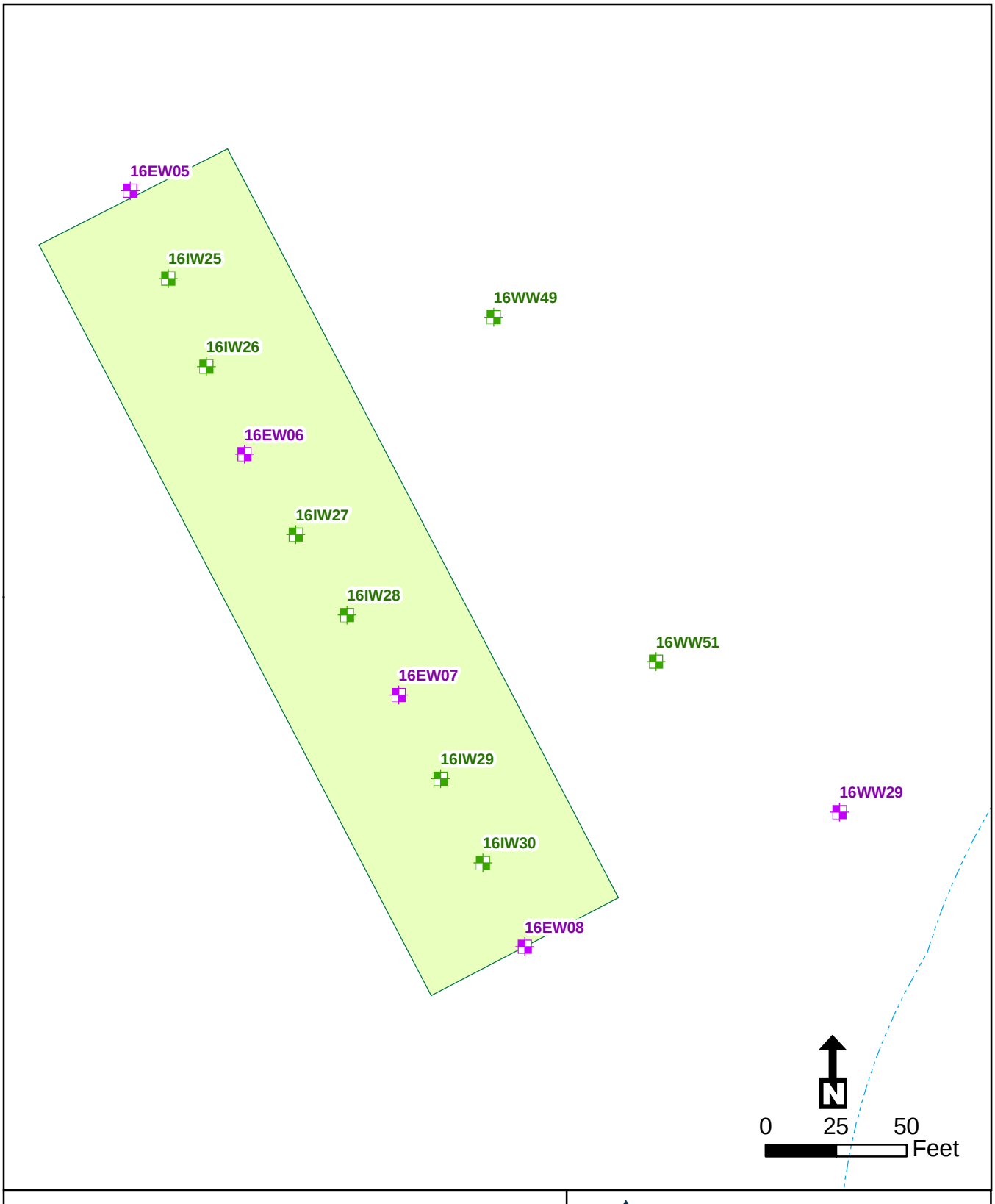

Existing Intermediate Injection/Extraction/Monitoring Well (EW)
Existing Intermediate Monitoring Well (WW)

Proposed Intermediate Zone Injection/Monitoring Well (IW);
Proposed Intermediate Zone Monitoring Well (WW)

Stream

Intermediate Zone Situ Bioremediation Area

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Figure 3-7

Mid Plume Intermediate Groundwater Zone
Proposed Remediation
LHAAP-16 RAWP

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 2/22/2018

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP16\RAWP\Fig3-7_Biobarrier_Intermediate_Prop_Rem.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

ISB In situ bioremediation

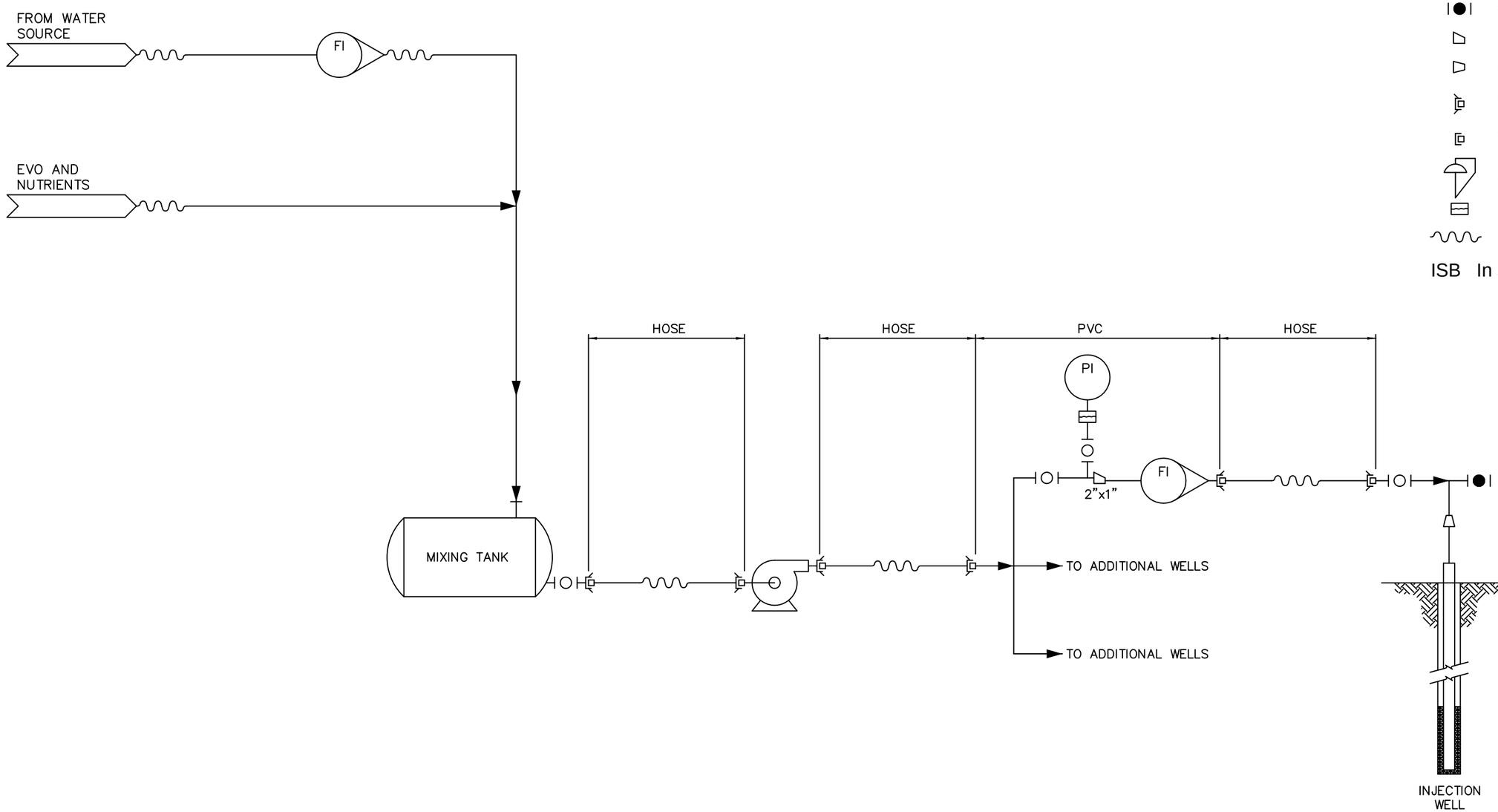

Figure 4-1

ISB Injection System
Hydrogeologic Testing/Pilot Test
Longhorn Army Ammunition Plant, Karnack, TX

