



DEPARTMENT OF THE ARMY
US ARMY INSTALLATION MANAGEMENT COMMAND
US ARMY ENVIRONMENTAL COMMAND
2455 REYNOLDS ROAD
JOINT BASE SAN ANTONIO FORT SAM HOUSTON, TX 78234-7588

June 23, 2026

SUBJECT: Final (100%) Remedial Design for LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production, Longhorn Army Ammunition Plant, Karnack, Texas

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

Dear Ms. Palmie,

The above-referenced document is available on DoD Safe for your review. The document includes revisions based upon the Texas Commission on Environmental Quality's (TCEQ) comments on the draft Final version received on May 19, 2026, and the Environmental Protection Agency's (EPA) comments received on May 4, 2026. Tables of responses to TCEQ and EPA comments on all versions of the document are included with this final document. In accordance with the Federal Facility Agreement, this document will be considered final after 30 days without further comment.

The document was prepared by HDR Environmental, Operations and Construction, Inc. (HDR) on behalf of the Army as part of HDR's contract for the facility. I ask that Greg Kelly, HDR'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 (210) 793-7900, or by email at: Kelly.U.Norwood.civ@army.mil.

Sincerely,

Kelly Norwood, Geologist
ESM, West and Pacific Division
U.S. Army Environmental Command

Electronic copies furnished:
A. Berehe, TCEQ, Austin, TX
M. Stead, USEPA Region 6, Dallas, TX
J. Reyes, USEPA Region 6, Dallas, TX

E. Duerkop, USFWS, Caddo Lake NWR, TX
C. Montoya, USACE, Tulsa District, OK
A. Williams, USACE, Tulsa District, OK
K. Russell, BRAC, Huntsville, AL



DEPARTMENT OF THE ARMY
US ARMY INSTALLATION MANAGEMENT COMMAND
US ARMY ENVIRONMENTAL COMMAND
2455 REYNOLDS ROAD
JOINT BASE SAN ANTONIO FORT SAM HOUSTON, TX 78234-7588

June 23, 2026

SUBJECT: Final (100%) Remedial Design for LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production, Longhorn Army Ammunition Plant, Karnack, Texas

Mr. Mark Stead
U.S. Environmental Protection Agency
1201 Elm Street, Suite 500
Dallas, TX 75270-2002

Dear Mr. Stead,

The above-referenced document is available on DoD Safe for your review. The document includes revisions based upon the Texas Commission on Environmental Quality's (TCEQ) comments on the draft Final version received on May 19, 2026, and the Environmental Protection Agency's (EPA) comments received on May 4, 2026. Tables of responses to TCEQ and EPA comments on all versions of the document are included with this final document. In accordance with the Federal Facility Agreement, this document will be considered final after 30 days without further comment.

The document was prepared by HDR Environmental, Operations and Construction, Inc. (HDR) on behalf of the Army as part of HDR's contract for the facility. I ask that Greg Kelly, HDR'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 (210) 793-7900, or by email at: Kelly.U.Norwood.civ@army.mil.

Sincerely,

Kelly Norwood, Geologist
ESM, West and Pacific Division
U.S. Army Environmental Command

Electronic copies furnished:
A. Palmie, TCEQ, Austin, TX
A. Berehe, TCEQ, Austin, TX
J. Reyes, USEPA Region 6, Dallas, TX

E. Duerkop, USFWS, Caddo Lake NWR, TX
C. Montoya, USACE, Tulsa District, OK
A. Williams, USACE, Tulsa District, OK
K. Russell, BRAC, Huntsville, AL



Comments Response Matrix
30% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: May 14, 2025

Submitted by: TCEQ
Responded by: HDR
Date Responded: 09/11/2025

1. Respondent concurs (C) or does not concur (D)
2. Commenter agrees (A) or does not agree (D) with response.

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
Reviewer #1: April Palmie and Midori Campbell, TCEQ						
1.	General	CSM, GWBU descriptions	This relates to EPA's comment #5 and a few others. The CSM for the various groundwater bearing units (GWBU) at LHAAP-47 has been confusing for a long time and the names for and understanding of various intervals has changed through time. Nobody's fault, this is just the way things have evolved. Going forward we have an opportunity to explain things clearly. A few suggestions. • Using "former", as noted by EPA in comment 26, would help. • It would also help if the shallow description changed to shallow perched. • If the RD could explain <u>one time</u> the relationship between the current terminology and former terminology and then move on, that would also help. • Establish a new and clear naming convention and use it going forward. Don't repeat "current" and "formerly" or "then" or "previously referred to". It would help if the naming style was consistent with other LHAAP sites – for example including "zone" or not including "zone". • Consider adding a crosswalk table with depths, historic terminology, and current terminology. • For figures from historic reports there can be a disconnect. Can you add updates to the legends – replacing old terms with new terms? Or can you put updated terms in parentheses? Or can you add a general note?	C	In Intermediate (60%) Design Analysis Report, Section 1.5, an attempt to clarify the CSM for the various groundwater bearing units have been made by revising the text. Based on the review, further revisions in response to comments or suggestions on the 60% Design will be incorporated into the Draft Final RD submittal.	



Comments Response Matrix
30% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: May 14, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
2.	General		Please avoid use of {}, use nested parentheses or straight brackets instead.	C	Brackets were revised as requested.	
3.	2.4.1	1/2	Change to “and extend” (the soils...extend)	C	Comment noted. In Intermediate (60%) Design Analysis Report, Section 1.7.1, sentence was revised to say “was detected” instead of “and extend” in a new sentence.	
4.	2.4.2/4	2/1-2	Fix different font sizes.	C	Font sizes were fixed for consistency as requested.	
5.	2.4.2/4	3/5-6	This sentence will be updated if you address comment 1. Suggest something like this (use of zone to be determined): it also reported that most now identified as of the Shallow Perched Zone wells, were dry and that the locations and concentrations of groundwater COCs appeared to have had shifted.	C	In Intermediate (60%) Design Analysis Report, Section 1.5, an attempt to clarify the CSM for the various groundwater bearing units have been made by revising the text. Based on the review, further revisions in response to comments or suggestions on the 60% Design will be incorporated into the Draft Final RD submittal.	
6.	4/6-7		For all tables - repeat table headings on each page.	C	Table headings was added on each page as requested.	
7.	Table 1/10	Sloped volume column	While the total volume estimates for each excavation area are correct, applying the formula for the volume of a pyramidal frustum, it's unclear how the sloped volumes were calculated. Please provide the formula for calculating the sloped volume.	C	The formula used to calculate the volume of the sloped area will be included in the Design Calculation Appendix and submitted with the Draft Final RD. Basic formula used as below: $V = \frac{1}{3} h (A_1 + A_2 + \sqrt{A_1 A_2})$	
8.	Attachment 1		Figure 5 - In future packages, please include shallow figures before intermediate figures. Figure 6 – add date for the groundwater data. Figure 12 – check call-out boxes for the results by Building 25-D. The perchlorate results should be in that location and they should be noted as different, since the other results are for TCE.	C	Shallow Zone Figures are now presented before the Shallow/Intermediate Zone figures A note was added in the groundwater Figure that “Groundwater data was taken from May to June 2023.” Figure 12: Perchlorate concentration for LHSMW60 and notes were added to the Figure 1-12.	



Comments Response Matrix
30% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: May 14, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
9.	Attachment 2		Cover page - What is the green bordered area on this figure? Suggest removing the green border. General – Some text and building/MW/sampling point labels throughout are not clear even at 150% scale, see G001 G002. In comparison, the LHAAP-29 drawings are legible at 100% on my set up. In future packages, please check the drawings carefully for readability and optimize the files, including flattening the layers, so they render quickly.	C	The green border was removed. Drawings were enhanced for clarity and labels were adjusted to match the appropriate scale.	
10.	Attachment 2	Sheet 01C101	At their closest point, excavation areas 1 and 2 appear to be separated by a distance of less than 10 feet. With sloped sides, the two excavation areas would overlap. Can these areas be combined into one excavation area, or will each excavation be backfilled before the next excavation proceeds?	C	Comment noted. In the Draft Final RD submittal, detailed cross-sections for the excavation areas will be provided. Excavation areas will be combined where appropriate based on the sloping and grading evaluation. All designated areas will be excavated prior to backfilling the larger combined footprint.	



Comments Response Matrix
30% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: May 14, 2025

Submitted by: USEPA

Responded by: HDR

Date Responded: 09/11/2025

3. Respondent concurs (C) or does not concur (D)

4. Commenter agrees (A) or does not agree (D) with response.

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
Reviewer #1:						
1	1/1	3 rd /2-3	Sentence refers “perchlorate and/or VOCs near Buildings 35, 46A, 49B, and 47B” As far as I can tell, this is the only time that buildings 35, 49B, and 47B are referred to in the text and figures. Were they included in this sentence by mistake?	C	All figures have these buildings labelled and are within treatment zones, except for building 35. Since there is no treatment marked for this building location, Building 35 was removed from the sentence (Report Section 1, 4 th paragraph). Report Section 1.7.2 3 rd paragraph, sentence was also revised to include contamination near Buildings 46A, 49B and 47B.	



Comments Response Matrix
30% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: May 14, 2025

2	2.3/2	2 nd /1-4	The following description of the geology is confusing because the 2nd sentence makes it sound like the relatively thin layer of silty to poorly sorted sand extends across the site, whereas the 3rd sentence seems to suggest that thick silty clay underlies the subsurface layer, which shouldn't be possible if the relatively thin layer extends across the site..."The shallow subsurface layer is typically composed of clay to silty clay at the surface, underlain by a relatively thin (approximately 3-foot-thick) layer of silty to poorly sorted sand that extends across the site. In the east-central portion of the site, this shallow subsurface layer is underlain by thick silty clay."	C	In Intermediate (60%) Design Analysis Report, Section 1.5.1 , The sentence was replaced with the following text to address comment: "The subsurface geology at LHAAP consists primarily of a thin veneer of Quaternary alluvium, mantling Tertiary age formations of the Wilcox and Midway Groups. Underlying these sediments are the Cretaceous age formations of the Navarro and Taylor Groups (Jacobs 2002). In general, boring logs generated across LHAAP show the Wilcox Group typically consist of a series of three sandy water-bearing zones separated by layers of silty clay. The uppermost portion of the Wilcox Group at LHAAP consists of medium plastic sandy silts and clays, which range from approximately 5 to 15 feet thick. These surficial sediments are underlain by the shallow saturated zone, which varies from 10 to 20 feet thick. This sand zone consists of silty, fine-grained sand, containing some silt and clay lenses. At the ground surface, this zone is dry to moist and becomes saturated 15 to 20 feet below ground surface (bgs). A 5- to 20-feet thick, medium to highly plastic silt and clay aquitard underlies the shallow saturated zone. An intermediate saturated sand zone, consisting of a fine to medium silty sand, is encountered below the aquitard, 30 to 50 feet bgs. The intermediate saturated zone is generally less silty than the shallow saturated zone and exhibits a higher hydraulic conductivity. Beneath the intermediate saturated zone, a 5- to 30-feet silt to silty clay layer is encountered. Underlying this silt to silty clay layer is a massive, homogeneous, silty, clayey, fine
---	-------	----------------------	---	---	---



Comments Response Matrix
30% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: May 14, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
					sand that continues to the top of the underlying Midway Group Formation (Jacobs 2002)."	
3	2.3/3	1 st /4-5	It is unclear what is meant by the following statement..."The Deep Zone was defined as a saturated zone within the Wilcox Group, separated by Wilcox clay layers extending across the site." Are the clay layers contained within the Deep Zone? If so, what are they separating? Maybe replace "separated by Wilcox clay layers extending across the site" with "which includes multiple clay layers that extend across the site."	C	The description in Section 2.3 of the 30% RD was revised, and the Intermediate (60%) Design Analysis Report, Section 1.5.2, now contains an improved interpretation of the hydrogeologic conceptualization of the Site.	
4	2.3/3	1 st and 2 nd bullets	The description of the geology associated with the revised hydrogeology conceptualization is just as confusing as the geology associated with the original hydrogeologic conceptualization. Is the "Wilcox clay unit" present or absent in the east-central portion of the site? If it is present, does it underly or overly the "thick silty clay" in this area? Also...the term "Wilcox clay unit" seems to imply that the clay layer is a recognized unit within the Wilcox Group, which is inaccurate. It would be better to describe it as maybe a "laterally continuous clay layer within the Wilcox Group."	C	The description in Section 2.3 of the 30% RD was revised, and the Intermediate (60%) Design Analysis Report, Section 1.5.2, now contains an improved interpretation of the hydrogeologic conceptualization of the Site.	
5	2.3/3	3 rd and 4 th paragraphs	It is probably not worth changing the hydrogeologic conceptualization of the site again, but based on the description provided, it seems as though there is a perched aquifer in the central (or potentially east-central) portion of the site, which has a poor hydraulic connection with the underlying groundwater zone. Outside of this area, the shallow and shallow/intermediate zones should be considered as a single "groundwater zone" because of the minimal groundwater elevation differences between the shallow and shallow/intermediate zones.	C	The description in Section 2.3 of the 30% RD was revised, and the Intermediate (60%) Design Analysis Report, Section 1.5.2, now contains an improved interpretation of the hydrogeologic conceptualization of the Site.	



Comments Response Matrix
30% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: May 14, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
6	2.4.1/3	1 st /2-3	It would be helpful to know how the volume of contaminated soil was estimated, but I think it is critical to know what time period that estimated volume of contaminated soil is associated with. Does it predate the installation of the plastic liner or was an estimate made more recently based on soil sampling in 2010 (as shown in figure 3)?	C	Excavation boundaries were determined using soil sample data from the Jacobs Remedial Investigation (1998) and Shaw Feasibility Study (2010). The estimated volume of contaminated soil was determined has been further explained in the Intermediate (60%) Design Analysis Report, Section 2.2.	
7	2.4.1/4	1 st /2-4	Should specify that the following sentence (in quotes) refers to unsaturated soils because concentrations in excess of 3.3 mg/kg were observed at multiple locations in saturated soils. It may also be helpful to provide a sentence to distinguish between the saturated and unsaturated soil samples and why your discussion focuses on the unsaturated soils..."Detected TCE concentrations in soil generally ranged from 0.5 to 3.3 mg/kg, with the exception of a single boring (DPT-030) where the highest concentration of 16 mg/kg was observed, located behind the southwest corner of the Building 46A footprint." If saturated soil data was not considered when designing the remediation strategies, then it may be preferable to remove these data from figure 4.	C	The sentences describing the nature and extent of unsaturated and saturated soil were revised in Intermediate (60%) Design Analysis Report, Section 1.7.1.	
8	2.4.2/4	3 rd /11	This is the first time that a "perched...groundwater system" is referred to in the report. This concept should have been introduced and described in Section 2.3 Site Geology and Hydrogeology.	C	Reference to the perched groundwater has been removed in this sentence however, possibility of Site-specific areas assumed to have perched groundwater aquifer is mentioned in Section 1.5.2.	
9	2.4.2/4	4 th /2	I'm not sure why it would be "assumed when the concentration of TCE is greater than 10,000 µg/L" that DNAPL is present, when it is reported later in this same paragraph that the "highest <u>groundwater</u> PSI TCE concentration was observed at 47WW25R...at 120,000 µg/L."	D	Per EPA Publication 9355.4-13, EPA 540R-93-073 (September 1993) Evaluation of the Likelihood of DNAPL Presence at NPL Sites, TCE expressed as percentages of their pure-phase solubilities can be assumed to be in DNAPL phase.	



Comments Response Matrix
30% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: May 14, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
10	2.4.2/5	1 st /1-5	This paragraph claims that "...the VOC extent of contamination in the Shallow Zone was observed to be substantially reduced when compared to the 2010 results. ... This change is evident as shown on Figure 9 , showing the perchlorate plumes identified during previous investigations no longer exist and the TCE plume is much smaller." Perchlorate is not a VOC and, therefore, should not be used as an indicator of VOC extent.	C	In Intermediate (60%) Design Analysis Report, Section 1.7.2, the sentence has been revised to state "This change is evident as shown in Figure 1-5 that shows the TCE plume being much smaller than identified during previous investigations. Further, perchlorate plumes are no longer present in the Shallow Zone."	
11	2.4.2/5	2 nd /1-7	The TCE and perchlorate plume conceptualizations as described in this paragraph are very confusing because it seems as though the plumes were redefined in response to the addition of two new replacement wells (47WW11R and LHSMW43R), even though the replacement wells seem to be completed in a different groundwater zone (Shallow/Intermediate) from the original wells (Shallow). As a result, it is unclear as to why the two sets of contours would be presented collectively in Figure 5 based on the revised hydrogeologic conceptualization because comparing plume maps from two different groundwater zones that represent two different time periods wouldn't seem to have much use.	D	The data presented in Figure 1-10 is from the 2019 and 2020 PSI, solely and acceptable within the time frame. Shallow wells in this area during both of these PSI field efforts were dry and replaced with the mentioned wells. Since the Shallow Zone was dry, wells were installed in the Shallow/Intermediate, which are likely interconnected (as pointed out in an earlier comment). As such, with a receded water table the Shallow/Intermediate is representative. No change made to the text.	
12	3/5	2 nd /1-5	The claim should not be made that the selected remedies will "prevent" human exposure or contaminant migration. This is particularly true for the claim that the selected remedies will "prevent contaminated groundwater from reaching nearby surface waters." If Goose Prairie Creek is gaining within or east of the site boundaries, then "prevention" is already an impossibility because Goose Prairie Creek already bisects the existing Shallow Zone groundwater TCE plume (see Figure 9). It would be more appropriate if each instance of "preventing" was replaced with "reduce the likelihood of."	D	The sentence was removed and replaced sentence added in Intermediate (60%) Design Analysis Report, Section 1.11.	



Comments Response Matrix
30% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: May 14, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
13	3/6	1 st complete bullet	Claim is made that “leading edges of the Shallow Zone and Shallow/Intermediate Zone northern and southern perchlorate and VOC plumes will be treated using ISB via application of substrate in the form of biobarriers.” A biobarrier wall associated with the Shallow Zone is not included on Sheet 3 of Attachment 2.	C	Leading edges of the Shallow Zone plume in the southern portion will be treated using ISB via application of substrate in a grid configuration. Text was revised in Section 1.11 to state, “leading edges of the Shallow/Intermediate Zone perchlorate and VOC plumes will be treated using ISB via application of substrate in the form of biobarriers.”	
14	5/8	2 nd complete bullet	In the following sentence, change the second instance of “of” to “or”... “Metal exceedances in both the Shallow Zone and Shallow/Intermediate Zone were sporadic and did not indicate the presence of a plume of obvious source area.”	C	Text was revised as requested in DAR Section 1.13 as “Metal exceedances in both the Shallow Zone and Shallow/Intermediate Zone were sporadic and did not indicate the presence of plume(s) or obvious source area(s).”	
15	6/8	2 nd bullet/2 nd sub-bullet	LHAAP-47 was defined as the “Site” in Section 1 of this document, so in the following statement in quotes, “offsite” and “further offsite” should be added (as indicated in red) to account for Biobarriers 1 and 2. “Implementation of ISB biobarriers near the leading edges of the northern and southern perchlorate and VOC plumes, and at the northern and eastern edge of the perchlorate plume to mitigate the risk of contaminant migration offsite , further offsite , or further into the site.”	C	Text was revised as requested in DAR Section 1.14 “Implementation of three ISB biobarriers near the northern, southern, and eastern edge of the VOC plume, and at the northern and eastern edge of the perchlorate plume to mitigate the risk of contaminant migration off-site, further off-site, or further into the Site.”	
16	6.1/9	2 nd /3-5	It would be helpful if an explanation of the 1V:1H slope calculation of soil volume surrounding the excavation sites could be explained in greater detail. If this is a standard method for estimating the volume of soil that will need to be removed from the area that surrounds a proposed excavation site, then a citation should be added for one or more publications that describe the method. It would probably also be helpful if the areas that will need to be partially excavated around each proposed excavation site were also delineated on sheet 01C101 in Attachment 2.	C	Detailed calculation used to determine the sloped area volume will be included in the Draft Final RD submittal; however, the design assumptions for the sloped areas and volume have been revised in the Intermediate (60%) Design Analysis Report, Section 2.2.	



Comments Response Matrix
30% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: May 14, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
17	6.1/11	1 st /1-4	The confirmation sampling strategy is extremely vague and gives no indication of where the confirmation samples will be collected in each excavation area or the number of samples that will be collected in each excavation area. If that information will be forthcoming in later iterations of the remedial design, then it would be helpful if that information was included.	C	Text related to the confirmation sampling was included as requested in Intermediate (60%) Design Analysis Report, Section 2.3.	
18	6.2/11	2 nd /3-5	Should specify that the volumes referred to in the following sentence (in quotes) refer to the volume of soil containing residual DNAPL and not the actual volume of DNAPL..."ERH is anticipated to treat approximately 23,860 cy of residual DNAPL, with 4,775 cy and 19,075 cy in the Shallow Zone and Shallow/Intermediate Zones, respectively."	C	The sentence was revised as requested in Intermediate (60%) Design Analysis Report, Section 3.2.	
19	6.3.1/13	3 rd /11-15	The explanation of injection locations associated with the ISB grid is too vague. In what direction will the injection points be oriented relative to "sample locations with elevated levels of perchlorate and/or TCE"... to the north, east, south, and west of these sample locations or along (and perpendicular to) the longitudinal axes of each plume? What will be the spacing between injection points, and will it vary from one gridded area to the next. If these details will be provided in subsequent iterations of the remedial design process, it may be helpful to indicate that.	C	The recommended radius of influence for Shallow Zone and Shallow/Intermediate Zone has been included in Intermediate (60%) Design Analysis Report, Section 4.2.2.	



Comments Response Matrix
30% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: May 14, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
20	6.3.2/14	1 st /1-3	Reiterating comment 16. LHAAP-47 was defined as the “Site” in Section 1 of this document, so in the following statement in quotes, “offsite” and “further offsite” should be added (as indicated in red) to account for Biobarriers 1 and 2 because Biobarrier 1 is located offsite, and Biobarrier 2 is located almost exclusively along the site border, so neither of these biobarriers were really designed to “to mitigate the risk of contaminant migration further into the [LHAAP-47] site” “Biobarriers are proposed within the Shallow/Intermediate Zone near the leading edges of the northern and southern VOC plumes, as well as at the eastern and northern edges of the southern perchlorate plume, to mitigate the risk of contaminant migration further offsite, offsite, or further into the site.	C	The sentence was removed in Intermediate (60%) Design Analysis Report.	
21	6.3.2/14	Bullet 1/5-6	The claim is made that “the barrier alignment will follow the tributary of Goose Prairie Creek to the northeast,” but the northern extent of Biobarrier 1 extends in a northwesterly direction.	C	Text has been revised to “The barrier alignment will follow the tributary of Goose Prairie Creek to the northwest and Goose Prairie Creek at the southern corner of the site.” In Intermediate (60%) Design Analysis Report, Section 4.3.2.	



Comments Response Matrix
30% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: May 14, 2025

22	6.3.2/15	1 st /4-6	I have two comments/concerns related to the following sentence..."Monitoring data from the pilot tests will be used to identify the dechlorination rate and to demonstrate complete dechlorination to ethene within the target timeframe and refine the design parameters for the full-scale implementation." 1.) I don't think it will be possible to 'identify <u>the</u> dechlorination rate' because dechlorination rates will vary spatially (along the biobarriers), as a function of depth, and temporally. 2.) What will qualify as "complete dechlorination to ethene?" Would detecting ethene qualify? Or does "complete dichlorination" refer to a complete lack of any VOC detections downgradient of the biobarriers? If it is the latter, I'm not confident that the pilot tests will be able to achieve this within a reasonable timeframe, and it may never be achievable. Either way, it should be specified as to what qualifies as "complete dechlorination to ethene."	C	1.) Regarding the dechlorination rate: The comment acknowledged. It is understood that dechlorination rates will vary spatially, temporally, and with depth along the length of biobarriers. To clarify, the intent is not to define a unique uniform rate, but rather to evaluate trends and ranges in dechlorination activity based on monitoring data for proposed two years. The use of anion analysis plus VOC profiles at monitoring locations within the proposed Zone over time would be helpful in characterizing relative dechlorination performance and informing adjustments to the full-scale implementation. The details related to the performance monitoring to be included in Draft Final RD submittal will reflect the evaluation of dechlorination trends rather than identifying a fixed rate. 2.) Regarding "complete dechlorination to ethene": Comment acknowledged. It is understood that detecting ethene alone may indicate that dechlorination is occurring, but not necessarily that it is complete. For the purposes of the pilot test, our purpose for defining "complete dechlorination" as the observation of ethene as the dominant daughter product, with minimal or non-detect levels of daughter products (e.g., cis-DCE, VC) at select monitoring points. A complete degradation of VOC downgradient may not be feasible within the 2 years of pilot timeframe. The details related to the performance monitoring to be included in Draft Final RD submittal will reflect the language to clarify that the goal is to demonstrate the potential for complete dechlorination at specific monitoring points rather than to achieve it fully during the pilot.	
----	----------	----------------------	---	---	--	--



Comments Response Matrix
30% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: May 14, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
23	Attachment 1	Figure 5	Based on the title of the figure, 2010 and 2018 delineations of perchlorate and TCE plumes in the Intermediate Zone are supposed to be included in the figure, but the legend seems to suggest that the figure shows 2018 representations of the perchlorate and TCE plumes in the Shallow Zone and 2010 (and prior) representations of the perchlorate and TCE plumes in the Intermediate Zone. Which is correct...the figure caption or the legend?	C	Legend has been changed to address comment in Figure 1-10.	
24	Attachment 1	Figure 9	Based on the title of the figure, the 2018 delineation of the perchlorate plume in the shallow zone should be included in the figure but is not.	C	Title has been changed to address comment in Figure 1-9.	
25	Attachment 2	Sheet 3/Remedial Action Site Plan	1.) Legend indicates that ISTD will be used in the "Intermediate Groundwater Zone" but ISB will occur in the "Shallow/Intermediate Zone." Use the same naming convention for both. 2.) Use different colors to represent ISTD and ISB in the different groundwater zones 3.) The line styles used to represent the ISTD areas on the map do not match the line styles used to represent these areas in the legend and are difficult to see on the map.	C	Response to comment 1: Sheet 01C201 was revised to remove groundwater and says "ISTD Area - Shallow Zone" and "ISTD Area - Shallow/Intermediate Zone." Response to comment 2: No changes made in Sheet 01C201. Change made in Sheet 02C100 to differentiate color for groundwater zone. Response to comment 3: No changes made to 02C100, Confirmed that line work matches in ISTD drawings.	
26	General comment	Throughout text and figures	Terms used to describe the different groundwater zones must be used consistently for clarity. When referring to the three groundwater zones that were initially identified in the 2003 RI, perhaps "former" could be added to these groundwater zone names to distinguish them from current names (Former Shallow Zone and Former Intermediate Zone). Furthermore, the Shallow Zone should not also be referred to as the "Shallow Groundwater Zone," and the Shallow/Intermediate Zone should not also be referred to as the "Upper Intermediate Zone." Both of these issues are evident in the legend for figure 5, which refers to wells completed in the "Intermediate (Upper)," "Shallow/Intermediate," and the "Intermediate."	C	The description in Section 2.3 of the 30% RD was revised, and Section 1.5.2 of the Intermediate (60%) Design Analysis Report now includes an updated interpretation of the site's hydrogeologic conceptualization. Additional refinements to this section will be made based on comments and suggestions received during subsequent reviews.	



Comments Response Matrix
30% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: May 14, 2025

Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Submitted by: TCEQ on January 16, 2026

Responded by: HDR

Date Responded: March 18, 2026

1. Respondent concurs (C) or does not concur (D)
2. Commenter agrees (A) or does not agree (D) with response.

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
Reviewer: TCEQ, April Palmie and Midori Campbell						
1.	30% responses		We generally accept the responses to comments for the 30% RD.	C	Comment Acknowledged.	
2.	General	Adobe bookmarks	Check the adobe bookmarks after assembly. This version had most bookmarks but there were some missing for cover letters, RTCs, cover page, and Appendix B as well as duplicate bookmark sets for Appendix G.	C	Comment Acknowledged.	
3.	General	Track changes and CRM	Include a track changes version of the RD and complete CRM/RTC tables with the next submittal.	C	A tracked changed version of the RD with CRM/RTC tables will be included in the next submittal.	
4.	1.6.3/1-6	1 st /1 st	Close parentheses at the end of the 1 st sentence.	C	Text has been revised as requested.	
5.	1.7.1/ 1-8	References to Appendix C (throughout)	For the Appendix C figure references, add the source document to the figure number in the text. Example – last sentence of 1.7.1 would end “PSI Figure 10 of Appendix C” or similar.	C	Text has been revised to reference specific Figures from Appendix C.	
6.	1.11/1-12	ISB Grids bullet	Figures 1-3 and 1-4 do not indicate the areas of grid deployment. Revise text figure reference or revise figures.	C	In Draft (100%) Design Analysis Report, Section 1.11, The sentence was revised with the following text to address comment: “Figures 1-4 and 1-5 identify areas where VOC levels exceed 1,000 µg/L or perchlorate levels exceed 20,000 µg/L; these figures were used to develop the extent of grid deployment, as shown on Sheet 02C100 in Appendix A.”	

Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
7.	2/ 2-1	All of it	Add Figure 5-1 from the 2011 FS to show the excavation areas and reference that figure in this section. It would help if the areas were labeled to match the bullets. We are sharing an example. Figure 2-7 from the ROD does not include the FS excavation areas. Anywhere the term “condensed” is used, replace with “combined”. Some of the specific excavation areas included in the 2011 FS will be combined into one excavation area. First sentence of paragraph after the bullets, revise to this (or similar): The subsequent phases of PDI did not include soil samples in this area so there are no changes from the FS phase.	C	Figure 5-1 is included in Appendix C and the text has been revised as follows, “The FS identified unsaturated contaminated soil located near the former Building 25C (Figure 2-7 of Appendix C) containing perchlorate concentrations that exceeded the GWP-Ind standard. Based on the exceedances, eight excavation areas were initially identified in the FS (Figure 5-1 of Appendix C).” The text has been revised to state, “The subsequent phases of the PDI did not collect any soil samples. Therefore, the extent of areas for soil excavation were estimated based on the data provided in the Final FS (Shaw, 2011). The above eight excavation areas were combined into five excavation areas based on the delineating method described in Section 2.2.”	

Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

8.	2.2/ 2-2	1 st /lines 3-5	The description of the boundary placement is unclear. Is the boundary placed 15-20 feet outward from the contaminated sample locations or 15-20 feet inward from the clean sample location? If the clean sample COC concentration is just below the cleanup level, the boundary may need to extended outward. Consider conducting pre-excavation DPT soil screening to better determine the limits of excavation. The refined excavation boundaries would help reduce the down time from “chasing” the contamination while waiting for confirmation sample results.	C	In Draft (100%) Design Analysis Report, Section 2.2, The sentence was revised with the following text to address comment: “Where clean samples were available in close proximity to the excavated areas, limits were extended to those points. If the nearest clean sample was more than 30 feet from contamination, the boundary was placed approximately 15 to 20 feet outward from the contaminated sample.” The comment is acknowledged. While it is understood that “chasing” contamination during confirmation sampling can extend excavation time, the current approach provides a reasonable balance between conservative delineation and minimizing disturbance to clean soil during the RA phase. During remedial action implementation, post-excavation confirmation samples will be collected from all excavation sidewalls and bottoms to verify that contamination has been fully removed prior to backfilling with clean soil. Additionally, the contractor is required to prepare a Work Plan prior to conducting excavation activities. Conducting pre-excavation DPT soil screening constitutes detailed means and methods that the contractor may propose within their Work Plan, and those proposed methods can be evaluated at that time.	
----	----------	----------------------------	---	---	---	--

Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
9.	2.2/ 2-2	2 nd / lines 2-4	The assumption that contamination diminishes before reaching the clean sample is broad. As described above, if the clean sample barely meets cleanup level, the boundary could be biased outward instead of inward.	D	The assumption regarding diminishing contamination between contaminated and clean sample locations was applied solely for the purpose of developing the design boundaries and to reduce unnecessary removal of uncontaminated material. This approach provides a reasonable balance between conservative delineation and minimizing disturbance to clean soil during the RA phase. However, during remedial action implementation, post-excavation confirmation samples will be collected from all excavation sidewalls and bottoms to verify that contamination has been fully removed before backfilling with clean soil. Any exceedances identified in confirmation samples will result in additional excavation, regardless of initial design assumptions. Therefore, no changes were made in response to this comment.	

Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
10.	2.2/ 2-2 and 2-3	6 th – 12 th	It's still unclear how the slope volume was calculated. Applying the volume formula for a frustum, the calculated total volume of each excavation differs slightly, although not significant. Additionally, the Sloped Width for Excavation Area 3 should be 78 feet instead of 68 feet (30+24+24 = 78). See table attached to this matrix.	C	An error in calculating the sloped volume for the previously identified Excavation Area 3 (now Area 2) was identified and corrected. In Draft (100%) Design Analysis Report, Table 2-1 has been updated to reflect the revised calculations, which incorporate both the building footprint and applicable sloped areas. The updated quantities now represent the volume estimated using Civil 3D AutoCAD modeling as well as verification using the frustum volume formula. The sloped width has also been corrected when calculating the Area 2 volume, as noted in the comment.	

Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
11.	2.2/ 2-3	10 th /line 1	Sheet 01C101 indicates that Excavation Area 5 is benched. Note in Sheet 01C101 that the excavation walls could also be sloped at 1V:2H.	C	In Draft (100%) Design Analysis Report, Section 2.2 was revised to state, "In all areas except Excavation Area 4, excavation walls will be constructed using appropriate sidewall support due to sidewall heights exceeding 4 feet. Depending on field conditions, sidewall support may include sloping at 1V:2H or benching. All soil generated from sidewall support measures will be treated as impacted material and characterized prior to disposal. The estimated additional volume associated with these sidewall support measures is included in the cost estimate and in Table 2-1. A 1V:2H slope is assumed for design purposes, which satisfies the maximum allowable 1V:1.5H slope requirement stated in the Final Installation-Wide Work Plan for Longhorn Army Ammunition Plant (IWWP) Health and Safety Plan (HASP), Attachment 1 (Bhate, 2018), unless further soil analysis indicates otherwise." Note 5 on Sheet 01C101 in Appendix A was also revised accordingly.	
12.	2.2/ 2-4	1 st	See comment #2 for suggested DPT screening for final excavation limits to reduce downtime and possibly excavated volumes.	D	See response to comment #8.	

Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
13.	3.2/3-2	Area 4	PDI Figure 20 includes DPT results but does not include the results for 47WW25R. Is there another figure from the PDI that does include those results?	C	Figures provided in Appendix C have been incorporated as provided in previously approved reports. To remain consistent with the previously approved figure, changes are not recommended in that figure. However, in Draft (100%) Design Analysis Report, Section 3.2, The text was revised to reference the results for the 47WW25R: “Area 4, located in the Shallow/Intermediate Zone, is centered around abandoned well 47WW25R (PSI Figure 20 of Appendix C), which reported a maximum TCE concentration of 140,000 µg/L during the 2018 PSI (HDR, 2019a).”	
14.	3.4.1.2/ 3-7	1 st /line 1	The ISTD Areas are near the western-most edge of the observed potentiometric surface, where the direction of groundwater flow is inferred. One downgradient monitoring well may not be sufficient for evaluating hydraulic control. A minimum of two downgradient wells in each area is suggested to confirm the downgradient direction.	C	Text was revised to include two downgradient wells in each area.	
15.	3.4.4/ 3-9	1 st /second bullet	Identify the off-site facility which will treat and discharge wastewater generated from the ERH operations. Clarify if the GWTP at LHAAP-18/24 will be utilized.	C	In Draft (100%) Design Analysis Report, Section 3.4.4, The sentence was revised with the following text to address comment: “Wastewater generated from the ERH operations will be contained and transported to the existing GWTP located at LHAAP-18/24. For contingency purposes, the Contractor shall also include provisions for on-site treatment and off-site disposal, if necessary.”	

Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
16.	4/4-1	Target treatment bullet	Be mindful of the term “off-site” which should only be used to describe outside of LHAAP/CLNWR extent. For the 18/24 RD we used within and outside of containment area instead. Find a comparable descriptor to use in this case – maybe you could say within the boundary of LHAAP-47 and outside the boundary of LHAAP-47. Note if the area east of LHAAP-47 has been transferred to USFWS. Please check all uses of “off-site” in the RD. Add reference to Sheet 02C100.	C	Global changes have been made to address comment. On-site and off-site changed to “within LHAAP-47 boundary” and “outside of LHAAP-47 boundary” when describing the site treatment areas.	

Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
17.	4.1.1/ 4-18	1 st full paragraph/1 st bullet	If the pilot test for Area 1 is conducted concurrently with Phase 1 ERH activities, is it sufficient distance to limit impacts from the ERH treatment? If not, what effects will heating have on the selected injectant? Will the new Shallow Zone monitoring well, PMW-01, be constructed of durable material such as stainless steel instead of Schedule 40 PVC to withstand higher temperatures?	C	In Draft (100%) Design Analysis Report, Section 4.3.1, text was revised to reflect these changes. The bioremediation Pilot Test in Area 1 is revised not to be conducted concurrently with the Phase 1 ERH implementation. Instead, the ERH treatment will be completed first, and the Pilot Test 1 will follow only after subsurface temperatures have sufficiently decreased. Temperature monitoring will be performed at monitoring well PMW-01 following ERH shutdown to evaluate the rate of thermal dissipation. Once temperatures at PMW-01 have cooled to $\leq 30\text{--}35^{\circ}\text{C}$ ($86\text{--}95^{\circ}\text{F}$), the temperature range in which bioremediation processes and microbial cultures can safely and effectively function, the Pilot Test activities will proceed. By implementing the Pilot Test only after the subsurface has cooled to the appropriate temperature threshold, impacts from ERH heating on the selected bioremediation injectant will be avoided. Yes, as precaution, the new Shallow Zone monitoring well, PMW-01, will be constructed of durable material including stainless steel instead of Schedule 40 PVC to withstand higher temperatures.	

Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
18.	5.1/ 5-1	1 st / 2 nd bullet	1 st and 2 nd sentences – add “deed” before “notice”	C	The changes have been made to address comment.	
19.	5.1/ 5-2	1 st / 5 th bullet	Clarify when and how the LUC boundary will be determined. Remove the term “off-site”	C	In Draft (100%) Design Analysis Report, Section 5.1, The sentence was revised with the following text to address comment: “Finalize the boundaries for the LUCs after the additional investigation is completed as part of Phase I of the remedial action. In the interim, based on the PDI completed to date, the LUCs boundary will be finalized and recorded in the County as part of the remedial action.”	
20.	5.3.5/ 5-4	1 st /1 st & 6 th lines	Add TCEQ.	C	In Draft (100%) Design Analysis Report, Section 5.3.5, Text was revised to include “TCEQ”.	
21.	Figures and Tables	Figure 1-2	It would be better to remove the USFWS Refuge boundary from this figure and include another figure that shows all the LHAAP Army owned and CLNWR transferred property. I think the intent of the green border is to show the groundwater impacts are still within Army property but that isn’t clear from this figure. You only have the incomplete border relative to LHAAP-47 (rather than shading and depicting all transferred property). There are other Army-controlled units within the scale of this figure.	C	Concur. Figure 1-2 was revised to reflect LHAAP Army owned and CLNWR transferred property as well as the LHAAP-47 boundary.	
22.	Appendix A/G002	Remedial Action Phase I Activities – Soil Excavation and Disposal (2E)	In addition to visual inspection of the excavation, consider field screening for VOCs using a PID to determine when to collect confirmation samples.	C	In Appendix A, Sheet G002, Note 2.E was revised with the following text to address comment: “Visually inspect the excavation and field-screen the area for volatile organic compounds (VOCs) using a photoionization detector (PID). If no impacts are observed, collect sidewall and bottom confirmation samples.”	

Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
23.	Appendix A/G003	Site Plan Elevation Contour Lines	Label more contour line elevations to get a better perspective of drainage patterns. The only elevation visible is the 200' contour line at the bottom left corner of the sheet.	C	In Appendix A, Sheet G003, Site Plan Elevation Contours lines were labeled to get a better perspective of drainage patterns.	
24.	Appendix A/01C101	Excavation Volume Table	It's still unclear how the slope volume was calculated. Using the formula for a frustum, the calculated total volume of each excavation area is slightly off, although not significant. Additionally, the Sloped Width for Excavation Area 3 should be 78 feet instead of 68 feet ($30+24+24 = 78$)	C	See response to comment #10.	
25.	Appendix A/01C101	Notes	Under "Notes", it might be helpful to add an explanation that some FS Excavation Areas have been combined.	C	In Appendix A, Sheet 01C101, "The eight excavation areas identified in the final feasibility study (Shawn, 2011) were combined into five excavation areas" was added in Note 2.	
26.	Appendix A/01C101	Legend - Silt Fence	The silt fence symbol shown in the legend should be the same as the symbol depicted on the drawing.	C	The size of the symbol was changed on Sheet 01C101 in Appendix A.	
27.	Appendix B/ 1 of 4	Excavation/1.1.5.2	To allow for weather delays, consider survey work units to be per day instead of per ½ day.	C	Survey work unit was changed to per day basis instead of per ½ day basis.	
28.	Appendix B/ 1 of 4	Waste Disposal for Excavation/1.1.6.2	The unit cost for hazardous waste transportation seems to be low if the cost is per round trip. Is the hazardous waste disposal facility anticipated to be within the proximity of allowing one round trip per day?	C	The unit cost for hazardous waste transportation has been changed as per recent vendor cost.	
29.	Appendix B/ 1 of 4	Waste Disposal for Excavation/1.1.6.3	The unit cost for disposal seems to be low. Does hazardous waste disposal take into consideration other costs or fees, such as treatment which may be required to meet LDR or e-manifests?	C	The unit cost for hazardous waste transportation has been changed as per recent vendor cos.	
30.	Appendix B/ 1 of 4	Post-Excavation Restoration/1.1.7.1	The unit cost for backfill seems to be low if it includes delivery, placement, and compaction.	C	Unit cost for backfill was updated as per the most recent quote.	

Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
31.	Appendix B/ 1 of 4	Pre-Construction/ 1.2.3.7	The cost of drilling and installing a shallow monitoring well (up to 50 feet) seems to be high. Are these monitoring wells for evaluating ISTD performance?	C	The unit cost for drilling and installing monitoring wells include labor and material costs for well installation, completion, development and IDW management. These wells are included to determine the effectiveness of the ISTD system.	
32.	Appendix B/ 2 of 4	Site Preparation for ISB Pilot Tests/1.3.3.5	Are these monitoring wells for evaluating ISB performance?	C	Yes, these wells are included for conducting performance monitoring for the ISB.	
33.	Appendix B/ 3 of 4	Site Preparation for ISB/2.3.5	Are these monitoring wells for evaluating ISB performance?	C	Yes, these wells are included for conducting performance monitoring for the ISB.	
34.	Appendix C		Add a list of figures after the cover page	C	List of figures has been added as a cover page to Appendix C.	
35.	Appendix G	General	I just realized the RD for LHAAP-29 did not include specifications. The 29 RD says specs will be developed in RAWP phase which is not consistent with the other 2 RD sites. Will the Army refer to the 18/24 and 29 specs during contract procurement? Confirm that ISTD specs will not be included because they will be developed at the RAWP phase.	C	As stated in Draft (100%) Design Analysis Report, Section 3.4.1, As part of the RAWP, the Contractor will prepare and submit for approval an ISTD Work Plan in accordance with applicable sections of EM 200-1-21, Design: In Situ Thermal Remediation (USACE, 2014). The Work Plan will provide a detailed description of the ERH technology equipment, construction procedures, and operations, as well as all associated field activities and performance monitoring/system shutdown criteria. Yes, the RA Contractor will include the specific requirements in the future RAWP for all three sites.	

Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
36.	Appendix G, Section 31 23 10	1.1.D/ bullets 2-6	In each bullet, add the word “approximately” before the quantity of contaminated soil removed from each Excavation Area. Quantities are calculated estimates and are not exact.	C	Changes have been made in Section 31 23 10 to address comment.	



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Submitted by: EPA Region 6 on January 9, 2026

Responded by: HDR

Date Responded: March 19, 2026

1. Respondent concurs (C) or does not concur (D)
2. Commenter agrees (A) or does not agree (D) with response.

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
Reviewer #1: Christopher Braun (follow-up comments to 30% RD RTCs submitted May 14, 2025)						
1	1/1	3rd /2-3	Sentence refers “perchlorate and/or VOCs near Buildings 35, 46A, 49B, and 47B” As far as I can tell, this is the only time that buildings 35, 49B, and 47B are referred to in the text and figures. Were they included in this sentence by mistake?	C	All figures have these buildings labelled and are within treatment zones, except for Building 35. Since there is no treatment marked for this building location, Building 35 was removed from the sentence (Report Section 1, 4th paragraph). Report Section 1.7.2 3rd paragraph, sentence was also revised to include contamination near Buildings 46A, 49B and 47B.	A



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

2	2.3/2	2nd /1-4	The following description of the geology is confusing because the 2nd sentence makes it sound like the relatively thin layer of silty to poorly sorted sand extends across the site, whereas the 3rd sentence seems to suggest that thick silty clay underlies the subsurface layer, which shouldn't be possible if the relatively thin layer extends across the site..." The shallow subsurface layer is typically composed of clay to silty clay at the surface, underlain by a relatively thin (approximately 3-foot-thick) layer of silty to poorly sorted sand that extends across the site. In the east-central portion of the site, this shallow subsurface layer is underlain by thick silty clay."	C	In Intermediate (60%) Design Analysis Report, Section 1.5.1, The sentence was replaced with the following text to address comment: "The subsurface geology at LHAAP consists primarily of a thin veneer of Quaternary alluvium, overlying Tertiary age formations of the Wilcox and Midway Groups. Underlying these sediments are the Cretaceous age formations of the Navarro and Taylor Groups (Jacobs 2002). In general, boring logs generated across LHAAP show the Wilcox Group typically consist of a series of three sandy water bearing zones separated by layers of silty clay. The uppermost portion of the Wilcox Group at LHAAP consists of medium plastic sandy silts and clays, which range from approximately 5 to 15 feet thick. These surficial sediments are underlain by the shallow saturated zone, which varies from 10 to 20 feet thick. This sand zone consists of silty, fine-grained sand, containing some silt and clay lenses. At the ground surface, this zone is dry to moist and becomes saturated 15 to 20 feet below ground surface (bgs). A 5 to 20feet thick, medium to highly plastic silt and clay aquitard underlies the shallow saturated zone. An intermediate saturated sand zone, consisting of a fine to medium silty sand, is encountered	A - I agree with the response provided, although it refers to updates made to the description of site-wide LHAAP Geology and Hydrogeology, whereas my comment refers to a portion of the text that refers to site-specific LHAAP Geology and Hydrogeology. However, my concerns were addressed in the 60% Design document, so I went with "Agree" anyway. HDR Note: Changed mantling to overlying in Draft (100%) Design Analysis Report
---	-------	----------	--	---	---	--



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
					below the aquitard, 30 to 50 feet bgs. The intermediate saturated zone is generally less silty than the shallow saturated zone and exhibits a higher hydraulic conductivity. Beneath the intermediate saturated zone, a 5 to 30 feet silt to silty clay layer is encountered. Underlying this silt to silty clay layer is a massive, homogeneous, silty, clayey, fine sand that continues to the top of the underlying Midway Group Formation (Jacobs 2002)."	
3	2.3/3	1st /4-5	It is unclear what is meant by the following statement..."The Deep Zone was defined as a saturated zone within the Wilcox Group, separated by Wilcox clay layers extending across the site." Are the clay layers contained within the Deep Zone? If so, what are they separating? Maybe replace "separated by Wilcox clay layers extending across the site" with "which includes multiple clay layers that extend across the site."	C	The description in Section 2.3 of the 30% RD was revised, and the Intermediate (60%) Design Analysis Report, Section 1.5.2, now contains an improved interpretation of the hydrogeologic conceptualization of the Site.	A



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
4	2.3/3	1st and 2nd bullets	The description of the geology associated with the revised hydrogeology conceptualization is just as confusing as the geology associated with the original hydrogeologic conceptualization. Is the “Wilcox clay unit” present or absent in the east-central portion of the site? If it is present, does it underly or overly the “thick silty clay” in this area? Also...the term “Wilcox clay unit” seems to imply that the clay layer is a recognized unit within the Wilcox Group, which is inaccurate. It would be better to describe it as maybe a “laterally continuous clay layer within the Wilcox Group.”	C	The description in Section 2.3 of the 30% RD was revised, and the Intermediate (60%) Design Analysis Report, Section 1.5.2, now contains an improved interpretation of the hydrogeologic conceptualization of the Site.	A
5	2.3/3	3rd and 4th paragraphs	It is probably not worth changing the hydrogeologic conceptualization of the site again, but based on the description provided, it seems as though there is a perched aquifer in the central (or potentially east-central) portion of the site, which has a poor hydraulic connection with the underlying groundwater zone. Outside of this area, the shallow and shallow/intermediate zones should be considered as a single “groundwater zone” because of the minimal groundwater elevation differences between the shallow and shallow/intermediate zones.	C	The description in Section 2.3 of the 30% RD was revised, and the Intermediate (60%) Design Analysis Report, Section 1.5.2, now contains an improved interpretation of the hydrogeologic conceptualization of the Site.	A - The response and revised text in Section 1.5.2 of the Intermediate (60%) Design Analysis Report don’t really address my specified concerns related to the likely existence of a perched aquifer in the central (or potentially east-central) portion of the site, but I went ahead and approved of the response because it is likely not worth changing the hydrogeologic conceptualization of the site again. HDR note: concur.



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
6	2.4.1/3	1st /2-3	It would be helpful to know how the volume of contaminated soil was estimated, but I think it is critical to know what time period that estimated volume of contaminated soil is associated with. Does it predate the installation of the plastic liner or was an estimate made more recently based on soil sampling in 2010 (as shown in figure 3)?	C	Excavation boundaries were determined using soil sample data from the Jacobs Remedial Investigation (1998) and Shaw Feasibility Study (2010). The estimated volume of contaminated soil was determined has been further explained in the Intermediate (60%) Design Analysis Report, Section 2.2.	A
7	2.4.1/4	1st/2-4	Should specify that the following sentence (in quotes) refers to unsaturated soils because concentrations in excess of 3.3 mg/kg were observed at multiple locations in saturated soils. It may also be helpful to provide a sentence to distinguish between the saturated and unsaturated soil samples and why your discussion focuses on the unsaturated soils..."Detected TCE concentrations in soil generally ranged from 0.5 to 3.3 mg/kg, with the exception of a single boring (DPT-030) where the highest concentration of 16 mg/kg was observed, located behind the southwest corner of the Building 46A footprint." If saturated soil data was not considered when designing the remediation strategies, then it may be preferable to remove these data from figure 4.	C	The sentences describing the nature and extent of unsaturated and saturated soil were revised in Intermediate (60%) Design Analysis Report, Section 1.7.1.	A



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
8	2.4.2/4	3rd /11	This is the first time that a “perched...groundwater system” is referred to in the report. This concept should have been introduced and described in Section 2.3 Site Geology and Hydrogeology.	C	Reference to the perched groundwater has been removed in this sentence however, possibility of Site-specific areas assumed to have perched groundwater aquifer was mentioned in Section 1.5.2 in the Intermediate (60%) Design Analysis Report.	A
9	2.4.2/4	4th /2	I’m not sure why it would be “assumed when the concentration of TCE is greater than 10,000 µg/L” that DNAPL is present, when it is reported later in this same paragraph that the “highest groundwater PSI TCE concentration was observed at 47WW25R...at 120,000 µg/L.”	D	Per EPA Publication 9355.4-13, EPA 540R-93-073 (September 1993) Evaluation of the Likelihood of DNAPL Presence at NPL Sites, TCE expressed as percentages of their pure-phase solubilities can be assumed to be in DNAPL phase.	A HDR note: The text was further revised in the Draft (100%) Design Analysis Report, Section 1.7.2.to state “potential residual DNAPL” and “potentially residual DNAPL” and throughout the document, where appropriate.



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

10	2.4.2/5	1st/1-5	This paragraph claims that "...the VOC extent of contamination in the Shallow Zone was observed to be substantially reduced when compared to the 2010 results. ...This change is evident as shown on Figure 9, showing the perchlorate plumes identified during previous investigations no longer exist and the TCE plume is much smaller." Perchlorate is not a VOC and, therefore, should not be used as an indicator of VOC extent.	C	In Intermediate (60%) Design Analysis Report, Section 1.7.2 , the sentence has been revised to state "This change is evident as shown in Figure 1-5 that shows the TCE plume being much smaller than identified during previous investigations. Further, perchlorate plumes are no longer present in the Shallow Zone."	A - The rewrite seems fine, but I am not seeing a Figure 1-5 included in the Intermediate (60%) Design Analysis Report. HDR note: HDR's response to Comment #10 stating that the "This change is evident as shown in Figure 1-5 that shows the TCE plume being much smaller than identified during previous investigations. Further, perchlorate plumes are no longer present in the Shallow Zone." contains a typographical error. Figure 1-5 was not included in the Intermediate (60%) Design Analysis Report submittal. During the 60% RD submittal, all figures used to characterize the nature and extent of contamination were consolidated into Appendix C and presented without modification to their original titles or legends. These figures were extracted from previously approved reports and were included for reference purposes only. As a result, the same figure was presented as Figure 6 in Appendix C of the 60% RD. Based on the PSI 2018 results, only a TCE plume was observed in the Shallow
----	---------	---------	--	---	--	--



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
						Zone; perchlorate plumes identified in previous investigations were no longer present. To address the Comment #10, additional explanatory text was added to the Design Analysis Report (Draft 100% RD), Section 1.7.2, "Perchlorate plumes are no longer present in the Shallow Zone, therefore, perchlorate plumes beyond year 2018 are not shown in PSI Figure 6 and PDI Figure 27 of Appendix C."



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

11	2.4.2/5	2nd/1-7	The TCE and perchlorate plume conceptualizations as described in this paragraph are very confusing because it seems as though the plumes were redefined in response to the addition of two new replacement wells (47WW11R and LHSMW43R), even though the replacement wells seem to be completed in a different groundwater zone (Shallow/Intermediate) from the original wells (Shallow). As a result, it is unclear as to why the two sets of contours would be presented collectively in Figure 5 based on the revised hydrogeologic conceptualization because comparing plume maps from two different groundwater zones that represent two different time periods wouldn't seem to have much use.	D	The data presented in Figure 7 is from the 2019 and 2020 PSI, solely and acceptable within the time frame. Shallow wells in this area during both of these PSI field efforts were dry and replaced with the mentioned wells. Since the Shallow Zone was dry, wells were installed in the Shallow/Intermediate, which are likely interconnected (as pointed out in an earlier comment). As such, with a receded water table the Shallow/Intermediate is representative. No change made to the text.	A - The explanation seems fine, but I am not seeing a Figure 1-10 included in the Intermediate (60%) Design Analysis Report. HDR note: HDR's response to Comment #11 stating that the "The data presented in Figure 1-10 is from the 2019 and 2020 PSI, solely and acceptable within the time frame. Shallow wells in this area during both of these PSI field efforts were dry and replaced with the mentioned wells. Since the Shallow Zone was dry, wells were installed in the Shallow/Intermediate, which are likely interconnected (as pointed out in an earlier comment). As such, with a receded water table the Shallow/Intermediate is representative. No change made to the text." contains a typographical error. Figure 1-10 was not included in the Intermediate (60%) Design Analysis Report submittal. During the 60% RD submittal, all figures used to characterize the nature and extent of contamination were consolidated into Appendix C and presented without modification to their original titles or legends. These
----	---------	---------	---	---	---	--



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
						figures were extracted from previously approved reports and were included for reference purposes only. As a result, the same figure was presented as Figure 7 in Appendix C of the 60% RD. Figure 7 represents TCE and Perchlorate plums in Shallow/Intermediate Zone. To address the discrepancies between figure titles and legends identified in Comment #11, additional explanatory text was added to the Design Analysis Report (Draft 100% RD), Section 1.7.2, last paragraph.
12	3/5	2nd/1-5	The claim should not be made that the selected remedies will “prevent” human exposure or contaminant migration. This is particularly true for the claim that the selected remedies will “prevent contaminated groundwater from reaching nearby surface waters.” If Goose Prairie Creek is gaining within or east of the site boundaries, then “prevention” is already an impossibility because Goose Prairie Creek already bisects the existing Shallow Zone groundwater TCE plume (see Figure 9). It would be more appropriate if each instance of “preventing” was replaced with “reduce the likelihood of.”	D	The sentence was removed and replaced sentence added in Intermediate (60%) Design Analysis Report, Section 1.11.	A



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
13	3/6	1st complete bullet	Claim is made that “leading edges of the Shallow Zone and Shallow/Intermediate Zone northern and southern perchlorate and VOC plumes will be treated using ISB via application of substrate in the form of biobarriers.” A biobarrier wall associated with the Shallow Zone is not included on Sheet 3 of Attachment 2.	C	Leading edges of the Shallow Zone plume in the southern portion will be treated using ISB via application of substrate in a grid configuration. Text was revised in Section 1.11 to state, “leading edges of the Shallow/Intermediate Zone perchlorate and VOC plumes will be treated using ISB via application of substrate in the form of biobarriers.”	A
14	5/8	2nd complete bullet	In the following sentence, change the second instance of “of” to “or”... “Metal exceedances in both the Shallow Zone and Shallow/Intermediate Zone were sporadic and did not indicate the presence of a plume of obvious source area.”	C	Text was revised as requested in DAR Section 1.13 as “Metal exceedances in both the Shallow Zone and Shallow/Intermediate Zone were sporadic and did not indicate the presence of plume(s) or obvious source area(s).”	A
15	6/8	2nd bullet/2 nd sub-bullet	LHAAP-47 was defined as the “Site” in Section 1 of this document, so in the following statement in quotes, “offsite” and “further offsite” should be added (as indicated in red) to account for Biobarriers 1 and 2. “Implementation of ISB biobarriers near the leading edges of the northern and southern perchlorate and VOC plumes, and at the northern and eastern edge of the perchlorate plume to mitigate the risk of contaminant migration offsite, further offsite, or further into the site.”	C	Text was revised as requested in DAR Section 1.14 “Implementation of three ISB biobarriers near the northern, southern, and eastern edge of the VOC plume, and at the northern and eastern edge of the perchlorate plume to mitigate the risk of contaminant migration off-site, further off-site, or further into the Site .”	A



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
16	6.1/9	2nd/3-5	It would be helpful if an explanation of the 1V:1H slope calculation of soil volume surrounding the excavation sites could be explained in greater detail. If this is a standard method for estimating the volume of soil that will need to be removed from the area that surrounds a proposed excavation site, then a citation should be added for one or more publications that describe the method. It would probably also be helpful if the areas that will need to be partially excavated around each proposed excavation site were also delineated on sheet 01C101 in Attachment 2.	C	Detailed calculation used to determine the sloped area volume will be included in the Draft Final RD submittal; however, the design assumptions for the sloped areas and volume have been revised in the Intermediate (60%) Design Analysis Report, Section 2.2.	A
17	6.1/11	1st/1-4	The confirmation sampling strategy is extremely vague and gives no indication of where the confirmation samples will be collected in each excavation area or the number of samples that will be collected in each excavation area. If that information will be forthcoming in later iterations of the remedial design, then it would be helpful if that information was included.	C	Text related to the confirmation sampling was included as requested in Intermediate (60%) Design Analysis Report, Section 2.3.	A



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
18	6.2/11	2nd/3-5	Should specify that the volumes referred to in the following sentence (in quotes) refer to the volume of soil containing residual DNAPL and not the actual volume of DNAPL..."ERH is anticipated to treat approximately 23,860 cy of residual DNAPL, with 4,775 cy and 19,075 cy in the Shallow Zone and Shallow/Intermediate Zones, respectively."	C	The sentence was revised as requested in Intermediate (60%) Design Analysis Report, Section 3.2.	A
19	6.3.1/13	3rd/11-15	The explanation of injection locations associated with the ISB grid is too vague. In what direction will the injection points be oriented relative to "sample locations with elevated levels of perchlorate and/or TCE"... to the north, east, south, and west of these sample locations or along (and perpendicular to) the longitudinal axes of each plume? What will be the spacing between injection points, and will it vary from one gridded area to the next. If these details will be provided in subsequent iterations of the remedial design process, it may be helpful to indicate that.	C	The recommended radius of influence for Shallow Zone and Shallow/Intermediate Zone has been included in Intermediate (60%) Design Analysis Report, Section 4.2.2.	A



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
20	6.3.2/14	1st/1-3	Reiterating comment 16. LHAAP-47 was defined as the “Site” in Section 1 of this document, so in the following statement in quotes, “offsite” and “further offsite” should be added (as indicated in red) to account for Biobarriers 1 and 2 because Biobarrier 1 is located offsite, and Biobarrier 2 is located almost exclusively along the site border, so neither of these biobarriers were really designed to “to mitigate the risk of contaminant migration further into the [LHAAP-47] site” “Biobarriers are proposed within the Shallow/ Intermediate Zone near the leading edges of the northern and southern VOC plumes, as well as at the eastern and northern edges of the southern perchlorate plume, to mitigate the risk of contaminant migration further offsite, offsite, or further into the site.	C	The sentence was removed in Intermediate (60%) Design Analysis Report.	A
21	6.3.2/14	Bullet 1/5-6	The claim is made that “the barrier alignment will follow the tributary of Goose Prairie Creek to the northeast,” but the northern extent of Biobarrier 1 extends in a northwesterly direction.	C	Text has been revised to “The barrier alignment will follow the tributary of Goose Prairie Creek to the northwest and Goose Prairie Creek at the southern corner of the site.” In Intermediate (60%) Design Analysis Report, Section 4.3.2.	A



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

22	6.3.2/15	1st/4-6	I have two comments/concerns related to the following sentence...”Monitoring data from the pilot tests will be used to identify the dechlorination rate and to demonstrate complete dechlorination to ethene within the target timeframe and refine the design parameters for the full-scale implementation.” 1.) I don’t think it will be possible to ‘identify the dechlorination rate’ because dechlorination rates will vary spatially (along the biobarriers), as a function of depth, and temporally. 2.) What will qualify as “complete dechlorination to ethene?” Would detecting ethene qualify? Or does “complete dichlorination” refer to a complete lack of any VOC detections downgradient of the biobarriers? If it is the latter, I’m not confident that the pilot tests will be able to achieve this within a reasonable timeframe, and it may never be achievable. Either way, it should be specified as to what qualifies as “complete dechlorination to ethene.”	C	1.) Regarding the dechlorination rate: The comment acknowledged. It is understood that dechlorination rates will vary spatially, temporally, and with depth along the length of biobarriers. To clarify, the intent is not to define a unique uniform rate, but rather to evaluate trends and ranges in dichlorination activity based on monitoring data for proposed two years. The use of anion analysis plus VOC profiles at monitoring locations within the proposed Zone over time would be helpful in characterizing relative dechlorination performance and informing adjustments to the full-scale implementation. The details related to the performance monitoring to be included in Draft Final RD submittal will reflect the evaluation of dechlorination trends rather than identifying a fixed rate. 2.) Regarding “complete dechlorination to ethene”: Comment acknowledged. It is understood that detecting ethene alone may indicate that dechlorination is occurring, but not necessarily that it is complete. For the purposes of the pilot test, our purpose for defining “complete dechlorination” as the observation of ethene as the dominant daughter product, with minimal or non-detect levels of daughter products (e.g., cis-DCE,	A
----	----------	---------	---	---	---	---



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
					VC) at select monitoring points. A complete degradation of VOC downgradient may not be feasible within the 2 years of pilot timeframe. The details related to the performance monitoring to be included in Draft Final RD submittal will reflect the language to clarify that the goal is to demonstrate the potential for complete dechlorination at specific monitoring points rather than to achieve it fully during the pilot.	



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

23	Attachment 1	Figure 5	Based on the title of the figure, 2010 and 2018 delineations of perchlorate and TCE plumes in the Intermediate Zone are supposed to be included in the figure, but the legend seems to suggest that the figure shows 2018 representations of the perchlorate and TCE plumes in the Shallow Zone and 2010 (and prior) representations of the perchlorate and TCE plumes in the Intermediate Zone. Which is correct...the figure caption or the legend?	C	Legend has been changed to address comment in Figure 1-10.	D - I am not seeing a Figure 1-10 included in the Intermediate (60%) Design Analysis Report. HDR note: HDR's response to Comment #23 stating that the "Legend has been changed to address comment in Figure 1-10" contains a typographical error. Figure 1-10 was not included in the Intermediate (60%) Design Analysis Report submittal. During the 60% RD submittal, all figures used to characterize the nature and extent of contamination were consolidated into Appendix C and presented without modification to their original titles or legends. These figures were extracted from previously approved reports and were included for reference purposes only. As a result, the same figure was presented as Figure 7 in Appendix C of the 60% RD. To address the discrepancies between figure titles and legends identified in Comment #23, additional explanatory text was added to the Design Analysis Report (Draft 100% RD), Section 1.7.2, last paragraph.
----	--------------	----------	---	---	--	--



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

24	Attachment 1	Figure 9	Based on the title of the figure, the 2018 delineation of the perchlorate plume in the shallow zone should be included in the figure but is not.	C	Title has been changed to address comment in Figure 1-9.	D - I am not seeing a Figure 1-9 included in the Intermediate (60%) Design Analysis Report. HDR note: HDR's response to Comment #24 stating that the "Title has been changed to address comment in Figure 1-9" contains a typographical error. Figure 1-9 was not included in the Intermediate (60%) Design Analysis Report submittal. During the 60% RD submittal, all figures used to characterize the nature and extent of contamination were consolidated into Appendix C and presented without modification to their original titles or legends. These figures were extracted from previously approved reports and were included for reference purposes only. As a result, the same figure was presented as Figure 6 in Appendix C of the 60% RD. To address the discrepancies between figure titles and plumes identified in Comment #24, additional explanatory text was added to the Design Analysis Report (Draft 100% RD), Section 1.7.2, "Perchlorate plumes are no longer present in the
----	--------------	----------	--	---	--	--



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
						Shallow Zone, therefore, perchlorate plumes beyond year 2018 are not shown in PSI Figure 6 and PDI Figure 27 of Appendix C."
25	Attachment 2	Sheet 3/Remedial Action Site Plan	1.) Legend indicates that ISTD will be used in the "Intermediate Groundwater Zone" but ISB will occur in the "Shallow/Intermediate Zone." Use the same naming convention for both. 2.) Use different colors to represent ISTD and ISB in the different groundwater zones 3.) The line styles used to represent the ISTD areas on the map do not match the line styles used to represent these areas in the legend and are difficult to see on the map.	C	Response to comment 1: Sheet 01C201 was revised to remove groundwater and says "ISTD Area - Shallow Zone" and "ISTD Area - Shallow/Intermediate Zone." Response to comment 2: No changes made in Sheet 01C201. Change made in Sheet 02C100 to differentiate color for groundwater zone. Response to comment 3 :No changes made to 02C100, Confirmed that line work matches in ISTD drawings.	A - The line style used to represent the biobarrier wall on figure O2C100 doesn't match what is used in the legend, but otherwise...the updates to the figure seem appropriate. HDR note: Legend has been changed in Design Drawings.



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
26	General comment	Throughout text and figures	Terms used to describe the different groundwater zones must be used consistently for clarity. When referring to the three groundwater zones that were initially identified in the 2003 RI, perhaps “former” could be added to these groundwater zone names to distinguish them from current names (Former Shallow Zone and Former Intermediate Zone). Furthermore, the Shallow Zone should not also be referred to as the "Shallow Groundwater Zone," and the Shallow/Intermediate Zone should not also be referred to as the "Upper Intermediate Zone.” Both of these issues are evident in the legend for figure 5, which refers to wells completed in the “Intermediate (Upper),” “Shallow/Intermediate,” and the “Intermediate.”	C	The description in Section 2.3 of the 30% RD was revised, and Section 1.5.2 of the Intermediate (60%) Design Analysis Report now includes an updated interpretation of the site's hydrogeologic conceptualization. Additional refinements to this section will be made based on comments and suggestions received during subsequent reviews.	A



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
Reviewer #1: Christopher Braun (60% RD comments)						
1	1.5.2/1-4	3/1-3	The following sentence is a little bit confusing because the use of “underlain” suggests that the silty sand layer is beneath the shallow Wilcox Group soil, when, in fact, it represents the base of the shallow Wilcox Group soil based on the depth intervals provided for the shallow Wilcox Group soil (surface to approximately 35 feet bgs) and intermediate Wilcox Group soil (from approximately 35 to 65 feet bgs)...” The shallow Wilcox Group soil (surface to approximately 35 feet bgs) consists predominantly of clay to silty clay, underlain by a thin (approximately 3-foot-thick) layer of silty sand that is present across the Site with varying thickness and continuity.” Furthermore, the silty sand layer cannot be “present across the Site” but also have “varying...continuity.”	C	The text has been revised to help clarify the discontinuous nature and variable lithologies encountered in the Shallow Zone and the intermediate Wilcox Group. In Draft (100%) Design Analysis Report, Section 1.5.2, The sentence was revised with the following text to address comment: “The base of the Shallow Zone is predominantly a thin (approximately 3-foot-thick) layer of silty sand that is present across the Site with varying thickness and continuity.”	



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
2	1.5.2/1-4	3/8-10	The following sentence seems to conflict with previous sentences in the same paragraph that would seem to suggest that the base of the shallow Wilcox group is a silty sand layer and not a “bottom clay”...”The contact between the bottom clay of the shallow Wilcox Group and the underlying sand of the intermediate Wilcox Group varies significantly in depth.”	C	The text has been revised to help clarify the discontinuous nature and variable lithologies encountered in the Shallow Zone and the intermediate Wilcox Group. In Draft (100%) Design Analysis Report, Section 1.5.2, The sentence was revised with the following text to address comment: “The contact between the shallow Wilcox Group and the underlying intermediate Wilcox Group varies in lithology (silty sand to clay) and varies significantly in depth, contributing to localized hydraulic complexity.”	
3	1.5.2/1-5	2/1-8	The first full paragraph at the top of page 1-5 makes the following conflicting claims...”Groundwater in the Shallow/Intermediate Zone has been observed at depths ranging from 26 to 29 feet bgs, with higher elevations associated with locations where the silty sand unit occurs closer to the surface. Groundwater in this Shallow/Intermediate Zone flows to the northeast/north and extends to approximately 65 feet bgs...” I’m assuming that the first sentence is actually describing the Shallow Zone, but that should be clarified.	C	In Draft (100%) Design Analysis Report, Section 1.5.2, The sentence was revised with the following text to address comment: “Groundwater in the Shallow Zone has been observed at depths ranging from 26 to 29 feet bgs, with higher elevations associated with locations where the silty sand unit occurs closer to the surface.”	



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
4	1.5.2/1-5	4/3-5	It is unclear what is meant by the following statement..."Comparisons between shallow and intermediate wells were either minimal or not evaluated due to anomalous conditions in the shallow zone." It seems as though "comparisons" needs to be replaced with a different word, but I'm not sure what the word should be.	C	In Draft (100%) Design Analysis Report, Section 1.5.2, The sentence was revised with the following text to address comment: "Comparisons of gradients between the Shallow Zone and intermediate wells could not reliably be evaluated due to anomalous conditions in the Shallow Zone."	
5	1.6.3/1-7	1/7-8	The following sentence conflicts with Figure 1-2, which identifies all three wells as "potable water wells"... None of these three wells are currently used for drinking water at LHAAP, although they may supply water for non-potable uses."	C	The legend in Figure 1-2 (a new figure) has been revised to state the wells located on LHAAP are "Non-potable Water Wells." Additionally, Section 1.6.3 has been revised to clarify that "Three water supply wells are located within the boundary of LHAAP itself (identified as Non-Potable Water Wells in Figure 1-2)." Additional revisions are made to describe the locations of the non-potable water wells and the Public Water Supply Well.	
6	1.8/1-10	6/1	The first sentence in the last paragraph of this section claims that "There is no present or projected future use of the groundwater at LHAAP-47," even though the last sentence in Section 1.6.3 states that "The future industrial scenario for LHAAP assumes limited use of groundwater as a drinking water source." Please resolve this discrepancy.	C	In Draft (100%) Design Analysis Report, Section 1.8, The sentence was revised to state: "The reasonably anticipated future use of the Site is a wildlife refuge with minimal projected future use of groundwater."	



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
7	1.13/1-14	3/6-8	The statement is made that “Based on new data from wells 47WW64, 47WW65, and 47WW63, the shape and extent of the TCE plumes were revised, resulting in a narrower leading edge.” It appears as though these revised versions of the plumes are not included in the 60% Remedial Design Report...why is that?	D	The TCE plumes were updated during the 2023 PDI and 2024 PDI Addendum. In the 60% RD, these updates are reflected in the TCE plumes shown in Figure 1-5.	
8	1.14/1-15	1 st bullet	An explanation should be provided for why the number of areas identified for DNAPL removal near Building 46A was reduced from 4 in the 30% design to 2 in the 60% design?	C	The following text is added in the Draft (100%) Design Analysis Report, Section 3.2. “At this site, ERH treatment of the deeper Shallow/Intermediate Zone will also require heating of the overlying Shallow Zone. Therefore, the four distinct areas identified in the 2022 ROD were evaluated and consolidated into two treatment zones based on the vertical extent of contamination: one targeting the Shallow Zone and the other encompassing both the Shallow and Shallow/Intermediate Zones.” Therefore, ISTD Area 2 and 3 from the 30% RD were combined into ISTD Area 1 in the 60% RD. In addition, a portion of the ISTD Area 1 which overlapped ISTD Area 4 has been combined into ISTD Area 2 in the 60% RD.”	



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
9	2.2/2-2	3/1	Unclear what is meant by the following statement..." Where perchlorate was vertically delineated, excavation extended to the top of the delineating sample." What is the "delineating sample?"	C	"Delineating sample" was replaced with "clean sample." Excavation areas were vertically delineated to the depth where the first sample free of perchlorate was observed.	
10	2.3/2-4	Entire section	There is no discussion of how the confirmation samples will be analyzed. Will they be sent to the lab for analyses or analyzed in the field. If they will be shipped to the lab for analyses, the iterative process of extending the excavated area based on findings from the analytical results could be very time consuming if characterization samples continue to exceed cleanup levels as excavation areas expand to remove the contaminated soils.	C	Specifications Section 01 35 45 and Section 31 23 10 describe the procedures for collecting and analyzing confirmation samples. Because confirmation sampling is an iterative process, expanding the excavation based on analytical results can be time-consuming when contaminant concentrations continue to exceed cleanup levels. Unless pre-excavation sampling is required to define the extent of contamination prior to excavation.	
11	2.4/2-4 to 2-5	Entire section	Based on the way that the waste is being characterized for disposal, it would be impossible "that approximately 10 percent of the total excavated impacted material, estimated at 1,020 in-place cy, will be classified as hazardous waste resulting from the remedial activities." A total of 12 samples are planned for submittal, and the samples associated with each of the excavated areas will represent a different volume of excavated material. It would probably better to say that it is assumed that only 1 or 2 of the composite samples submitted for waste characterization will be classified as hazardous waste.	C	Text has been revised as follows, "For cost estimating purposes, it is assumed that approximately 10 percent (%) of the total excavated impacted material, estimated at 990 in-place cy, will be disposed as hazardous waste resulting from the remedial activities. It is assumed that two of the composite samples will meet the criteria for classification as hazardous waste."	



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
12	2.3 and 2.7.3		Section 2.3 indicates that “if the confirmation sample is above the cleanup level, additional soil will be removed (2 to 5 feet laterally and 1 foot vertically).,” whereas Section 2.7.3 indicates that “If contaminants are detected above their cleanup levels during the confirmation sampling, secondary excavation will be performed at least one additional foot deeper or 2 to 5 additional feet sideways.” Which is it? Please clarify the appropriate section of the text, as needed.	C	In Draft (100%) Design Analysis Report, Section 2.7.4, The sentence was revised to address comment: “If contaminants are detected above their cleanup levels during the confirmation sampling, secondary excavation will be performed (either 2 to 5 feet laterally and 1 foot vertically).” Specification Section 31 23 10 paragraph 3.7 bullet C and D further provides information regarding secondary excavation.	
13	3.2/3-2 and 3-3	Last paragraph on page 3-2 which extends to top of page 3-3	The text indicates that ERH will be implemented to remove residual DNAPL and TCE sources in... one larger area treating the Shallow/Intermediate Zone also encompassing the Shallow Zone (from 21 feet bgs to 47 feet bgs), as shown in Sheet 01C201 in Appendix A. Based on the Legend for Sheet 01C201, the larger area (delineated in purple on the map) will only target the Shallow/Intermediate Zone and not the Shallow Zone. Which is correct?	C	Sheets 01C201 and 01C100 were revised to show ISTD Area 2 will target Shallow Zone and Shallow/Intermediate Zone.	



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
14	3.2/3-4	2/2-3	The statement is made that “The system will then operate for the period of time required to reach shutdown criteria.” This may not be realistic because the ISTD system could reach a point at which it is no longer effectively removing VOCs, at which point it may be prudent to turn the system off for reevaluation. I have seen this happen at other sites. It would probably be a good idea to have a contingency plan in place in the event that the ISTD system reaches a point at which it is no longer effective.	C	A contingency for diminishing returns can be incorporated as one of the requirements for shut-down criteria. In Draft (100%) Design Analysis Report, Section 3.4, Text was added to address comment: “If VOC mass-removal rates decline to levels indicating limited additional benefit, the Contractor will notify the U.S. Army and the regulators and initiate a reevaluation of the shutdown criteria in the approved ISTD Work Plan. This reevaluation step provides a defined mechanism to pause operations, assess treatment effectiveness, and determine whether system optimization, modification, or shutdown is warranted rather than continuing operation solely to meet the criteria initially established.”	