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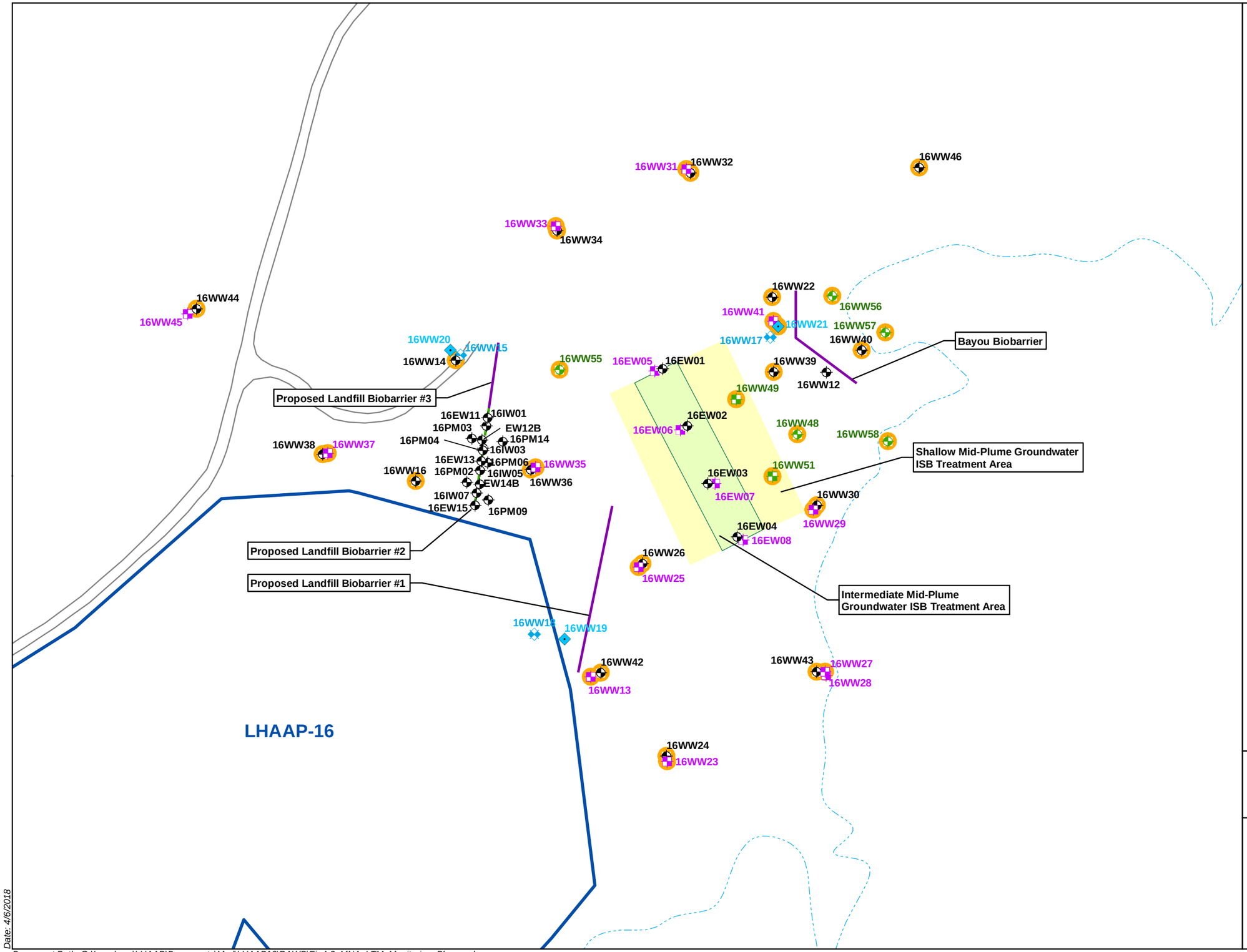

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Figure 4-2

MNA and LTM Monitoring Plan
LHAAP-16 RAWP

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 4/6/2018

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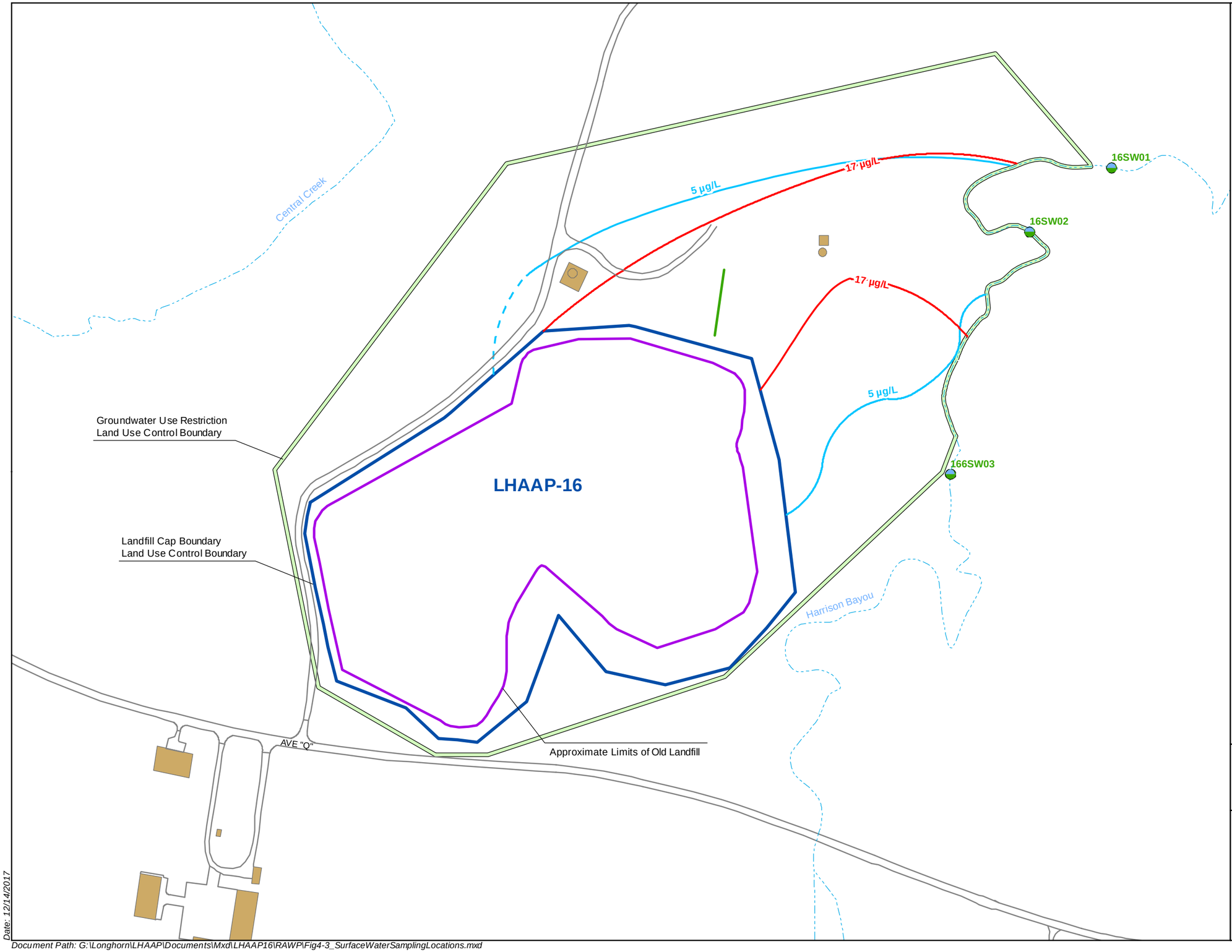

Proposed Surface Water Sample Location

Extent of Perchlorate Contamination > 17 µg/L in Intermediate and Shallow Zones (May 2013)

Extent of TCE Contamination > 5 µg/L in Intermediate and Shallow Zones (Dashed Where Inferred) (May 2013)

Location of Semi-Passive Biobarrier Demonstration (February 2004 through June 2006 [ESTCP 2009])

Stream

Road

Groundwater Use Restriction Land Use Control Boundary

LHAAP-16 Landfill Fence

N

0 110 220 Feet

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Figure 4-3

Surface Water Sampling Locations
LHAAP-16 RAWP

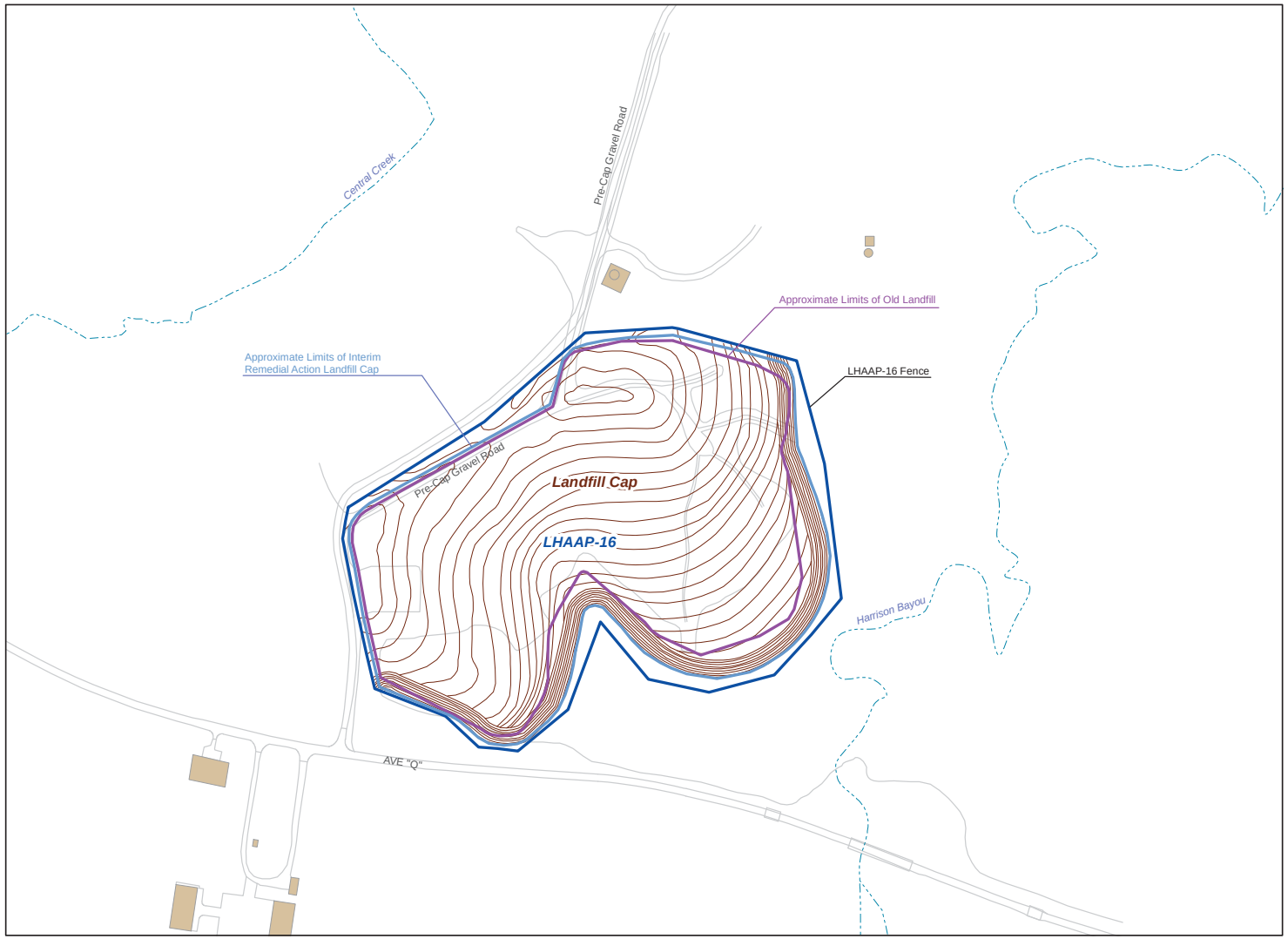
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Date: 12/14/2017