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
15	3.3/3-4 to 3-5	Entire section	This section calls out “predominant features of the ISTD area’s geology based on the PSI (HDR, 2021a), especially Figures 13 to 16 provided in Appendix C , near Building 46A,” but the ISTD areas are not shown on any of these figures. Furthermore, there isn’t an easy way to interpret how the “predominant features of the ISTD area’s geology” that are discussed in this section relate to the hydrogeologic units of interest (Shallow, Shallow/Intermediate, and Intermediate Zones) spatially because these zones are not depicted on the figures either.		The predominant features of the ISTD treatment area were interpreted using subsurface data developed during the PSI (HDR, 2021a), including information presented in Figures 13 through 16 in Appendix C, in conjunction with cross-sections provided on Sheet 01C202 in Appendix A. Although ISTD treatment boundaries and hydrogeologic zone limits are not depicted on the PSI figures, PSI Figures have been previously approved so changes to these Figures will not be made but sources used for determining the ISTD area features. In Draft (100%) Design Analysis Report, Section 3.3, The sentence was revised to state that “Predominant features of the ISTD area’s geology based on the PSI (HDR, 2021a), especially PSI Figures 13 to 16 provided in Appendix C, and cross-sections presented on Sheet 01C202 in Appendix A, near Building 46A are identified as follows.”	



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
16	3.4.1.2/3-7	1/ 4-10	Is it appropriate that the trigger (based on VOC concentrations) for additional action for the downgradient monitoring wells is “concentrations greater than 1 order of magnitude above baseline conditions.” I know that was only offered as an example, but that seems high considering that the goal of this exercise is to have VOC concentrations decrease. Seems like it might be a problem if VOCs are mobilizing at increasing concentrations in response to the ERH.	C	The trigger of “concentrations greater than 1 order of magnitude above baseline conditions” was provided only as an example to show how exceedance criteria may be evaluated during ERH operations. The final monitoring criteria and action thresholds will be established based on the detailed design and performance monitoring in the work plan submitted by the Contractor. If monitoring data indicate increasing VOC concentrations downgradient, such as mobilization of contaminants in response to heating, the Contractor will be required to notify and coordinate with the U S Army and Regulators to determine and implement the appropriate mitigation strategy.	
17	3.4.3/3-8	3 rd bullet	It would be helpful if an explanation could be provided as to why “existing monitoring wells located within the ISTD areas will be decommissioned.”	C	In Draft (100%) Design Analysis Report, Section 3.4.3, The sentence was revised to state that “Implementation of ISTD is expected to damage the integrity of existing wells within the ISTD areas; therefore, existing monitoring wells located within the ISTD areas will be decommissioned in accordance with 16 TAC 76.104, as applicable, by a Texas-licensed driller and as described in Section 3.4.10. ”	



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
18	3.4.7.1/3-11	1/7-9	It would be helpful if an explanation was provided as to how it will be determined whether or not “shallow vacuum monitoring points” need to be “installed every 50 feet around the perimeter of the ISTD areas...to verify negative pressure at these locations” if the monitoring points were not already in place to make that determination.	C	The criterion to install shallow vacuum monitoring points every 50 feet around the ISTD perimeter is provided as a typical industry practice to ensure adequate negative pressure during thermal operations; however, this value is presented only as an example. Because ISTD is a performance based design component, the final criteria and action thresholds will be established in the detailed design and performance monitoring Work Plan submitted by the Contractor. The Work Plan will be subject to U.S. Army and regulatory review and approval prior to implementation, and this criterion may be revised as necessary based on the Contractor’s proposed means and methods and the final system design.	



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
19	3.4.10/3-13	1/1-3	Is it required that “all heating elements/wells, temperature monitoring points, vapor recovery wells, and vacuum monitoring points will be abandoned or removed at the completion of treatment?” It seems as though some of this infrastructure could be useful in the future. What if ERH wants to be revisited in the future? It may be worth having a discussion with the regulators after ERH has been discontinued to determine if some of the infrastructure that was installed in conjunction with the ISTR may be useful for other purposes in the future.	C	For the purpose of the design and bidding, we need to include the requirement for site restoration. In Draft (100%) Design Analysis Report, Section 3.4.10 outlines the system shut down criteria which mentions that the Contractor may perform an initial shutdown based on their assessment that preliminary results meet the performance goals; however, the final shutdown is contingent upon the U.S. Army and regulatory review, and subsequent approval, requiring up to 10 business days. At that time, the U.S. Army and regulators can determine if some of the infrastructure that was installed in conjunction with the ISTR may be useful for other purposes in the future.	
20	3.4.10/3-15	Paragraphs 1 and 2	It is unclear how “the Contractor will prevent vertical migration of fluids in the borehole and prevent intermixing of waters from different water-bearing zones” “when conducting well abandonment activities” during removal of the well materials if the removal process will be “implemented by over-drilling the well casing.” The very nature of that process seems like it would lend itself to “vertical migration of fluids in the borehole and intermixing of waters from different water-bearing zones.”	C	Well abandonment will be conducted based on the approved procedures outlined in the existing 2018 Work Plan and Regulation 16 TAC 76.104.	



Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
21	4.3.1/4-21	3/2-3	I didn't really see much of a mention of timing of ISB implementation other than the following sentence..."ISB will follow ERH implementation, if needed, near Building 46A, where ERH is expected to reduce VOC concentrations and shrink the ISB footprint in ISB Grid Areas 1S and 1SI." Has consideration been given to how ISB might be affected by the elevated temperatures associated with the ERH? Do temperatures need to fall below a certain level before ISB can be implemented? Please add a brief discussion related to this issue in the text.	C	Text was added in Section 4.3.1 of the Draft (100%) Design Analysis Report, "ISB Pilot Test Area 1, located adjacent to the ISTD Areas, will be initiated after subsurface temperatures decline to levels suitable for effective bioremediation. Following the ERH shutdown, temperature monitoring will be conducted at monitoring well PMW-01 to evaluate thermal dissipation. ISB pilot test activities will be initiated once the temperatures at PMW-01 cool to $\leq 30\text{--}35^{\circ}\text{C}$ ($86\text{--}95^{\circ}\text{F}$), the range in which bioremediation processes and microbial cultures can function effectively. This delay is necessary to prevent temperatures from adversely affecting the bioremediation injectant or microbial activity."	
22	Appendix C		None of the cross sections depict the boundaries between the Shallow, Shallow/Intermediate, and Intermediate Zones. It would be very helpful if those hydrogeologic units were distinguished from one another.	D	Figures provided in Appendix C have been incorporated as provided in previously approved reports. To remain consistent with the previously approved figure, changes are not recommended. No changes were made; however, detailed cross-sections of the ISTD areas are provided in the design drawings.	

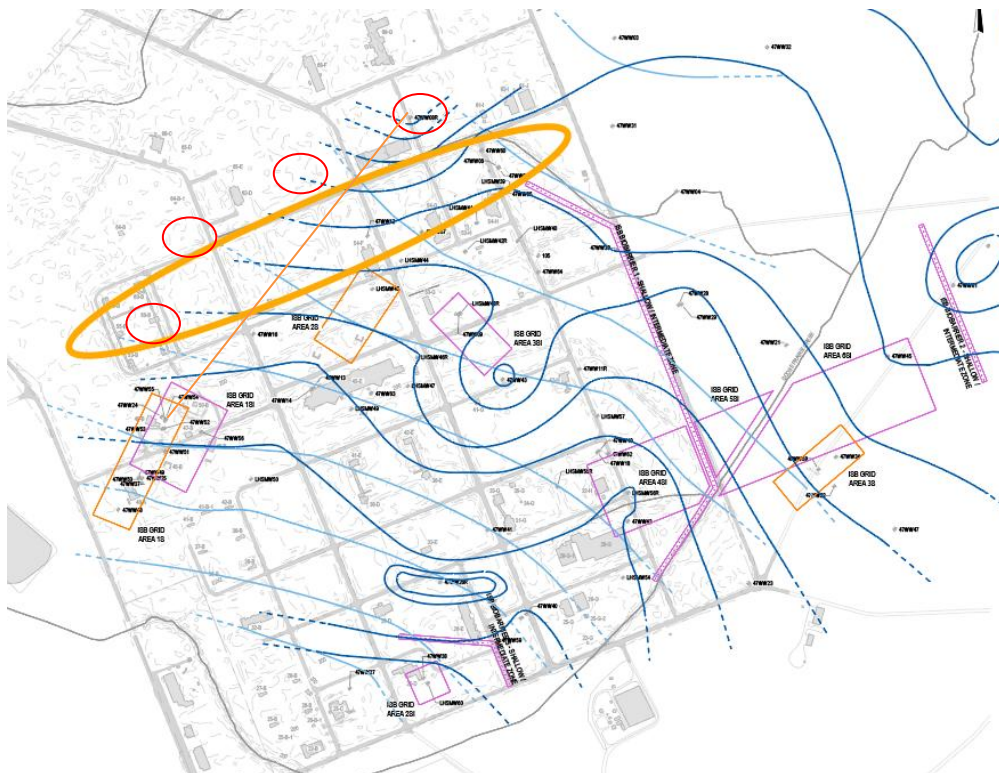


Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

General Comments:

- 1.) Looking at the ISB Biobarrier delineations relative to groundwater flow direction in the shallow (light blue) and shallow/intermediate zones (dark blue) in the image shown below, it seems like the most likely direction for offsite migration would be to the north in the area circled in orange. Plume containment in this area would also seem to be most critical considering that the highest TCE concentrations at the site are in the area around building 46-A, which currently does not have any associated plume containment.

Response: Draft (100%) RD now includes a requirement for installing and sampling four new monitoring wells for the purpose of LTM during Phase I, prior to full-scale implementation of the ISB treatment. These monitoring wells will provide the data necessary to adjust the barrier wall alignment if offsite migration is observed to the north in the area circled in orange. In addition, In Draft (100%) Design Analysis Report, Section 4.1 requires the Contractor to submit a Field Pilot Test Report following completion of the ISB pilot tests. This report will document the pilot test implementation, findings, results, and recommendations for full-scale ISB implementation during the Phase II RA. At that time, if necessary, the alignment of the biobarrier wall can be revised to ensure effective plume containment to the north.



- 2.) Based on the design of the ISB systems with respect to radii of influence for the DPT injection points (6.5 feet for the Shallow Zone and 13.5 feet for the Shallow/Intermediate Zone) relative to the spacing between the DPT points (13 feet apart in the Shallow Zone and 27 feet apart in the Shallow/Intermediate Zone), there will be a fair amount of space that falls outside of the radii of influence (refer to areas inside the red box shown below that are not shaded in green) and would thus be unaffected by ISB activities based on the theoretical radii of influence. Is that typical in ISB system design?

Response: Yes, this is typical for ISB system design. Unlike ISCO, where direct oxidant–contaminant contact is required and overlapping radius of influence (ROI) are critical to ensure adequate treatment, ISB relies on long-term amendment dispersion and biologically mediated degradation. In ISB applications, the ROI serves as a design guideline for placing injection points, but full overlap is not necessary because the injected substrate continues to migrate, diffuse, and mix with groundwater over time. As a result, biodegradation extends beyond the initial theoretical ROI, and the system relies on sustained microbial activity rather than immediate contact. Therefore, the presence of areas outside the theoretical ROI is consistent with typical ISB design practices.

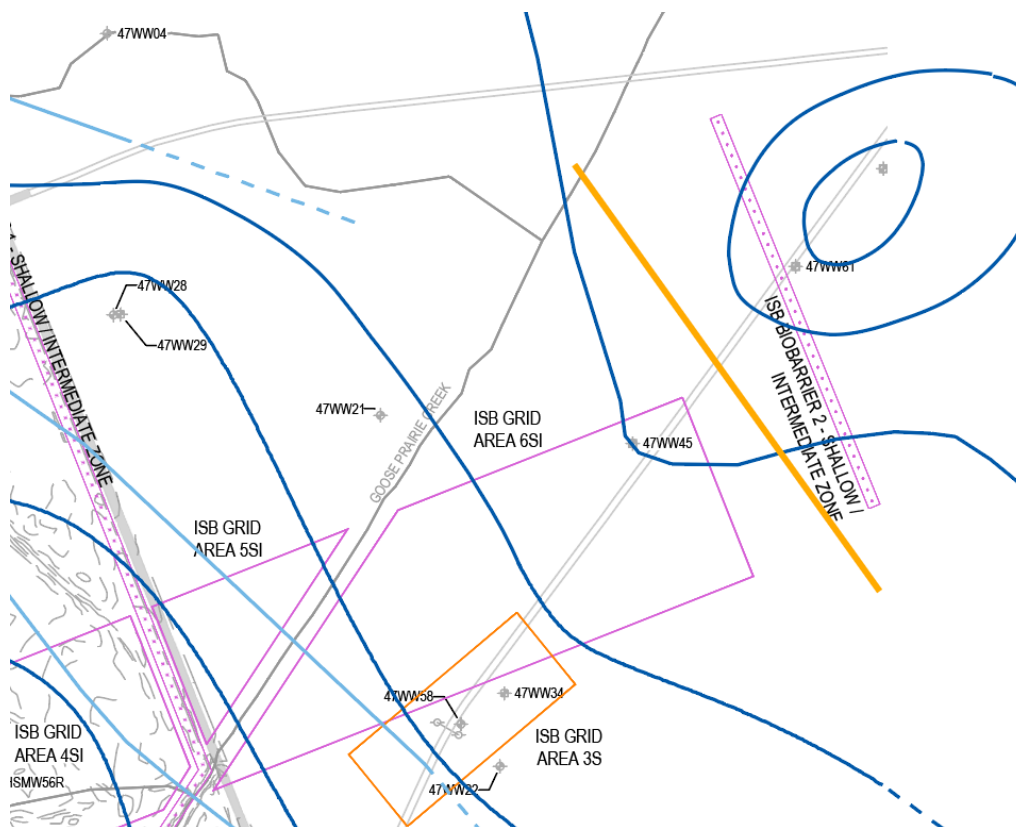




Comments Response Matrix
60% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: December 2, 2025

- 3.) It would probably be more effective if the ISB Biobarrier 2 was oriented perpendicular to flow as opposed to being parallel to the easternmost edge of ISB Grid Area 6SI...less chance of contaminated groundwater flowing further offsite between Goose Prairie Creek and the northernmost end of the ISB Biobarrier 2. –

Response: ISB Biobarrier 2 alignment was revised to orient perpendicular to the flow as suggested.





Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Submitted by: TCEQ Project Manager: April Palmie and Abiy Berehe

Responded by: HDR

Date Responded: 5.19.2026

1. Respondent concurs (C) or does not concur (D)

2. Commenter agrees (A) or does not agree (D) with response.

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
Reviewer #1:						
	60% responses		We generally accept the responses to comments for the 60% RD with exceptions noted below		Acknowledged	
	#2		Comment regarding adobe bookmarks – After all revisions, check the Adobe bookmarks for the final 100% design. Adobe bookmarks for several appendices are hidden other appendices – D, F, and G. Appendix G also needs bookmarks for each specification. Nested bookmarks for Appendix D would also help (approximately 300 pages of well logs). More comments on Appendix D below.	C	Bookmarks have been formatted as requested.	
	#3		The CRM from 30% was not included. Include all CRMs in the final RD for the site record (30%, 60%, and 100% DF). Thank you for the RLSO files.	C	CRMs from the 30%, 60%, and 90/100% DF have been included.	
1	General		For the Final RD, consider including Appendix A Drawings and Appendix D Well logs as two stand-alone pdf files. The rest of the RD could be one pdf.	C	Appendix A and D have been provided as separate pdf files.	
2	General		Consider making a general statement about the IWWP to allow use of the most recent version if the 2018 IWWP has been replaced.	C	The following text has been added at the end of Section 1.14: “For the purposes of this Remedial Design, the 2018 Installation-Wide Work Plan (IWWP)(Bhate, 2018) was used as the most current version of the IWWP. However, the Remedial Action will follow the most current IWWP available at the time of execution.”	



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
3	Term “potential DNAPL”		Please reconsider usage of “potential DNAPL” or “potentially residual DNAPL” and revise to “residual DNAPL”. The term used in the ROD is “residual DNAPL”. This change may have been an attempt to address a comment from EPA. In some places, the revisions misrepresent information from the ROD and other reports for this site (see 1.11). In other places “potential” is unnecessary. Residual means “remaining after the greater part or quantity has gone” which should be sufficient to indicate the expected conditions.	C	The text has been revised as recommended.	
4	1.7.3, 1-9		2 nd paragraph, 1 st sentence – revise the end to “principal threat waste” [remove “to”].	C	The text has been revised as recommended.	
5	2.5, 2-5		Sentence beginning “Borrow source”, replace “f” with “rate of”.	C	The text has been revised as follows: “Borrow source samples will be collected at a frequency of one sample per 1,000 cy of borrow soil.”	
6	2.7.6, 2-8		1 st sentence, add “report” after “completion”.	C	The text has been revised as recommended.	
7	3.4.2, 3-7		This is the only part of the RD that discusses permitting. Since there is not a section for permitting elsewhere in the RD, Underground Injection Control must be added. Consider moving this section before Section 2, because some components are applicable to other phases of the work (not just ISTD). Maybe you could add a General Implementation section after the introduction and include permitting there.	C	Section 3.4.2 has been revised and added as Section 1.14.1 to provide a more general statement of permitting.	
8	3.4.10, 3-14		Last paragraph - Consider removing the Texas Water Development Board since well abandonment reports and notices are required by Texas Department of Licensing and Regulation rules.	C	The text has been revised as recommended.	
9	3.4.11, 3-14		Last sentence - revise the end to “heating elements and sampling and monitoring points...”	C	The text has been revised as recommended.	



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
10	4.1, 4-17 (should be 4-1)		Fix section 4 page numbering. For clarity, revise this sentence before the 2 nd group of bullets: The ISB implementation approach consists of two coordinated components: target treatment areas and plume containment, both of which will be refined using data generated during Phase I pilot testing.	C	The text has been revised as recommended.	
11	4.2.3, misnumbered 4-19		First paragraph – why is this text included? It is not necessary. “...whereas a larger droplet size is more favorable for fractured rock applications where adsorption to the formation is the primary objective.”	C	The text has been removed as recommended.	



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

12	4.3.2, misnumbered 4-21 and 4.4	Questions below relate to ISB Pilot Test Area 3 and northern part of ISB Biobarrier 1. For context, on this flow path TCE results are 47WW39 17.5 J µg/L and 47WW32 26.9 J µg/L. Do the concentrations in this part of the site warrant such an extensive biobarrier network? The ROD included a short biobarrier downgradient from 47WW39. This part of the remedy has expanded from the ROD and the data doesn't indicate high concentrations. For the pilot test, are the concentrations in this area high enough to evaluate performance? Wouldn't a pilot test downgradient of LHSMW56R provide more useful information? Pilot test area 4 is also on that flow path. Concurrent pilots on the flow path would be useful, or at least probably not problematic.	C	The conceptual ISB biobarrier alignments originally identified in the 2022 ROD (ROD Figure 2-10 in Appendix C) were intended to be located along the leading edges of both the northern and southern perchlorate and VOC plumes to mitigate the potential for contaminant migration beyond the LHAAP-47 property boundary. In the Design Drawings (Sheet 02C100 in Appendix A), these alignments have been refined based on updated groundwater plume delineation from the PDI and subsequent coordination with the U.S. Army and regulatory agencies (May 20, 2026). Consistent with these refinements, the extent of ISB Biobarrier 1 along the northeastern portion of the Site has been reduced and is no longer proposed to fully address the distal, lower-concentration extent of the northern VOC plume. Groundwater concentrations in the vicinity of well 47WW39 (17.5 µg/L TCE) closely represents the attenuated leading edge of the plume. In contrast, higher-concentration source and core plume area, near well LHSMW56R (5,190 µg/L TCE), continue to be targeted for active treatment through ISB grids and the southeastern biobarrier. This refinement prioritizes active treatment in areas with elevated contaminant mass and greater potential for continued southern VOC plume migration, while relying on MNA to
----	---------------------------------	--	---	--



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
					address the lower-concentration, distal portion of the northern VOC plume. This approach is consistent with the overall remedial strategy, which includes transition to MNA in areas outside the active treatment footprint where attenuation processes can effectively reduce contaminant concentrations over time. To verify that plume stability is maintained under this approach, additional monitoring wells have been incorporated into the northeastern portion of the Site. These wells will support long-term performance monitoring to confirm that MNA processes are occurring, plume migration remains controlled, and RAOs continue to be met. If monitoring data indicates that MNA is not effectively controlling plume migration, contingency ISB injections may be implemented in accordance with the adaptive management framework described in the ROD.	
13	5.1, 5-2		First bullet, 2 nd sentence beginning "The LUCs boundary presented in this RD..." Clarify the term "off-site" by stating that it means outside the boundary of LHAAP-47.	C	The sentence was revised to state that "The LUCs boundary presented in this RD is subject to change as the limits of groundwater contamination are not well defined outside the LHAAP-47 boundary area."	
14	6.1, 6-1		2 nd paragraph, 1 st sentence needs some clean up.	C	The text has been revised for clarity.	
15	7		Text was not updated	C	The text has been updated as per latest Cost Estimate.	



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
16	Performance MW names		Are the performance MW names simply placeholders? Make sure the wells have 47 in the name. Would G001 be an appropriate place to include a note about this expectation?		In Appendix A, Sheet 02C100, Note 6 states the following: “New performance monitoring wells (PMW) shall include the prefix “47” in the well ID. PMW ID’s currently display placeholder well ID’s in the format PMW-XX.”	
17	Append A		Please flatten the design drawings (save as optimized is one option) before including Appendix A in the Final RD. Rendering each drawing makes the pdf very cumbersome. I was able to optimize Appendix A for our review but some image in Appendix B-F returned errors. I think it was the well logs since I didn’t have that problem with the 60% file.	C	The drawings have been flattened as requested.	
18	Append A		Throughout the drawings it is very difficult to distinguish between the shallow vs. shallow/intermediate new well icons. Try to add more contrast between these icons (color, size, and/or shape).	C	Design Drawings were revised to adjust the symbology contrast of the new performance monitoring well locations.	
19	Append A G001		Well notes, revise #5 – most permanent wells at LHAAP have the protective barrier but text implies it is limited to high traffic areas.	C	The notes have been revised to indicate protective barriers will be installed without reference to traffic/equipment.	
20	Append A, 01C201		The text in wells to be abandoned table is not very clear.	C	Change has been made as per request in Append A Sheet 01C201.	
21	Append A, 01D100		The specification text on the bottom left is cut off.	C	Change has been made as per request. In Append A Sheet 01D100, Text is visible.	
22	Append A, 04C100 & 04C101		The blue and green icons for the new and LTM wells are not very visible. Please select colors with more contrast. The groundwater gradient contours need to be added to the legend.	C	The LTM well icons were revised from green to red to enhance visibility, and the groundwater contour symbology was added to the legend on Sheets 04C100 and 04C101.	
23	Appendix D		Run recognize text on this appendix so the well logs are searchable, save as optimized or reduced size, and add Adobe bookmarks for each location (or some sort of structure by groups of wells.)	C	The well logs have been updated as requested.	



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Submitted by: USEPA/USGS

Responded by: HDR

Date Responded: 4/27/2026

1. Respondent concurs (C) or does not concur (D)
2. Commenter agrees (A) or does not agree (D) with response.

Follow-up comments on 60% RD						
Number	Section/Page	Paragraph/Line	Comment	C/D	Response	A,D
1	1.5.2/1-4	3/1-3	The following sentence is a little bit confusing because the use of “underlain” suggests that the silty sand layer is beneath the shallow Wilcox Group soil, when, in fact, it represents the base of the shallow Wilcox Group soil based on the depth intervals provided for the shallow Wilcox Group soil (surface to approximately 35 feet bgs) and intermediate Wilcox Group soil (from approximately 35 to 65 feet bgs)...” The shallow Wilcox Group soil (surface to approximately 35 feet bgs) consists predominantly of clay to silty clay, underlain by a thin (approximately 3-foot-thick) layer of silty sand that is present across the Site with varying thickness and continuity.” Furthermore, the silty sand layer cannot be “present across the Site” but also have “varying...continuity.”	C	The text has been revised to help clarify the discontinuous nature and variable lithologies encountered in the Shallow Zone and the intermediate Wilcox Group. In Draft (100%) Design Analysis Report, Section 1.5.2, The sentence was revised with the following text to address comment: “The base of the Shallow Zone is predominantly a thin (approximately 3-feet-thick) layer of silty sand that is present across the Site with varying thickness and continuity.”	A



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Follow-up comments on 60% RD						
Number	Section/Page	Paragraph/Line	Comment	C/D	Response	A,D
2	1.5.2/1-4	3/8-10	The following sentence seems to conflict with previous sentences in the same paragraph that would seem to suggest that the base of the shallow Wilcox group is a silty sand layer and not a “bottom clay”...”The contact between the bottom clay of the shallow Wilcox Group and the underlying sand of the intermediate Wilcox Group varies significantly in depth.”	C	The text has been revised to help clarify the discontinuous nature and variable lithologies encountered in the Shallow Zone and the intermediate Wilcox Group. In Draft (100%) Design Analysis Report, Section 1.5.2, The sentence was revised with the following text to address comment: “The contact between the shallow Wilcox Group and the underlying intermediate Wilcox Group varies in lithology (silty sand to clay) and varies significantly in depth, contributing to localized hydraulic complexity.”	A
3	1.5.2/1-5	2/1-8	The first full paragraph at the top of page 1-5 makes the following conflicting claims...”Groundwater in the Shallow/Intermediate Zone has been observed at depths ranging from 26 to 29 feet bgs, with higher elevations associated with locations where the silty sand unit occurs closer to the surface. Groundwater in this Shallow/Intermediate Zone flows to the northeast/north and extends to approximately 65 feet bgs...” I’m assuming that the first sentence is actually describing the Shallow Zone, but that should be clarified.	C	In Draft (100%) Design Analysis Report, Section 1.5.2, The sentence was revised with the following text to address comment: “Groundwater in the Shallow Zone has been observed at depths ranging from 26 to 29 feet bgs, with higher elevations associated with locations where the silty sand unit occurs closer to the surface.”	A



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Follow-up comments on 60% RD						
Number	Section/Page	Paragraph/Line	Comment	C/D	Response	A,D
4	1.5.2/1-5	4/3-5	It is unclear what is meant by the following statement..."Comparisons between shallow and intermediate wells were either minimal or not evaluated due to anomalous conditions in the shallow zone." It seems as though "comparisons" needs to be replaced with a different word, but I'm not sure what the word should be.	C	In Draft (100%) Design Analysis Report, Section 1.5.2, The sentence was revised with the following text to address comment: "Comparisons of gradients between the Shallow Zone and intermediate wells could not reliably be evaluated due to anomalous conditions in the Shallow Zone."	A Does "anomalous conditions" refer to the areas discussed previously in this section that have anomalously high water levels that the authors believe are associated with perched groundwater? If so, it would be helpful to clarify that point. If "anomalous conditions" refers to something else...please specify what those conditions might be. HDR reply: In Final (100%) Design Analysis Report, Section 1.5.2, the sentence was revised as follows: "Comparisons of gradients between the Shallow Zone and intermediate wells could not reliably be evaluated due to anomalous conditions in the Shallow Zone, which are attributed to perched groundwater."



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Follow-up comments on 60% RD						
Number	Section/Page	Paragraph/Line	Comment	C/D	Response	A,D
5	1.6.3/1-7	1/7-8	The following sentence conflicts with Figure 1-2, which identifies all three wells as “potable water wells...” None of these three wells are currently used for drinking water at LHAAP, although they may supply water for non-potable uses.”	C	The legend in Figure 1-2 (a new figure) has been revised to state the wells located on LHAAP are “Nonpotable Water Wells.” Additionally, Section 1.6.3 has been revised to clarify that “Three water supply wells are located within the boundary of LHAAP itself (identified as Non-Potable Water Wells in Figure 1-2).” Additional revisions are made to describe the locations of the nonpotable water wells and the Public Water Supply Well.	A
6	1.8/1-10	6/1	The first sentence in the last paragraph of this section claims that “There is no present or projected future use of the groundwater at LHAAP-47,” even though the last sentence in Section 1.6.3 states that “The future industrial scenario for LHAAP assumes limited use of groundwater as a drinking water source.” Please resolve this discrepancy.	C	In Draft (100%) Design Analysis Report, Section 1.8, The sentence was revised to state: “The reasonably anticipated future use of the Site is a wildlife refuge with minimal projected future use of groundwater.”	A



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Follow-up comments on 60% RD						
Number	Section/Page	Paragraph/Line	Comment	C/D	Response	A,D
7	1.13/1-14	3/6-8	The statement is made that “Based on new data from wells 47WW64, 47WW65, and 47WW63, the shape and extent of the TCE plumes were revised, resulting in a narrower leading edge.” It appears as though these revised versions of the plumes are not included in the 60% Remedial Design Report...why is that?	D	The TCE plumes were updated during the 2023 PDI and 2024 PDI Addendum. In the 60% RD, these updates are reflected in the TCE plumes shown in Figure 1-5.	D - The reason that I originally thought that the revised versions of the plume map were not included in the 60% Remedial Design Report was because the text in that report indicates that “in the Shallow/Intermediate Zone, the 2024 PDI Addendum confirmed two distinct TCE plumes were identified, one originating near Building 46A and another in the mid-southern portion of LHAAP-47,” when three distinct TCE plumes are shown in Figure 1-5. Please resolve this discrepancy. HDR response: Please note, Figure 1-5 depicts three TCE plumes at concentrations above 1,000 ug/L which included data from new wells 47WW64, 47WW65, and 47WW63 as presented in the PDI Addendum report. In Appendix C, Figure 28, two TCE plumes are shown because the contours are based on a concentration above 5 ug/L and was contoured prior to the installation of wells 47WW64, 47WW65, and 47WW63. No changes to text required.



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Follow-up comments on 60% RD						
Number	Section/Page	Paragraph/Line	Comment	C/D	Response	A,D
8	1.14/1-15	1 st bullet	An explanation should be provided for why the number of areas identified for DNAPL removal near Building 46A was reduced from 4 in the 30% design to 2 in the 60% design?		The following text is added in the Draft (100%) Design Analysis Report, Section 3.2. “At this site, ERH treatment of the deeper Shallow/Intermediate Zone will also require heating of the overlying Shallow Zone. Therefore, the four distinct areas identified in the 2022 ROD were evaluated and consolidated into two treatment zones based on the vertical extent of contamination: one targeting the Shallow Zone and the other encompassing both the Shallow and Shallow/Intermediate Zones.” Therefore, ISTD Area 2 and 3 from the 30% RD were combined into ISTD Area 1 in the 60% RD. In addition, a portion of the ISTD Area 1 which overlapped ISTD Area 4 has been combined into ISTD Area 2 in the 60% RD.”	A - The text that has been added to the Draft (100%) Design Analysis Report, Section 3.2 why the number of areas identified for DNAPL removal was reduced from 4 to 2, but I think that the Draft (100%) Design Analysis Report would also benefit from the inclusion of the additional explanation shown in red. HDR reply: In Draft (100%) Design Analysis Report, Section 3.2, the following sentence was added: “Therefore, ISTD Area 2 and 3 from the 30% RD were combined into ISTD Area 1 in the 60% RD. In addition, a portion of the ISTD Area 1 which overlapped ISTD Area 4 has been combined into ISTD Area 2 in the 60% RD and Final Remedial Design.”
9	2.2/2-2	3/1	Unclear what is meant by the following statement...” Where perchlorate was vertically delineated, excavation extended to the top of the delineating sample.” What is the “delineating sample?”	C	“Delineating sample” was replaced with “clean sample.” Excavation areas were vertically delineated to the depth where the first sample free of perchlorate was observed.	A



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Follow-up comments on 60% RD						
Number	Section/Page	Paragraph/Line	Comment	C/D	Response	A,D
10	2.3/2-4	Entire section	There is no discussion of how the confirmation samples will be analyzed. Will they be sent to the lab for analyses or analyzed in the field. If they will be shipped to the lab for analyses, the iterative process of extending the excavated area based on findings from the analytical results could be very time consuming if characterization samples continue to exceed cleanup levels as excavation areas expand to remove the contaminated soils.	C	Specifications Section 01 35 45 and Section 31 23 10 describe the procedures for collecting and analyzing confirmation samples. Because confirmation sampling is an iterative process, expanding the excavation based on analytical results can be time-consuming when contaminant concentrations continue to exceed cleanup levels. Unless pre-excavation sampling is required to define the extent of contamination prior to excavation.	A
11	2.4/2-4 to 2-5	Entire section	Based on the way that the waste is being characterized for disposal, it would be impossible “that approximately 10 percent of the total excavated impacted material, estimated at 1,020 in-place cy, will be classified as hazardous waste resulting from the remedial activities.” A total of 12 samples are planned for submittal, and the samples associated with each of the excavated areas will represent a different volume of excavated material. It would probably better to say that it is assumed that only 1 or 2 of the composite samples submitted for waste characterization will be classified as hazardous waste.	C	Text has been revised as follows, “For cost estimating purposes, it is assumed that approximately 10 percent (%) of the total excavated impacted material, estimated at 990 in-place cy, will be disposed as hazardous waste resulting from the remedial activities. It is assumed that two of the composite samples will meet the criteria for classification as hazardous waste.”	A



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Follow-up comments on 60% RD						
Number	Section/Page	Paragraph/Line	Comment	C/D	Response	A,D
12	2.3 and 2.7.3		Section 2.3 indicates that “if the confirmation sample is above the cleanup level, additional soil will be removed (2 to 5 feet laterally and 1 foot vertically).,” whereas Section 2.7.3 indicates that “If contaminants are detected above their cleanup levels during the confirmation sampling, secondary excavation will be performed at least one additional foot deeper or 2 to 5 additional feet sideways.” Which is it? Please clarify the appropriate section of the text, as needed.	C	In Draft (100%) Design Analysis Report, Section 2.7.4, The sentence was revised to address comment: “If contaminants are detected above their cleanup levels during the confirmation sampling, secondary excavation will be performed (either 2 to 5 feet laterally and 1 foot vertically).” Specification Section 31 23 10 paragraph 3.7 bullet C and D further provides information regarding secondary excavation.	D - The revised text (shown in red) is still inconsistent with other discussions in the text related to these confirmation samples. Delete “either” from the text shown in red. HDR reply: In Final (100%) Design Analysis Report, Section 2.7.4, The sentence was revised to address comment: “If contaminants are detected above their cleanup levels during the confirmation sampling, secondary excavation will be performed (2 to 5 feet laterally and 1 foot vertically).”
13	3.2/3-2 and 3-3	Last paragraph on page 3-2 which extends to top of page 3-3	The text indicates that ERH will be implemented to remove residual DNAPL and TCE sources in... one larger area treating the Shallow/Intermediate Zone also encompassing the Shallow Zone (from 21 feet bgs to 47 feet bgs), as shown in Sheet 01C201 in Appendix A .” Based on the Legend for Sheet 01C201, the larger area (delineated in purple on the map) will only target the Shallow/Intermediate Zone and not the Shallow Zone. Which is correct?	C	Sheets 01C201 and 01C100 were revised to show ISTD Area 2 will target Shallow Zone and Shallow/Intermediate Zone.	A



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Follow-up comments on 60% RD						
Number	Section/Page	Paragraph/Line	Comment	C/D	Response	A,D
14	3.2/3-4	2/2-3	The statement is made that “The system will then operate for the period of time required to reach shutdown criteria.” This may not be realistic because the ISTD system could reach a point at which it is no longer effectively removing VOCs, at which point it may be prudent to turn the system off for reevaluation. I have seen this happen at other sites. It would probably be a good idea to have a contingency plan in place in the event that the ISTD system reaches a point at which it is no longer effective.	C	A contingency for diminishing returns can be incorporated as one of the requirements for shut-down criteria. In Draft (100%) Design Analysis Report, Section 3.4, Text was added to address comment: “If VOC mass-removal rates decline to levels indicating limited additional benefit, the Contractor will notify The U.S. Army and the regulators and initiate a reevaluation of the shutdown criteria in the approved ISTD Work Plan. This reevaluation step provides a defined mechanism to pause operations, assess treatment effectiveness, and determine whether system optimization, modification, or shutdown is warranted rather than continuing operation solely to meet the criteria initially established.”	A



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Follow-up comments on 60% RD						
Number	Section/Page	Paragraph/Line	Comment	C/D	Response	A,D
15	3.3/3-4 to 3-5	Entire section	This section calls out “predominant features of the ISTD area’s geology based on the PSI (HDR, 2021a), especially Figures 13 to 16 provided in Appendix C , near Building 46A,” but the ISTD areas are not shown on any of these figures. Furthermore, there isn’t an easy way to interpret how the “predominant features of the ISTD area’s geology” that are discussed in this section relate to the hydrogeologic units of interest (Shallow, Shallow/Intermediate, and Intermediate Zones) spatially because these zones are not depicted on the figures either.	...	The predominant features of the ISTD treatment area were interpreted using subsurface data developed during the PSI (HDR, 2021a), including information presented in Figures 13 through 16 in Appendix C, in conjunction with cross-sections provided on Sheet 01C202 in Appendix A. Although ISTD treatment boundaries and hydrogeologic zone limits are not depicted on the PSI figures, PSI Figures have been previously approved so changes to these Figures will not be made but sources used for determining the ISTD area features. In Draft (100%) Design Analysis Report, Section 3.3, The sentence was revised to state that “Predominant features of the ISTD area’s geology based on the PSI (HDR, 2021a), especially PSI Figures 13 to 16 provided in Appendix C, and cross-sections presented on Sheet 01C202 in Appendix A, near Building 46A are identified as follows.”	A - HDR did not indicate whether they concurred or did not concur with my 15th comment HDR reply: concur



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Follow-up comments on 60% RD						
Number	Section/Page	Paragraph/Line	Comment	C/D	Response	A,D
16	3.4.1.2/3-7	1/ 4-10	Is it appropriate that the trigger (based on VOC concentrations) for additional action for the downgradient monitoring wells is “concentrations greater than 1 order of magnitude above baseline conditions.” I know that was only offered as an example, but that seems high considering that the goal of this exercise is to have VOC concentrations decrease. Seems like it might be a problem if VOCs are mobilizing at increasing concentrations in response to the ERH.	C	The trigger of “concentrations greater than 1 order of magnitude above baseline conditions” was provided only as an example to show how exceedance criteria may be evaluated during ERH operations. The final monitoring criteria and action thresholds will be established based on the detailed design and performance monitoring in the work plan submitted by the Contractor. If monitoring data indicate increasing VOC concentrations downgradient, such as mobilization of contaminants in response to heating, the Contractor will be required to notify and coordinate with the U S Army and Regulators to determine and implement the appropriate mitigation strategy.	A
17	3.4.3/3-8	3 rd bullet	It would be helpful if an explanation could be provided as to why “existing monitoring wells located within the ISTD areas will be decommissioned.”	C	In Draft (100%) Design Analysis Report, Section 3.4.3, The sentence was revised to state that “Implementation of ISTD is expected to damage the integrity of existing wells within the ISTD areas; therefore, existing monitoring wells located within the ISTD areas will be decommissioned in accordance with 16 TAC 76.104, as applicable, by a Texas-licensed driller and as described in Section 3.4.10. ”	A