Document Path: G:\Longhorn\LHAAP\Documents\Mxd\LHAAP16\RAWP\Fig4-3_SurfaceWaterSamplingLocations.mxd

Appendix A

Figures from Final Remedial Design

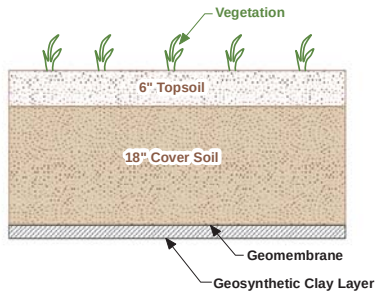


Legend

- Landfill Cap Contours
- Stream
- Road
- Building
- LHAAP-16 Landfill Fence

N

Source:
1. Construction Completion Report, Interim Remedial Action, Landfills 12 and 16 Cap Construction (OHM 1998).
2. LHAAP-16 Record of Decision (U.S.Army 2011).



Cap Cross Section

0 125 250 500 Feet

AECOM

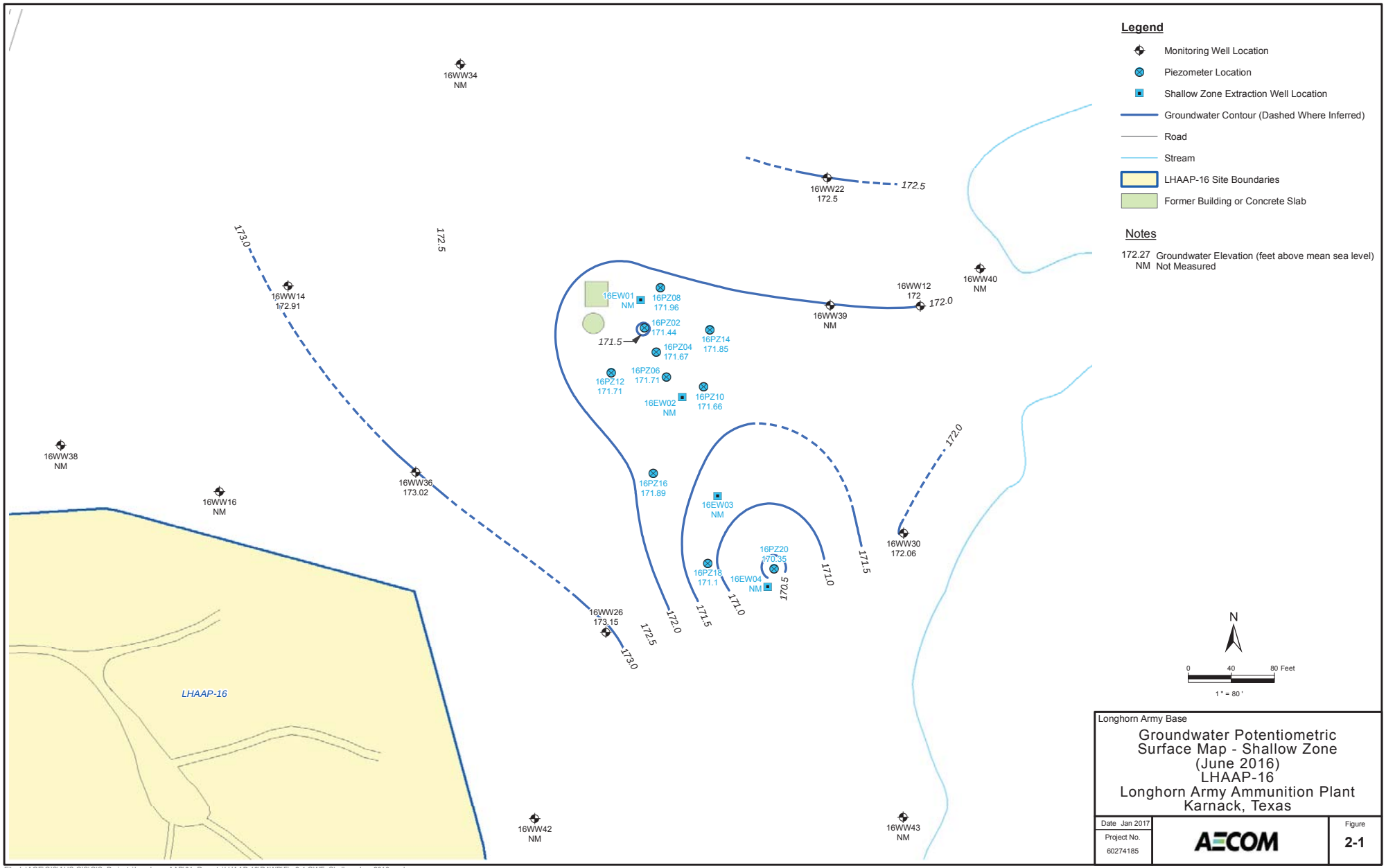
Figure 3-1
Landfill Cap
LHAAP-16 Remedial Design

Longhorn Army Ammunition Plant
Karnack, Texas

60256135

January 2017

Path: L:\AGE\GIS\AUS GIS\GIS_Projects\Longhorn_AAP\01_Reports\LHAAP-16\RAWP\Fig 3-1 LHAAP-16 Landfill Figure.mxd



Longhorn Army Base

Groundwater Potentiometric Surface Map - Shallow Zone (June 2016) LHAAP-16 Longhorn Army Ammunition Plant Karnack, Texas

Date Jan 2017	AECOM	Figure 2-1
Project No. 60274185		

File: L:\AGE\GIS\AUS GIS\GIS_Projects\Longhorn_AAP\01_Reports\LHAAP-16\RAWP\Fig 2-1 GWE_Shallow_Jun_2016.mxd
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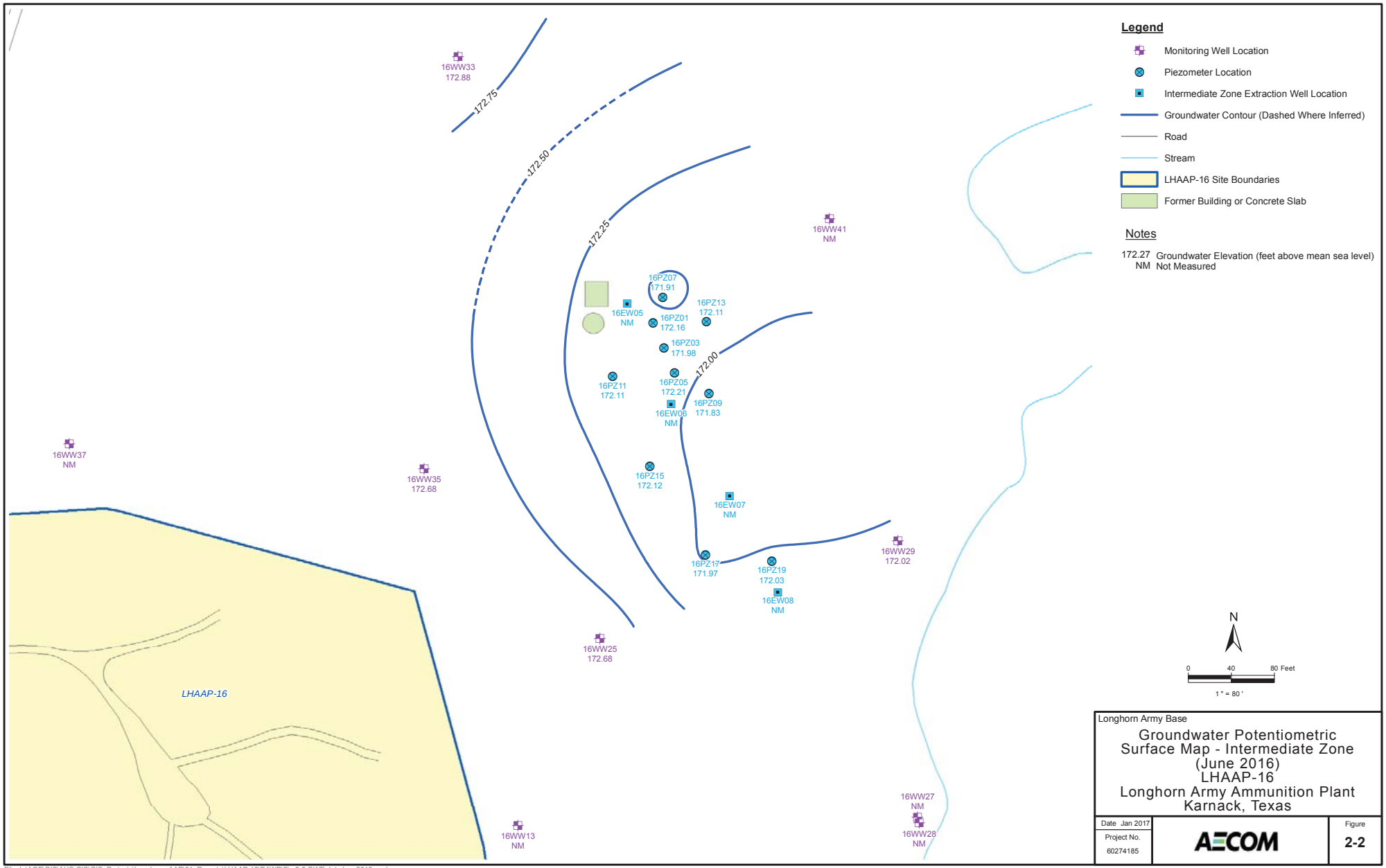

Longhorn Army Base

Groundwater Potentiometric Surface Map - Intermediate Zone (June 2016) LHAAP-16 Longhorn Army Ammunition Plant Karnack, Texas

Date	Jan 2017		Figure
Project No.	60274185	AECOM	2-2

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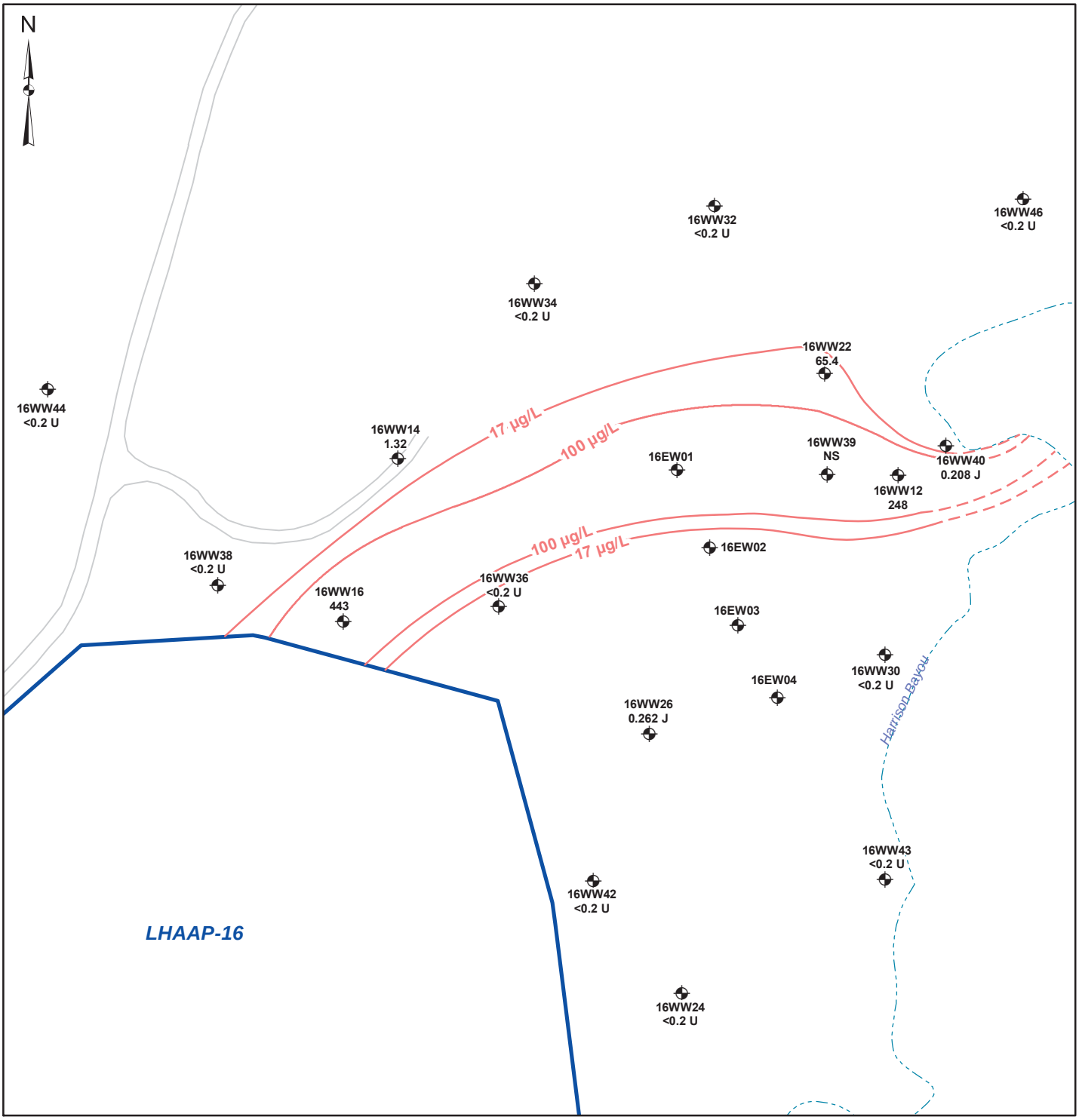


Legend

- Shallow Monitoring Well
- Perchlorate Concentration Contour (Dashed Where Inferred)
- Stream
- Road
- LHAAP-16 Landfill Fence

Notes:
Results are in micrograms per liter (µg/L)
TRRP Residential PCL for Perchlorate = 17 µg/L.
J - Estimated: The analyte was positively identified, the quantitation is an estimation due to discrepancies in meeting certain analyte-specific quality control criteria.
U - Undetected: The analyte was analyzed for, but not detected.
NS - Not Sampled

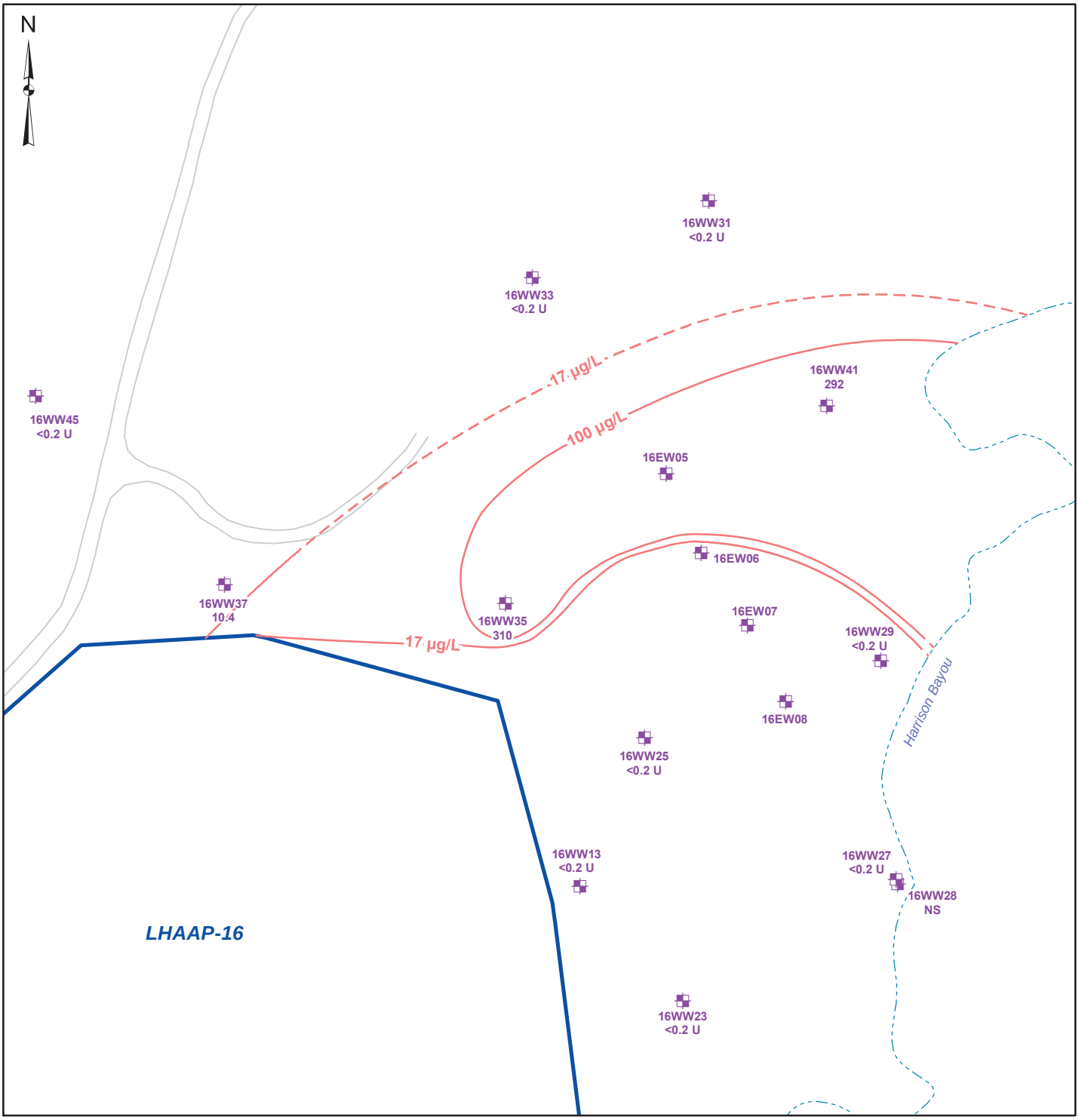
0 85 170 340 Feet

AECOM

Figure 2-4
Perchlorate Concentrations in Groundwater
Shallow Zone - May 2013
LHAAP-16 Remedial Design
Longhorn Army Ammunition Plant
Karnack, Texas