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Follow-up comments on 60% RD						
Number	Section/Page	Paragraph/Line	Comment	C/D	Response	A,D
18	3.4.7.1/3-11	1/7-9	It would be helpful if an explanation was provided as to how it will be determined whether or not “shallow vacuum monitoring points” need to be “installed every 50 feet around the perimeter of the ISTD areas...to verify negative pressure at these locations” if the monitoring points were not already in place to make that determination.	C	The criterion to install shallow vacuum monitoring points every 50 feet around the ISTD perimeter is provided as a typical industry practice to ensure adequate negative pressure during thermal operations; however, this value is presented only as an example. Because ISTD is a performance based design component, the final criteria and action thresholds will be established in the detailed design and performance monitoring Work Plan submitted by the Contractor. The Work Plan will be subject to U.S. Army and regulatory review and approval prior to implementation, and this criterion may be revised as necessary based on the Contractor’s proposed means and methods and the final system design.	A



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Follow-up comments on 60% RD						
Number	Section/Page	Paragraph/Line	Comment	C/D	Response	A,D
19	3.4.10/3-13	1/1-3	Is it required that “all heating elements/wells, temperature monitoring points, vapor recovery wells, and vacuum monitoring points will be abandoned or removed at the completion of treatment?” It seems as though some of this infrastructure could be useful in the future. What if ERH wants to be revisited in the future? It may be worth having a discussion with the regulators after ERH has been discontinued to determine if some of the infrastructure that was installed in conjunction with the ISTR may be useful for other purposes in the future.	C	For the purpose of the design and bidding, we need to include the requirement for site restoration. In Draft (100%) Design Analysis Report, Section 3.4.10 outlines the system shut down criteria which mentions that the Contractor may perform an initial shutdown based on their assessment that preliminary results meet the performance goals; however, the final shutdown is contingent upon the U.S. Army and regulatory review, and subsequent approval, requiring up to 10 business days. At that time, the U.S. Army and regulators can determine if some of the infrastructure that was installed in conjunction with the ISTR may be useful for other purposes in the future.	A
20	3.4.10/3-15	Paragraphs 1 and 2	It is unclear how “the Contractor will prevent vertical migration of fluids in the borehole and prevent intermixing of waters from different water-bearing zones” “when conducting well abandonment activities” during removal of the well materials if the removal process will be “implemented by over-drilling the well casing.” The very nature of that process seems like it would lend itself to “vertical migration of fluids in the borehole and intermixing of waters from different water-bearing zones.”	C	Well abandonment will be conducted based on the approved procedures outlined in the existing 2018 Work Plan and Regulation 16 TAC 76.104.	No comment. I don’t have access to 2018 Work Plan and Regulation 16 TAC 76.104 to determine if the well abandonment procedures outlined in that document “will prevent vertical migration of fluids in the borehole and prevent intermixing of waters from different water-bearing zones.” HDR reply: acknowledged



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Follow-up comments on 60% RD						
Number	Section/Page	Paragraph/Line	Comment	C/D	Response	A,D
21	4.3.1/4-21	3/2-3	I didn't really see much of a mention of timing of ISB implementation other than the following sentence..."ISB will follow ERH implementation, if needed, near Building 46A, where ERH is expected to reduce VOC concentrations and shrink the ISB footprint in ISB Grid Areas 1S and 1SI." Has consideration been given to how ISB might be affected by the elevated temperatures associated with the ERH? Do temperatures need to fall below a certain level before ISB can be implemented? Please add a brief discussion related to this issue in the text.	C	Text was added in Section 4.3.1 of the Draft (100%) Design Analysis Report, "ISB Pilot Test Area 1, located adjacent to the ISTD Areas, will be initiated after subsurface temperatures decline to levels suitable for effective bioremediation. Following the ERH shutdown, temperature monitoring will be conducted at monitoring well PMW-01 to evaluate thermal dissipation. ISB pilot test activities will be initiated once the temperatures at PMW-01 cool to $\leq 30\text{--}35^{\circ}\text{C}$ ($86\text{--}95^{\circ}\text{F}$), the range in which bioremediation processes and microbial cultures can function effectively. This delay is necessary to prevent temperatures from adversely affecting the bioremediation injectant or microbial activity."	A
22	Appendix C		None of the cross sections depict the boundaries between the Shallow, Shallow/Intermediate, and Intermediate Zones. It would be very helpful if those hydrogeologic units were distinguished from one another.	D	Figures provided in Appendix C have been incorporated as provided in previously approved reports. To remain consistent with the previously approved figure, changes are not recommended. No changes were made; however, detailed cross-sections of the ISTD areas are provided in the design drawings.	A

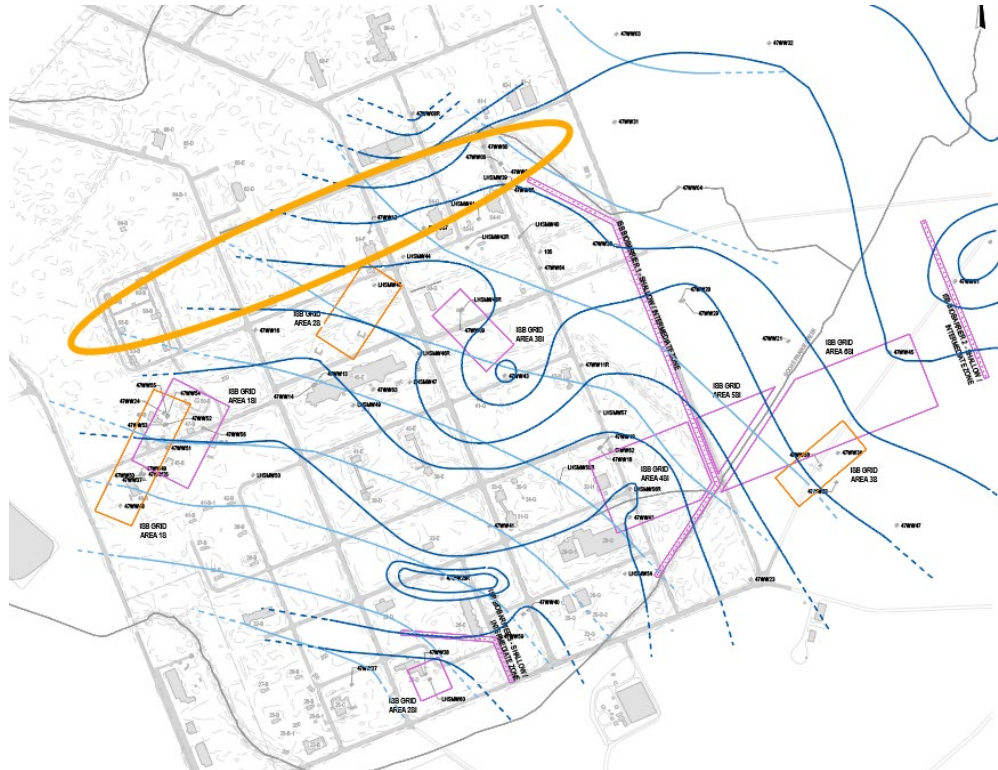
Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

General Comments:

- 1.) Looking at the ISB Biobarrier delineations relative to groundwater flow direction in the shallow (light blue) and shallow/intermediate zones (dark blue) in the image shown below, it seems like the most likely direction for offsite migration would be to the north in the area circled in orange. Plume containment in this area would also seem to be most critical considering that the highest TCE concentrations at the site are in the area around building 46-A, which currently does not have any associated plume containment.

Response: Draft (100%) RD now includes a requirement for installing and sampling four new monitoring wells for the purpose of LTM during Phase I, prior to full-scale implementation of the ISB treatment. These monitoring wells will provide the data necessary to adjust the barrier wall alignment if offsite migration is observed to the north in the area circled in orange. In addition, In Draft (100%) Design Analysis Report, Section 4.1 requires the Contractor to submit a Field Pilot Test Report following completion of the ISB pilot tests. This report will document the pilot test implementation, findings, results, and recommendations for full-scale ISB implementation during the Phase II RA. At that time, if necessary, the alignment of the biobarrier wall can be revised to ensure effective plume containment to the north.

Accept



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

- 2.) Based on the design of the ISB systems with respect to radii of influence for the DPT injection points (6.5 feet for the Shallow Zone and 13.5 feet for the Shallow/Intermediate Zone) relative to the spacing between the DPT points (13 feet apart in the Shallow Zone and 27 feet apart in the Shallow/Intermediate Zone), there will be a fair amount of space that falls outside of the radii of influence (refer to areas inside the red box shown below that are not shaded in green) and would thus be unaffected by ISB activities based on the theoretical radii of influence. Is that typical in ISB system design?

Response: Yes, this is typical for ISB system design. Unlike ISCO, where direct oxidant–contaminant contact is required and overlapping radius of influence (ROI) are critical to ensure adequate treatment, ISB relies on long-term amendment dispersion and biologically mediated degradation. In ISB applications, the ROI serves as a design guideline for placing injection points, but full overlap is not necessary because the injected substrate continues to migrate, diffuse, and mix with groundwater over time. As a result, biodegradation extends beyond the initial theoretical ROI, and the system relies on sustained microbial activity rather than immediate contact. Therefore, the presence of areas outside the theoretical ROI is consistent with typical ISB design practices.

Accept

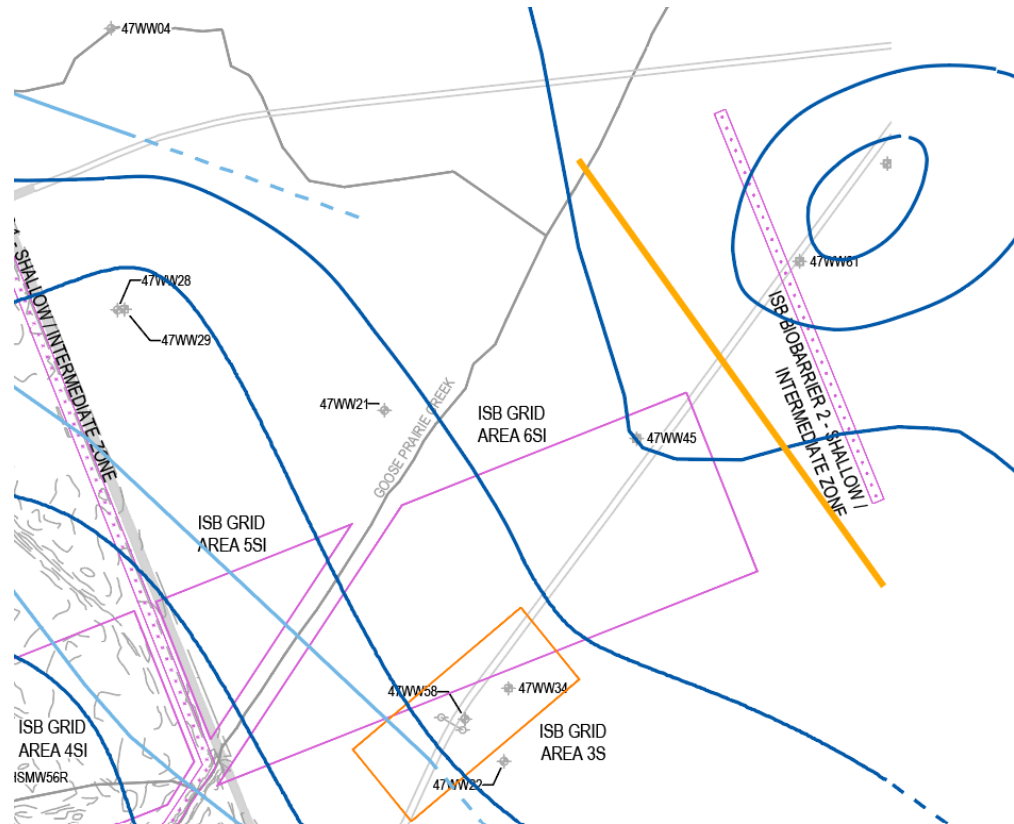


Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

- 3.) It would probably be more effective if the ISB Biobarrier 2 was oriented perpendicular to flow as opposed to being parallel to the easternmost edge of ISB Grid Area 6SI...less chance of contaminated groundwater flowing further offsite between Goose Prairie Creek and the northernmost end of the ISB Biobarrier 2.

Response: ISB Biobarrier 2 alignment was revised to orient perpendicular to the flow as suggested.

Accept





Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

1. Respondent concurs (C) or does not concur (D)
2. Commenter agrees (A) or does not agree (D) with response.

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
Reviewer #1:						
1	1.6.3/1-6	2/1-2	Why is Figure 2-2 in Appendix C called out as the figure which shows the five active water supply wells as opposed to Figure 1-2?	C	In Final (100%) Design Analysis Report, Section 1.6.3, The text has been revised to cite Figure 1-2.	
2	1.7.1/1-7	3/8-10	What does “fixed laboratory analytical results” refer to in the following sentence and how do these results compare to the “field laboratory soil sample results” referred to in the previous sentence? “Similarly, fixed laboratory analytical results from the PSI (HDR, 2021a) reported TCE concentrations ranging from 0.5 to 15.6 mg/kg, with the exception of DPT-030, which exhibited a concentration of 59.6 mg/kg at a depth interval of 10-11 ft bgs.”	D	Fixed laboratory analytical results refer to samples that were analyzed at an offsite permanent structure laboratory as opposed to a mobile laboratory that is used to analyze samples onsite when rapid turn-around times are required. Re-evaluation and comparisons of historical PSI and PSI Addendum sampling data are not within the scope of this RD.	
3	1.7.2/1-9	1/5-7	The statement is made that...”Perchlorate plumes are no longer present in the Shallow Zone, therefore, perchlorate plumes beyond year 2018 are not shown in PSI Figure 6 and PDI Figure 27 of Appendix C. ” even though the perchlorate plume in the Shallow Zone is shown in Figure 6.	D	Please note, the Figure 6 Legend states the perchlorate contours are for 2010 and prior.	



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

4	2.2/2-2 to 2-3	7/3-9	The excavation areas and potential volumes as described in this paragraph don't really add up. The extent of the original Excavation Area 1 (790 square feet) was combined with the extent of the original Excavation Area 2 (495 square feet) to form a new Excavation Area 1 that has an extent of 3,110 square feet. How is the extent of the new Excavation Area 1 more than double the combined extents of the original Excavation Areas 1 and 2 when only a small sliver of land area was added to connect the old Excavation Areas. Likewise the potential volume excavated was listed as 9,480 cubic feet in the original Excavation Area 1 and 5,925 cubic feet in the original Excavation Area 2, so how is the potential volume excavated from the new Excavation Area 1 (37,320 cubic feet) more than double the potential volumes excavated from the original Excavation Areas 1 and 2?	D	The original Excavation Areas 1 and 2 (790 sf / 9,480 cf and 495 sf / 5,925 cf, respectively) mentioned in the comment represent FS-level conceptual quantities. As noted in the report, these extents were later determined to be impractical for implementation and were subsequently revised using the methodology described in this section. The revised Excavation Area 1 (3,110 sf / 37,320 cf [1,390 cy]) represents a redefined and expanded excavation footprint developed during design to establish a single, continuous, and implementable excavation area. Similarly, the increase in volume reflects the application of a consistent excavation depth (approximately 12 feet bgs) across the revised footprint, as opposed to the earlier conceptual FS estimates. When compared to the intermediate design stage, the revised quantities are consistent. Specifically: • 60% RD combined areas/volumes when summing up Area 1 & 2: approximately 3,000 sf and 36,000 cf (1,350 cy) • 100% RD Excavation Area 1 (combined with Area 2): approximately 3,110 sf and 37,320 cf (1,390 cy) The 100% RD excavation area and volume are consistent with prior design-stage estimates, and that the apparent increase relative to FS values reflects refinement
---	----------------	-------	---	---	---



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
					from conceptual estimates to final design quantities.	
5	2.5/2-5	1/3-4	Some words appear to be missing from the following sentence...I took a best guess at what I thought might have been the intended wording. "Borrow source samples will be collected at a frequency of one sample per 1,000 cy of borrow soil."	C	In Final (100%) Design Analysis Report, Section 2.5, The sentence was revised to address comment: "Borrow source samples will be collected at a frequency of one sample per 1,000 cy of borrow soil."	



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
6	3.4.10/3-14	2/1-2	The statement is made that “after shutdown approval, all heating elements/wells, temperature monitoring points, vapor recovery wells, and vacuum monitoring points will be abandoned or removed after treatment.” Would it not be preferable to wait to see if COC concentrations rebound? Doing so would provide the option to resume ERH at a later date without having to reinstall all of the required infrastructure.	D	The intent here is to define a clear and practical approach for shutdown and post-treatment activities as part of the design and bidding process. Keeping the ISTD infrastructure in place after shutdown would add ongoing costs to maintain idle equipment and systems, which is not considered reasonable when the system is no longer operating. ISTD is being applied to address the source areas. Once the verification sampling is completed and performance goals for ISTD are met the system will be decommissioned. When temperature conditions of the surface have stabilized, wells inside the ISTD area will be installed and sampled. Any remaining contamination or potential rebound will be managed through the planned follow-on remedy (ISB). Resuming ERH/ISTD at a later date is not typically considered feasible or standard practice. These systems are designed and implemented as a one-time source treatment, and retaining infrastructure in place for possible future use would create unnecessary cost and uncertainty during bidding without a clear benefit. For these reasons, the approach to remove the ISTD infrastructure after shutdown would be appropriate, with any residual or rebound conditions addressed through subsequent treatment.	



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
7	--	--	The Safety Data Sheet section (3.6.4) from the Draft (60%) Remedial Design report did not make it into the Draft (100%) Remedial Design report. Was that an oversight or an intentional choice?	C	The text associated with Safety Data Sheet section was inadvertently omitted from the Draft (100%) Remedial Design Report. This omission has been corrected in the Final (100%) Design Analysis Report, where the Safety Data Sheet text is included in Section 3.4.12.3 under the first bullet.	
8	4.3.2/4-21	1 st bullet	The TCE concentration values listed for 47WW52 and 47WW53 differ between the Draft (100%) Remedial Design report (1,610 µg/L and 1,040 µg/L, respectively) and the Draft (60%) Remedial Design report (5,990 µg/L and 5,540 µg/L, respectively). I think the values from the Draft (60%) Remedial Design report are correct, but I wanted to point the discrepancy out just to confirm.	D	The TCE concentration values reported for 47WW52 and 47WW53 in the Draft (60%) Remedial Design report were sourced from PSI (HDR, 2021a). In the Draft (100%) Remedial Design report, we updated values to match with most recent groundwater data which is from the PDI Report (HDR, 2024). Therefore, no changes are necessary.	



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
9	4.3.3/4-22	3/2-4	In the following sentence, I'm not sure that "hydraulic fracturing of the formation" needs to be accounted for considering that the shallow and shallow/intermediate zones are contained in unconsolidated sediments. Perhaps injection pressures greater than 200 psi could be used if it can be determined that these pressures would not lead to unintended amendment migration. "Injection pressures will be maintained at relatively low levels, generally up to approximately 200 psi, to prevent hydraulic fracturing of the formation or unintended amendment migration."	C	Comment acknowledged. The injection pressure range presented (up to approximately 200 psi) reflects a typical, conservative design value used for planning and bidding purposes, rather than a fixed operational limit. As noted, site conditions consist of unconsolidated sediments; however, the specified pressure is intended to provide a reasonable upper bound during design to minimize the potential for unintended amendment migration or loss of injection control. Final injection pressures will not be set until pilot testing is completed. Following pilot testing, the Contractor will develop a detailed injection plan outlining the means and methods for implementation, including the appropriate pressure range that can be applied safely under site-specific conditions. This plan will account for maintaining amendment distribution within the target treatment zones while avoiding unintended migration or equipment-related issues. Accordingly, the design value of 200 psi should be considered preliminary and subject to refinement based on field testing and Contractor-developed procedures.	



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
10	4.6/4-29	2/1-3	The following sentence calls out Sheet 02C100, but that sheet doesn't show the eight proposed sampling locations on Goose Prairie Creek. Is Sheet 02C100 only intended to show the trace of Goose Prairie Creek? "During each monitoring round, surface water samples will be collected at eight locations in Goose Prairie Creek: upgradient, downgradient, and immediately adjacent to LHAAP-47 (Sheet 02C100 in Appendix A)."	D	The Sheet 02C100 show eight surface water performance monitoring locations along the tributary leading to and along Goose Prairie Creek (symbols shown as inverted triangles).	
11	4.6/4-29	2/9-11	In the following sentence, what does "injection solution" refer to? "Monitoring of the surface water may include visual inspection, field measurements such as dissolved oxygen, conductivity, turbidity, pH, ORP, and temperature, and/or water sample analysis specific to the COCs and injection solution."	C	In this context, "injection solution" refers to the selected amendments used for injection as part of the remedy, along with any associated indicator parameters that represent the presence or behavior of those amendments in the system. The specific analytes evaluated will depend on the type of amendment selected for the project. Accordingly, monitoring may include parameters that are indicative of amendment impacts in addition to the COCs. Examples would include dissolved organic carbon (DOC) or total organic carbon (TOC) (for EVO/SRS®-SD), Volatile fatty acids (VFAs) or organic acids (e.g., lactate fermentation products), Alkalinity and pH (for buffering effects), ORP and dissolved oxygen (to confirm anaerobic conditions) Specific indicators of bioaugmentation activity, as applicable. The exact analytes will be finalized based on the amendments selected and implemented in the field and are intended to confirm amendment impacts in addition to monitoring COCs.	



Comments Response Matrix
Draft 100% Remedial Design, LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production,
Longhorn Army Ammunition Plant, Karnack, Texas Submitted: April 21, 2026

Number	Section/Page	Paragraph/Line	Comment	C,D	Response	A,D
12	5.1/5-1	4 th bullet	Language in the two sentences shown in quotes below is confusing because it sounds like the LUC boundaries will be finalized twice..."Finalize the boundaries for the LUCs after the additional investigation is completed as part of Phase I of the remedial action. In the interim, based on the PDI completed to date, the LUCs boundary will be finalized and recorded with the County as part of the remedial action."	C	In Final (100%) Design Analysis Report, Section 5.1, the second sentence in the 4 th bullet has been revised as follows: "The finalized LUCs boundary will be recorded with the County as part of the remedial action."	
13	6.1/6-1	3 rd bullet under "Soil excavation and disposal"	The third activity listed under the "Soil excavation and disposal" list of tasks is "Remove impermeable liner and soil cover previously installed in November 1999." Is the impermeable liner going to be replaced at the conclusion of the Phase II RA activities, or is it the general consensus that the impermeable liner will no longer be necessary after the remedial activities are complete?	C	The impermeable liner and soil cover installed in November 1999 were originally implemented to manage perchlorate-impacted soils. Following completion of the Phase I RA activities, including removal of the perchlorate-impacted soil, the source material requiring containment will no longer be present. Based on this, the current assumption is that replacement of the impermeable liner will not be necessary after remedial activities are complete, as the conditions that warranted its installation will have been addressed.	

* Note – The use of "potential DNAPL" or "potentially residual DNAPL" has been revised throughout the document to use only "DNAPL" or "residual DNAPL" to remain consistent with the ROD.

**FINAL
Design Analysis Report
Final (100%) Remedial Design
For
LHAAP – 47
Former Longhorn Army Ammunition Plant (LHAAP) 47,
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

Prepared for:



U.S. Army Corps of Engineers, Tulsa District
Contract No. W912BV15D0016
Task Order No. W912BV20F0096

Prepared by:

HDR Environmental, Operations and Construction, Inc.
369 Inverness Parkway, Suite 325
Englewood, Colorado 80112

June 2026

TABLE OF CONTENTS

1	INTRODUCTION	1-1
1.1	Longhorn Army Ammunition Plant (LHAAP) Background	1-1
1.2	LHAAP-47 Site Description and Background	1-2
1.2.1	LHAAP-47 Site History	1-2
1.3	History of Investigative Activities	1-2
1.4	Surface Water Hydrology	1-3
1.5	Geology and Hydrogeology	1-3
1.5.1	Site-Wide LHAAP Geology and Hydrogeology	1-3
1.5.2	Site-Specific LHAAP-47 Geology and Hydrogeology	1-4
1.6	Current and Future Land and Resource Uses	1-5
1.6.1	Current and Future Land Uses	1-5
1.6.2	Current and Future Surface Water Uses	1-6
1.6.3	Current and Future Groundwater Uses	1-6
1.7	Nature and Extent of Contamination	1-7
1.7.1	Soil	1-7
1.7.2	Groundwater	1-8
1.7.3	Principal Threat Wastes	1-9
1.8	Conceptual Site Model	1-9
1.9	Basis of Action	1-10
1.10	Remedial Action Objectives	1-10
1.11	Selected Remedy	1-11
1.12	Site Cleanup Levels	1-13
1.13	Pre-Design Investigation	1-13
1.14	Planned Remedial Action	1-14
1.14.1	Permitting	1-15
2	SOIL EXCAVATION REMEDIAL DESIGN	2-1
2.1	Design Criteria	2-1
2.2	Excavation Areas	2-2
2.3	Post-Excavation Confirmation Sampling	2-4
2.4	Waste Characterization and Disposal	2-4
2.5	Backfill and Site Restoration	2-5
2.6	Other Design Considerations	2-5
2.7	Implementation of Soil Excavation Remedial Design	2-5
2.7.1	Mobilization and Site Preparation	2-5
2.7.2	Surveying	2-6
2.7.3	Soil Excavation and Disposal	2-7
2.7.3.1	Area Preparation	2-7
2.7.3.2	Soil Excavation and Disposal	2-7
2.7.4	Confirmation Soil Sampling	2-8
2.7.5	Backfilling and Site Restoration	2-8
2.7.6	Reporting	2-8
2.7.7	As-Built Survey Drawings	2-8
3	IN-SITU THERMAL DESORPTION (ISTD) DESIGN	3-1
3.1	Design Criteria	3-1
3.2	ISTD Treatment Areas	3-2

3.3	ISTD Area Characteristics	3-3
3.4	Implementation of ISTD.....	3-4
3.4.1	Preparation of the ISTD Work Plan	3-5
3.4.1.1	ISTD Design Calculations	3-6
3.4.1.2	ISTD Design	3-6
3.4.2	Mobilization and Site Preparation	3-7
3.4.3	New Utilities	3-8
3.4.4	Surveying	3-9
3.4.5	ISTD Treatment System Installation	3-9
3.4.5.1	ISTD Well-Field Installation	3-9
3.4.5.2	Liquid And Vapor Recovery and Treatment System Installation	3-10
3.4.6	System Operation	3-11
3.4.6.1	Safety and Environmental Controls	3-11
3.4.6.2	VOC Removal and Emissions	3-11
3.4.6.3	Process Monitoring Requirements	3-11
3.4.7	System Decontamination and Residuals Management	3-13
3.4.8	Verification Sampling and Initial System Shutdown	3-13
3.4.9	System Shutdown and Decommissioning	3-14
3.4.10	Demobilization.....	3-14
3.4.11	Site Restoration and Post-ISTD Monitoring.....	3-14
3.4.12	Reporting.....	3-15
3.4.12.1	Weekly Operational Progress Reports.....	3-15
3.4.12.2	Effectiveness Monitoring Results.....	3-15
3.4.12.3	Daily Contractor Quality Control (CQC) Reports	3-16
3.4.13	ISTD Completion Report.....	3-16
4	IN-SITU BIOREMEDIATION (ISB) DESIGN	4-1
4.1	ISB Implementation Strategy.....	4-1
4.1.1	Target Treatment Areas (ISB Grid Areas).....	4-1
4.1.2	Plume Containment (ISB Biobarriers)	4-1
4.2	Common ISB Design Approach	4-2
4.2.1	General Substrate Injection Strategies.....	4-2
4.2.2	Radius of Influence and Injection Point Spacing	4-3
4.2.3	Substrate Selection.....	4-3
4.2.4	Bioaugmentation Culture Selection and Injection.....	4-4
4.3	Phase I - Field Pilot Testing.....	4-4
4.3.1	Basis for Pilot Testing	4-4
4.3.2	Pilot Field Test Area Selection.....	4-5
4.3.3	Pilot Test Injection Plan	4-6
4.3.4	Installation and Sampling of Monitoring Wells.....	4-7
4.3.5	Pilot Test Performance Monitoring	4-7
4.3.6	Pilot Testing Reporting.....	4-8
4.4	Phase II - Full-Scale ISB.....	4-8
4.4.1	ISB Grid Area Design.....	4-9
4.4.2	ISB Biobarrier Design	4-10
4.4.3	ISB Performance Monitoring.....	4-11
4.4.3.1	Pre-ISB Implementation Groundwater Sampling.....	4-11
4.4.3.2	Post-injection Performance Monitoring.....	4-12
4.5	MNA Performance Monitoring.....	4-12

4.5.1.1	Contingency Action for MNA Areas	4-13
4.5.1.2	Follow-up Injections in Biobarriers	4-13
4.6	Surface Water Monitoring	4-13
4.7	Long-Term Monitoring – Year 3 through Five-Year Review.....	4-14
4.7.1	Performance Monitoring Following Five-Year Review	4-14
5	LAND USE CONTROLS REMEDIAL DESIGN	5-1
5.1	LUCs Implementation.....	5-1
5.2	Maintenance and Monitoring Requirements	5-2
5.3	Reporting of LUCs Inspection and Monitoring	5-3
5.3.1	Notice of Planned Property Conveyances.....	5-3
5.3.2	Opportunity to Review Text of Intended Land Use Controls.....	5-4
5.3.3	Notification Should Action(s) which Interfere with land Use Control Effectiveness be Discovered Subsequent to Conveyance.....	5-4
5.3.4	Land Use Control Enforcement	5-4
5.3.5	Modification or Termination of Land Use Controls	5-4
6	REMEDIAL CONSTRUCTION SCHEDULE.....	6-1
6.1	Construction Sequence	6-1
6.2	Preliminary Schedule	6-3
7	SUMMARY OF PROJECT COSTS	7-1
8	REFERENCES	8-1
9	LIST OF ACRONYMS AND ABBREVIATIONS.....	9-1

LIST OF FIGURES

Figure 1-1	Site Location Map
Figure 1-2	LHAAP-47 and Surrounding Land Status
Figure 1-3	Site Plan
Figure 1-4	PDI Shallow Zone Trichloroethene Iso-Concentration Contours, May - June 2023
Figure 1-5	Shallow/Intermediate Zone and Intermediate Zone Trichloroethene and Perchlorate Iso-Concentration Contours, June 2023, and July 2024
Figure 6-1	General Remedial Action Construction Schedule

LIST OF TABLES

Table 1-1	Summary of Sampling Events
Table 1-2	Cleanup Levels for Target COCs in Soil
Table 1-3	Cleanup Levels for Target COCs in Groundwater
Table 1-4	Monitoring Levels for Perchlorate and VOCs in Surface Water
Table 2-1	Excavation Areas
Table 3-1	Groundwater Seepage Velocity and Travel Time
Table 3-2	ISTD Treatment Areas
Table 3-3	ISTD Treatment System - Minimum Process Monitoring Reporting Requirements
Table 4-1	ISB Pilot Test Areas
Table 4-2	ISB Grid Areas
Table 4-3	Shallow/Intermediate ISB Biobarrier Areas
Table 4-4	Baseline Sampling Plan for Pilot Test Areas
Table 4-5	ISB Performance Monitoring Sampling Plan (Years 1 and 2) in the Pilot Test Areas
Table 4-6	Pre-ISB Implementation Groundwater Sampling Plan for ISB Grid Areas
Table 4-7	Pre-ISB Implementation Groundwater Sampling Plan for ISB Biobarriers
Table 4-8	ISB Performance Monitoring Sampling Plan (Years 1 and 2) in ISB Grid Areas
Table 4-9	ISB Performance Monitoring Sampling Plan (Years 1 and 2) in ISB Biobarriers
Table 4-10	MNA and LTM Performance Monitoring Plan

LIST OF APPENDICES

Appendix A	Final (100%) Remedial Design Drawings
Appendix B	(100%) Remedial Design Cost Estimate
Appendix C	Pertinent Figures from Previous Investigations
Appendix D	Existing Monitoring Well Logs
Appendix E	ISB Substrate Calculation Sheets
Appendix F	Annual LUCs Compliance Documentation Form
Appendix G	Specifications

1 INTRODUCTION

This design report presents the technical basis, design methodologies, and supporting documents for a Final (100%) remedial design (RD) to achieve the Remedial Action Objectives (RAOs) specified in the Revised Final Record of Decision (ROD) for Longhorn Army Ammunition Plant (LHAAP) Site 47 (LHAAP-47). The ROD was prepared by the U.S. Army & Environmental Protection Agency (USEPA) (U.S. Army & USEPA, 2022) to address soil impacted by perchlorate and groundwater impacted by perchlorate and volatile organic compounds (VOCs) at the former LHAAP site, LHAAP-47 (the "Site"), Plant 3 Area - Solid Rocket Motor Fuel Production located in Karnack, Texas (**Figures 1-1 & 1-2**). This design report addresses the active remediation areas within and outside the LHAAP-47 boundary, herein collectively referred to as "the Site". The RD documents were prepared under the U.S. Army Corps of Engineers (U.S. Army Tulsa District Contract Number W912BV19D0016 Task Order No. W912BV20F0096).

Tables, figures, and appendices included in this design report provide additional information, summarize relevant data, and serve as the basis for design decisions. In addition, the design report consistently references the RD documents, including Design Drawings and a cost estimate for the remedial action (RA), both submitted as **Appendix A** and **B**, respectively.

The design report was prepared based on the nature and extent of contamination and the conceptual site model (CSM) defined in the following documents:

- Final Remedial Investigation (RI) Report for the Group 4 Sites, Sites 35A, 35B, 35C, 46, 47, 48, 50, 60, and Goose Prairie Creek (Jacobs, 2002).
- Final Feasibility Study (FS) LHAAP-47, Plant 3 Area, Group 4 (Shaw, 2011).
- LHAAP-47 Post Screening Investigation (PSI) Addendum No. 2 Report for LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production (HDR, 2021a).
- Revised Final ROD for LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production (U.S. Army & USEPA, 2022).
- Pre-Design Investigation (PDI) Report for LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production (HDR, 2024) & PDI Addendum for LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production (HDR, 2025).

These reports refined the extent of soil perchlorate contamination east of Building 25-C, and the extent of perchlorate and/or VOCs groundwater contamination near Buildings 46-A, 49-B, and 47-B (**Sheet G003 in Appendix A**), and in areas near or along the eastern Site boundary of LHAAP-47. Pertinent figures illustrating the nature and extent of contamination from previous reports are provided in **Appendix C**.

1.1 Longhorn Army Ammunition Plant (LHAAP) Background

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

LHAAP was placed on the Superfund National Priorities List (NPL) on August 9, 1990. Remedial activities began in 1990. After its listing on the NPL, the U.S. Army, the USEPA, and the Texas Water Commission [currently known as the Texas Commission on Environmental Quality (TCEQ)] entered into a Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) 42 U. S. C. §9620 Federal Facilities Agreement (FFA) for remedial activities at LHAAP. The FFA became effective December 30, 1991. LHAAP operated until 1997 when it was placed on inactive status and classified by the U.S. Army Armament, Munitions, and Chemical Command as excess property. The majority of LHAAP, not including LHAAP-47, has been transferred by the U.S. Army to the U.S. Fish and Wildlife Service (USFWS) for management as the Caddo Lake National Wildlife Refuge.

1.2 LHAAP-47 Site Description and Background

LHAAP-47 (Plant 3 Area) is located in the north-central portion of LHAAP and covers an area of approximately 275 acres (**Figure 1-2**). LHAAP-46 bounds LHAAP-47 to the north, Karnack Avenue to the east, Marshall Avenue to the south, and Avenue “P” to the west. LHAAP-6 and LHAAP-7 are within the LHAAP-47 boundary. LHAAP-35B (37) is to the southwest of LHAAP-47, and LHAAP-50 and LHAAP-8 are to its south (**Figure 1-3**). ROD **Figure 2-2** in **Appendix C** also shows the general site vicinity map.

A general Site Plan with topographic elevation contours is included as **Sheet G003** in **Appendix A**. The surface features at LHAAP-47 are a mixture of asphalt-paved roads, parking areas, building foundation remnants, old building remnants, and overgrown wooded and grassy vegetation-covered areas. The topography in this area is relatively flat, with the surface drainage flowing into tributaries of Goose Prairie Creek. Runoff from the Site enters Caddo Lake via Goose Prairie Creek.

1.2.1 LHAAP-47 Site History

LHAAP-47 was identified through historical records as Plant 3, producing rocket motors and later pyrotechnic and illumination devices. Construction of Plant 3 began in July 1953, and production of rocket motors began in December 1954. Rocket motor production continued until the early 1980s. Some of the rocket motor production facilities were converted to produce pyrotechnic and illumination devices and were active until approximately 1997. Industrial solid waste and possibly hazardous waste, such as parts cleaners and spent solvents, may have been generated by these activities. Fifty waste process sumps and three waste rack sumps were identified within the Plant 3 Area, which were used to contain industrial solid waste and possibly hazardous waste (such as parts cleaners and solvents) that were generated by the activities on-site. All sumps at LHAAP-47 have been removed or taken out of service and are no longer potential sources of groundwater contamination.

1.3 History of Investigative Activities

A brief history of the investigative activities conducted at the LHAAP and specifically at the LHAAP-47 Site is provided and summarized in **Table 1-1**.

Environmental investigations at the LHAAP began in 1976 under the U.S. Army's Installation Restoration Program, followed by installation-wide assessments and a record search conducted by the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA, 1980). Early groundwater sampling and contamination surveys were performed by Environmental Protection Systems, Inc. (EPS, 1984) and further evaluated under the Resource Conservation and Recovery Act (RCRA) by the U.S. Army Environmental Hygiene Agency (USAEHA, 1987). A preliminary RCRA Facility Assessment (Maley, 1988) and Pre-Remedial Investigations (Pre-RIs) by EPS, BCM Engineers, and

USACE (1992–1993) laid the groundwork for formal RI conducted in three phases between 1993 and 1998 (Jacobs, 2002), with additional investigation-related efforts continuing through 2001.

The FS was completed in 2011 (Shaw, 2011), evaluating remedial alternatives in accordance with CERCLA criteria. The Draft Final Proposed Plan and Draft ROD were prepared in 2013, and the Revised Final ROD was issued in 2022 (U.S. Army & USEPA, 2022). Before finalizing the 2022 ROD, multiple PSIs were conducted between 2018 and 2020 to update groundwater data and refine the CSM (HDR, 2019a, 2019b, and 2021a). These efforts identified residual trichloroethylene (TCE) dense non-aqueous phase liquid (DNAPL) near Building 46-A and potential unsaturated soil sources. PDIs were completed in 2024 (HDR, 2024) and supplemented in 2025 (HDR, 2025), which included installation of new monitoring wells, groundwater sampling, and aquifer testing to support the RD.