60256135 January 2017

Path: L:\AGE\GIS\AUS GIS\GIS_Projects\Longhorn_AAP\01_Reports\LHAAP-16\RAWP\Fig 2-4 LHAAP-16 Perchlorate in Shallow Zone May 2013.mxd



Legend

- Intermediate Monitoring Well
- Perchlorate Concentration Contour (Dashed Where Inferred)
- Stream
- Road
- LHAAP-16 Landfill Fence

Notes:
Results are in micrograms per liter (µg/L)
TRRP Residential PCL for Perchlorate = 17 µg/L.
J - Estimated: The analyte was positively identified, the quantitation is an estimation due to discrepancies in meeting certain analyte-specific quality control criteria.
U - Undetected: The analyte was analyzed for, but not detected.
NS - Not Sampled

0 85 170 340
Feet

AECOM

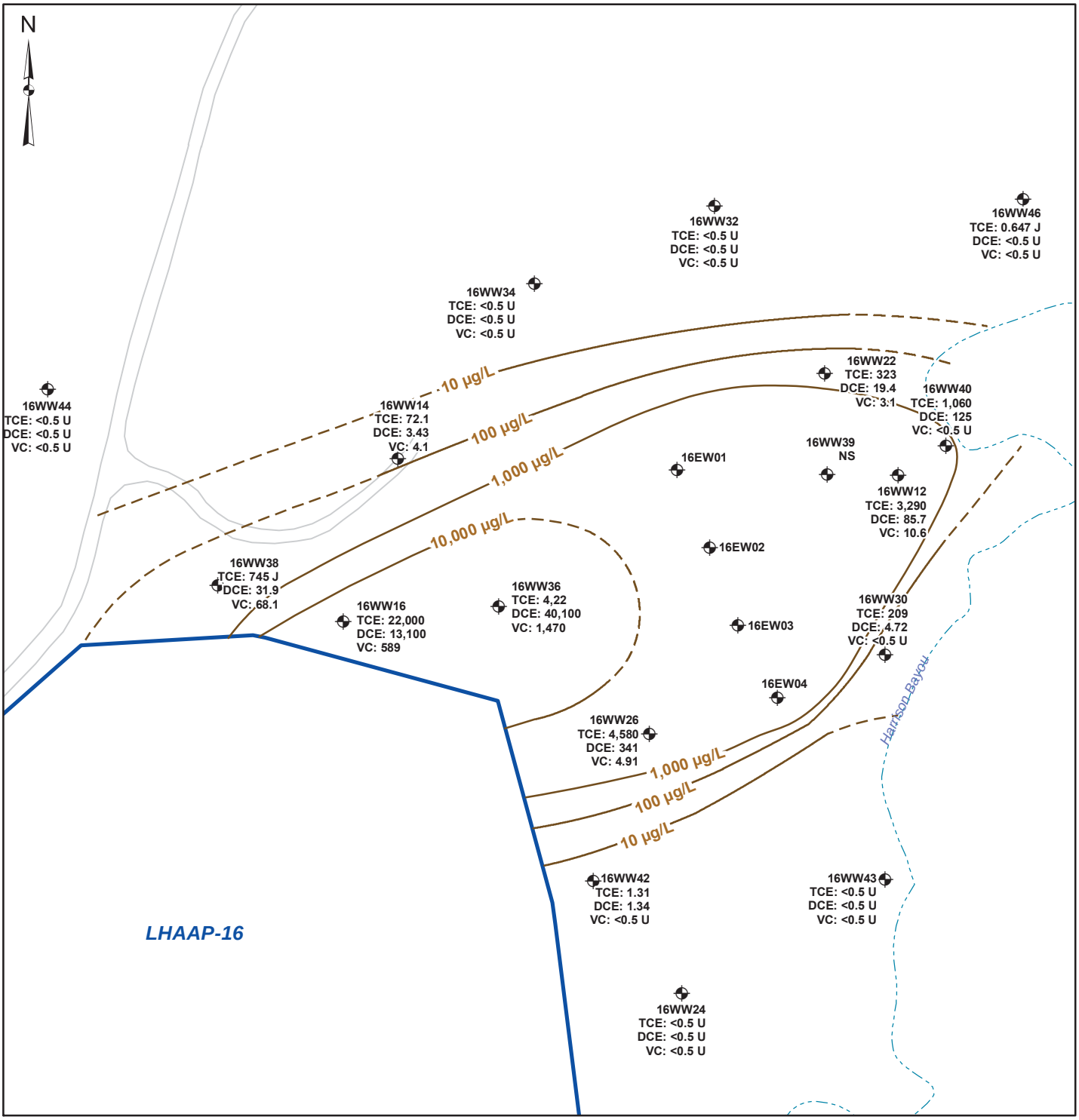
Figure 2-5
Perchlorate Concentrations in Groundwater Intermediate Zone - May 2013 LHAAP-16 Remedial Design

Longhorn Army Ammunition Plant
Karnack, Texas

60256135

January 2017

Path: L:\AGE\GIS\AUS GIS\GIS_Projects\Longhorn_AAP\01_Reports\LHAAP-16\RAWP\Fig 2-5 LHAAP-16 Perchlorate in Intermediate Zone May 2013.mxd



Legend

- Shallow Monitoring Well
- TCE Concentration Contour (Dashed Where Inferred)
- Stream
- Road
- LHAAP-16 Landfill Fence

Notes:
Results are in micrograms per liter (µg/L)
DCE - cis-1,2-Dichloroethene
U - Undetected: The analyte was analyzed for, but not detected.
J - Estimated Value
NS - Not Sampled
TCE - Trichloroethene
VC - Vinyl Chloride
VOC - Volatile Organic Compound