1.4 Surface Water Hydrology

Surface water at LHAAP generally drains northeast toward Caddo Lake through four main drainage systems: Saunders Branch, Harrison Bayou, Central Creek, and Goose Prairie Creek. Caddo Lake is part of the Big Cypress Bayou watershed. Around the LHAAP-47 area, Goose Prairie Creek enters from the southwest, runs along the southern Site boundary, and curves through the southeastern portion of the Site. The Site itself is relatively flat with gentle slopes that direct drainage northeast to east toward a tributary of Goose Prairie Creek in the northeast corner, and southward toward the main channel of Goose Prairie Creek, located approximately 180 feet from the southern Site boundary. These two features, the tributary and the creek, are the primary surface water bodies influencing local hydrology. Surface water moves through shallow ditches and intermittent overland flow, shaped by site topography and seasonal rainfall. Goose Prairie Creek sits at a lower elevation than the surrounding shallow groundwater table, and no other perennial surface water bodies are present within the Site. Under normal conditions, hydrologic connectivity between site drainage features and the creek is limited, with flow primarily occurring during storm events.

1.5 Geology and Hydrogeology

1.5.1 Site-Wide LHAAP Geology and Hydrogeology

The subsurface geology at LHAAP consists primarily of a thin veneer of Quaternary alluvium, overlying Tertiary age formations of the Wilcox and Midway Groups. Underlying these sediments are the Cretaceous-age formations of the Navarro and Taylor Groups (Jacobs, 2002).

In general, boring logs generated across the LHAAP show that the Wilcox Group typically consists of a series of three sandy water-bearing zones separated by layers of silty clay. The uppermost portion of the Wilcox Group at LHAAP consists of medium plastic sandy silts and clays, which range from approximately 5 to 15 feet thick. These surficial sediments are underlain by the shallow saturated zone, which varies from 10 to 20 feet thick. This sand zone consists of silty, fine-grained sand, containing some silt and clay lenses. At the ground surface, this zone is dry to moist and becomes saturated 15 to 20 feet below ground surface (bgs). A 5 to 20 feet thick, medium to highly plastic silt and clay aquitard underlies the shallow saturated zone. An intermediate saturated sand zone, consisting of a fine to medium silty sand, is encountered below the aquitard, 30 to 50 feet bgs. The intermediate saturated zone is generally less silty than the shallow saturated zone and exhibits a higher hydraulic conductivity. Beneath the intermediate saturated zone, a 5 to 30 feet silt to silty clay layer is encountered. Underlying this silt to silty clay layer is a massive, homogeneous, silty, clayey, fine sand that continues to the top of the underlying Midway Group Formation (Jacobs, 2002).

1.5.2 Site-Specific LHAAP-47 Geology and Hydrogeology

At LHAAP-47, the subsurface is composed of stratified units within the Wilcox Group consisting of three primary groundwater zones.

The shallow Wilcox Group soil (surface to approximately 35 feet bgs) consists predominantly of clay to silty clay. The base of the Shallow Zone is predominantly a thin (approximately 3-feet-thick) layer of silty sand that is present across the Site with varying thickness and continuity. This sand layer is hydraulically significant, as it supports groundwater within the Shallow Zone. The Shallow Zone was observed at depths ranging from approximately 10 feet bgs to 35 feet bgs and generally flows to the northeast across LHAAP-47 towards Caddo Lake. Cross-sectional data show that the sand and clay units in this interval are undulating and discontinuous, with dominant lithologies including clay mixed with fine sand, silt, and sandy/silty mixtures. The contact between the shallow Wilcox Group and the underlying intermediate Wilcox Group varies in lithology (silty sand to clay) and varies significantly in depth, contributing to localized hydraulic complexity. The groundwater presence in the Shallow Zone is closely tied to the sandy units; however, several shallow boring and wells screened primarily in clay were either dry or contained minimal water (less than one foot), indicating limited saturation in clay-dominated intervals. Additionally, some Shallow Zone wells exhibited anomalously high water levels, which are estimated to indicate isolated areas of perched groundwater, particularly in the central and potentially east-central portions of the Site, due to the presence of a discontinuous clay unit in these areas (HDR, 2024).

Beneath the shallow subsurface soils, the intermediate Wilcox Group soil (from approximately 35 to 65 feet bgs) consists of predominantly silty sands interbedded with thin silty clay layers of varying thickness. This interval holds both the Shallow/Intermediate Zone (formerly defined as the Upper Intermediate Zone [HDR, 2021a] or Intermediate Zone during the RI [Jacobs, 2002]). The contact between the shallow Wilcox Group and the underlying intermediate Wilcox Group is notably undulant and discontinuous across the Site, with significant variation in depth. This variability is evident in cross-sectional data (provided as **Appendix C Figures** from the PDI Report [HDR, 2024]) and reflects the complex depositional nature of the site.

Both saturated zones, the Shallow Zone and the Intermediate Zone, were refined to reflect the site conditions defined by the additional investigation conducted during the PSI (HDR, 2021a). The Shallow Zone was then defined between approximately 25 and 32 feet bgs, within a laminated clay/sand unit that overlies a clay layer separating it from the Upper Intermediate Zone. Historically, the Upper Intermediate Zone corresponds to the sandy unit beneath the laminated clay/sand and separating clay layers. The Upper Intermediate Zone wells with completion depths ranging between 35 and 55 feet bgs were re-classified as being in the Shallow/Intermediate Zone and were grouped with Intermediate Zone wells for groundwater elevation and plume mapping. Based on PDI data interpretation (HDR, 2024), several other wells were also reclassified into the combined Shallow/Intermediate Zone due to observed hydraulic connectivity, as supported by site cross-sections (provided in **Appendix C**). A few wells remained designated as Intermediate Zone wells based on deeper screened intervals within the lower portion of the intermediate Wilcox Group, clearly separated by the clay layer at the base of the shallow Wilcox Group. Inevitably, the depth of these groundwater zones varied in depth across the Site.

Groundwater in the Shallow Zone has been observed at depths ranging from 26 to 29 feet bgs, with higher elevations associated, with locations where the silty sand unit occurs closer to the surface. Groundwater in the Shallow/Intermediate Zone flows to the northeast/north and extends to approximately 65 feet bgs. The Shallow/Intermediate Zone exhibits greater saturation and more

consistent groundwater presence, particularly in areas where the sand units are thicker, most notably in the central and southeastern portions of the Site. The overlapping depth ranges of previously installed wells and minimal differences in groundwater elevations between the Shallow and Shallow/Intermediate Zones indicate hydraulic connectivity.

The deep Wilcox Group soils observed at approximately depths ranging from 70 to 95 feet bgs consist of a continuous sandy clay unit that overlies the deepest saturated interval consisting of sand and terminates near the top of the Midway Group. This geologic unit corresponds to the Deep Zone, which is hydraulically isolated from the overlying zones by a thick sandy clay layer. Three wells, 47WW07, 47WW15, and 47WW20, were installed in the Deep Zone at depths ranging from 83 to 95 feet bgs. Groundwater flow direction in the Deep Zone, based on 2007 measurements, is estimated to be toward the north-northeast across the Site towards the Caddo Lake.

Across the Site, groundwater elevation comparisons among the three saturated zones generally showed downward gradients, indicating potential vertical flow between zones; however, the gradient between intermediate and deep zones was nearly flat. Comparisons of gradients between the Shallow Zone and intermediate wells could not reliably be evaluated due to anomalous conditions in the Shallow Zone, which are attributed to perched groundwater. These observations suggest variable vertical hydraulic gradients across the site, with localized differences in groundwater behavior.

Rising head slug tests were performed on some wells at LHAAP-47 to calculate hydraulic conductivity values using the Bouwer-Rice method. The hydraulic conductivities in the various zones varied from 5×10^{-6} to 2×10^{-3} centimeters per second (Jacobs, 2002).

1.6 Current and Future Land and Resource Uses

1.6.1 Current and Future Land Uses

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

LHAAP has been an industrial facility since 1942. Production activities and associated waste management activities continued until 1997, when it was placed on inactive status and classified by the U.S. Army Armament, Munitions, and Chemical Command as excess property. The plant area has been relatively dormant since that time. LHAAP is surrounded by a fence (except on the border with Caddo Lake), and current security measures at the LHAAP limit public access to areas within the fence. The fence now represents the National Wildlife Refuge boundary. Approved access for hunters is limited.

The reasonably anticipated future use of LHAAP-47 is part of a national wildlife refuge. This use is based on a Memorandum of Agreement (MOA) (U.S. Army, 2004) between the USFWS and the U.S. Army. That MOA documents the transfer process of the LHAAP acreage to USFWS to become the Caddo Lake National Wildlife Refuge and will be used to facilitate a future transfer of LHAAP-47. Presently, the Caddo Lake National Wildlife Refuge occupies a little more than 7,100 acres of the 8,416-acre former installation. In accordance with the National Wildlife Refuge System Administration Act of 1966 and its amendments (16 USC 668dd), the land will remain as a national wildlife refuge unless there is a change brought about by an act of Congress or the land is part of an exchange authorized by the Secretary of the Interior.

1.6.2 Current and Future Surface Water Uses

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

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

1.6.3 Current and Future Groundwater Uses

Groundwater near LHAAP is currently used as a drinking water source with water extracted from aquifers 250 to 430 feet bgs (herein referred to as the drinking water aquifer). The drinking water aquifer should not be confused with LHAAP “deep zone” groundwater, which extends only to a depth of approximately 151 feet bgs. The Deep Zone groundwater and the drinking water aquifer are distinct from each other, and there is no known evidence of connectivity between the contaminated zone and the drinking water aquifer. (U.S. Army & USEPA, 2022).

Five active water supply wells near LHAAP are completed in the drinking water aquifer as shown in **Figure 1-2** (identified as Public Water Supply Well Locations). A Well identified as CLSP is located in and owned by Caddo Lake State Park. This well is completed to a depth of 315 feet bgs and has been in use since 1935. A second well, KWSC, owned by the Karnack Water Supply Corporation, services the town of Karnack and is located approximately 0.3 miles northwest of town. This well is completed to approximately 430 feet bgs and has been in use since 1942. The Caddo Lake Water Supply Corporation owns three wells (CLWSC #1, 2 & 3), and they are located both north and northwest of LHAAP. These wells are identified as Caddo Lake Water Supply Corporation Wells 1, 2, and 3, and all are hydraulically upgradient of LHAAP (Jacobs, 2002). These wells are completed deeper than the deepest zone of contamination at LHAAP. The distance from the closest water supply, CLWSC #2, to LHAAP-47 is at least 5,900 feet (1.1 miles). Because of this and the large distance between these wells and LHAAP-47, water removal from these wells is not expected to affect groundwater flow at the Site.

In addition, there are several livestock and domestic wells located in the vicinity of LHAAP with depths averaging approximately 250 feet bgs.

Three water supply wells are located within the boundary of LHAAP itself (identified as Non-Potable Water Wells in **Figure 1-2**). One well is located at the Fire Station with a total depth of 128 feet and a screened interval from 58 to 128 feet bgs; the second well is located approximately 0.35 miles southwest of the Fire Station. The third well is located north of the USFWS administration building for Caddo Lake National Wildlife Refuge, near the main entrance to LHAAP. These three water supply wells were completed at depths greater than the zone of contamination described at LHAAP-47. None of these three wells are currently used for drinking water at LHAAP, although they may supply water for non-potable uses. Two additional wells (not shown in **Figure 1-2**) previously supplied water to the installation, but these have been plugged and abandoned.

As per the 2022 ROD, although the anticipated future use of the facility as a wildlife refuge does not include the use of the groundwater at LHAAP-47 as a drinking water source, the State of Texas (30 TAC 335.563[h][1]) designates all groundwater as potential drinking water, unless otherwise classified.

The future industrial scenario for LHAAP assumes limited use of groundwater as a drinking water source.

1.7 Nature and Extent of Contamination

Nature and extent of contamination based on the investigations conducted prior to the pre-design investigation are summarized below.

1.7.1 Soil

Analytical data submitted by the off-site laboratory from the PSI (HDR, 2021a) were used as the most recent basis for determining the extent of each remedial design element. Figures included in **Appendix C**, provided as references, also include field laboratory data to bridge laboratory data. Consequently, the TCE concentrations reported herein may not perfectly align with the data shown in the figures in **Appendix C**.

To determine the nature and extent of contamination in soil, the TCEQ (TCEQ, 2006) soil medium specific concentration (MSC) for industrial use based on groundwater protection (GWP-Ind) was used in accordance with 30 Texas Administrative Code (TAC) 335.559(g)(2). As shown in ROD **Figure 2-7** of **Appendix C**, perchlorate-contaminated soils were identified near the former Building 25-C. Soil contamination above the GWP-Ind for perchlorate of 7.2 milligrams per kilogram (mg/kg) was detected to depths greater than 10 feet bgs. Based on historical sampling results and consistent with the 2022 ROD, the originally estimated volume of impacted soil was approximately 9,000 cubic yards (cy). A plastic liner (i.e., existing impermeable liner) was placed around Building 25-C by the U.S. Army over areas known to contain perchlorate in the soil in November 1999. The primary objective of the liner placement was to mitigate perchlorate runoff to Goose Prairie Creek and mitigate leaching of perchlorate from soil to groundwater. The liner was repaired in 2015 after a reconnaissance survey identified three areas where the topsoil cover was eroded. One area with an exposed liner was repaired with a new 16-mil liner and 6 inches of clean imported soil. Remaining eroded areas, approximately 1,200 square feet (sf), 400 sf, and 100 sf, respectively, were covered with erosion matting clean topsoil, and seeded with rye grass (Aaron Williams, personal communication, January 6, 2022).

The PSI and PSI Addendum Reports (HDR, 2019a, 2019b, and 2021a) documented that TCE concentrations in unsaturated soil near Building 46-A exceeded the GWP-Ind criterion of 0.5 mg/kg. The depth of the unsaturated zone was estimated to be approximately 23 bgs. Elevated TCE concentrations in these soils suggested that TCE might serve as an ongoing source of groundwater contamination. Based on field laboratory soil sample results (HDR, 2021a), TCE exceedances in unsaturated soil around Building 46-A generally ranged from 0.5 to 3.3 mg/kg, except for a single boring (DPT-030), where a concentration of 16 mg/kg was observed at a depth of 10–11 feet bgs (PSI **Figure 10** of **Appendix C**). Similarly, fixed laboratory analytical results from the PSI (HDR, 2021a) reported TCE concentrations ranging from 0.5 to 15.6 mg/kg, with the exception of DPT-030, which exhibited a concentration of 59.6 mg/kg at a depth interval of 10-11 ft bgs.

Given the groundwater elevation of approximately 23 feet bgs, saturated soil data indicated the highest TCE concentration of 15.8 mg/kg in Boring DPT-003, collected at 29–30 feet bgs. Boring DPT-030 is located behind the southwest corner of the Building 46-A footprint, while Boring DPT-003 is situated immediately adjacent to the northwest corner. Direct push technology (DPT) soil results based on field laboratory analysis for the area near Building 46-A are presented in PSI **Figure 10** of **Appendix C**.

1.7.2 Groundwater

Perchlorate, VOCs, semi-volatile organic compounds (SVOCs), trinitrotoluene (TNT), 2,4-dinitrotoluene (DNT), 2,6-DNT, and metals are the groundwater Contaminants of Concern (COCs) that exceed the respective maximum contaminant levels (MCLs) or, in the absence of federal drinking water standards, the Texas Risk Reduction Program (TRRP) Tier 1 Residential Groundwater Protective Concentration Levels (PCLs). Perchlorate and TCE groundwater plumes exist at the LHAAP-47 Site (PDI **Figures 27 and 28 of Appendix C**). The perchlorate plume is limited to the Shallow/Intermediate Zone, whereas TCE plumes are present in both the Shallow and Shallow/Intermediate Zones based on the most recent PDI data. Plumes for TCE daughter products 1,1-Dichloroethene (1,1-DCE), cis-1,2-Dichloroethene (cis-1,2-DCE), and Vinyl Chloride (VC) generally follow the TCE plumes in the Shallow and Shallow/Intermediate Zone groundwater. They are entirely within the extent of TCE plumes (refer to PDI **Figures 27 and 28 of Appendix C**). The other COCs (SVOCs, TNT, 2,4-DNT, 2,6-DNT) in groundwater are isolated and do not indicate a plume of contamination (Shaw, 2011).

A PSI was conducted between 2018 and 2020 to assess changes in groundwater and surface water conditions since 2010 and evaluate their impact on the initial 2013 Draft Final ROD prior to its signature in 2022 (i.e., Revised Final ROD [USACE/EPA, 2022]). While the PSI generally confirmed the conclusions of the FS (Shaw, 2011) and confirmed that groundwater flow direction to the northeast remained largely unchanged, it reported that Shallow Zone wells were dry. The locations and concentrations of groundwater COCs appeared to have shifted. Despite extensive contamination remaining at the Site, the majority of groundwater contamination was observed within the Shallow/Intermediate Zone (previously referred to as Upper Intermediate Zone). An extended drought in East Texas, compounded by the cessation of washdown activities in 1997 (which may have previously contributed recharge to the shallow groundwater systems), likely caused significant drying of the Shallow Zone. Consequently, the extent of VOC contamination was substantially reduced compared to the 2010 FS results.

A significant PSI finding was the discovery of residual TCE DNAPL (assumed when the concentration of TCE is greater than 10,000 µg/L and worst-case scenario for remedial design purposes) in the Shallow Zone and Shallow/Intermediate Zone groundwater near Building 46-A, 49-B, and 47-B (HDR, 2021a). Three areas of residual DNAPL were defined in the Shallow Zone, and one larger area was defined in the Shallow/Intermediate Zone (formerly identified as Intermediate Zone in the 2022 ROD). The apparent separation of the Shallow Zone residual DNAPL was caused by some of the wells and DPT soil and groundwater sampling locations that appeared dry during sampling or did not recharge sufficiently to allow samples to be collected, even though the depths were at or greater than 23 feet bgs (the depth assumed to represent the saturated zone). The residual DNAPL lies within the TCE plumes in both zones. The highest groundwater PSI TCE concentration (140,000 µg/L) was observed at 47WW25R (HDR, 2019a). The observed concentration was significantly higher than the 13,300 µg/L TCE concentration in 47WW25, the well it replaced (PSI **Figures 19 and 20 of Appendix C**).

As a result of the decline in water levels, the VOC extent of contamination in the Shallow Zone was observed to be substantially reduced and limited to the vicinity of LHSMW44 and LHSMW45 in July 2018 when compared to the 2010 RI results (refer to PSI **Figure 6 of Appendix C**). As documented in the PSI (HDR, 2021a), groundwater samples collected during the 2020 sampling event from temporary DPT wells, as well as from existing and newly installed monitoring wells, confirmed the presence of VOC plumes in the Shallow Zone near Building 46-A, as shown in PSI **Figure 19 of Appendix C**. PSI **Figures 19 and 20 in Appendix C** depict the expanded extent of the Shallow and

Shallow/Intermediate Zone TCE plume based on the 2020 PSI conducted specifically to investigate the area around Building 46-A. Further, based on the PDI (HDR, 2024), the extent of Shallow and Shallow/Intermediate Zone TCE and perchlorate plumes was refined and depicted on PDI **Figures 27 and 28** provided in **Appendix C**. Perchlorate plumes are no longer present in the Shallow Zone, therefore, perchlorate plumes beyond year 2018 are not shown in PSI **Figure 6** and PDI **Figure 27** of **Appendix C**.

In 2018, due to the lack of groundwater in the Shallow Zone, replacement wells for dry Shallow Zone wells were completed through the sand-laminated clay underlying the Shallow Zone and into the Shallow/Intermediate groundwater zone to provide additional data points. The additional data provided from the replacement wells led to redefining the contaminant plumes. Two separate VOC plumes depicted in the FS are shown to be connected as a result of analytical data obtained from replacement well 47WW11R in the PSI **Figure 7** of **Appendix C**. There is a discrepancy between the plume legends and the title of PSI **Figure 7** of **Appendix C**. Plumes labeled as the Shallow Zone in the figure legend should instead be identified as the Intermediate Zone. However, the joined VOC plume depicted in the PSI **Figure 7** of **Appendix C** were subsequently separated after additional data was collected during the PDI. The results of this well, in addition to LHSMW43R, also defined the presence of an additional small perchlorate plume that was not defined in the FS.

1.7.3 Principal Threat Wastes

Per the 2022 ROD (U.S. Army & USEPA, 2022), perchlorate-contaminated soil is considered a principal threat waste at the Site. The perchlorate-contaminated soil provides a source for perchlorate impacts to groundwater (via the impacted soil leaching to groundwater pathway) as well as to surface water (via the overland impacted surface soil migration into surface water). The migration pathways are temporarily mitigated with the existing impermeable liner placed on top of the majority of the perchlorate-impacted soil. The 2022 ROD estimated a volume of approximately 9,000 cy of perchlorate-impacted soil, representing the principal threat.

The TCE concentrations reported in groundwater near Building 46-A, representative of residual DNAPL, indicate that TCE in the saturated zone in this area is a principal threat waste. The 2022 ROD estimated the volumes of residual DNAPL to range from 237,799 to 532,669 gallons in the Shallow Zone and 261,890 to 586,634 gallons in the Shallow/Intermediate Zone (formerly identified as the Upper Intermediate Zone).

1.8 Conceptual Site Model

There are areas of highly contaminated groundwater at the Site, including residual TCE DNAPL near Building 46-A, which may have resulted from releases from the former sumps or spills during the Site operations. All sumps at LHAAP-47 have been either removed or taken out of service and are no longer a potential source of groundwater contamination. TCE is present in the soil near Building 46-A. The TCE soil to groundwater pathway is considered complete. Perchlorate concentrations in the soil near Building 25-C exceed the GWP-Ind; therefore, the perchlorate soil to groundwater pathway is considered complete.

Metals, SVOCs, and VOCs have been detected in groundwater at concentrations exceeding their respective MCLs or TRRP Tier 1 Residential Groundwater PCLs. However, available data for metals, SVOCs, and VOCs (other than TCE) do not indicate the presence of associated soil contamination that may leach to the groundwater. For all contaminants, risks from exposure to contaminated soil were found to be acceptable.

Overland surface water does not currently appear to be contributing to a migration of contaminants, as the ditch surface water did not contain VOCs, SVOCs, explosives, pesticides, or polychlorinated biphenyls exceeding their respective cleanup levels. Likewise, the sediment data show no detections of VOCs, SVOCs, explosives, or pesticides. Some metals that occur naturally were detected in the surface water and sediment at low concentrations. Historical surface water sampling prior to the RI and prior to placement of the existing impermeable liner around Building 25-C indicated perchlorate had seeped into Goose Prairie Creek at concentrations exceeding its cleanup level. However, the RI and subsequent investigations indicated that no contaminants, including perchlorate, have been identified in Goose Prairie Creek at concentrations exceeding their respective cleanup levels. Although contaminant concentrations remain below their cleanup levels, for perchlorate, the soil to surface water pathway is considered complete due to the temporary nature of the plastic liner remedy now in place. The TCE soil to surface water pathway is not likely due to the depth of the contamination.

The surface soil to surface water migration pathway and groundwater to surface water migration pathway are considered potentially complete pathways due to the potential for the COCs in soil and groundwater to migrate into surface water.

While the groundwater to surface water migration pathway is not likely to be complete under current conditions, this pathway could potentially become complete should groundwater elevations rise in the future. Preventing contaminated groundwater from migrating into surface water is included as a Remedial Active Objective (RAO) in the 2022 ROD.

The reasonably anticipated future use of the Site is a wildlife refuge with minimal projected future use of groundwater. The hypothetical pathway considered for groundwater remediation is potential ingestion by the hypothetical future maintenance worker.

1.9 Basis of Action

The remedial action selected in the 2022 Revised Final ROD (U.S. Army & USEPA, 2022) is necessary to protect the public health and welfare and the environment from actual or threatened releases of hazardous substances, pollutants, or contaminants into the environment. Actions for groundwater are required to address the potential for human health risks in the unlikely event that there is an attempt to use groundwater as a potable water source. Actions for the soil are necessary to address the migration pathways of perchlorate and TCE in soil into groundwater and perchlorate into surface water. **Tables 1-2 and 1-3** present the COCs and the final cleanup levels for both soil and groundwater. Monitoring levels were identified for surface water based on the list of COCs in groundwater and are presented in **Table 1-4**.

1.10 Remedial Action Objectives

The RAOs for LHAAP-47, which address contamination associated with the media at the Site and take into account the future uses of LHAAP surface waters, land, and groundwater, are:

- Protect future maintenance workers by preventing exposure to unacceptable levels of contaminants in groundwater via the groundwater ingestion pathway.
- Prevent perchlorate in soil from migrating to groundwater and surface water and prevent TCE in soil from migrating to groundwater.
- Prevent groundwater contaminated with perchlorate from migrating into nearby surface water.
- Return of groundwater to its potential beneficial use, wherever practicable, within a reasonable time period given the particular site circumstances (40 CFR §300.430[a][1][iii][F]).

The last RAO recognizes USEPA's policy to return all groundwater to beneficial uses based on the programmatic expectation in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and is consistent with the NCP regulations requiring the lead agency, the U.S. Army in this case, to establish RAOs specifying contaminants and media of concern, potential exposure pathways, and remediation goals (40 CFR § 300.430[a][1][iii][F]).

Per these RAOs, and consistent with the NCP, groundwater will be returned to its beneficial use, wherever practicable. In the absence of federal drinking water standards, the groundwater clean-up level at the Site is the TRRP Tier 1 Residential Groundwater PCL. It is protective of human health and the environment.

1.11 Selected Remedy

The selected remedy, documented in the 2022 ROD, for LHAAP 47 includes:

- Excavation and off-site disposal of perchlorate-impacted soil near Building 25-C.
- Groundwater treatment to remove DNAPL from Shallow and Shallow/Intermediate Zones utilizing in-situ thermal desorption (ISTD) near Building 46-A.
- In-situ bioremediation (ISB) of DNAPL within targeted areas near Building 46-A and the eastern Site boundary.
- Installation of biobarriers near Building 46-A and the southern site boundary to treat perchlorate and VOCs.
- Land Use Controls (LUCs), Monitored Natural Attenuation (MNA), and long-term monitoring (LTM).

The selected remedy employing treatment will significantly reduce contaminant concentrations. The performance of MNA will be evaluated following ISB after completion of quarterly sampling for eight events. If MNA is not found to be effective in areas outside of direct active treatment, additional treatment using ISB will be performed in that area. The need for additional treatment using ISB will be determined based on ISB and MNA performance evaluation.

The components of the selected remedy are summarized below. Refer to **Design Drawings** in **Appendix A** for general locations of the active remedies:

- Excavation: From locations near the former Building 25-C, excavation of the perchlorate-impacted soil and disposal in a permitted landfill will result in the removal of soil that is a potential source of perchlorate contamination to groundwater and surface water. With the removal of this soil, the potential migration of perchlorate from soil to groundwater and surface water will be eliminated, and long-term operations/management for impacted soil will not be required.
- ISTD: The residual TCE DNAPL in Shallow Zone and Shallow/Intermediate Zone, and TCE in subsurface soils near Building 46-A will be thermally treated using ISTD. Electrical Resistance Heating (ERH), the thermal technology proposed in the 2022 ROD, consists of subsurface electrodes connected to direct current through the subsurface, with a vapor extraction system to capture the volatilized water and contaminants. This consists of installing an array of electrodes and heating the residual DNAPL and surrounding groundwater to the boiling point. The steam produced from pore-water serves as a medium to carry out volatilized VOCs for capture via Soil Vapor Extraction (SVE) and subsequent ex-situ treatment of extracted vapors. The halo-effect of the heating is also expected to treat the TCE in soil overlying the residual DNAPL.

- ISB: Contaminated groundwater will be treated in target areas using ISB. ISB will be deployed using two strategies, including grids and biobarriers:
 - ISB Grids: This consists of treatment of higher VOC and perchlorate concentrations using ISB via application of a substrate in a grid configuration within target areas identified across the Site and within the vicinity of the Building 46-A ISTD target area, following ISTD implementation if necessary. Figures 1-4 and 1-5 identify areas where VOC levels exceed 1,000 µg/L or perchlorate levels exceed 20,000 µg/L; these figures were used to develop the extent of grid deployment, as shown on **Sheet 02C100** in **Appendix A**.
 - ISB Biobarriers: Leading edges of the Shallow/Intermediate Zone perchlorate and VOC plumes will be treated using ISB via application of substrate in the form of biobarriers. Multiple applications of substrate may be needed.
- MNA: Areas outside the influence of the active treatment will be monitored to evaluate that reductive dechlorination is occurring within the groundwater plume, and that contaminant concentrations are being reduced to attain groundwater standards/levels.
 - MNA Performance objectives will be evaluated after two years of MNA. During those two years, monitoring will be conducted quarterly. If MNA is found to be effective, it will continue, and LTM will be semiannual for three years. In subsequent years, LTM will be annual until the next Five-Year Review and annually thereafter until recommended otherwise by the Five-Year Review and with concurrence from EPA and TCEQ. The monitoring and reporting associated with this remedy will be used to track the effectiveness of MNA and will continue until recommended otherwise at the Five-Year Review.
 - If MNA is found to be ineffective, a contingency remedy to enhance MNA may be developed. The contingency remedy would consist of ISB injections to enhance contaminant degradation. The injection locations will be based on data available at the time it is determined that MNA is not effective. Development and specific description of the contingency remedy is not included in this RD but would be presented in a future RD/ Remedial Action Work Plan (RAWP). If the contingency remedy is required, it will require an update to the decision document (likely an Explanation of Significant Difference [ESD]).
- The LUCs to prohibit groundwater use (except for environmental testing and monitoring) as a potable source will be implemented to ensure protection of human health by preventing exposure to groundwater until the COC cleanup levels in groundwater are met. The LUCs restricting land use to nonresidential will be implemented until it is demonstrated that the surface and subsurface soil and groundwater COCs (i.e., including all hazardous substances, pollutants, and contaminants found at the Site at cleanup levels as listed in **Section 1.9**) are at levels that allow for unlimited use and unrestricted exposure. The LUCs will be used to maintain the integrity of any current or future remedial or monitoring systems until the COC cleanup levels in groundwater are met.
- LTM and reporting will continue until the cleanup levels are achieved in groundwater to confirm protection of human health by preventing exposure to groundwater until cleanup levels are met. LTM frequency will be re-evaluated during the Five-Year Review or during other periodic updates

to LTM planning documents, such as the annual monitoring report and with concurrence from EPA and TCEQ.

1.12 Site Cleanup Levels

From the 2022 ROD, **Tables 1-2 and 1-3** present the COCs and the final cleanup levels for both soil and groundwater (U.S. Army & USEPA, 2022).

1.13 Pre-Design Investigation

A PDI was conducted from 2022 to 2024 to better define the current extent of Shallow Zone and Shallow/Intermediate Zone groundwater contamination. The PDI involved the installation of additional monitoring wells and the collection of samples from both new and existing groundwater monitoring wells located near and within the historic plume extents. Based on the PDI results, the hydrogeologic CSM (**Section 1.8**) was updated accordingly. The results, summarized in the PDI Report (HDR, 2024) and PDI Addendum (HDR, 2025), were used to update concentration and groundwater flow maps to inform this RD. The key findings of the PDI are summarized below:

- Shallow Zone Groundwater VOC Plumes:
 - Four separate VOC plumes are present in the Shallow Zone groundwater, as illustrated in PDI **Figure 27** of **Appendix C**. TCE daughter product plumes were observed to be located within the TCE plume boundaries.
- Shallow/Intermediate Zone VOC Plumes:
 - Two larger VOC plumes are present in the Shallow/Intermediate Zone, as shown in PDI **Figure 28** of **Appendix C**. The TCE plumes are the largest in aerial extent; the northern TCE plume (referred to as the northern VOC plume herein) initiates near Building 46-A and extends to the northeast outside the LHAAP-47 boundary. The southeastern TCE plume (referred to as southern VOC plume herein) initiates in the mid-southern portion of LHAAP-47 and extends east outside the LHAAP-47 boundary. Limited detections of TCE daughter products were observed, which indicate limited natural attenuation is occurring in the Shallow/Intermediate Zone. TCE daughter product plumes are all located within the TCE plume boundaries.
- Shallow/Intermediate Zone Perchlorate Plumes:
 - Two perchlorate plumes were observed in the Shallow/Intermediate Zone as shown in PDI **Figure 28** of **Appendix C**. The northern perchlorate plume is present in the mid-eastern portion of the Site, and the southern perchlorate plume is present near the mid-southern boundary of the Site. The southern plume contained a high perchlorate concentration at its source only.

Metal exceedances in both the Shallow Zone and Shallow/Intermediate Zone were sporadic and did not indicate the presence of plume(s) or obvious source area(s).

Additional PDI was conducted in 2024 to supplement existing data collected as part of the PSI, PSI Addendums, and 2022-2024 PDI, and further support development of the selected RD by performing the following activities:

- Installation of four wells at historically dry well locations to determine the presence/concentration of COCs and collection of groundwater samples; and

- Conducting step-drawdown tests to calculate hydraulic properties of the aquifer within the proposed biobarrier area (the location was selected downgradient of the Building 46-A source area, where the greatest groundwater elevation gradient was present).

The 2024 PDI Addendum refined the VOC plume boundaries and defined the aquifer properties to support this RD. Based on new data from wells 47WW64, 47WW65, and 47WW63, the shape and extent of the TCE plumes were revised, resulting in a narrower leading edge as shown in **Figure 1-5**. The perchlorate plumes remained unchanged.

Hydraulic conductivity derived from step-drawdown tests showed consistency with published ranges for sand and silty sand, supporting their use in the RD. Specifically, the hydraulic conductivities calculated for the Shallow Zone at monitoring well 47WW13 ranged from 0.1 to 0.8 feet/day. The hydraulic conductivities calculated for the Shallow/Intermediate Zone at monitoring well LHSMW43R ranged from 8.3 to 18.9 feet/day. The hydraulic conductivities calculated for the Shallow/Intermediate Zone at monitoring well LHSMW46R ranged from 3.3 to 21.3 feet/day.

1.14 Planned Remedial Action

For the purpose of developing this RD, it is assumed that the RA will be implemented in two phases, as the design criteria for Phase II will depend on the monitoring and performance results of Phase I RA. The design approach considers the following phases.

- Phase I – Source Control and ISB Pilot Tests, Phase I will consist of the following remedial actions (summarized on **Sheets G002** and **01C100** in **Appendix A**):
 - Mobilization and site preparation.
 - Excavation of perchlorate-impacted unsaturated soil exceeding the soil cleanup level in five identified areas near Building 25-C (**Sheet 01C101** in **Appendix A**);
 - Implementation of ISTD to remove residual DNAPL in two identified areas near Building 46-A (**Sheets 01C201** in **Appendix A**) identified with TCE concentrations greater than approximately 10,000 micrograms per liter (µg/L); and,
 - Four ISB pilot tests (3 grids and 1 biobarrier) in strategically selected locations to determine the design parameters for the ISB remedy as shown on **Sheets 01C301** and **01C302** in **Appendix A**.
 - Implementation of LUCs:
 - To restrict land use to nonresidential use until it is demonstrated that the COCs in soil and groundwater are at levels that allow for unlimited use and unrestricted exposure.
 - To prohibit potable use of groundwater above the cleanup levels until it is demonstrated that the COCs in groundwater are at levels that allow for unlimited use and unrestricted exposure.
 - Installation of additional monitoring wells for LTM and baseline groundwater sampling.
- Phase II – ISB, Phase II will consist of the following remedial actions:
 - Mobilization and site preparation.
 - Implementation of ISB in grid configuration in nine target areas where perchlorate concentrations are greater than 20,000 µg/L and/or total VOC concentrations are

greater than 1,000 µg/L as shown in **Sheet 02C100** in **Appendix A** and **Figure 1-4** and **1-5**.

- Implementation of three ISB biobarriers near the southern and eastern edges of the VOC plume, and at the eastern edge of the perchlorate plume to mitigate the risk of contaminant migration outside LHAAP-47 boundary, further outside LHAAP-47 boundary, or further into the Site (refer to **Sheet 02C100** in **Appendix A**).
- Performance monitoring and reapplication of bio-amendments.

Groundwater and surface water monitoring to evaluate MNA performance in both groundwater zones to ensure continued degradation of COCs and daughter products, and that surface water in Goose Prairie Creek is not adversely affected by groundwater. MNA includes:

- Evaluation of MNA performance objectives after 2 years of quarterly monitoring after ISB injections.
- LTM semiannually for 3 years, then annually thereafter, until recommended otherwise by the Five-Year Review or during other periodic updates to the LTM planning documents and with concurrence with EPA and TCEQ. LTM will not be initiated until MNA performance monitoring data are evaluated to determine the effectiveness of MNA.

If MNA is determined not to be successful, a contingency remedy will be evaluated, which would consist of ISB injections to enhance contaminant degradation. The injection locations will be based on data available at the time it is determined that MNA is not effective. Development and specific description of the contingency remedy are not included in this RD but would be presented in a future RD/RAWP.

For the purposes of this Remedial Design, the 2018 Installation-Wide Work Plan (IWWP) (Bhate, 2018) was used as the most current version of the IWWP. However, the Remedial Action will follow the most current IWWP available at the time of execution.

1.14.1 Permitting

The Contractor may commence remedial action field activities after project approvals are obtained and permit equivalency documentation has been prepared and submitted, as applicable. Approval or issuance of permit equivalents is not required prior to initiation of remedial action under CERCLA.

All remedial activities will comply with the substantive requirements of applicable permits and permit equivalents, as necessary. Permit equivalents that may be applicable include, but are not limited to, the following:

- Well Drilling Permit; Well Sealing and Abandonment Permit
- Air Permit Equivalent for Emissions and Off-Gas Treatment
- Wastewater Discharge Permit Equivalent
- Construction or Building Permit, if applicable
- Stormwater Permit Equivalent
- Spill Prevention and Control Plans
- Underground Injection Control Authorization/Permit Equivalent for in-situ bioremediation amendment injections, including direct-push injection points and permanent injection wells

2 SOIL EXCAVATION REMEDIAL DESIGN

The basis of the soil excavation RD is provided in this section and in **Sheets 01C100 and 01C101 in Appendix A**. The leaching of perchlorate from the unsaturated soil to groundwater and surface water was considered a complete pathway that will be addressed during the RA. The FS identified unsaturated contaminated soil located near the former Building 25-C (ROD **Figure 2-7 of Appendix C**) containing perchlorate concentrations that exceeded the GWP-Ind standard. Based on the exceedances, eight excavation areas were initially identified in the FS (FS **Figure 5-1 of Appendix C**):

- Excavation Area 1: One location to the north of the former Building 25-C identified with perchlorate exceedances in soil between the depths of 0 and 10 ft bgs around locations 25C-08, 25C-09, and 25C-45.
- Excavation Area 2: One location to the northeast of the former Building 25-C identified with perchlorate exceedances in soil between the depths of 9 and 11 ft bgs around location 47SB-H6.
- Excavation Area 3: One location to the southeast of the former Building 25-C identified with perchlorate exceedances in soil between the depths of 0 and 10 ft bgs around locations 25C-01 and 25C-03.
- Excavation Area 4: One location to the east of the former Building 25-C identified with perchlorate exceedances in soil between the depths of 0 and 2 ft bgs around locations 25C-02 and 25C-04 (identified within the sloped sidewall area).
- Excavation Area 5: One location to the south of the former Building 25-C identified with perchlorate exceedances in soil between the depths of 0 and 2 ft bgs around locations 25C-07 and 25C-30.
- Excavation Area 6: One location to the southeast of the former Building 25-C identified with perchlorate exceedances in soil between the depths of 4 and 10 ft bgs around locations 25C-05 and 25C-06.
- Excavation Area 7: One location to the southeast of the former Building 25-C identified with perchlorate exceedances in soil between the depths of 12 and 13 ft bgs around locations 47SB-B10.
- Excavation Area 8: One location to the southeast of the former Building 25-C identified with perchlorate exceedances in soil between the depths of 1 and 2 ft bgs around locations 25C-32.

The subsequent phases of PDI did not collect any soil samples. Therefore, the extent of areas for soil excavation were estimated based on the data provided in the Final FS (Shaw, 2011). The above eight excavation areas were combined into five excavation areas based on the delineating method described in **Section 2.2**.

2.1 Design Criteria

The soil design criteria are based on the RAO of protection of human health and the environment by preventing perchlorate in soil from migrating to groundwater and surface water and preventing TCE in soil from migrating to groundwater. The soil cleanup levels included in the 2022 Revised Final ROD (U.S. Army & USEPA, 2022) are listed in **Table 1-2** and define the soil design criteria.

- Perchlorate 7.2 mg/kg

- Trichloroethene 0.5 mg/kg

The soil design criteria include excavation of contaminated soil until cleanup levels are achieved, as confirmed by confirmation sampling results, or until groundwater is encountered. If contamination is present at or below the groundwater level, excavation will be terminated at the depth where saturated conditions are encountered.

2.2 Excavation Areas

Excavation boundaries were determined using soil sample data from the RI (Jacobs, 2002) and FS (Shaw, 2011). Where clean samples were available in close proximity to the excavated areas, limits were extended to those points. If the nearest clean sample was more than 30 feet from contamination, the boundary was placed approximately 15 to 20 feet outward from the contaminated sample. This method balances the need to remove known impacted material while minimizing excavation of likely clean soil.

The overall boundary of the excavation area was delineated using clean samples collected at proposed excavation depths. In cases where a clean sample was located more than 30 feet from contamination, boundaries were biased inward, based on patterns observed across the Building 25-C area, under the assumption that contamination likely diminishes before reaching the clean sample. This inward adjustment helps reduce unnecessary removal of uncontaminated material while still addressing the full extent of known impacts.

Where perchlorate was vertically delineated, excavation extended to the top of the clean sample. In areas without vertical delineation, excavation was extended 2 feet beneath the deepest contaminated sample. This approach ensures the removal of all targeted contaminated material while minimizing unnecessary over-excavation.

After the overall primary excavation boundary near Building 25-C was established, the area was subdivided into individual interior excavation polygons based on contamination depth in adjacent locations. Typically, locations with a depth difference of 1 to 2 feet or within 35 feet of each other were grouped into a single excavation area. Once a cluster was defined, the vertical extent of excavation was set to the depth of the deepest vertical clean sample within that group (or 2 feet beneath the deepest contamination sample as discussed above).

In most cases, this approach ensures consistent and efficient delineation. However, there were a few minor exceptions. For example, Samples 25C-08 and 25C-45 were grouped per the FS report. In that instance, the excavation extent was revised to form a more rectangular shape than originally proposed in the FS.

The overall estimated in-place volume for removal and off-site disposal is approximately 9,900 cy, which includes the side slopes required for safe excavation. This volume aligns with the estimate provided in the FS (Shaw, 2011), which was approximately 9,000 cy. The overall estimated volume for removal and off-site disposal is presented in **Table 2-1** and shown on **Sheet 01C101** in **Appendix A**. Details regarding the development of excavation limits for each area, along with a summary of the excavation areas, comparing the in-place volume excluding the sloped areas, are provided below.

Excavation Area 1, as defined in the FS, was revised to encompass locations 47SB-H6 and 25C-21 in addition to locations 25C-08, 25C-09, and 25C-45. This revision consolidated FS-defined Excavation Areas 1 and 2. The original extent of Area 1 was approximately 790 square feet with a potential volume of 9,480 cubic feet (360 cy). The original extent of Area 2 was approximately 495 square feet with a potential volume of 5,925 (220 cy). However, the excavation extents defined in the

FS were not practical for field implementation. Therefore, Excavation Area 1 was revised using the methodology described earlier in this section. The revised area results in a total area of approximately 3,110 square feet and an estimated volume of 37,320 cubic feet (1,390 cy) with an excavation depth of approximately 12 feet bgs.

Excavation Area 2, as defined in the FS, included locations 47SB-F4, 25C-01, and 25C-03. The area was approximately 574 square feet with a volume of 6,890 cubic feet (260 cy). The revised area results in a total area of approximately 1,310 square feet with an estimated volume of 15,720 cubic feet (590 cy) with an excavation depth of approximately 12 feet bgs.

Excavation Area 3, defined in the FS, included location 25C-02, comprised approximately 4,430 square feet and 17,705 cubic feet (660 cy). The revised area includes location 25C-04, resulting in the updated dimensions of 50 feet by 15 feet, totaling approximately 750 square feet and an estimated volume of 5,250 cubic feet (200 cy) with an excavation depth of approximately 7 feet bgs.

Excavation Area 4, defined in the FS, was approximately 245 square feet with a volume of 985 cubic feet (40 cy). The revised area was expanded to 25 feet by 20 feet, resulting in approximately 500 square feet and an estimated volume of 2,000 cubic feet (80 cy) with an excavation depth of approximately 4 feet bgs.

Excavation Area 5, as defined in the FS, was revised to encompass locations 25C-32, 25C-56, and 47SB-B10 in addition to 25C-05 and 25C-06. This revision consolidated FS-defined Excavation Areas 6, 7, and 8. The original extent of Area 6 was approximately 880 square feet with a volume of 10,540 cubic feet (400 cy). The revised area was expanded to 70 feet by 50 feet, totaling approximately 3,500 square feet with an estimated volume of 49,000 cubic feet (1,820 cy) with an excavation depth of approximately 14 feet bgs.

In all areas except Excavation Area 4, excavation walls will be constructed using appropriate sidewall support due to sidewall heights exceeding 4 feet. Sidewall support methods may include sloping at 1V:2H or shoring or benching, as determined by the Contractor based on field conditions, geotechnical considerations, and their means and methods.

For design and estimating purposes, a slope of 1V:2H has been assumed as a conservative baseline, consistent with the maximum allowable 1V:1.5H slope requirement stated in the Final IWWP Health and Safety Plan (HASP), Attachment 1 (Bhate, 2018), unless further soil analysis indicates otherwise. The 2018 IWWP was utilized during development of this RD.

The Contractor may propose alternative slopes, including steeper configurations, where appropriate and supported by site-specific conditions, to reduce excavation volumes. All proposals shall demonstrate compliance with applicable safety requirements.

All soil generated from sidewall support measures will be treated as impacted material, characterized, and managed accordingly. The estimated volume associated with sidewall support measures is included in the cost estimate and in **Table 2-1**.

During the RA, contaminated soils in these areas will be excavated, stockpiled, sampled for characterization, and subsequently hauled off-site for disposal. Excavation will continue until the cleanup levels are achieved or groundwater is encountered. Based on the most recent groundwater elevation data, the average groundwater depth in this area is approximately 20 feet bgs. In comparison, the deepest proposed excavation within Area 5 is estimated to be at 14 feet bgs.

Confirmation samples will be collected to define the final excavation limits. If contamination is present in a preliminary confirmation sample above the cleanup levels, the excavation limits will be extended in increments of 1 foot vertically and 2 to 5 feet horizontally until confirmation samples are below the cleanup levels or saturated conditions are encountered.

2.3 Post-Excavation Confirmation Sampling

Post-excavation confirmation samples will be collected from the sidewalls and bottom of each excavation area to confirm contamination has been removed before backfilling with clean soil. Additional excavation will be conducted if contaminants are detected above the cleanup levels in the confirmation samples. Confirmation sampling for each excavation area will consist of one 5-point composite bottom sample per 1,000 square feet of the excavation bottom and one 5-point composite sidewall sample per 1,000 square feet of vertical sidewall. Each bottom sample will be composited from 0 to 3 inches at five points at the bottom of the excavation. The five points for each composite sidewall sample will be selected to represent the full height of the sidewall. Based on the primary excavation limits shown in **Sheet 01C101** in **Appendix A**, approximately 12 confirmation samples will be collected from the excavated bottom, and approximately 26 confirmation samples will be collected from the sidewalls of the excavation areas.

- Excavation Area 1: Approximately 4 composite bottom samples and 8 composite sidewall samples.
- Excavation Area 2: Approximately 2 composite bottom samples and 6 composite sidewall samples.
- Excavation Area 3: Approximately 1 composite bottom sample and 4 composite sidewall samples.
- Excavation Area 4: Approximately 1 composite bottom sample and 4 composite sidewall samples.
- Excavation Area 5: Approximately 4 composite bottom samples and 4 composite sidewall samples.

The results of the samples collected will be reviewed to confirm that the cleanup levels have been met. If the confirmation sample is above the cleanup level, additional soil will be removed (2 to 5 feet laterally and 1 foot vertically). After each secondary excavation, additional confirmation samples will be collected from the excavation bottom and/or sidewall(s) as needed. This process of excavation and collection of additional confirmation samples will continue until the cleanup levels are attained or saturated conditions are encountered.

2.4 Waste Characterization and Disposal

The excavated material will be transported and disposed of off-site at approved disposal facilities, in compliance with all federal, state, and local regulations and in accordance with Specification 01 35 45 Chemical Data Quality Control. For purposes of the cost estimate, waste characterization samples are assumed to be collected at a rate of one sample for every 1,000 cy of excavated soil to characterize the waste. Based on the estimated volume, four samples from Area 1, two samples from Area 2, one sample from Area 3, one sample from Area 4, and four samples from Area 5 are anticipated to be collected to characterize the excavated materials. It is anticipated, based on previous sample results, that soil will be classified as non-hazardous. Samples will be analyzed for the analytes required by the selected waste disposal facility. For cost estimating purposes, it is assumed that approximately 10 percent (%) of the total excavated impacted material, estimated at 990 in-place cy, will be disposed of

as hazardous waste resulting from the remedial activities. It is assumed that two of the composite samples will meet the criteria for classification as hazardous waste.

2.5 Backfill and Site Restoration

Following the receipt of clean confirmation samples for a given excavation area, common fill will be placed in the excavation and compacted in accordance with Specification 31 23 00 Backfill, Compaction, and Grading. For purposes of the cost estimate, it is assumed that clean fill will be imported from an off-site borrow source. Fill will be considered clean if it meets the criteria specified in Specification 31 23 00 Backfill, Compaction, and Grading (**Appendix G**). Approximately 12,100 loose cy of clean backfill (borrow soil) will be brought on-site. For the purpose of estimating backfill volume, a 90% compaction factor, a 110% conversion from bank cubic yards of excavated impacted material to embankment cubic yards of backfill, and a total of 9,900 cubic yards of excavated material (including sloped sidewall areas) were used, with backfill calculated as $9,900 \times 1.1 / 0.90$. Borrow source samples will be collected at a frequency of one sample per 1,000 cy of borrow soil. Topsoil (meeting the criteria specified in Specification 31 23 00 Backfill, Compaction, and Grading [**Appendix G**]) will be placed over common fill, and the Site will be reseeded with a native grass and wildflower mix selected in coordination with the USFWS.

2.6 Other Design Considerations

Several of the bridges at LHAAP have weight limits. Routes for trucks filled with excavated soil, as well as for trucks bringing backfill from borrow sources, will be selected with coordination from USFWS. Additional access points/gates, besides the main gate in Karnack, may need to be unlocked to allow access to and from LHAAP to avoid bridges where weight limits may be exceeded with loaded trucks.

2.7 Implementation of Soil Excavation Remedial Design

This section describes the RA field activities planned at the Site for the unsaturated soil excavation. A RAWP that will include the Excavation and Handling Plan (in accordance with Specification Section 31 23 10 Excavation and Handling of Contaminated Materials) for the unsaturated soil excavation and off-site disposal will be prepared by the Contractor for the regulators' review and approval. Prior to the initiation of the field activities, regulators will be notified at least 10 days in advance of mobilization. The construction sequence for site-specific soil excavation activities is outlined below and described in detail in the following subsections:

- Mobilization and Site Preparation
- Surveying
- Soil Excavation and Disposal
- Confirmation Soil Sampling
- Backfilling and Site Restoration
- Reporting
- As-built Survey Drawings

2.7.1 Mobilization and Site Preparation

The following field activities will be conducted as part of the mobilization and Site preparation activity.

- **Site Safety and Health:** The responsibility for the development, implementation, and enforcement of the Accident Prevention Plan (APP) and HASP lies with the Contractor and their

health and safety personnel. An APP/HASP will be developed by the Contractor, including programs for accident prevention, personnel protection, medical surveillance, site control/decontamination, emergency response/contingency planning, and air monitoring. The Contractor's APP/HASP will be submitted to the regulators for approval prior to the commencement of any on-site activities.

- **Mobilization:** The Contractor will mobilize to the Site appropriate personnel, subcontractors, and equipment necessary to perform excavation and disposal.
- **Site Access:** The U.S. Army will be responsible for providing site access needed to complete the work. Improvement of the Site access road using geotextile and additional gravel may be performed to allow trucks and heavy equipment to enter and exit the Site safely. USFWS will be consulted regarding any improvements to minimize the impact on the surrounding terrain to the degree possible.
- **Pre-Construction Documentation:** Prior to the start of any site preparation activities, a pre-construction video/photographic recording of the excavation areas will be conducted. This recording will document the existing conditions of the Site and any other features of interest on and adjacent to the Site. The Contractor will enlist the services of a qualified surveyor, licensed in the State of Texas, to field verify the existing site conditions. This pre-construction survey will identify and mark out the limits of construction, limits of excavation, existing site topography, property boundaries, and capture any structures and other existing physical features of the Site.
- **Clearing:** Prior to the mobilization, work locations for overhead and ground level accessibility will be evaluated. In areas that have excessive vegetation and/or tree growth, a backhoe or other appropriate earthmoving equipment will be used to clear the areas to allow equipment access. Clearing is anticipated to consist of the felling, trimming, and cutting of trees and other vegetation, as required to perform the work. The Contractor will be permitted to remove existing walls, slabs, or other structural elements as required to perform excavation. The Contractor shall coordinate all removal activities with the U.S. Army and shall comply with applicable safety and environmental requirements.
- **Utility Mark-outs:** After coordinating with underground utility locators for utility clearances, excavation locations, and areas that require soil removal, the locations will be located and staked.
- **Soil erosion and sediment controls (SESCs):** SESC's will be installed at the Site where necessary to prevent the migration of sediment into non-contaminated areas. The controls anticipated for use include, but are not limited to, the installation of silt fence around the area of disturbance and stockpile area, hay bales, and diversion berms to control storm water flow. Additional controls to prevent the migration of sediment may be employed if necessary.
- **Decontamination:** Equipment and personnel decontamination procedures should be included and detailed in the HASP. Temporary decontamination pads will be constructed or as needed at approved on-site locations to decontaminate equipment and prevent cross-contamination between the excavation areas. Wash water will be contained and transported off-site for disposal when necessary.

2.7.2 Surveying

The limits of excavation, utility mark-outs, and locations of soil confirmation samples will be preliminary surveyed using GPS equipment. After the excavation is completed, a professional land surveyor

licensed in the State of Texas will survey the final horizontal excavation limits, the bottom of the excavation surface, and the restored surface to the nearest 0.01 foot.

2.7.3 Soil Excavation and Disposal

The limits and plans for excavation are described in **Section 2.2**. Prior to excavation, the existing liner adjacent to Building 25-C will be removed and disposed of off-site with the excavated soil. Excavation of the soil will consist of preparing each excavation area, excavating contaminated soils, and stockpiling for loadout into trucks for off-site disposal. All soils generated from sidewall support measures, including those from slopes needed to complete excavations deeper than 4 ft bgs, will be treated as impacted material, characterized, and disposed of off-site. . When excavation depths are reached, confirmation samples will be collected, and once confirmed, followed by surveying of the excavation limits and confirmation sample locations, then backfilled and restored. Excavations performed under this RA are expected to be less than one acre in size and are not subject to the stormwater pollution prevention requirements of Chapter 26 of the Texas Water Code and TCEQ General Permit TXR15000. However, best SESC practices (silt fencing, berms, etc.) will be used where appropriate to prevent excess runoff of sediment from the excavation and stockpile areas.

2.7.3.1 Area Preparation

The excavation areas, as shown on **Sheet 01C101** in **Appendix A**, will be established using global positioning system (GPS) and excavation limits will be physically marked with survey stakes, pin flags, paint, or other appropriate marking. A temporary decontamination station will be constructed near the area of excavation as needed. Most of the Site is an open field with low vegetation and will be used for construction staging. A temporary soil staging/stockpile area, consisting of a berm with polyethylene sheeting, will be constructed near the excavation area for stockpiling soil prior to collecting waste characterization and off-site transport and disposal (refer to Detail 3 on **Sheet 01D101** of **Appendix A** and Section 3.10 of Specification Section 31 23 10 Excavation and Handling of Contaminated Materials).

2.7.3.2 Soil Excavation and Disposal

Excavation in each area will be initiated after the preliminary excavation limits are established. Except for Excavation Area 4, the excavation depths will exceed 4 feet. Each side of the excavation will either be sloped using a side slope of 1V:2H or benched or shored along the existing building foundation for safety reasons. The Contractor will need to stabilize excavations in Excavation Area 2 along the existing Building 25-C foundation using shoring or other approved support of excavation method(s). Vertical excavation will stop if saturated conditions are encountered.

A selected disposal facility will require waste characterization to provide pre-excavation acceptance of the soil from the excavation areas. Licensed transporters will be used to haul the excavated soil to the pre-approved landfill for hazardous and non-hazardous material disposal.

If possible, pre-excavation acceptance from samples collected in place will allow direct loading of contaminated soil and avoid staging and double handling of material. In these instances, the soil will be removed from the excavation and placed directly in transport trailers or dump trucks for immediate transport to the disposal facility. If the direct loading is not implemented, then the excavated soil will be temporarily staged on plastic sheeting in a designated soil staging/stockpile area adjacent to the excavation while awaiting loading. The stockpile(s) will be covered by polyethylene sheeting to protect the pile from rainfall and reduce the potential for erosion and contaminated soil runoff.

For stockpiled materials, it is anticipated that composite samples will be collected at a rate of one sample per 1,000 cy and analyzed for the necessary analytes to obtain acceptance at the selected

disposal facility. The requirements for waste characterization sample frequency will be determined by the selected disposal facility(s). Each composite sample will consist of equal parts of five samples collected at evenly spaced locations within the stockpile. Once characterized, contaminated soil will be loaded onto trucks and removed from the Site for proper disposal in accordance with state and federal regulations. Loading of trucks will be coordinated with USFWS to ensure that load ratings for bridges along the haul route are not exceeded.

2.7.4 Confirmation Soil Sampling

Confirmation soil sampling will be conducted concurrently with excavation and will document that the remaining soil meets the established cleanup levels presented in **Table 1-2**. After the initial excavation, confirmation samples will be collected from the sidewalls and floor of the excavation and analyzed in accordance with the approved Quality Assurance Project Plan (QAPP). Excavation will continue until concentrations in the soil are less than the cleanup levels or saturated conditions are encountered. The Contractor shall be responsible for selecting appropriate confirmation sample locations based on the Specification 31 23 10 Excavation and Handling of Contaminated Materials (**Appendix G**).

GPS coordinates of each discrete sample location will be recorded. Vertical wall height will be manually measured and recorded. Each sample location will be numbered sequentially in order of collection, labeled on a map, and identified using the nomenclature provided in the approved RAWP.

If contaminants are detected above their cleanup levels during the confirmation sampling, secondary excavation will be performed (2 to 5 feet laterally and 1 foot vertically). This will continue until confirmation samples demonstrate that the contaminants remaining in the soil are below their cleanup level or until saturated conditions are encountered.

2.7.5 Backfilling and Site Restoration

The backfill operations will proceed after excavation confirmation samples are below cleanup levels for a definable area. The excavation areas will be backfilled with fill material that meets the criteria for satisfactory materials as listed in Section 1.2.B of Specification 31 23 00 Backfill, Compaction, and Grading (**Appendix G**). If the soil is saturated from rain events, the bottom of the excavation will be stabilized with an appropriate product that will not adversely impact the soil pH prior to placing the backfill. The backfill will be placed in 12-inches lifts in accordance with Specification 31 23 00 Backfill, Compaction, and Grading. After backfilling is complete, the area will be graded, with a mound approximately one foot above finished grade to allow for settling without creating depression and facilitating positive drainage. The top 6 inches will have topsoil that will be suitable for vegetative growth. The surface will be reseeded with native grass and wildflower seed mixture selected in coordination with USFWS.

2.7.6 Reporting

After the soil excavation RA has been completed, the Contractor will prepare a removal action completion report to document the implementation of the soil excavation RA. The removal action completion report will include a description of the remedy as constructed, a discussion of any problems encountered during construction, along with their resolution, a description of any changes to the design, and quantities and concentrations of contaminants removed. The report will also include documentation on all waste manifests or waste disposal tickets and results of all analyses.

2.7.7 As-Built Survey Drawings

An as-built drawing will document the final restoration. The drawing will include the location of all soils removed, indicating the surveyed limits of the excavation and the location of all documentation samples. As-built Survey Drawings will be certified by a State of Texas licensed Engineer.

3 IN-SITU THERMAL DESORPTION (ISTD) DESIGN

ISTD will be used to treat residual DNAPL near Building 46-A. The extent of residual DNAPL in this area was delineated during the PSI investigations (HDR, 2019a, 2019b, and 2021a), and these data were used to define the ISTD treatment areas. Residual DNAPL was assumed to be present where TCE concentrations exceeded 10,000 µg/L. PSI **Figures 19** and **20** in **Appendix C** depict areas with residual TCE DNAPL greater than 10,000 µg/L in the Shallow Zone and Shallow/Intermediate Zone, which formed the basis for estimating the ISTD treatment areas.

ISTD involves the application of heat to the subsurface to mobilize COCs for removal and treatment and is effective for VOCs under both saturated and unsaturated conditions. A key consideration for applying ISTD in saturated zones is groundwater velocity, as elevated flow rates can result in heat losses that must be managed. As shown in **Table 3-1**, groundwater velocities near Building 46-A range from approximately 0.01 to 0.17 feet per day, which are well below the threshold of 1 foot per day that could limit effective thermal treatment. Installation and operation of the ISTD system may be conducted concurrently with the soil excavation activities described in **Section 2**.

ISTD will be implemented using ERH, which employs arrays of subsurface electrodes to deliver electrical current through the soil and groundwater. The soil acts as a resistive medium, and groundwater, together with water injected at the electrodes, facilitates heat transfer through convection. The inherent electrical resistance of the subsurface materials generates heat, increasing temperatures to near the co-boiling point of water and the target COCs. This process mobilizes VOCs, which may be recovered through SVE and extraction wells, if warranted. Captured vapors will be treated ex-situ as depicted on **Sheet 01C203** in **Appendix A**. ERH is particularly effective in low-permeability formations and can treat both saturated and unsaturated media, making it well-suited for the complex subsurface conditions at the Site. Implementation of the ISTD system will require the installation of a new power supply.

In addition to direct contaminant removal, ISTD may enhance naturally occurring biodegradation processes. Thermal remediation and extraction have been shown to remove up to 99 percent of residual DNAPL mass, including in low-permeability units and fractured bedrock (Camp, Dresser & McKee [CDM] Smith, 2018). Thermal treatment can also increase the mobilization of organic matter from soil to groundwater, which may further promote biodegradation of COCs. Research indicates that modest increases in subsurface temperature during system startup and cooldown periods, particularly during winter conditions, can enhance microbial activity, with optimal biodegradation observed at temperatures up to approximately 30 to 35 degrees Celsius (°C), above which bacterial activity declines (USEPA, 2015).

3.1 Design Criteria

Since there are no specific criteria for residual DNAPL, the performance goals for the ISTD treatment to demonstrate DNAPL removal are proposed below:

- Saturated and Unsaturated Soil: 0.5 mg/kg (TCE)
- Groundwater: 100 µg/L (TCE)

The design for ISTD includes a robust performance monitoring plan that identifies system shutdown criteria and verification sampling to achieve the performance goals.

3.2 ISTD Treatment Areas

The 2022 ROD identified areas of residual TCE DNAPL exceeding 10,000 µg/L in the Shallow and Shallow/Intermediate zones, as shown in ROD **Figure 2-10** of **Appendix C**. These areas were targeted for ISTD treatment. Based on the results of the PSI (HDR, 2021a), four distinct ISTD treatment areas were defined:

- Area 1, located in the Shallow Zone, represents the smallest residual DNAPL footprint and is centered on location DPT-029 (PSI **Figure 19** of **Appendix C**), with a maximum TCE concentration of 22,000 µg/L.
- Area 2, also in the Shallow Zone, lies beneath and adjacent to Building 46-A (PSI **Figure 19** of **Appendix C**), with a maximum TCE concentration of 57,000 µg/L at DPT-013.
- Area 3, in the Shallow Zone southwest of Building 46-A, is centered on locations DPT-031 and 47WW48 (PSI **Figure 19** of **Appendix C**), which reported maximum TCE concentrations of 41,000 µg/L and 54,100 µg/L, respectively.
- Area 4, located in the Shallow/Intermediate Zone, is centered around abandoned well 47WW25R (PSI **Figure 20** of **Appendix C**), which reported a maximum TCE concentration of 140,000 µg/L during the 2018 PSI (HDR, 2019a).

All four treatment areas fall within the footprint of the broader TCE plume, which exceeds the ISTD performance goal of 100 µg/L.

As previously described, ERH is the selected thermal treatment method. At this site, ERH treatment of the deeper Shallow/Intermediate Zone will also require heating of the overlying Shallow Zone. Therefore, the four distinct areas identified in the 2022 ROD were evaluated and consolidated into two treatment zones based on the vertical extent of contamination: one targeting the Shallow Zone and the other encompassing both the Shallow and Shallow/Intermediate Zones. Therefore, ISTD Area 2 and 3 from the 30% RD were combined into ISTD Area 1 in the 60% RD. In addition, a portion of the ISTD Area 1 which overlapped ISTD Area 4 has been combined into ISTD Area 2 in the 60% RD and Final Remedial Design.

Additionally, location DPT-030, installed within the Shallow Zone, exhibited the highest detected TCE concentration in soil, 59.6 mg/kg, at a depth of approximately 11 feet bgs. The Shallow Zone well at DPT-030 was dry, and no Shallow/Intermediate Zone well was installed at this location. However, residual TCE DNAPL is potentially present in the Shallow Zone surrounding DPT-030, with elevated TCE concentrations observed in groundwater at the upgradient location DPT-031 and downgradient location DPT-004. Based on this distribution, the Shallow Zone area between the two previously defined ISTD treatment areas was expanded to include the vicinity of DPT-030.

ERH will be implemented to remove residual DNAPL and TCE sources in these two areas, with one area treating the Shallow Zone (from approximately 22 feet bgs to 34 feet bgs) and one larger area treating the Shallow/Intermediate Zone, also encompassing the Shallow Zone (from 21 feet bgs to 47 feet bgs), as shown in **Sheet 01C201** in **Appendix A**.

ISTD Area 1, the residual DNAPL source in the Shallow Zone, is located adjacent to Building 46-A, as shown on **Sheet 01C201** in **Appendix A**. The extent of residual DNAPL was delineated using results from DPT-004, DPT-012, DPT-003, DPT-030, 47WW48, and DPT-031, which indicate impacts both adjacent to and beneath the building footprint. Groundwater in this area flows north/northeast, suggesting that the source, originating south/southwest of Building 46-A, has migrated into the

Shallow/Intermediate Zone along the flow path towards north/northeast. Southwest of the building, DPT-031 and 47WW48 reported TCE concentrations of 41,000 µg/L at 33 feet bgs and 54,100 µg/L at 32 feet bgs, respectively. Proposed treatment depths for this area are shown on Profile A-A' on **Sheet 01C202** in **Appendix A**.

Removal of residual DNAPL from the bottom clay of the Shallow Zone and the underlying sand of the Shallow/Intermediate Zone is necessary to prevent limitations on contaminant extraction and substrate distribution during in-situ remediation. Because residual mass may persist at the clay/sand interface, the treatment area north/northeast of Building 46-A, previously identified within the Shallow Zone only, is now incorporated into the Shallow/Intermediate Zone treatment area. In this portion of the treatment area, the residual DNAPL extent was delineated by DPT-013, which reported the highest Shallow Zone TCE concentration in the area, 57,000 µg/L at 33 feet bgs.

ISTD Area 2, the residual DNAPL source within the Shallow and Shallow/Intermediate Zones north/northeast of Building 46-A, is shown on **Sheet 01C201** in **Appendix A**. The extent of residual DNAPL was defined using data from DPT-029, DPT-028, DPT-018, DPT-022, DPT-008, DPT-010, DPT-007, 47WW25R, DPT-011, DPT-013, and DPT-026, which collectively indicate deeper-zone contamination. Although DPT-036 was initially excluded because the boring was dry and no sample was collected, review of the PSI No. 2 Report (HDR, 2021a) determined that the well was screened in a clay layer that likely limited yield. The well screen was located within the clay separating the Shallow and Shallow/Intermediate Zones rather than within the sandier clay where most residual DNAPL was detected. Accordingly, ISTD Area 2 was expanded to include DPT-036, differing from what is shown in the 2022 ROD.

ISTD Area 2 is centered around well 47WW25R, which reported a maximum TCE concentration of 140,000 µg/L during the 2018 PSI (HDR, 2019a). At DPT028 and DPT029, TCE concentrations of 11,000 µg/L and 10,300 µg/L were detected at 45 feet bgs. Within the central portion of the treatment area, DPT013, DPT018, DPT022, and DPT007 reported concentrations of 57,000 µg/L at 33 feet bgs, 36,000 µg/L at 40 feet bgs, 66,000 µg/L at 36 feet bgs, and 77,000 µg/L at 36 feet bgs, respectively. Along the eastern boundary, DPT010 and DPT011 reported concentrations of 18,000 µg/L and 22,000 µg/L at 36 and 38 feet bgs. The southern boundary is defined by DPT026, which reported 40,000 µg/L at 45 feet bgs. Proposed treatment depths for this area are provided in Profiles BB,' CC,' and DD' on **Sheet 01C202** in **Appendix A**.

As presented in **Table 3-2**, in ISTD Area 1, thermal treatment will cover approximately 18,500 square feet, with a target depth ranging from 22 to 34 feet bgs. In ISTD Area 2, treatment will cover approximately 34,000 square feet, with a target depth ranging from 21 to 47 feet bgs. The combined ISTD treatment area encompasses approximately 52,500 square feet, with a total impacted volume of soil containing residual DNAPL of approximately 41,500 cy.

3.3 ISTD Area Characteristics

ISTD areas will be implemented for the area/zones and depths bgs provided in **Table 3-2** and depicted on **Sheet 01C201** and **Sheet 01C202** in **Appendix A**. The total ISTD area encompasses approximately 52,500 square feet and a total impacted volume of soil containing residual DNAPL of approximately 41,500 cy. The surface features within the ISTD treatment areas consist of foundation remnants from Building 46-A, an asphalt-paved roadway, and areas covered with overgrown vegetation, including wooded and grassy zones.

Predominant features of the ISTD area's geology, based on the PSI (HDR, 2021a), especially PSI **Figures 13 to 16** provided in **Appendix C**, and cross-sections presented on **Sheet 01C202** in **Appendix A**, near Building 46-A, are identified as follows:

- The depth of the unsaturated zone overlying historical high groundwater levels in the Shallow Zone is estimated to be approximately 23 feet bgs.
- Across the ISTD areas, the subsurface consists of undulating, discontinuous silty sand layers interbedded with clay and clay mixed with fine sand, silt, and sandy/silty mixtures. These clay-rich units dominate the Shallow Zone. The undulating nature of the sand and clay is especially pronounced at the interface between the shallow Wilcox Group soil bottom clay and the underlying shallow and intermediate Wilcox Group sand, where the contact depth varies from 28 feet bgs to 41 feet bgs, with an average depth of 35 feet bgs.
- Groundwater presence in the Shallow Zone is influenced by the occurrence of sandy units within the discontinuous silty sand layer. Several shallow borings and wells completed during previous investigations were either dry or contained minimal water (less than one foot) and typically were screened in clay or predominantly clay units.
- In ISTD Area 1, residual DNAPL and TCE sources were generally observed within the discontinuous silty sand layer of the Shallow Zone at approximately 28 feet bgs.
- In ISTD Area 2, residual DNAPL and TCE sources were typically present in the Shallow Zone and just below the clay-sand interface in the Shallow/Intermediate Zone at approximately 34 feet bgs.
- All Shallow/Intermediate Zone DPT borings and wells exhibited groundwater depths ranging between 26 and 32 feet bgs. Higher groundwater elevations were associated with locations where the clay-sand interface was encountered closer to the ground surface.
- Groundwater flow direction is consistently toward the northeast in both the Shallow and Shallow/Intermediate Zones.

Localized groundwater is first encountered in the Shallow Zone at a depth ranging from 27 to 31 ft bgs and similarly, in the Shallow/Intermediate Zone at a depth ranging from 26 to 32 ft bgs. As shown in **Table 3-1**, an estimated groundwater flow velocity of 0.17 feet/day for ISTD Area 1 and 0.01 feet/day for ISTD Area 2 was determined based on the available hydraulic conductivity, effective porosity, and horizontal gradient data.

3.4 Implementation of ISTD

This section describes the RA field activities associated with implementing ISTD treatment using ERH technology. The ISTD Contractor will be responsible for designing and executing the ISTD system, selecting means and methods appropriate for Site conditions, and ensuring cost-effective performance. As part of the RAWP, the Contractor will prepare an ISTD Treatment Work Plan (herein referred to as the ISTD Work Plan) for submittal to the regulators for review and approval. Regulators will be notified at least 10 days prior to the start of field activities.

System installation and startup for both ISTD Areas are expected to require approximately nine months. Following startup, the system will operate until the shutdown criteria specified in the approved ISTD Work Plan are achieved. If VOC mass-removal rates decline to levels indicating limited additional benefit, the Contractor will notify the U.S. Army and the regulators and initiate a reevaluation of the

shutdown criteria in the approved ISTD Work Plan. This reevaluation step provides a defined mechanism to pause operations, assess treatment effectiveness, and determine whether system optimization, modification, or shutdown is warranted, rather than continuing operation solely to meet the criteria initially established.

System operation and decommissioning are estimated to require an additional eight months. Prior to decommissioning, verification soil and groundwater samples will be collected to verify that cleanup goals have been met. Once verified, the Site will be restored to its original condition.

The Contractor may remove existing walls, slabs, or other structural elements as necessary to install and operate the ISTD system. Such removal will be limited to what is required for installation, operation, and performance of the ISTD system. All removal activities will be coordinated with the U.S. Army and conducted in accordance with applicable safety and environmental requirements.

The construction sequence for ISTD treatment is outlined below and described in detail in the following subsections:

- Preparation of the ISTD Work Plan
- Mobilization and Site Preparation
- New Utilities
- Surveying
- ISTD Treatment System Installation
- System Operation
- System Decontamination and Residuals Management
- Verification Sampling and Initial System Shutdown
- System Shutdown and Decommissioning
- Demobilization
- Site Restoration
- Monitoring Well Installation and Sampling
- Reporting

3.4.1 Preparation of the ISTD Work Plan

As part of the RAWP, the Contractor will prepare and submit for approval an ISTD Work Plan in accordance with applicable sections of EM 200-1-21, Design: In Situ Thermal Remediation (USACE, 2014). The Work Plan will provide a detailed description of the ERH technology equipment, construction procedures, and operations, as well as all associated field activities and performance monitoring/system shutdown criteria. The ISTD Work Plan will address all items specified in this section, as listed below, and other relevant information, including detailed information to verify that it meets substantive requirements and a project schedule. The ISTD Work Plan will need to include the following information:

- A basis of design for the ERH equipment and approach, including mass calculations, targeted design temperature, heating element layout/spacing, and design approach/basis for vapor/liquid treatment equipment.

- Modeled estimates of energy needed to reach the target temperature and the duration of heating necessary.
- Equipment sizing.
- Well-field layout (number, spacing, and depths of heating elements, SVE wells, and all other wells).
- Process piping and instrumentation diagrams.
- Electrical one-line diagrams.
- Vapor/liquid collection and treatment system layout plans.
- Component process flow diagrams.
- The estimated amount of energy, water, fuel, and other consumable materials (e.g., granular activated carbon) to operate the ERH system during the duration of the treatment period.
- Performance monitoring and system shutdown criteria.
- Other information as required to describe the design, construction, and operations approach of the system to implement the remediation in accordance with the Contract Documents.

3.4.1.1 ISTD Design Calculations

An estimate of the residual DNAPL and TCE mass to be addressed by the ERH treatment will be developed by the Contractor, and the basis/rationale for their mass estimate calculations will be included in their ISTD Work Plan. The Contractor will be responsible for appropriately designing, procuring, installing, and operating all required ERH treatment equipment based on their understanding of the ISTD areas and other site characteristics. The ISTD Work Plan will include an evaluation of the potential range in the mass estimate based on the degree of uncertainty in the calculations, and a discussion of the factors of safety incorporated into the process design (e.g., equipment sizing/selection) to accommodate the potential range in mass. In addition, the Contractor will provide all other equipment/operational measures required to address any other characteristics of the ISTD areas (e.g., metals, soil total organic content, moisture content) and/or other relevant site conditions (e.g., groundwater flow, power supply needs), as obtained through available site data/historical reports, that may affect their ERH treatment operations and/or compliance with associated air emissions/liquid discharge requirements. If the Contractor identifies any data gaps/additional data needs as part of their bid preparation, then they will need to identify the data collection requirements and associated costs in their bid.

3.4.1.2 ISTD Design

Location, number, and design of heating elements, extraction wells, and temperature/pressure monitoring points will be provided by the Contractor in site plan layouts included with their ISTD Work Plan and in accordance with **Section 3.4.7.3**. Capabilities will be incorporated into the ISTD Work Plan to allow safe and effective monitoring of vapor concentrations, air pressures and vacuums, air flows, water flows, and subsurface temperatures over the course of the treatment and post-treatment periods.