0 85 170 340 Feet

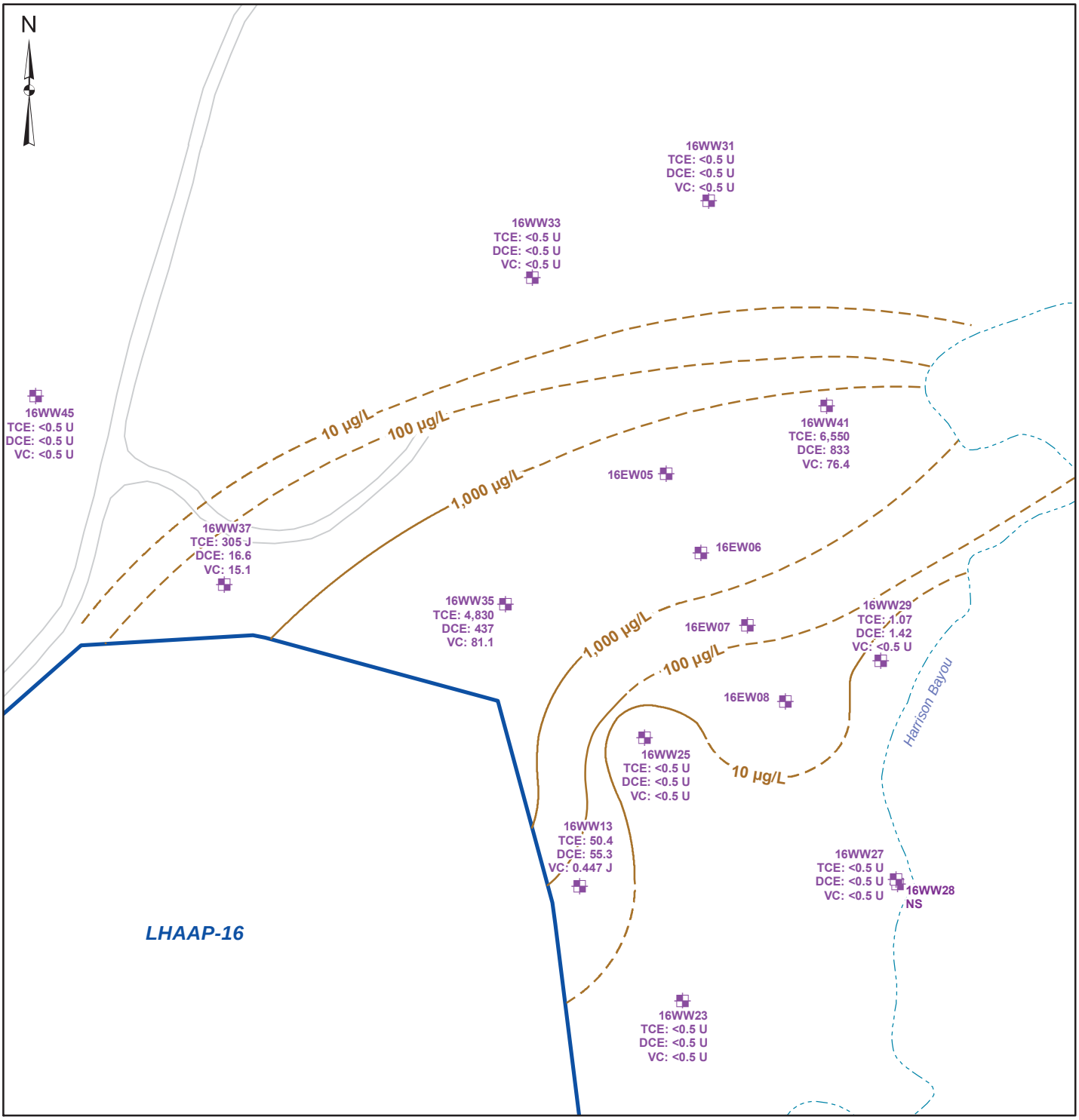
AECOM

Figure 2-6
VOCs in Groundwater
Shallow Zone - May 2013
LHAAP-16 Remedial Design
Longhorn Army Ammunition Plant
Karnack, Texas

60256135

January 2017

Path: L:\AGE\GIS\AUS GIS\GIS_Projects\Longhorn_AAP\01_Reports\LHAAP-16\RAWP\Fig 2-6 LHAAP-16 VOCs in Shallow Zone May 2013.mxd



Legend

- Intermediate Monitoring Well
- TCE Concentration Contour (Dashed Where Inferred)
- Stream
- Road
- LHAAP-16 Landfill Fence

Notes:
Results are in micrograms per liter (µg/L)
DCE - cis-1,2-Dichloroethene
U - Undetected: The analyte was analyzed for, but not detected.
J - Estimated Value
NS - Not Sampled
TCE - Trichloroethene
VC - Vinyl Chloride
VOC - Volatile Organic Compound

0 85 170 340 Feet

AECOM

Figure 2-7
VOCs in Groundwater
Intermediate Zone - May 2013
LHAAP-16 Remedial Design
Longhorn Army Ammunition Plant
Karnack, Texas

60256135

January 2017

Path: L:\AGE\GIS\AUS GIS\GIS Projects\Longhorn AAP\01 Reports\LHAAP-16\RAWP\Fig 2-7 LHAAP-16 VOCs in Intermediate Zone May 2013.mxd

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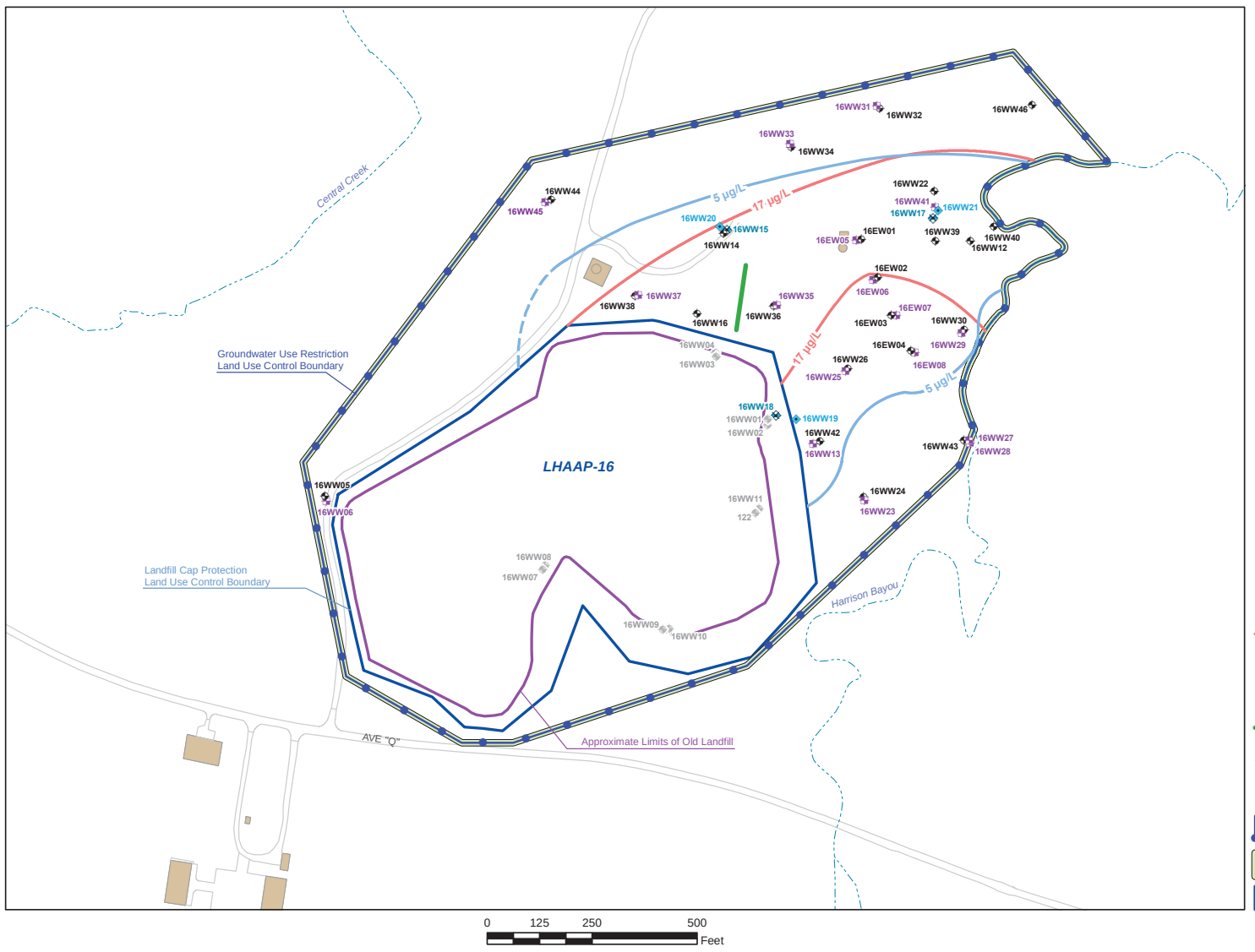


Legend

- Existing Shallow Monitoring Well
- Existing Intermediate Monitoring Well
- Existing Upper Deep Monitoring Well
- Existing Lower Deep Monitoring Well
- Abandoned or Plugged Well
- Extent of Perchlorate Contamination > 17 ug/L in Intermediate and Shallow Zones (May 2013)
- Extent of TCE Contamination > 5 ug/L in Intermediate and Shallow Zones (Dashed Where Inferred) (May 2013)
- Location of Semi-Passive Biobarrier Demonstration (February 2004 through June 2006 [ESTCP 2009]).
- Road
- Stream
- Remedial and Monitoring System Boundary
- Groundwater Use Restriction Land Use Control Boundary
- LHAAP-16 Landfill Fence

AECOM

Figure 5-1
Land Use Contol Boundaries
LHAAP-16 Remedial Design

Longhorn Army Ammunition Plant
Karnack, Texas

60256135

January 2017

Path: L:\AGE\GIS\AUS GIS\GIS_Projects\Longhorn AAP\01_Reports\LHAAP-16\RAWP\Fig 5-1 LHAAP-16 Land Use Control Boundaries.mxd

Appendix B

Annual Land Use Control Compliance Inspection Form

Annual Land Use Control Compliance Inspection Form

In accordance with the Remedial Design dated _____ for LHAAP-16 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;
- Landfill integrity - preserve the integrity of the landfill cap and restrict intrusive activities (e.g., digging) that would degrade or alter the cap;
- 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 landfill intrusive activities (e.g., digging) that would degrade or alter the landfill cap; maintenance of vegetative cover and repair of soil subsidence or erosion areas on the cap;
- 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.

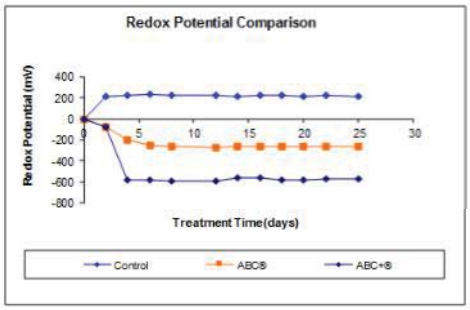
Appendix C

Safety Data Sheets

REDOX TECH, LLC
Providing Innovative In Situ Soil & Groundwater Treatment

ABC+

ANAEROBIC BIOCHEM PLUS (ABC®+)



ABC+ an enhanced version of our industry proven Anaerobic Biochem (ABC®) formula, promoting both anaerobic biodegradation and reductive dechlorination of halogenated solvents in groundwater. This product, Anaerobic Biochem Plus (ABC+), is a mixture of our ABC® formula and Zero Valent Iron (ZVI). Formulated and mixed on a site-by-site basis, up to fifty percent (50%) by weight of ZVI can be added. ZVI has been proven and widely accepted as an effective in situ remediation technology of chlorinated solvents such as TCA, PCE, TCE, and daughter products. The degradation process using ZVI is an abiotic reductive dechlorination process occurring on the surface of the granular iron, with the iron acting as an electron donor.