If the Contractor determines that either extraction wells or other measures (e.g., hydraulic barriers) are needed to maintain hydraulic control of the ISTD area during the ERH operations, the Contractor will need to clearly indicate the proposed number, locations, and depths of the extraction wells and indicate the anticipated groundwater extraction rates required for maintaining hydraulic control

throughout the operations period. If hydraulic control is determined to be necessary, groundwater may be collected and treated at the Groundwater Treatment Plant (GWTP) located at LHAAP-18/24.

The Contractor will need to install a minimum of two new downgradient monitoring wells in each area (ISTD Area 1 and ISTD Area 2) for the purposes of monitoring hydraulic control effectiveness during ERH operations. The wells shall be installed approximately 30 feet downgradient from the ISTD boundary and screened appropriately for each area. The new monitoring wells will be monitored monthly for VOCs and temperature during ERH operations, including once prior to commencement of ERH operations to establish baseline conditions. Results during system operation with elevated VOCs (e.g., concentrations greater than 1 order of magnitude above baseline conditions) or elevated temperatures above baseline conditions may trigger additional action such as more frequent monitoring, adjustment of ERH operations, or implementation of additional groundwater extraction or hydraulic control measures. The Contractor is required to notify and coordinate with the U.S. Army and Regulators if unexpected monitoring results are received to determine and implement the appropriate additional actions.

3.4.2 Mobilization and Site Preparation

The following field activities will be conducted as part of the mobilization and site preparation activity.

- **Site Safety and Health:** The responsibility for the development, implementation, and enforcement of the APP and HASP lies with the Contractor and its health and safety personnel. APP/HASP will be developed by the Contractor, including programs for accident prevention, personnel protection, medical surveillance, site control/decontamination, emergency response/contingency planning, and air monitoring. The Contractor's APP/HASP will be submitted to the regulators for approval prior to the commencement of any on-site activities.
- **Mobilization:** The Contractor will mobilize appropriate personnel, subcontractors, and equipment necessary to install and operate the ISTD treatment system, including the ERH well-field installation and liquid and vapor recovery and treatment systems.
- **Site Access:** The U.S. Army will be responsible for providing site access needed to complete the work. Improvement of the Site access road using geotextile and additional gravel may be performed to allow drilling and heavy equipment to enter and exit the ISTD areas safely. USFWS will be consulted regarding any improvements to minimize the impact on the surrounding terrain to the degree possible.
- **Pre-Construction Documentation:** Prior to the start of any site preparation activities, a pre-construction video/photographic recording of the ISTD areas will be conducted. This recording will document the existing conditions of the Site, and any other features of interest on and adjacent to the Site. The Contractor will enlist the services of a qualified surveyor, licensed in the State of Texas, to field verify the existing site conditions. This pre-construction survey will identify and mark out the limits of ISTD areas, existing site topography, site features, property boundaries, and capture any structures and other existing physical features of the Site.
- **Clearing:** Prior to the mobilization, work locations for overhead and ground level accessibility will be evaluated. In areas that have excessive vegetation and/or tree growth, a backhoe or other appropriate earthmoving equipment will be used to clear the areas to allow equipment access. Grubbing is not anticipated. Clearing may consist of the felling, trimming, and cutting of trees and other vegetation, as required to perform the work. Only the foundation remnants of Building 46-A and portions of the existing paved roadway are located within the footprint of the ISTD treatment

areas at the Site. These existing surface features may serve as the cover for the thermal system during implementation. The required ERH system components, including electrodes, vapor and/or groundwater recovery wells, and temperature monitoring points, will be installed through these structural elements to facilitate subsurface heating and vapor extraction without the need for extensive surface demolition.

- **Utility Mark-outs:** After coordinating underground utility locators for utility clearances, excavations required for new utilities, and areas that require ISTD treatment system installation will be located and staked.
- **Existing Monitoring Wells:** Implementation of ISTD is expected to damage the integrity of existing wells within the ISTD areas; therefore, existing monitoring wells located within the ISTD areas will be decommissioned in accordance with 16 TAC 76.104, as applicable, by a Texas-licensed driller and as described in Section 3.4.10. The existing monitoring wells include 47WW48 in ISTD Area 1 and 47WW37, 47WW25, 47WW49, 47WW50, 47WW51 in ISTD Area 2. Prior to decommissioning, baseline groundwater sampling will be conducted at the existing monitoring wells located within the ISTD areas, as well as at two surrounding wells (47WW53 and 47WW52).
- **Decontamination:** Equipment and personnel decontamination procedures should be included and detailed in the HASP. Temporary decontamination pads may be constructed or as needed at approved on-site locations to decontaminate equipment and prevent cross-contamination between the drilling locations. Wash water will be contained and transported to either the GWTP located at LHAAP-18/24 or treated on-site and transported to the off-site disposal facility for disposal when necessary.

3.4.3 New Utilities

The capacity of the existing overhead lines at the Site entrance is approximately 7,200 volts. The Contractor will be responsible for the design, procurement, and installation of the primary power service drop to supply all required power for the Contractor's selected operations, including all required coordination with/submittals to the local power utility company. The Contractor's power service design will need to include all coordination required with local power utility representatives and engineering support required to confirm the adequacy of the existing overhead service at the LHAAP Site for supporting the Contractor's power needs, based on the Contractor's ISTD Work Plan.

The power service drop installation will include all infrastructure required to connect to the existing overhead power service at the main transformer located on the LHAAP facility, and to bring the required power to the Contractor's ISTD infrastructure, including furnishing and installation of all conductors, conduits, trenching work, transformers, metering equipment, primary and secondary power distribution equipment, and grounding, fencing, or other safety and security measures. The power service drop will include separate service metering as required to allow tracking of the Contractor's power usage/costs. The Contractor is advised that the design, coordination with the regulators for approvals, procurement, and installation of the power service drop may require an extended time period, and that the scheduling for these activities shall be incorporated into the Contractor's project schedule. The Contractor shall notify the U.S. Army if additional submittal reviews are needed prior to Work Plan approval to facilitate power drop coordination.

During the ISTD operations, the Contractor will be responsible for all utility costs associated with energy, water, fuel, and other consumable materials to operate all equipment related to the ISTD

treatment system. The Contractor will design, furnish, and install all utilities required to support the selected operations, as listed below:

- Process Water Supply – Contractor is responsible for supplying the potable water needed for the ERH system installation and operations.
- Water Discharges – Wastewater generated from the ERH operations will be contained and transported to the existing GWTP located at LHAAP-18/24. For contingency purposes, the Contractor shall also include provisions for on-site treatment and off-site disposal, if necessary.
- Secondary Containment – All liquid storage and treatment equipment shall be located within secondary containment constructed of impermeable surfaces suitable to contain a spill or release of liquid. Impermeable means having a maximum permeability for any hazardous substance that is being contained of $10E-7$ cm/sec at the maximum anticipated hydrostatic pressure. The secondary containment system shall be capable of containing the volume of the largest container plus 6 inches of stormwater (if the area is exposed to stormwater).

3.4.4 Surveying

The limits of ISTD areas and locations of ERH well points will be surveyed preliminarily using GPS equipment. A professional land surveyor licensed in the State of Texas will survey the performance borehole/well locations to the nearest 0.01 foot.

3.4.5 ISTD Treatment System Installation

3.4.5.1 ISTD Well-Field Installation

It is anticipated that one ERH treatment system will be installed and operated for both ISTD Area 1 and ISTD Area 2. The following elements (subsurface and aboveground components) of the ERH system will be installed as part of the installation:

- Heating elements
- Temperature and pressure monitoring points
- Vapor recovery extraction wells
- Vapor recovery vacuum monitoring points
- Groundwater monitoring and extraction wells (if determined necessary)

Heating elements, wells, and monitoring points will be compatible with the ERH technology and will be constructed and installed in accordance with 16 TAC 76.100(i) and other applicable local, state, and federal regulations, statutes, and codes. The Contractor will secure any applicable approvals and notifications, which can include federal, state, and local requirements (i.e., S16 TAC 76.100 for well installation, notification of Texas 811), prior to the commencement of drilling and well installation operations. All required utility clearances will be completed prior to conducting invasive activities.

All heating elements and monitoring points/wells will be installed in accordance with the approved ISTD Work Plan. Drill cuttings and other waste generated during installation will be containerized and disposed of off-site. Installation of heating elements and monitoring points/wells may require penetration through slabs and other materials. A complete review of current site conditions, available utility maps, and other available site information will be provided prior to conducting invasive site activities. Drawings showing details and locations of the electrodes and monitoring points will need to be provided as part of the ISTD Work Plan. Locations for the heater elements and monitoring

points/wells within each treatment area will be surveyed to verify the correct placement of the required ERH treatment components within each ISTD area.

3.4.5.2 Liquid And Vapor Recovery and Treatment System Installation

A detailed installation procedure of the ISTD treatment liquid and vapor recovery equipment, and site plan layouts/figures depicting the locations of all proposed treatment system equipment will be included in the ISTD Work Plan. The location of each component of the ERH treatment system will be communicated prior to installation. Site preparation may be required, including identifying a staging area and setting out secondary containment. The equipment location, power requirements, acquisition of a new utility service for treatment, location of the heating elements, wells, and monitoring points, as well as any trenching, compaction, or construction requirements, will be included in the ISTD Work Plan. Existing access roads within the LHAAP Site can be used to access the ISTD areas; however, if required, additional safe and stable access will be constructed by the Contractor. This may be required for equipment (e.g., drilling rigs) to enter the ISTD wellfield for wellfield installation or collecting soil/groundwater samples for demonstrating attainment with the performance goals identified in **Section 3.1**.

The ISTD Work Plan will indicate whether an additional thermal insulating cap or cover, besides the existing surface features, is required for the ERH implementation. If required, the thermal insulating cap(s) or cover(s) will be properly graded to prevent stormwater ponding on the cap. If deemed necessary, the cap/cover will include a low-permeability vapor barrier (e.g., geomembrane) to mitigate the potential for fugitive emissions from the well-field surface during ERH operations. Any backfill required during the installation of liquid and vapor recovery piping will meet the definitions of certified clean fill requirements in accordance with Section 1.2.B of Specification 31 23 00 Backfill, Compaction, and Grading (**Appendix G**).

All necessary electrical requirements for the ISTD system installation and operation will be required to meet the National Electrical Code (NEC), National Fire Protection Association (NFPA), and Occupational Safety and Health Association (OSHA) requirements for hazardous locations. Proper electrical grounding will be installed for all equipment as applicable. All wiring, conduits, and interconnections will be installed appropriately for a fully operable system. All wiring and distribution cables, lighting, ventilation fans, heaters, disconnects, instrumentation, and controls will be installed in accordance with the electrical single-line design.

A suitably sized source of back-up/secondary power (e.g., generator) will be included to continue uninterrupted operation in the event of a loss of utility power. Back-up power is required for vapor and liquid recovery to prevent fugitive vapor mitigation, maintain hydraulic control, if needed, treatment system equipment to keep the process line operational, and other required controls. Back-up power for the well-field heating elements is not required; however, all efforts should be made to bring the well-field heating elements back online as quickly as possible. The backup power source will need to allow for a minimum of 24 hours of operation without the need for refueling. The Contractor will maintain the ability to power the system in backup mode, for a period equal to the original system operating duration after shutdown, if needed to prevent contaminant migration outside the ISTD area.

All piping and other lines will be constructed in such a manner (sloped towards the vapor and liquid recovery system) to prevent any media from condensing or collecting where it would not be recoverable. When completed, the system construction details will be submitted as part of the as-built drawings. All piping and other materials of construction will meet the anticipated temperature and pH. For all vapor treatment component equipment, particularly those units after the vacuum blower or

Granular Activated Carbon (GAC) units, the manufacturer's recommendation will be followed. Piping, hoses, and orifices to be installed are of sufficient size to transmit soil vapor, groundwater/process water, blow-down, treated air, and other media without any significant pressure drop or restriction to the system. All piping/connections will be installed, properly supported, and maintained in a neat and organized manner.

3.4.6 System Operation

3.4.6.1 Safety and Environmental Controls

The Contractor will be required to ensure that no excessive steam pressure is created in the subsurface that can create a hazardous site condition. The ERH system will be operated in a manner that minimizes migration of the impacted groundwater plume and effectively captures soil gas vapors within the established heating area. Because electric heating is used, stray voltage will need to remain below 15 Volts within the ISTD area boundaries. Testing of the stray voltage potential must occur during the commissioning of the system. Efforts to mitigate any surface expression of excessive heat, steam, or electrical current will be undertaken. If needed, shallow vacuum monitoring points will be installed every 50 feet around the perimeter of the ISTD areas, and weekly monitoring will be conducted to verify negative pressure at these locations.

3.4.6.2 VOC Removal and Emissions

Vapor recovery will be performed throughout the heating operations and during the cool-down phase following termination of active heating. All recovered vapors will be treated for removal and/or destruction of VOCs as shown in the SVE Schematic in **Sheet 01C203**. Emission rates and monitoring/reporting requirements will be in consistent with all applicable regulations. The method of vapor VOC treatment will be provided in the approved ISTD Work Plan.

3.4.6.3 Process Monitoring Requirements

Process Monitoring will be required to monitor Contractor performance toward meeting the System Shutdown and Discharge Criteria identified in the approved ISTD Work Plan. Process monitoring shall be performed by the Contractor throughout the ERH treatment program (before, during, and immediately following shut-down). At a minimum, process monitoring will include the parameters listed in **Table 3-3** and described below. Parameters are to be monitored in real time, and their recommended reporting frequencies during the remediation process are indicated in **Table 3-3**.

- **Temperature/Vapor-Pressure Monitoring:** The Contractor will obtain temperature/vapor-pressure measurements daily at a minimum of one monitoring location for every 2,500 square feet of heating area footprint, and at the boundary of each ISTD area, to document the changes in subsurface temperature/vapor-pressure. The locations and numbers of temperature/vapor-pressure monitoring locations may be adjusted based on the Contractor's review of the specific targeted heating area geometry and depth variations. These locations will provide temperature/vapor-pressure monitoring across the horizontal extents of the treatment area and at regular and discrete vertical intervals (minimum every 5 feet, or more frequently as specified by the Contractor) throughout the treatment zone volume, as described/depicted in the Contractor's ISTD Work Plan and associated plans/figures.
- **Heating Duration:** The Contractor will operate the system continuously, 24 hours a day, 7 days a week. Once minimum temperatures have been reached, the Contractor will continue operating the system for the duration needed to meet the shutdown criteria. System up-time will be tracked and documented. The Contractor will specify the means and methods used to monitor power

consumption continuously (both instantaneous and cumulative), as well as consumption rates for other required utilities/services (e.g., water service).

- **Recovered Vapor Flow:** The Contractor will operate the vapor recovery system to optimize the removal of volatilized VOCs from the subsurface. Vacuum and flow rates shall be monitored and managed to maximize mass removal from the subsurface and control migration of contaminants outside of the targeted ISTD areas. Daily measurements of the recovered vapor flow at the well-field vapor influent manifold, blower inlet, and blower outlet will be obtained and recorded to confirm mass removal, both at discrete times and cumulatively.
- **Safety and Environmental Controls:** The Contractor will operate the system and monitor key indicators in accordance with **Table 3-3** to ensure that certain conditions are under control. These include monitoring of subsurface pressures and vapors to prevent enhanced migration of contaminants outside of the targeted ISTD areas. Stray voltage, pressure, and noise monitoring will be performed at least weekly to document safe conditions both within and outside the ISTD areas. The Contractor's ISTD Work Plan will indicate the proposed locations and means and methods for collecting field measurements to evaluate pneumatic capture and stray current potential. If monitoring of these two parameters indicates exceedances, mitigation steps shall be necessary to ensure the continued safe operation of the system. Safety and environmental control also include monitoring VOC concentrations by collecting groundwater samples and recording temperature data from newly installed downgradient monitoring wells monthly. The Contractor's ISTD Work Plan will include required safety and environmental controls to ensure effective and safe operation of the system during inclement weather. These measures may include site preparation with proper grading and drainage to minimize water accumulation and the potential for runoff, weather monitoring, erosion, and sediment controls, necessary containment measures to prevent contaminants from migrating, and adequate worker safety measures. The Work Plan will need to outline procedures for system monitoring (i.e., emergency shutdown), maintenance, and damage mitigation during/after adverse weather conditions, to enable the identification of potential issues or malfunctions.
- **VOC Vapor Destruction Efficiency:** In accordance with **Table 3-3**, the Contractor will provide appropriate collection and treatment of recovered vapors and operate and monitor the vapor collection and treatment system in compliance with the Air Contaminants – General Nuisance Rules (30 TAC 101.4), based on their ISTD Work Plan and associated air emissions control equipment. Samples will be analyzed in accordance with Specification 01 35 45 Chemical Data Quality Control.
- **Process Water:** The Contractor shall continuously monitor recovery of process water and generation of process blowdown as indicators of the Site's groundwater balance. The Contractor will need to provide their required process water supply needs (e.g., flow rates, water quality) and all anticipated wastewater (e.g., extracted groundwater, blow-down, steam condensate, NAPL) information (rate, quality, location, estimated volume, etc.) in the ISTD Work Plan. Documentation of the ISTD process water, blowdown, and drip irrigation stream flow (if applicable), and total volumes shall be provided during operation. Wastewater generated from ERH operations will be contained and transported to either the GWTP located at LHAAP-18/24 or treated on-site and transported to the off-site facility for disposal when necessary. The Contractor will be solely responsible for any discharge violations resulting from their operations.

3.4.7 System Decontamination and Residuals Management

The Contractor will provide all labor, materials, and equipment necessary for on-site storage of hazardous and non-hazardous waste material and off-site transportation and disposal of waste materials at an approved off-site disposal facility. Anticipated waste materials are drill cuttings, sediments from well development, purge water, personal protective equipment (PPE), soils, and debris generated during trenching, decontamination water, GAC, and water generated as process water during the ISTD, as necessary. Vapor treatment residuals generated from the ISTD operations will be contained and transported off-site for disposal when necessary. Wastewater will be contained and transported to either at the GWTP located at LHAAP-18/24 or treated on-site and transported to the off-site facility for disposal when necessary.

3.4.8 Verification Sampling and Initial System Shutdown

The Contractor will demonstrate attainment of the ISTD performance goals specified in **Section 3.1** through verification sampling of soil and groundwater within the ISTD treatment areas.

For soil, the Contractor will achieve the performance goals on average at 95 percent of sampling locations, with no individual sampling location exceeding ten times the applicable performance goals within each treatment area, based on the approved verification sampling program described in the ISTD Work Plan. If measured soil concentrations exceed the performance goals, continue treatment in the affected area until the performance goals are met.

For groundwater grab samples, the Contractor will achieve the performance goals on average at 95 percent of sampling locations, with no individual sampling location exceeding ten times the groundwater performance goals specified in **Section 3.1**, based on the approved verification sampling program described in the ISTD Work Plan. If groundwater concentrations exceed the performance goals, continue treatment in the affected area. Containment or continue treatment actions will be implemented if exceedances of downgradient groundwater concentration limits are observed in monitoring wells 47WW53 and 47WW52.

Verification soil samples will be collected using a hot soil sampling protocol described in the ISTD Work Plan and consistent with industry practices (e.g., Gaberell et al., Battelle, May 2002, or equivalent). Soil samples will be analyzed for VOCs using EPA Method 8260.

Samples will be collected from soil borings advanced using direct-push or other drilling methods selected by the Contractor on an approximate 50-foot by 50-foot grid across each ISTD area, with a minimum of approximately 40 sampling locations. The verification sampling approach will ensure representative coverage, including locations between heater elements and areas of previously elevated VOC concentrations, as outlined in the ISTD Work Plan. Soil samples will be collected from each 5-foot vertical interval (or portion thereof) within the saturated soil column and at least one interval above and below the treatment zone. One groundwater grab sample will be collected from each location.

Sampling locations within each interval will be selected based on field photoionization detector readings, visual observations, or olfactory indications of impacts. If no indications are present, locations will be selected to provide representative coverage. The Contractor will address any VOC impacts identified at concentrations exceeding the performance goals within each interval sampled.

The Contractor will determine the appropriate timing for verification sampling based on evaluation of system performance (e.g., temperature, vapor data, and mass removal) as defined in the ISTD Work

Plan. The Contractor may perform interim sampling at its discretion to optimize operations. The U.S. Army may identify up to 10 additional boring locations at the time of final verification sampling.

The Contractor will temporarily de-energize the thermal treatment system in the vicinity of sampling in accordance with approved health and safety procedures. Soil borings will be completed by a licensed driller, and all borings will be properly grouted or abandoned in accordance with 16 TAC 76.104. The Contractor will identify the anticipated timing of verification sampling events in the ISTD Work Plan.

3.4.9 System Shutdown and Decommissioning

The Contractor may cease applying further thermal treatment to the ISTD area(s) (or portion thereof) upon receipt of preliminary analytical results indicating that performance goals are likely achieved in accordance with the criteria specified in **Section 3.4.8**. The Contractor may perform an initial shutdown based on their assessment that preliminary results meet the performance goals; however, the final shutdown is contingent upon the U.S. Army and regulatory review, and subsequent approval, requiring up to 10 business days. If sequential or phased shutdown of portions of the ISTD area is proposed, the Contractor shall describe the strategy/approach for the sequential shut-down(s) in the ISTD Work Plan, including how effective heating conditions (e.g., temperatures, hydraulic/pneumatic control) will be maintained in adjacent active treatment areas.

Following approval of system shutdown, all heating elements/wells, temperature monitoring points, vapor recovery wells, and vacuum monitoring points will be removed or abandoned. Decommissioning and abandonment shall be performed in accordance with 16 TAC 76.104 by a Texas-licensed driller. Well abandonment reports and required notifications to the Texas Department of Licensing and Regulation shall be submitted upon completion. Additional guidance is provided in SOP A16 – Soil Boring/Monitoring Well Abandonment in Appendix A of the IWWP (Bhate, 2018).

3.4.10 Demobilization

Once areas have achieved the performance goals and approval is received, the Contractor will demobilize all equipment and materials from the ISTD areas. All equipment and materials shall be removed from the Site. Nothing shall be abandoned in place except for the boreholes used for installing heating elements and sampling and monitoring points abandoned in accordance with **Section 3.4.10**.

3.4.11 Site Restoration and Post-ISTD Monitoring

Upon determination that no further ISTD treatment will be required, the Contractor will remove all the equipment, material, temporary facilities, and supplies from the Site and restore the area. If a thermal cap is used, the Contractor will remove and dispose of the cap materials off-site in accordance with applicable local, state, and federal requirements and other applicable aspects of waste disposal identified in the contract documents. The Site shall be restored to the condition that existed before the ISTD RA commencement.

If the Contractor elects to protect existing infrastructure from elevated temperatures in the ISTD zone, then these means and methods shall be outlined in their ISTD Work Plan. Testing shall be conducted during restoration to document that restored conditions match or exceed baseline conditions.

Site restoration activities will include the reinstallation of wells, specifically, 47WW48 in ISTD Area 1 and 47WW37, 47WW25, 47WW49, 47WW50, and 47WW51 in ISTD Area 2, that were previously abandoned during site preparation. These wells will be installed in accordance with the procedures described in Section 3.2 Task 2 - Monitoring Well/Compliance Well Installation, and SOP A7-Monitoring Well Installation, of Appendix A of the IWWP (Bhate, 2018) at their approximate original locations (shown in **Sheet 01C201** in **Appendix A**). Installation will occur no sooner than six months

after the ERH system shutdown or once soil and groundwater temperatures within the treatment zone fall below 120 degrees Fahrenheit (50°C), whichever occurs first.

The Contractor will perform two rounds of groundwater sampling at the newly installed wells (47WW48 in ISTD Area 1 and 47WW37, 47WW25, 47WW49, 47WW50, and 47WW51 in ISTD Area 2) and at wells (47WW53 and 47WW52) surrounding the ISTD zones. The first round shall be at a point when groundwater temperatures have dropped below 120 degrees Fahrenheit (50°C). The second sampling event shall take place within 12 to 16 weeks after the first sampling event. Groundwater samples will be analyzed for VOCs.

3.4.12 Reporting

3.4.12.1 Weekly Operational Progress Reports

The Contractor will submit an electronic version of the process monitoring result reports on a weekly basis during the ERH treatment system start-up, testing, operation, and maintenance phases of the project to document progress. The electronic data will be submitted as a spreadsheet (e.g., Microsoft Excel). The process monitoring data is specified in **Section 3.4.7.3**, and additionally will include the following parameters, tabulated, when possible, with a short-associated text description:

- a. Power and energy input during the weekly period,
- b. Temperatures at each measurement point and depth,
- c. Pressures at each measurement point and depth,
- d. Vacuums and flow rates from each vapor recovery well are totalized for the entire system,
- e. Vapor TCE measurements at each location monitored,
- f. Mass (discrete and cumulative) of total TCE removed,
- g. Running mass (discrete points and cumulative total) of TCE emissions from the well-field,
- h. Running indication of vapor treatment removal efficiency,
- i. Amount of groundwater/process water generated during the period,
- j. Description of any waste generated during the reporting period and its disposition,
- k. System run-time hours, and downtime log with description of reasons and corrective actions, and
- l. Any other data (soil, groundwater, soil gas, etc.) obtained during the period.

Sampling results shall be generated and submitted in accordance with the procedures/scheduling as detailed in the ISTD Work Plan.

3.4.12.2 Effectiveness Monitoring Results

The Contractor will submit a Technical Memorandum containing the effectiveness monitoring results and the Contractor's evaluation/recommendations regarding the ISTD progress after completion of the effectiveness monitoring events (e.g., baseline, operational - monthly, and post-treatment phase). The electronic data will be submitted in a spreadsheet (e.g., Microsoft Excel). Preliminary results will be submitted 10 days following completion of the effectiveness monitoring event, followed by submission of final results 30 days after the monitoring event.

3.4.12.3 Daily Contractor Quality Control (CQC) Reports

The Contractor will submit daily CQC reports during ERH system installation, start-up, and operation. The daily CQC reports will be dated and signed by the CQC Manager. It will include weather information at the time of sampling, description of the field equipment used, health and safety inspections conducted, and any problems encountered. It will include conforming and deficient features and a statement that equipment and materials were properly incorporated in the work. Photo documentation of any deficiencies and their resolutions will be provided. The original and one copy of these records shall be produced within 24 hours after the date covered in the report, except for the days when no work was performed. Submittals may be provided digitally and would not require original or hard copies. The daily CQC reports shall include copies of any test reports.

- Safety Data Sheet (SDS): The Contractor will maintain a complete compilation of all SDSs on-site for the chemicals/substances used as part of the Contractor's operations. SDSs will be submitted and/or available for review upon request.
- Maintenance Manuals: ISTD Operations and Maintenance (O&M) manual will be submitted at least 30 days prior to commencement of ISTD system operations. The O&M manual will include procedures for operations and maintenance of all ISTD equipment/components, including the vapor/liquid treatment systems.
- Chemical Data Final Report (CDFR): The CDFR will include the quality control practices employed and all chemical parameter measurement activities conducted as discussed in this Section. The CDFR will be submitted within 30 days of completing the ISTD work, before final payment of the ISTD portion of the work.

3.4.13 ISTD Completion Report

Upon completion of ISTD treatment, the Contractor will prepare and submit for approval an ISTD Completion Report. The ISTD Completion Report will include, but not be limited to, the following:

- Summary of field operations including applied power and energy, duration of treatment, temperatures reached, and water consumed,
- Evaluation of ISTD effectiveness relative to treatment objectives,
- All sampling results, process monitoring results, and interim monitoring results,
- Any deviations from the approved Work Plan, and rationale/justification for each,
- Wastes generated and disposition (including characterization analysis of wastes),
- Chemical data final report (if interim samples are collected), and
- Summary of Project Cost as an appendix.

4 IN-SITU BIOREMEDIATION (ISB) DESIGN

In accordance with the selected remedy described in the 2022 ROD, ISB will be implemented at the Site to remediate groundwater impacted by VOCs, including TCE, and perchlorate. The following documents served as the technical foundation for evaluating the feasibility and design of the ISB remedy:

- Final RI for the Group 4 Sites (Jacobs, 2002).
- An evaluation of natural attenuation of groundwater contaminants at LHAAP-47 is presented as Appendix A in the Final FS (Shaw, 2011).
- 2022 ROD (U.S. Army & USEPA, 2022).
- PDI Report (HDR, 2024) & PDI Addendum (HDR, 2025).

4.1 ISB Implementation Strategy

ISB will be conducted in two phases as part of the broader remedial strategy for the Site. Specific to the ISB, the RA is assumed to be implemented in two phases, with Phase II ISB design criteria dependent on the monitoring and performance results generated during Phase I. The ISB components of the design to be conducted are as follows:

- Phase I – ISB Pilot Tests consisting of four ISB pilot tests (three grids and one biobarrier) in strategically selected locations to determine key ISB design parameters, along with the installation of additional monitoring wells for baseline and long-term monitoring.
- Phase II – Full-Scale ISB, consisting of implementation of ISB grid injections in nine target areas where perchlorate concentrations exceed 20,000 µg/L and/or total VOC concentrations exceed 1,000 µg/L, construction of three ISB biobarriers at the southern and eastern edges of the VOC and perchlorate plumes, and performance monitoring and reapplication of bio-amendments as well as groundwater and surface water monitoring to evaluate MNA performance.

ISB is a key technology for addressing residual source-area groundwater impacts (originating from Buildings 46-A and 25-D) and the larger dissolved-phase plumes within the Shallow and Shallow/Intermediate Zones. ISB is designed to reduce concentrations to levels supportive of MNA and long-term plume stability (refer to ROD **Figure 2-10** in **Appendix C**).

The ISB implementation approach consists of two coordinated components: target treatment areas and plume containment, both of which will be refined using data generated during Phase I pilot testing.

4.1.1 Target Treatment Areas (ISB Grid Areas)

This strategy applies to areas where Perchlorate concentrations exceed 20,000 µg/L, and/or Total VOC concentrations exceed 1,000 µg/L (but are below approximately 10,000 µg/L). Target treatment areas extend both within and outside the LHAAP-47 boundary in the Shallow and Shallow/Intermediate Zones (**Figures 1-4 and 1-5**). In these areas, ISB will be applied via grid-based DPT injections, enabling flexible and targeted substrate delivery without the need for permanent wells.

4.1.2 Plume Containment (ISB Biobarriers)

Plume containment for high concentrations will be achieved using linear biobarriers configured to transect the leading edges of the VOC and perchlorate plumes extending both within and outside the LHAAP-47 boundary in the Shallow/Intermediate Zone. These will include a combination of DPT injection points and permanent injection wells to allow multiple substrate applications over time.

The conceptual ISB biobarrier alignments originally identified in the 2022 ROD (ROD **Figure 2-10** in **Appendix C**) were intended to be located along the leading edges of both the northern and southern perchlorate and VOC plumes to mitigate the potential for contaminant migration beyond the LHAAP-47 property boundary. In the Design Drawings (**Sheet 02C100** in **Appendix A**), these alignments have been refined based on updated groundwater plume delineation from the PDI.

Consistent with these refinements, the extent of ISB Biobarrier 1 along the northeastern portion of the Site has been reduced and is no longer proposed to fully address the distal, lower-concentration extent of the northern VOC plume. Groundwater concentrations in the vicinity of well 47WW39 (17.5 µg/L TCE) closely represents the attenuated leading edge of the plume. In contrast, higher-concentration source, and core plume area, near well LHSMW56R (5,190 µg/L TCE), continue to be targeted for active treatment through ISB grids and the southeastern biobarrier.

This refinement prioritizes active treatment in areas with elevated contaminant mass and greater potential for continued southern VOC plume migration, while relying on MNA to address the lower-concentration, distal portion of the northern VOC plume. This approach is consistent with the overall remedial strategy, which includes transition to MNA in areas outside the active treatment footprint where attenuation processes can effectively reduce contaminant concentrations over time.

To verify that plume stability is maintained under this approach, additional monitoring wells have been incorporated into the northeastern portion of the Site. These wells will support long-term performance monitoring to confirm that MNA processes are occurring, plume migration remains controlled, and RAOs continue to be met. If monitoring data indicates that MNA is not effectively controlling plume migration, contingency ISB injections may be implemented in accordance with the adaptive management framework described in the ROD.

4.2 Common ISB Design Approach

This section presents the common design approach for implementing ISB during both Phase I pilot testing and Phase II full-scale applications. The ISB system will utilize a combination of direct-push injection and permanent injection wells to deliver amendments that promote the anaerobic biodegradation of VOCs and perchlorate in groundwater. The design elements described below apply to all ISB treatment areas regardless of whether they are configured as grid-based treatment zones or linear biobarriers.

4.2.1 General Substrate Injection Strategies

Amendments will be delivered using either direct-push technology (DPT) or permanent injection wells, depending on site-specific subsurface conditions (as specified in sections below) and long-term reapplication needs. ISB injections will be conducted in accordance with Specification Section 02 53 17 ISB Injection Procedures and Monitoring. DPT will be used for most pilot and full-scale ISB locations, providing flexibility for targeted amendment placement and allowing injection points to be installed and abandoned as needed. Temporary DPT points will typically be advanced at 2- to 3-foot vertical intervals to fully treat the designated depth range within the Shallow and Shallow/Intermediate Zones. A top-down injection method will be utilized to minimize preferential flow, prevent backflow through the tool string, and support uniform vertical amendment distribution. A general schematic of ISB injections is provided in **Sheet 02C109** in **Appendix A**. ISB injections will be conducted in accordance with Specification 02 53 17 ISB Injection Procedures and Monitoring.

Injection pressures will be maintained at relatively low levels, generally up to approximately 50-100 psi for DPT injection and 10-25 psi for permanent injection wells, to avoid fracturing the formation or

causing unintended amendment migration. Where feasible, DPT points may be manifolded to increase injection efficiency.

Permanent injection wells will be installed in selected locations where specified in the design and repeated amendment applications are anticipated or where DPT is less effective due to hydrogeologic constraints. Substrate will be injected through these wells using gravity feed or low-pressure pumping. If field conditions warrant, groundwater extraction and recirculation may be employed to enhance the lateral distribution of injected amendments. Extracted groundwater may be blended with substrate at a central dosing unit to achieve the desired dilution before reinjection. Chase water may be introduced after substrate injection to promote distribution, limit biological fouling, and maintain well functionality.

4.2.2 Radius of Influence and Injection Point Spacing

Injection point spacing for both pilot-scale and full-scale ISB activities is based on estimated radius of influence (ROI) derived from site-specific hydrogeologic conditions and industry best practices. For DPT applications, a ROI of approximately 6.5 feet in the Shallow Zone and 13.5 feet in the Shallow/Intermediate Zone is assumed. Accordingly, DPT injection points will generally be spaced at approximately 13 feet in the Shallow Zone and 27 feet in the Shallow/Intermediate Zone. For permanent injection wells, an ROI of 13.5 feet is also applied, resulting in a nominal 27-foot spacing between wells. ROIs and associated injection spacing will be confirmed during Phase I pilot testing, and spacing may be refined for Phase II full-scale implementation based on monitoring results.

4.2.3 Substrate Selection

The selected substrate for the pilot and full-scale ISB applications is emulsified vegetable oil (EVO). There are various formulations of EVO commercially available for groundwater remediation. Droplet size affects the substrate's radius of influence and associated operational costs; a small droplet size will optimize the substrate's radius of influence. The specific formulation of EVO recommended by the vendor for the Site is the 60% Slow-Release Substrate (SRS®-SD) small droplet product (0.60 microns) available from Terra Systems of Delaware (TSD) (**Appendix E**).

The specific formulation of SRS®-SD evaluated for the pilot test and full-scale locations consists of soybean oil mixed with water, sodium lactate, emulsifiers, nutrients, and vitamin B12. SRS®-SD contains 60 % soybean oil suspended in water. Once injected, the oil droplets adhere to the soil and provide a long-lasting, slow release of carbon and hydrogen to promote the growth of microorganisms responsible for the biodegradation of chlorinated solvents. Of note, and appropriate for site-specific conditions, SRS®-SD includes 10% sodium lactate or glycerol to provide a fast-release carbon source that accelerates the generation of anaerobic conditions in preparation for the injection of a consortium of microorganisms. SRS®-SD contains 7.5% to 10% nutrients and vitamin B12 to enhance the activity and growth of dechlorinating bacteria. The vendor can provide SRS®-SD as a water-mixable oil that contains no water as shipped; therefore, it can be mixed in the field or at an established local mixing plant. This will reduce the cost and environmental footprint associated with transporting higher volumes of more dilute substrate to the Site. Based on vendor recommendations (**Appendix E**), the quantity of SRS®-SD required for the pilot test areas, full-scale ISB grid areas, and full-scale biobarrier areas is estimated at 990, 62,000, and 4,060 gallons, respectively, for the first injection application.

In addition to the EVO, sodium bicarbonate will be injected as a pH buffer to neutralize acidic conditions and increase native pH levels. Average pH levels were determined using geochemical results provided in Table A-3 from the natural attenuation evaluation of groundwater contaminants at LHAAP-47, presented as Appendix A in the Final FS (Shaw, 2011). The average pH level in the Shallow Zone is approximately 6.11, with maximum and minimum observed pH values of 7.03 and 5.15, respectively.

In comparison, the average pH in the Shallow/Intermediate Zone is approximately 6.84, with maximum and minimum observed values of 10.28 and 5.48, respectively. Based on vendor recommendations, biotic dichlorination rates are higher at pH 7 than at pH 6. Dichlorination of chlorinated solvents commonly produces hydrochloric acid, which can lower pH below 6, hindering the survival and effectiveness of microorganisms. Based on vendor recommendations (**Appendix E**), the quantity of sodium bicarbonate required for the pilot test areas, full-scale ISB grid areas, and full-scale biobarrier areas is estimated at 530, 36,830, and 1,700 pounds, respectively, for the first injection application.

4.2.4 Bioaugmentation Culture Selection and Injection

In addition to the SRS®-SD, implementation of ISB in pilot test areas, biobarriers, and grid areas will include a dechlorinating bioaugmentation culture (TSI-DC) containing multiple strains of *Dehalococcoides mccartyi* (DHC) to promote biotic dichlorination of chlorinated solvents, including PCE and TCE, to ethene. KB-1®, another commercially available DHC culture, was also evaluated as an alternative during the design process; however, based on vendor information, cost efficiency, and availability, TSI-DC is proposed as the preferred culture for this Site. The Contractor may propose either TSI-DC or KB-1® as part of their implementation approach, provided the selected culture is demonstrated to be cost-effective and meets the performance requirements of the ISB remedy.

Based on vendor recommendations (**Appendix E**), the total volume of TSI-DC DHC culture required for the pilot test areas, full-scale ISB grid areas, and full-scale biobarrier areas is estimated at 150, 10,250, and 480 liters, respectively. The DHC microbial consortium is supplied in 19-liter stainless steel kegs equipped with pressure relief valves. During transportation, the kegs are pressurized with nitrogen gas to approximately 15 psi. Unused contents shall be disposed of in accordance with federal, state, and local requirements.