The addition of ZVI to the ABC® mixture provides a number of advantages for enhanced reductive dechlorination (ERD). The ZVI will provide an immediate reduction. The ABC® will provide short-term and long-term nutrients to anaerobic growth, which also assists to create a reducing environment. ABC® contains soluble lactic acid and a phosphate buffer that provides phosphates, which are a micronutrient for bioremediation, and maintains the pH in a range that is best suited for microbial growth. In addition, the corrosion of iron metal yields ferrous iron and hydrogen, both of which are possible reducing agents. The hydrogen gas produced is also an excellent energy source for a wide variety of anaerobic bacteria.

The ABC® and ZVI are mixed with potable water and emplaced in the subsurface simultaneously. The dilution factor (i.e. water content) can be adjusted to achieve optimal dispersion and distribution based on site-specific parameters such as well spacing, permeability of the formation, and contaminant concentrations. The solution can be emplaced by a variety of techniques, including injection through wells or drill rods (for permeable geologic environments such as sands and fractured rock), hydraulic fracturing (for lower permeable environments such as silt and clay), and through soil blending (for all unconsolidated shallow depth applications less than 20 ft bgs). All of these techniques are part of Redox Tech's service offerings.

Benefits of ABC+ include:

- The presence of ZVI allows for the rapid and complete dechlorination of target compounds. Degradation rates using ZVI are several orders of magnitude greater than under natural conditions. As a consequence, the process does not result in the formation of daughter products other than ethane, ethane, and methane.
- ABC® will last up to 12-24 months in the subsurface environment due to slow releasing compounds, allowing for long-term anaerobic biodegradation
- By creating a reducing environment, ABC+ has the ability to provide long term immobilization of heavy metals (e.g. Ni, Zn, Hg, As)
- Does not require direct contact to act on target constituents.
- Does not divert groundwater flow. ABC is typically mixed at a 15% by weight solution with water. The viscosity of the solution is similar to sugar water and therefore does not measurably influence groundwater flow paths. Due to the relatively low volume of ZVI used, it does not measurably lower the bulk permeability of the formation
- Does not divert groundwater flow. ABC is typically mixed at a 15% by weight solution with water. The viscosity of the solution is similar to sugar water and therefore does not measurably influence groundwater flow paths. Due to the relatively low volume of ZVI used, it does not measurably lower the bulk permeability of the formation
- Patent protection: Redox Tech is licensed under Enviromental Technologies, Inc. (an Adventus Company) who is the current holder of patents pertaining to remediation using ZVI. Therefore, Redox Tech is able to market, sell, and emplace our ABC+ product. There is no patent infringement risk to the client in selecting the ABC+ approach.
- Price advantage. The cost of the ABC+ formula is an extremely competitive approach in relation to other ERD products on the market.

SUB MENU

ABC®
ABC+
ABC-OLÉ
OBC™
OBC+
NUBUFF
ZVI

ANAEROBIC BIOCHEM

Anaerobic Biochem (ABC®), is a patented mixture of lactates, fatty acids, and a phosphate buffer that promotes anaerobic biodegradation of halogenated solvents in groundwater.

ABC® BROCHURE
Adobe PDF File
Click here

LATEST NEWS

Redox Tech Introduces NuBuff
Redox Tech, LLC Renews Comarketing Relationship with Carus Corporation
New Soil Blender Debuts in Cambridge, Mass
ABC® and ABC+ Applied at Over 350 Sites
Anaerobic BioChem (ABC®), The "Green" Substrate

- ABC+ produces a significantly lower redox potential of approximately –600 mV

Let Redox Tech help formulate an enhanced anaerobic program for your site today. For more information contact our Main Office.

ADDITIONAL INFO

BROCHURES & PRESENTATIONS	ABC+ Presentation (713.91 kB) ABC+ Presentation (58.6 kB)
CASE STUDIES	ABC+ TCA Case Study (101.76 kB)
OTHER DOCUMENTS	ABC versus Emulsified Oils (55.99 kB) Site Profile for Cost Estimate (27.11 kB) Florida Remediation Conference (2.23 MB) Lactate (webpage)

[1]ABC® is protected by US Patent 6,001,252.

SAFETY DATA SHEET
Anaerobic BioChem (ABC)

1. PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: **Anaerobic BioChem**
GENERAL USE: **Bioremediation of halogenated organics and metals**

MANUFACTURER:

Redox Tech, LLC
200 Quade Drive
Cary, NC 27513
919-678-0140

EMERGENCY TELEPHONE:

Within USA and Canada: 1-800-424-9300
+1 703-527-3887 (collect calls accepted)

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW: Product is generally recognized as safe. May cause irritation exposure to eyes. Long term contact to skin may cause some drying and minor irritation.

3. COMPOSITION INFORMATION ON INGREDIENTS

Proprietary mixture of fatty acids, glycerol, lactates and dipotassium phosphate.

4. FIRST AID MEASURES

EYES: Immediately flush with water for up to 15 minutes. If irritation persists, seek medical attention.

SKIN: Rinse with water. Irritation is unlikely, but if irritation occurs or persists, seek medical attention.

INGESTION: Generally safe to ingest but not recommended.

INHALATION: No first aid required.

5. FIRE FIGHTING MEASURES

EXTINGUISHING MEDIA: Deluge with water

FIRE/EXPLOSION HAZARDS: Product is combustible only at temperatures above 600C

FIRE FIGHTING PROCEDURES: Use flooding with plenty of water, carbon dioxide or other inert gasses. Wear full protective clothing and self-contained breathing apparatus. Deluging with water is the best method to control combustion of the product.

FLAMMABILITY LIMITS: non-combustible

SENSITIVITY TO IMPACT: non-sensitive

SENSITIVITY TO STATIC DISCHARGE: non-senstive

6. ACCIDENTAL RELEASE MEASURES

Confine and collect spill. Transfer to an approved DOT container and properly dispose. Do not dispose of or rinse material into sewer, stormwater or surface water. Discharge of product to surface water could result in depressed dissolved oxygen levels and subsequent biological impacts.

7. HANDLING AND STORAGE

HANDLING: Protective gloves and safety glasses are recommended.

STORAGE: Keep dry. Use first in, first out storage system. Keep container tightly closed when not in use. Avoid contamination of opened product. Avoid contact with reducing agents.

8. EXPOSURE CONTROLS – PERSONAL PROTECTION

EXPOSURE LIMITS

Chemical Name	ACGIH	OSHA	Supplier
ABC	**NA**	**NA**	**NA**

ENGINEERING CONTROLS: None are required

PERSONAL PROTECTIVE EQUIPMENT

EYES and FACE: Safety glasses recommended
RESPIRATOR: none necessary
PROTECTIVE CLOTHING: None necessary
GLOVES: rubber, latex or neoprene recommended but not required

9. PHYSICAL AND CHEMICAL PROPERTIES

Odor:	none to mild pleasant organic odor
Appearance:	clear to light amber
Auto-ignition Temperature	Non-combustible
Boiling Point	>600 C
Melting Point	NA
Density	1.15 gram/cc
Solubility	infinite
pH	7-9

10. STABILITY AND REACTIVITY

CONDITIONS TO AVOID: Do not contact with strong oxidizers
STABILITY: product is stable
POLYMERIZATION: will not occur
INCOMPATIBLE MATERIALS: strong oxidizers
HAZARDOUS DECOMPOSITION PRODUCTS:

11. TOXICOLOGICAL INFORMATION

Acute Toxicity
A: General Product Information
Acute exposure may cause mild skin and eye irritation.
B: Component Analysis - LD50/LC50

No information available.

B: Component Analysis - TDLo/LDLo
TDLo (Oral-Man) none

Carcinogenicity
A: General Product Information
No information available.
B: Component Carcinogenicity
Product is not listed by ACGIH, IARC, OSHA, NIOSH, or NTP.

Epidemiology
No information available.

Neurotoxicity
No information available.

12. ECOLOGICAL INFORMATION

Ecotoxicity
Discharge to water may cause depressed dissolved oxygen and subsequent ecological stresses
Environmental Fate
No potential for food chain concentration

13. DISPOSAL CONSIDERATIONS

DISPOSAL METHOD: Material is not considered hazardous, but consult with local, state and federal agencies prior to disposal to ensure all applicable laws are met.

14. TRANSPORT INFORMATION

NOTE: The shipping classification information in this section (Section 14) is meant as a guide to the overall classification of the product. However, transportation classifications may be subjectto change with changes in package size. Consult shipperrequirements under I.M.O., I.C.A.O. (I.A.T.A.) and 49 CFR to assure regulatory compliance.

US DOT Information
Shipping Name: Not Regulated
Hazard Class: Not Classified
UN/NA #: Not Classified
Packing Group:None
Required Label(s):None

50th Edition International Air Transport Association (IATA):
Not hazardous and not regulated

INTERNATIONAL MARITIME DANGEROUS GOODS (IMDG)

Material is not regulated under IMDG

15. REGULATORY INFORMATION

UNITED STATES

SARA TITLE III

SECTION 311 No Hazard for Immediate health Hazard
SECTION 312 No Threshold Quanitity
SECTION 313 Not listed

CERCLA NOT REGULATED UNDER CERCLA

TSCA NOT REGULATED UNDER TSCA

CANADA (WHIMS): NOT REGULATED

16. OTHER INFORMATION

HMIS:

Health	1
Flammability	0
Physical Hazard	0
Personal Protection	E

E: Safety Glasses, gloves

Material Safety Data Sheet

Shaw Environmental, Inc.

17 PRINCESS ROAD
LAWRENCEVILLE, N.J. 08648
(609) 895-5340

SECTION 1 - MATERIAL IDENTIFICATION AND INFORMATION

Material Name: DHC microbial consortium (SDC-9) MSDS #: ENV 1033

Date Prepared: 10/06/2003 CAS #: N/A (Not Applicable)

Prepared By: Simon Vainberg Formula #: N/A

Material Description: Non-hazardous, naturally occurring non-altered anaerobic microbes and enzymes in a water-based medium.

SECTION 2 - INGREDIENTS

Components	%	OSHA PEL	ACGIH TLV	OTHER LIMITS
Non-Hazardous Ingredients	100	N/A	N/A	N/A

SECTION 3 - PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point: 100°C (water)

Specific Gravity (H_2O = 1): 0.9 - 1.1

Vapor Pressure @ 25°C: 24 mm Hg (water)

Melting Point: 0°C (water)

Vapor Density: N/A

Evaporation Rate (H_2O = 1): 0.9 - 1.1

Solubility in Water: Soluble

Water Reactive: No

pH: 6.0 - 8.0

Appearance and Odor: Murky, yellow water. Musty odor.

SECTION 4 - FIRE AND EXPLOSION HAZARD DATA

Flash Point: N/A

Flammable Limits: N/A

Extinguishing Media: Foam, carbon dioxide, water

Special Fire Fighting Procedures: None

Unusual Fire and Explosion Hazards: None

SECTION 5 - REACTIVITY DATA

Stability: Stable

Conditions to Avoid: None

Incompatibility (Materials to Avoid): Water-reactive materials

Hazardous Decomposition Byproducts: None

SECTION 6 - HEALTH HAZARD DATA

HEALTH EFFECTS

The effects of exposure to this material have not been determined. Safe handling of this material on a long-term basis will avoid any possible effect from repetitive acute exposures. Below are possible health effects based on information from similar materials. Individuals hyper allergic to enzymes or other related proteins should not handle.

Ingestion: Ingestion of large quantities may result in abdominal discomfort including nausea, vomiting, cramps, diarrhea, and fever.

Inhalation: Hypersensitive individuals may experience breathing difficulties after inhalation of aerosols.

Skin Absorption: N/A

Skin Contact: May cause skin irritation. Hypersensitive individuals may experience allergic reactions to enzymes.

Eye Contact: May cause eye irritation.

FIRST AID

Ingestion: Get medical attention if allergic symptoms develop (observe for 48 hours). Never give anything by mouth to an unconscious or convulsing person.

Inhalation: Get medical attention if allergic symptoms develop.

Skin Absorption: N/A

Skin Contact: Wash affected area with soap and water. Get medical attention if allergic symptoms develop.

Eye Contact: Flush eyes with plenty of water for at least 15 minutes using an eyewash fountain, if available. Get medical attention if irritation occurs.

NOTE TO PHYSICIANS: All treatments should be based on observed signs and symptoms of distress in the patient. Consideration should be given to the possibility that overexposure to materials other than this material may have occurred.

SECTION 7 - SPILL AND LEAK PROCEDURES

Reportable quantities (in lbs of EPA Hazardous Substances): N/A

Steps to be taken in case of spill or release: No emergency results from spillage. However, spills should be cleaned up promptly. All personnel involved in the cleanup must wear protective clothing and avoid skin contact. Absorb spilled material or vacuum into a container. After clean-up, disinfect all cleaning materials and storage containers that come in contact with the spilled liquid.

Waste Disposal Method: No special disposal methods are required. The material may be sewered, and is compatible with all known biological treatment methods. To reduce odors and permanently inactivate microorganisms, mix 100 parts (by volume) of DHC consortium with 1 part (by volume) of bleach. Dispose of in accordance with local, state and federal regulations.

SECTION 8 - HANDLING AND STORAGE

Hand Protection: Rubber gloves.

Eye Protection: Safety goggles with side splash shields.

Protective Clothing: Use adequate clothing to prevent skin contact.

Respiratory Protection: Surgical mask.

Ventilation: Provide adequate ventilation to remove odors.

Storage & Handling:
Material may be stored for up to 3 weeks at 2-4°C without aeration.

Other Precautions: An eyewash station in the work area is recommended.

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.

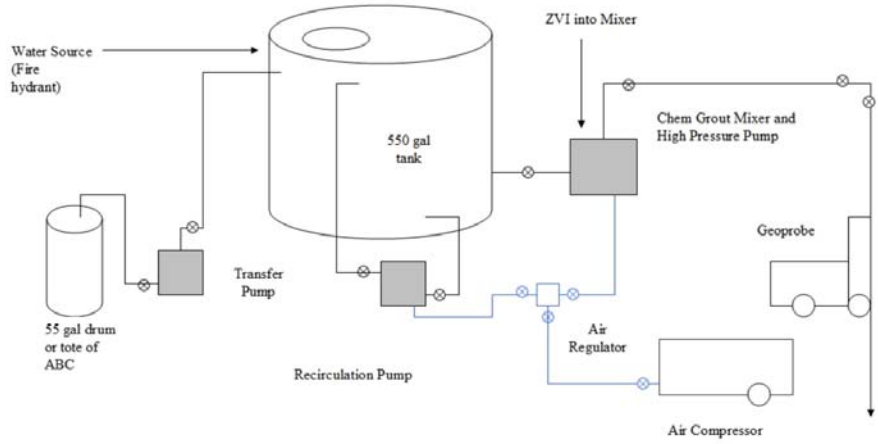
Appendix D

ABC Plus Amendment Preparation Procedure

ABC+ Injections

Anaerobic Biochem ABC® is a patented mixture of lactates, fatty acids, and a phosphate buffer. ABC® contains soluble lactic acid as well as slow- and long-term releasing components. The phosphate buffer provides phosphates, which are a micronutrient for bioremediation. In addition, the buffer helps to maintain the pH in a range that is best suited for microbial growth. Using a Geoprobe® and proprietary injection equipment, Redox Tech is able to inject ABC® in most geologic environments, including low-permeability silt and clay. For low permeability environments, Redox Tech utilizes hydraulic fracturing.

In July 2006, the ABC formula was offered with a mixture of ZVI. The new product, marketed as ABC+, provided significant advantages over ABC alone. The ZVI provides an immediate chemical reduction of chlorinated solvents and quickly drives the *in situ* system to reducing conditions. The hydrogen produced from the corrosion of the ZVI also provides nutrients to a wide range of bacteria.



ABC+ injections are initiated by mixing the ABC product in a 550 gallon mixing tank. Complete mixing is achieved by use of a recirculation pump and then it is transferred into an air powered ChemGrout CG500 high pressure mixing unit. The ABC solution is mixed in the 70 gallon paddle hoppers where guar gum is used to increase the viscosity. Once the viscosity is increased, the ZVI product is introduced where a slurry is formed. The slurry is transferred to the 3 inch positive placement pump and is pumped to the top of the Geoprobe rods and out of the bottom via an expendable tip, to the desired remediation zone.

The ChemGrout CG500 high pressure mixing plant unit has two 70 gallon mixing hoppers so mixing and pumping can be performed simultaneously. The Geprobe rods are raised to other specified injection intervals to inject the ABC+ slurry to predetermined intervals.

Appendix E

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-16							
Total Volume 0							

Appendix F

Inspection and Maintenance Checklist

RAO Inspection and Maintenance Checklist

General Information	
Project Name	RAO Inspection and Maintenance, LHAAP-16 Landfill, 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 ----------

Description		**Yes**	**No**	**N/A**	**Comments** (Attach photos/location sketches)	**Corrective Action** (Attach photos)
A. CAP Cover Surface						
A.1	Are there any significant cracks present?					
A.2	Is there any evidence of significant/ clearly visible erosion, settlement, or other deterioration?					
A.3.	Are there any damaged areas?					
A.4	Is there any ponded water present?					
A.5	Are the drainage systems in poor condition?					
A.6	Any other relevant observations?					
B. CAP Vegetation and Animal Burrows						
B.1	Are there signs of stressed/ dead vegetation?					
B.2	Are there any significant bare spots?					

Description		Yes	No	N/A	**Comments** (Attach photos/location sketches)	**Corrective Action** (Attach photos)
B.3	Are deep-rooted plants present?					
B.4	Are there signs of animal burrows?					
B. 5	Any other relevant observations?					
C. Groundwater Monitoring Wells						
C.1	Are the installed groundwater monitoring wells in poor condition?					
C.2	Is the well cleared of vegetation and accessible?					
C.3	Are there any significant cracks present?					
C.4	Are there any damaged areas?					
C.5	Any other relevant observations?					
D. Site Access Features						
D.1	Gate(s) damaged?					
D.2	Litter encountered within the area?					
D.3	Are the gate locks missing?					
D.4	Are signs to prevent unauthorized entry down or missing?					
D.5	Are the access roads in unusable or poor condition?					
D.6	Any other relevant observations?					