DHC is a strict anaerobe that requires a negative ORP and dissolved oxygen concentrations less than 1.0 mg/L to survive. Sodium ascorbate is used to create anaerobic conditions by removing dissolved oxygen in preparation for and prior to the injection of TSI-DC. Sodium ascorbate is shipped in 55-pound boxes and shall be stored away from sources of heat in a cool, dry, and ventilated area. Containers and unused contents shall be disposed of at an approved waste disposal facility in accordance with federal, state, and local requirements. Contamination of this product may change the waste management options. Based on vendor recommendations (**Appendix E**), the total quantity of sodium ascorbate required for the pilot test areas, full-scale ISB grid areas, and full-scale biobarrier areas is estimated at 90, 5,140, and 340 pounds, respectively, for the first injection application. The manufacturer's product information sheets are provided in **Appendix E**.

4.3 Phase I - Field Pilot Testing

4.3.1 Basis for Pilot Testing

Previous investigations lacked sufficient information to confirm that the ISB approach would be effective in both the Shallow Zone and the Shallow/Intermediate Zone or across the Site. As a result, the RD includes field pilot testing prior to implementing the full-scale remedy in four designated areas, as shown on **Sheets 01C301** and **01C302** in **Appendix A**. These areas are selected to establish design parameters for the ISB remedy that account for variability. The pilot tests will be conducted to determine:

- The efficacy of ISB (particularly for VOCs) under varying bio-geochemical conditions, such as high dissolved oxygen (DO)/oxidation-reduction potential (ORP) in the Shallow Zone and lower DO/ORP in the Shallow/Intermediate Zone. The efficacy of ISB will also be tested across a range

of pH values, considering the site-wide pH values range from as low as 4.6 at 47WW13/47WW33 to as high as 13.0 at 47WW36.

- The efficacy of ISB across different lithological layers will be evaluated. These variations include the contaminant distribution in the Shallow Zone and Shallow/Intermediate Zone, which consists of layers of silty sand of varying thickness embedded within a shallow subsurface layer composed of clay.
- The means and methods for effectively delivering amendments into the depth intervals, considering the highest levels of contamination are present in both the Shallow Zone and Shallow/Intermediate Zone.
- The influence of hydrogeologic parameters on amendment injection spacing and the potential need for an injection/recirculation delivery method.

All four pilot tests will be conducted during Phase I of the RA and are anticipated to be completed in 18 to 24 months. ISB Pilot Test Area 1, located adjacent to the ISTD Areas, will be initiated after subsurface temperatures decline to levels suitable for effective bioremediation. Following the ERH shutdown, temperature monitoring will be conducted at monitoring well PMW-01 to evaluate thermal dissipation. ISB pilot test activities will be initiated once the temperatures at PMW-01 cool to $\leq 30\text{--}35^{\circ}\text{C}$ ($86\text{--}95^{\circ}\text{F}$), the range in which bioremediation processes and microbial cultures can function effectively. This delay is necessary to prevent temperatures from adversely affecting the bioremediation injectant or microbial activity.

4.3.2 Pilot Field Test Area Selection

The ISB field pilot test locations were selected based on the groundwater data from the PDI (HDR, 2024 and 2025). Available soil boring logs and monitoring well completion logs, provided in **Appendix D**, were evaluated to develop design parameters for each pilot test. A brief rationale for selecting each of the pilot test areas is provided below:

- ISB Pilot Test Area 1: ISB Pilot Test Area 1 (refer to **Sheet 01C301 of Appendix A**) is located downgradient of Building 46-A, adjacent to Building 49-B within the northern VOC plume, surrounding wells 47WW52 and 47WW53, which exhibit TCE concentrations of 1,610 $\mu\text{g/L}$ and 1,040 $\mu\text{g/L}$, respectively. This area represents both the Shallow and Shallow/Intermediate groundwater contamination zones. The pilot test will evaluate differences in substrate distribution between these two geological units and assess how varying biogeochemical conditions influence contaminant degradation. The pilot will also help confirm the radius of influence in both zones.
- As this location is near the ISTD treatment area, ISB implementation will occur only after subsurface temperatures decline to $\leq 30\text{--}35^{\circ}\text{C}$ ($86\text{--}95^{\circ}\text{F}$), the optimal temperature range for microbial viability. Pilot results, combined with ISTD performance data, will refine the full-scale footprint for ISB Grid Areas 1S and 1SI.
- ISB Pilot Test Area 2: ISB Pilot Test Area 2 (refer to **Sheet 01C301 of Appendix A**) is located within the northern VOC plume and targets an area inside the LHAAP-47 boundary, surrounding wells 47WW09 and LHSMW43R, which exhibit estimated TCE concentrations of 1,230 $\mu\text{g/L}$ and 2,970 $\mu\text{g/L}$, respectively. LHSMW43R also exhibits a perchlorate concentration of 91 $\mu\text{g/L}$. This area represents Shallow/Intermediate Zone groundwater with elevated VOC and perchlorate concentrations.

- This pilot test will help determine the ISB substrate distribution behavior in the presence of perchlorate co-contamination and evaluate impacts on electron donor demand, geochemical conditions, and perchlorate degradation pathways.
- ISB Pilot Test Area 3: ISB Pilot Test Area 3 (refer to **Sheet 01C302 of Appendix A**) is located along the eastern LHAAP-47 boundary where an ISB biobarrier is proposed for plume containment. The proposed location is hydraulically downgradient of well LHSMW56R, which exhibits an estimated TCE concentration of 5,190 µg/L, exceeding the EPA maximum contaminant level of 5 µg/L. This area represents Shallow/Intermediate Zone groundwater contamination at the leading edge of the southern VOC plume. Pilot Test Area 3 specifically supports the evaluation of permanent-well injection performance, substrate distribution, and potential need for groundwater extraction/recirculation during full-scale implementation.
- ISB Pilot Test Area 4: ISB Pilot Test Area 4 (refer to **Sheet 01C302 of Appendix A**) is located within the southern VOC plume, targeting an area outside of LHAAP-47 boundary surrounding well 47WW58 which exhibits an estimated TCE concentration of 1,890 µg/L. This area represents Shallow Zone groundwater with elevated VOC concentrations near Goose Prairie Creek. This pilot test will assess how biogeochemical conditions influence contaminant degradation in the portion of the plume.

This test will assess amendment distribution under shallow groundwater conditions near creek influences and evaluate biogeochemical responses in the southern plume.

4.3.3 Pilot Test Injection Plan

Each of the four ISB pilot tests will be implemented during Phase I to evaluate the effectiveness of substrate delivery, confirm the radius of influence (ROI), assess biogeochemical responses within the treatment zones, and validate key design assumptions required for full-scale ISB implementation. The pilot testing program is expected to require approximately 18 to 24 months to complete and will provide the design basis for refining substrate dosing, injection spacing, monitoring well placement, and amendment delivery methods for the Phase II remedy.

The injection approach for the pilot tests is designed to evaluate the performance of ISB under the range of hydrogeologic and contaminant conditions present across the Site. Substrate will primarily be delivered using temporary DPT injection points in Pilot Areas 1, 2, and 4. In Pilot Area 3, permanent injection wells will be installed to evaluate the biobarrier configuration and to assess whether permanent infrastructure improves substrate distribution at the leading edge of the plume. Injection intervals will target the Shallow Zone and Shallow/Intermediate Zone in accordance with the injection depths presented in **Table 4-1**. A Detailed approach for substrate injection is provided in **Section 4.2.1**.

Below is a summary of the pilot test injection points and associated performance monitoring wells:

- Pilot Test Area 1: Up to nine temporary DPT injection points installed to a maximum depth of ~40 feet. One new Shallow Zone monitoring well (PMW-01) will be installed. Performance monitoring will use PMW-01 and existing wells: 47WW24, 47WW52, 47WW51, 47WW53, 47WW54, 47WW55, and 47WW56.
- Pilot Test Area 2: Up to nine DPT injection points installed to a maximum depth of 38 feet. Four new monitoring wells (PMW-02 through PMW-05) will be installed. Existing wells 47WW09 and LHSMW43R will also be used for performance monitoring.

- Pilot Test Area 3: Up to five permanent injection wells installed to a maximum depth of ~40 feet to evaluate the biobarrier configuration. Performance monitoring will use five new monitoring wells (PMW-06 through PMW-09 and upgradient well, PMW-27).
- Pilot Test Area 4: Up to 24 temporary DPT injection points installed to a maximum depth of ~25 feet. Performance monitoring will use five new monitoring wells (PMW-10 through PMW-14) and existing well 47WW58.

A top-down injection method will be used to promote uniform distribution of the substrate throughout the vertical injection interval and to minimize the development of preferential pathways. Injection pressures will be maintained at relatively low levels, generally up to approximately 200 psi, to prevent hydraulic fracturing of the formation or unintended amendment migration. In Pilot Area 3, groundwater extraction and recirculation may be incorporated, if needed, to enhance the delivery and distribution of substrate away from injection wells. Following the injection, chase water will be used to flush the well screens and minimize biological fouling.

4.3.4 Installation and Sampling of Monitoring Wells

A network of new performance monitoring wells will be installed as part of Phase I to support both pilot test evaluations and subsequent full-scale design refinement. These wells are required to characterize pre-injection baseline conditions, monitor amendment distribution, evaluate geochemical changes, and assess concentrations of COCs and their degradation products.

In addition to the performance monitoring wells described in **Section 4.3.3**, a total of twelve (12) Shallow/Intermediate Zone monitoring wells (herein referred to as the Phase I investigation wells) will also be installed along the northern LHAAP-47 boundary and in the northeastern and eastern areas outside the boundary, as shown on **Sheet 01C100** in **Appendix A**. These wells supplement the existing monitoring network and provide the additional data necessary to optimize the design of the full-scale biobarrier and northern full-scale treatment areas. All monitoring wells will be installed in accordance with the procedures described in Section 3.2, Task 2 – Monitoring Well/Compliance Well Installation, and SOP A7 – Monitoring Well Installation, of Appendix A of the IWWP (Bhate, 2018).

A single baseline groundwater sampling event, as listed in **Table 4-4**, will be performed following installation of all Phase I wells (i.e., the pilot test performance wells plus the additional Phase I investigation wells listed in **Table 4-10**). This sampling will characterize concentrations of COCs, geochemical indicators, and site-specific parameters required for Phase I evaluation. Groundwater results from the pilot test performance wells will be compared to post-injection monitoring results to evaluate ISB performance, as described in **Table 4-5**. These wells will also serve as part of the long-term monitoring network for MNA and LTM, as presented in **Section 4.5**.

4.3.5 Pilot Test Performance Monitoring

Performance monitoring during the pilot tests is designed to evaluate substrate distribution, confirm that the intended ROIs have been achieved, and assess the initial biological and geochemical response to amendment addition. Monitoring will focus on changes in dissolved oxygen, oxidation–reduction potential, pH, alkalinity, and other parameters that indicate successful establishment of reducing conditions required for ISB. Monitoring will also include measurement of contaminant concentrations and their degradation products to evaluate reductions in perchlorate, TCE, and site-specific VOCs, as well as formation of intermediate products such as DCE and VC. The monitoring program will assess how lithologic variability between the Shallow Zone and Shallow/Intermediate

Zone influences amendment distribution and evaluate the effect of site-specific geochemical conditions, including variable pH and high dissolved oxygen in portions of the Shallow Zone.

Pilot test monitoring will include a baseline sampling event prior to substrate injection, as summarized in **Table 4-4** and **Section 4.3.4**. Shortly after substrate injection, up to two performance sampling events will be conducted within the first two months to evaluate early distribution of the amendment and the immediate geochemical response, as summarized in **Table 4-5**. Quarterly sampling will be conducted for Years 1 and 2 to evaluate longer-term contaminant reductions, substrate utilization, and sustain biogeochemical changes consistent with effective ISB treatment. The quarterly events are consistent with the early-phase performance monitoring requirements described for Years 1 and 2 of full-scale ISB implementation.

4.3.6 Pilot Testing Reporting

The data generated during Phase I will be used to refine injection spacing, optimize well configuration, and determine substrate dosing requirements for the Phase II full-scale ISB remedy. The results will also inform monitoring frequency, well placement, and performance metrics for the early years of full-scale ISB operation. Upon completion of the pilot tests, a comprehensive Field Pilot Test Report will be prepared summarizing implementation methods, monitoring results, observed performance trends, and recommendations for full-scale ISB deployment.

4.4 Phase II - Full-Scale ISB

Following completion of Phase I pilot testing, the full-scale ISB remedy will be implemented across the Site using the design parameters, injection spacing, radii of influence, and geochemical responses confirmed during Phase I. The full-scale ISB system consists of two coordinated treatment components:

- ISB Grid configuration for the areas with perchlorate concentrations exceeding 20,000 µg/L and/or total VOCs concentrations that are present at concentrations greater than 1,000 µg/L but below 10,000 µg/L; and,
- ISB biobarriers to control plume migration at the leading edges of dissolved phase VOC and perchlorate plumes.

The full-scale design reflects the hydrogeologic conceptual model developed from historical investigations and updated groundwater plume delineation from the PDI. Contaminant impacts occur within both the Shallow Zone and the Shallow/Intermediate Zone, and both zones are influenced by the spatial heterogeneity of the subsurface. Variability in water levels, localized perched groundwater, and discontinuities in clay units affect hydraulic connectivity and influence the distribution of amendments. In the Shallow Zone, groundwater flow generally trends to the northeast; however, the presence of discontinuous low permeability layers have created isolated areas of shallow saturation and higher contaminant concentrations. These conditions support the use of grid based ISB treatment in the Shallow Zone. In contrast, the Shallow/Intermediate Zone exhibits more consistent saturation, making it suitable for both grid based treatment and biobarrier placement. The relevant features of the Site hydrogeologic conceptual model that influence full-scale ISB design include the following:

- ISB grid areas are present in both the Shallow and Shallow/Intermediate Zones where perchlorate and/or VOC concentrations exceed the applicable concentration criteria. The grid design accounts for spatial variability in plume migration, hydraulic gradients, hydraulic conductivities, and soil heterogeneity, all of which influence hydraulic connectivity between the two zones. Target

areas for ISB grids in the Shallow/Intermediate Zone were conservatively delineated and may be refined upon completion of the pilot tests.

- Groundwater flow in the Shallow Zone generally trends northeast across LHAAP-47; however, subsurface heterogeneity results in variable groundwater levels within this zone. For example, some wells were observed to be dry or contain less than 2 feet of water. In contrast, others exhibited anomalously high water levels due to a discontinuous clay unit identified during previous investigations. These conditions indicate the presence of perched groundwater and localized contamination. Accordingly, ISB injections using a grid configuration are proposed for the Shallow Zone, while ISB biobarriers are proposed for the Shallow/Intermediate Zone.
- ISB biobarrier placement within the Shallow/Intermediate Zone is proposed primarily at the leading edges of the southern VOC plume and along the eastern and northern boundaries of the southern perchlorate plume. These barriers intend to prevent further migration of contaminants outside the LHAAP-47 boundary or further into the Site interior, including areas near Goose Prairie Creek. The lower-concentration portion of the northern VOC plume will be managed through MNA with performance monitoring to ensure plume stability.
- The placement of ISB biobarriers was refined from the 2022 ROD based on updated groundwater contours developed during the PDI. In particular, flow patterns near Building 25-C indicate that groundwater is migrating away from Goose Prairie Creek rather than toward it, requiring adjustments to the originally proposed southern barrier alignment. The refined biobarrier locations better reflect plume stability, potential migration pathways, and the need to prevent further movement of contamination both within and outside the LHAAP-47 boundary.

The following subsections describe the design of the ISB grid areas and the ISB biobarriers for full-scale implementation.

4.4.1 ISB Grid Area Design

Target areas for ISB grid-based injections include locations both within and outside the LHAAP-47 boundary where groundwater impacts occur in the Shallow Zone and the Shallow/Intermediate Zone, as shown on **Sheet 02C100** in **Appendix A**. These grid areas were delineated using analytical data and groundwater contours developed during the final PDI (HDR, 2024), with boundaries based on isoconcentration lines for total VOCs between 1,000 and 10,000 µg/L and perchlorate concentrations greater than 20,000 µg/L. Where individual wells exhibiting elevated VOC concentrations, such as LHSMW56R, 47WW34, and 47WW45, were located along the apparent centerline of a plume, their areas of influence were merged to form larger, contiguous ISB grid areas.

In total, the delineated grids encompass approximately 33.1 acres (**Sheets 02C100** through **02C102** and **02C104** through **02C108** in **Appendix A**). Because monitoring well density in several grid areas is limited, site-specific injection depths could not be defined for subareas. To ensure conservative coverage, a uniform treatment approach was applied: the Shallow Zone was assigned an estimated saturated thickness of 10 feet. In comparison, the Shallow/Intermediate Zone was assigned to a saturated thickness of 20 feet. These treatment intervals were derived from lithologic and hydrogeologic interpretations, including saturated thickness data from earlier investigations and groundwater analytical results from the 2024 and 2025 PDI datasets.

A total of nine ISB grids will be implemented to address the target VOC and perchlorate concentrations inside and outside the LHAAP-47 boundary. Full-scale ISB activities in the western portion of the Site will be coordinated with ERH operations near Building 46-A. Because ERH is expected to reduce VOC

concentrations in this area substantially, the ISB footprint for Grid Areas 1S and 1SI may be reduced during implementation.

Grid construction will utilize DPT injection points spaced approximately 13 feet apart in the Shallow Zone and 27 feet apart in the Shallow/Intermediate Zone, resulting in approximately 3,797 total injection points covering roughly 1,466,000 square feet (refer to **Sheets 02C101 through 02C102 and 02C104 through 02C108 in Appendix A**). The grids include:

Shallow Zone Grids (3 areas)

- Grid Area 1S (**Sheet 02C101 in Appendix A**): Targets Shallow Zone VOC contamination in the western portion of the boundary downgradient of Building 46-A. This area overlaps ISB Area 1SI and ISTD Areas 1 and 2, encompassing ~167,000 square feet.
- Grid Area 2S (**Sheet 02C102 in Appendix A**): Targets Shallow Zone VOC contamination in the northern VOC plume near well LHSMW45, covering ~123,000 square feet.
- Grid Area 3S (**Sheet 02C105 in Appendix A**): Targets Shallow Zone contamination outside the boundary near well 47WW58, covering ~103,000 square feet. This area lies across Goose Prairie Creek and overlaps Grid Area 6SI.

Shallow/Intermediate Zone Grids (6 areas)

- Grid Area 1SI (**Sheet 02C101 in Appendix A**): Addresses VOC contamination in the western portion of the boundary downgradient of Building 46-A, where the highest TCE concentrations have been detected. It overlaps Grid Area 1S and ISTD Area 2 and cover ~181,000 square feet.
- Grid Area 2SI (**Sheet 02C108 in Appendix A**): Addresses perchlorate contamination in the southern perchlorate plume, covering ~36,000 square feet.
- Grid Area 3SI (**Sheet 02C102 in Appendix A**): Addresses combined perchlorate and VOC impacts in the northern plumes, covering ~94,000 square feet.
- Grid Areas 4SI, 5SI, 6SI (**Sheets 02C104 through 02C107 in Appendix A**): Address VOC contamination within and outside the boundary across the southern plume and collectively encompass ~762,000 square feet. Areas 5SI and 6SI extend across Goose Prairie Creek, and Area 6SI overlaps Grid Area 3S.

Table 4-2 presents groundwater perchlorate and TCE concentrations within each grid area, along with the delineated areal extents and treatment depths. Across all grids, the ISB remedy will target between 10 and 20 feet of saturated thickness to a maximum depth of 60 feet bgs, based on the observed vertical distribution of contaminants in adjacent monitoring wells.

4.4.2 ISB Biobarrier Design

The full-scale ISB plume containment system includes three ISB biobarriers, two within the LHAAP47 boundary and one outside the boundary, installed exclusively in the Shallow/Intermediate Zone (refer to **Sheet 02C100 in Appendix A**). All biobarriers consist of amendment injection points spaced approximately 27 feet apart, corresponding to an estimated radius of influence of 13.5 feet for both temporary and permanent injection infrastructure. Depending on site conditions and the projected need for repeated injections, amendment delivery will occur through either permanent injection wells or temporary DPT points.

Collectively, the biobarriers span approximately 3,000 linear feet and incorporate roughly 109 injection points. Individual barrier alignments are described below:

- ISB Biobarrier 1 (**Sheets 02C106 and 02C107 in Appendix A**): A continuous ~1,200-foot barrier constructed along the eastern boundary of LHAAP47. This barrier transects the southern VOC plume. Its alignment follows the Goose Prairie Creek near the southern LHAAP-47 boundary.
- ISB Biobarrier 2 (**Sheet 02C104 in Appendix A**): A ~1,000-foot barrier located outside the LHAAP47 boundary, transecting the leading edge of the southern VOC plume across Goose Prairie Creek.
- ISB Biobarrier 3 (**Sheet 02C108 in Appendix A**): A ~800-foot barrier installed within the boundary along the eastern and northern edge of the southern perchlorate plume to prevent further intrusion of contaminants into the Site.

As shown on **Sheets 02C104 and 02C106 through 02C108 in Appendix A**, injection depths vary by biobarrier based on contaminant distributions and geologic conditions. **Table 4-3** summarizes the length, perchlorate, and TCE concentrations, and targeted injection intervals for each biobarrier.

4.4.3 ISB Performance Monitoring

ISB performance monitoring during Phase II will evaluate the effectiveness of ISB injections, characterize geochemical trends, and document contaminant degradation within and outside the active ISB treatment areas. Active ISB areas are defined as locations where amendments are directly injected during full-scale implementation, including all ISB grid areas and ISB biobarriers where substrate, buffer, and/or bioaugmentation cultures are applied. Monitoring efforts will assess both the immediate response to amendment delivery and the long-term behavior of the plumes. Monitoring within the active ISB areas will focus on geochemical indicators (e.g., DO, ORP, pH, alkalinity) and contaminant concentrations, including degradation products. Monitoring outside the active treatment footprint will be used to ensure that plume migration is not occurring as a consequence of ISB implementation.

Short-term performance monitoring will occur within the first 2 months after injection to evaluate amendment distribution and initial geochemical change in both the Shallow and Shallow/Intermediate Zones.

4.4.3.1 Pre-ISB Implementation Groundwater Sampling

The pre-ISB implementation groundwater sampling for the full-scale ISB areas will be performed as a single, comprehensive event to characterize existing COC concentrations and to establish baseline geochemical conditions in both the Shallow Zone and the Shallow/Intermediate Zone. This sampling will occur after completion of the Phase I RA and before the start of full-scale ISB implementation to ensure that representative pre-injection conditions are fully documented. The sampling network will include wells located upgradient, within, and downgradient of the planned ISB Grid and Biobarrier areas to capture spatial variability across the treatment zones and provide a robust understanding of baseline groundwater quality.

As described in **Section 4.3.4**, twelve (12) newly installed Shallow/Intermediate Zone monitoring wells will be incorporated into this pre-implementation event as listed in **Table 4-10**. These wells were specifically added to strengthen the monitoring network. They will serve a dual purpose, providing critical baseline information for ISB design optimization and supporting future MNA/LTM performance

evaluations. Data from these new wells will enhance the spatial resolution of baseline conditions and ensure that migration pathways and plume boundaries are adequately characterized.

The results of the pre-ISB sampling event will be used to refine and optimize the final placement of DPT injection points for the ISB biobarrier system, ensuring that injection locations effectively target zones of elevated contamination and align with the most current groundwater conditions. In addition, the pre-injection baseline dataset will form the benchmark for evaluating changes in groundwater chemistry and contaminant concentrations following substrate emplacement. Comparisons between baseline and post-injection monitoring results will be used to assess the performance and effectiveness of the full-scale ISB remedy. The baseline sampling plan, including the list of monitoring locations and analyte requirements for ISB grid areas and ISB biobarriers, is summarized in **Tables 4-6** and **4-7**.

4.4.3.2 Post-injection Performance Monitoring

Within the first two months after the full-scale ISB remedy implementation, groundwater data will be collected from the various monitoring points in and around the treatment areas to evaluate the effectiveness of injectate distribution and the occurrence of geochemical changes. Up to two sets of groundwater samples will be collected before the first quarterly sampling is implemented. The ISB performance monitoring plans for each of the ISB grid areas and ISB biobarriers are presented in **Tables 4-8** and **4-9**. These tables present the proposed monitoring locations along with the rationale for the selection of each monitoring location.

Performance monitoring in Years 1 and 2 will be conducted in accordance with the monitoring plans summarized in **Tables 4-8** and **4-9**. These tables present the proposed monitoring locations along with the rationale for the selection of each monitoring location. After each monitoring round, the data will be reviewed to evaluate progress towards attainment of remedial action objectives/cleanup levels. Optimization/changes of the monitoring plans will be conducted as warranted by the results of the data reviews. The optimizations/changes will be presented to the regulatory agencies prior to implementation.

4.5 MNA Performance Monitoring

MNA is a component of the selected remedy for LHAAP-47 and is intended to reduce contaminant concentrations and restore groundwater to its potential beneficial use where practicable. A preliminary evaluation of natural attenuation (NA) processes for TCE and perchlorate in both the Shallow and Shallow/Intermediate Zones was previously performed (Shaw, 2011). This evaluation provided important insight into the concentration ranges at which active treatment may be transitioned to MNA. It demonstrated the need to ensure that ongoing degradation processes continue to protect surface water in Goose Prairie Creek from impacts that could cause exceedances of surface water standards for COCs and their degradation products.

A total of 48 new groundwater monitoring wells is installed for performance monitoring and/or long-term MNA/LTM monitoring. Of these 48 wells, 17 new wells, along with eleven existing wells, comprise the monitoring network to be used for implementing MNA across the Site. The MNA monitoring plan covering both the Shallow and Shallow/Intermediate Zones is presented in **Table 4-10** and shown on the Design Drawings (**Sheet 04C100** with 6 monitoring wells and **04C101** with 23 monitoring well in **Appendix A**). As specified in the ROD, MNA performance will be evaluated using data from eight quarters of monitoring in combination with historical groundwater data to determine whether natural physical, chemical, and biological processes are effectively reducing contaminant concentrations.

The following performance objectives will be used after two years of monitoring to evaluate MNA effectiveness:

Plume stability: Contaminant concentrations must be decreasing in the majority of performance wells, and plume area must remain stable or be contracted as demonstrated by compliance wells.

MNA potential: Evaluation will include biodegradation screening scores based on USEPA guidance.

MNA process evaluation: Attenuation rates will be calculated using empirical monitoring data, and process demonstration will rely on evidence of degradation, including daughter products and bacterial culture counts.

Longterm MNA performance monitoring will occur semiannually for the first three years following establishment of the baseline, and annually thereafter until the next Five-Year Review. Monitoring will continue at this frequency through subsequent review cycles until groundwater concentrations meet cleanup levels throughout the Site.

4.5.1.1 Contingency Action for MNA Areas

As required by the 2022 ROD, a contingency remedy will be implemented for any passive MNA areas, defined as areas outside active ISB treatment zones, if MNA performance does not meet the required performance objectives defined above. The contingency remedy consists of an additional application of ISB using temporary injection points to address the deficiencies identified in the MNA evaluation. The scope and extent of the contingency remedy will be determined based on the magnitude of deviation from the MNA performance criteria and the specific locations exhibiting such deviations. Any contingency action implemented will be documented in an Explanation of Significant Differences (ESD).

4.5.1.2 Follow-up Injections in Biobarriers

As specified in the 2022 ROD, follow-up injections for the biobarriers using injection wells will be implemented based on ISB performance groundwater monitoring results. The EVO for the grid areas and biobarriers is specified to last between 3 and 5 years. Nonetheless, the decision for reapplication of organic carbon will be made based on groundwater monitoring results. Three criteria for determining the need to be reinjected are:

- Depletion of organic carbon to below 20 mg/L;
- ORP increases above -50 mV; or
- Contaminant concentrations in groundwater downgradient of ISB Shallow Zone Biobarriers 1, 2, and in surface water remain above the cleanup standards.

If any of these conditions occur, then reinjection of organic carbon will be conducted, but only in those specific areas that meet any of the above criteria.

4.6 Surface Water Monitoring

Surface water monitoring will be conducted to confirm that surface water standards for the contaminants and by-product contaminants are not exceeded in Goose Prairie Creek, which flows into Caddo Lake. The surface water sampling events will be conducted concurrently with the groundwater sampling events for performance monitoring. If surface water samples could not be collected from Goose Prairie Creek during the quarterly sampling events, samples from Goose Prairie Creek would be collected outside the routine quarterly sampling events following significant rain events. The goal is to collect four surface water samples every monitoring year.

During each monitoring round, surface water samples will be collected at eight locations in Goose Prairie Creek: upgradient, downgradient, and immediately adjacent to LHAAP-47 (**Sheet 02C100 in Appendix A**). Surface water samples will be collected following the protocols included in Section 3.7 of the IWWP for LHAAP (Bhate, 2018). These surface water samples will be analyzed for the COCs. The sample concentrations will be compared to the Texas surface water quality standards outlined in 30 TAC 307.6(d)(1) or if those standards are not available, the TRRP Tier 1 Residential Groundwater PCLs will be used for TCE (5 µg/L), PCE (5 µg/L), 1,2-DCA (5 µg/L), 1,1-DCE (7 µg/L), chloroform (70 µg/L), and VC (0.23 µg/L) for LHAAP-47 as per the 2022 ROD. Monitoring of the surface water may include visual inspection, field measurements such as dissolved oxygen, conductivity, turbidity, pH, ORP, and temperature, and/or water sample analysis specific to the COCs and injection solution.

Surface water samples are collected for the purpose of evaluating potential impacts from groundwater COC. Therefore, at these locations and during surface water sampling, the groundwater elevations in wells PMW-35, PMW-34, PMW-30, and 47WW04 will be gauged and compared to the bottom elevation of the creek to determine whether there is groundwater contribution to surface water.

4.7 Long-Term Monitoring – Year 3 through Five-Year Review

If MNA is determined to be effective based on the first two years of performance monitoring data, LTM will be initiated. Per the 2022 ROD, LTM will be implemented at a semiannual frequency for three years, then annually until recommended otherwise by the Five-Year Review or during other periodic updates to the LTM planning documents and with concurrence of EPA and TCEQ. For LTM, the performance monitoring plan presented in **Table 4-10** will be modified as appropriate based on the review of the first two years of data.

If MNA is found to be ineffective, a contingency remedy will be implemented to include the application of bio-amendments to address the ineffective aspects of MNA. If the bio-amendments are reapplied, the ISB and MNA performance monitoring plans presented in the above sections, and the frequency of monitoring will be modified as appropriate based on the review of the first two years of data.

The selected remedy in the 2022 ROD indicates that monitoring for metals will be evaluated at the first Five-Year Review to determine if any further monitoring for metals is warranted. As part of the next Five-Year Review after remedy implementation, groundwater samples will be collected. All the wells listed in **Table 4-10** will also be analyzed for TAL metals. 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 Five-Year Review report.

4.7.1 Performance Monitoring Following Five-Year Review

Per the 2022 ROD, the results from performance monitoring will be reviewed during the Five-Year Review. Unless otherwise indicated by the data, the well locations will then be sampled during each Five-Year Review and with concurrence of EPA and TCEQ.

5 LAND USE CONTROLS REMEDIAL DESIGN

This section describes the LUCs RD for LHAAP-47. In accordance with the 2022 ROD, the LUCs RD will be finalized as the land use component of the RD. Per the 2022 ROD, LUCs' performance objectives are to:

- Preventing the use of groundwater above cleanup levels for potable water use.
- Maintaining the integrity of any current or future remedial or monitoring systems.

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

For portions of the Site subject to LUCs that have been transferred out of U.S. Army control, the U.S. Army will monitor and report on the implementation, maintenance, and enforcement of LUCs, and coordinate with federal, state, and local governments and owners and occupants of properties subject to LUCs. The Army remains responsible for ensuring that the remedy remains protective of human health and the environment. The Army will fulfill its responsibility and obligations under CERCLA and the NCP as it implements, maintains, and reviews the selected remedy.

5.1 LUCs Implementation

The actions required to implement the LUCs for LHAAP-47 are described below. The first of these, the initial notice of LUCs, was completed, and a figure depicting the preliminary LUC boundaries as presented in the 2022 ROD is provided as ROD **Figure 2-11** of **Appendix C**. The following actions either were completed or will be undertaken to implement the LUCs for LHAAP-47:

- Provide subsequent notice of the LUCs before remedial action is implemented.
- Develop the initial deed notice of the groundwater and soil (surface and subsurface) contamination and any land use restrictions referenced in the 2022 ROD. The deed notice will consist of a brief description of the contaminants present in groundwater and soil, a written description of the LUCs, and a figure depicting the preliminary LUCs boundaries presented in ROD **Figure 2-11** of **Appendix C**.
- 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 were transmitted within 90 days of ROD signature, September 6, 2023. The notices were sent to federal, state, and local officials, including U.S. Senator Ted Cruz, U.S. Senator John Cornyn, U.S. Congressman Louie Gohmert, State Senator Bryan Hughes, Harrison County Judge Chad Sims, Harrison County Commissioner Precinct 1 William D. Hatfield, and City of Uncertain Mayor Sam Canup. Notice was also sent to the Caddo Lake National Wildlife Refuge Manager Erik Duerkop, the Leigh Water Supply Corporation Board of Directors, and the Caddo Lake Water Supply Corporation Board of Directors.
- Finalize the boundaries for the LUCs after the additional investigation is completed as part of Phase I of the remedial action. The finalized LUCs boundary will be recorded with the County as part of the remedial action.

- Revise the boundaries if necessary. The LUCs boundary presented in this RD is subject to change as the limits of groundwater contamination are not well defined outside the LHAAP-47 boundary area. 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); and to notify well drillers of groundwater use prohibition and the remedial or monitoring system LUCs (maintain the integrity of any current or future remedial or monitoring systems); will be reviewed during remedial action 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 TCEQ pursuant to the FFA, and a State-licensed surveyor will survey the LUCs boundaries. A legal description of the areas surveyed will be appended to the survey plat.
- Record the LUCs in Harrison County. The LUCs plat, legal description, and LUCs restriction language will be recorded in the Harrison County Courthouse in accordance with TAC Title 30, §335.565.
- Notify the Texas Department of Licensing and Regulation of the groundwater LUCs. The Texas Department of Licensing and Regulation will be notified of the groundwater restrictions, which include the prohibition of water well installation for any purpose other than environmental monitoring and testing without prior approval from the U.S. Army, the USEPA, and the TCEQ. The survey plat, legal boundary, and description of the groundwater restriction of LUCs, in conjunction with a locator map, will be provided in hard and electronic copies.

5.2 Maintenance and Monitoring Requirements

The LUCs will be maintained in place as follows:

- The LUCs restricting the use of groundwater to environmental monitoring and testing will only remain in place until the levels of COCs (i.e., including contaminants found at the Site at cleanup levels as listed in the 2022 ROD) in groundwater allow for unlimited use and unrestricted exposure.
- The LUCs to maintain the integrity of any current or future remedial or monitoring systems will remain in place until groundwater cleanup levels of COCs (i.e., including all contaminants found at the Site at cleanup levels as listed in the 2022 ROD) are met; and,
- The LUCs prohibiting groundwater use (except for environmental monitoring and testing) as a potable source will remain in place until the levels of COCs (i.e., all contaminants found at the Site at cleanup levels as listed in the 2022 ROD) in soil and groundwater allow for unlimited use and unrestricted exposure.

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

- Annual field inspections of the Site to confirm that no violations of the LUCs have occurred. Documentation of the inspection will be included in the Inspection and Maintenance Checklist (provided in **Appendix F**).

- Annual certifications that no LUC-restricted activities have been authorized, and that site conditions and use are consistent with the LUCs. (The Certification Form is provided in the Draft Final RD submittal.
- Periodic transmittal of a LUCs Notice to federal, state, and local authorities, and to owners and occupants of LHAAP-47. The notice will include the groundwater and soil (surface and subsurface) contamination and any land use restrictions referenced in the 2022 ROD, a written description of the LUCs, and a figure depicting the LUCs' boundaries. The transmittal will coincide with each Five-Year Review and will be documented in the report.
- The final LUCs RD appendix of the RACR will be added to the Comprehensive LUCs Management Plan, and the plan will be provided to the owner or occupant of LHAAP-47.

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

5.3 Reporting of LUCs Inspection and Monitoring

Beginning with the finalization of this RD and approval of the Inspection and Maintenance forms and the Annual Certification Form, the U.S. Army will undertake inspections and certify continued compliance with the LUC's objectives. The U.S. Army, or the transferee after transfer, will retain the LUCs Inspection and Certification documents in the project files for incorporation into the five-year review reports, and these documents will be made available to USEPA and TCEQ upon request. In addition, should any violations be found during the certification, the U.S. Army will provide to USEPA and TCEQ, along with the document, a separate written explanation indicating the specific violations found and what efforts or measures have or will be taken to correct those violations. The need to continue inspections and certifications will be revisited at five-year reviews. COCs that have decreased to concentrations below cleanup levels, or are non-detect, or only detected sporadically below cleanup levels, or consistent with background, will be removed from the monitoring program after review by the U.S. Army, USEPA, and TCEQ.

5.3.1 Notice of Planned Property Conveyances

Upon transfer of Army-owned property, the Army will provide written notice to the transferee of the LHAAP-47 groundwater and soil (surface and subsurface) contamination and any land use restrictions referenced in the 2022 ROD. Within 15 days of transfer, the U.S. Army will provide written notice to USEPA and TCEQ of the division of implementation, maintenance, and enforcement responsibilities unless the information has already been provided in the LUCs RD. The notice will describe the mechanism by which the LUC will continue to be implemented, maintained, inspected, reported, and enforced. Upon transfer, such responsibilities may shift to the transferee via appropriate provisions placed in the Environmental Condition of Property (ECP) or other environmental document for transfer. Although the US Army may transfer responsibility for various implementation actions, the U.S. Army will also retain ultimate responsibility for the remedy integrity. This means that the U.S. Army is responsible for addressing substantive violations of the LUCs performance objectives that would undermine the U.S. Army's CERCLA remedy. The US Army will also be responsible for incorporating RD information and outlining the transferee's LUCs obligations into property transfer documentation. In the event property is transferred out of Federal control, the LUCs relating to property and groundwater restrictions shall be recorded in the deed and shall be enforceable by the United States and the state of Texas.

5.3.2 Opportunity to Review Text of Intended Land Use Controls

The US Army will provide a copy of the groundwater and land use restriction notification to TCEQ for review and approval prior to its recordation in Harrison County. USEPA will also receive a copy for review. The US Army will produce an ECP or other environmental document for the transfer of LHAAP-47. Still, before executing the transfer, the US Army will provide USEPA and TCEQ with a copy of the ECP or other environmental document for transfer so that they may have a reasonable opportunity, before transfer, to review all LUC-related provisions.

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

Should the US Army discover after conveyance of the Site any activity on the property inconsistent with the LUCs performance objectives, the US Army shall notify USEPA and TCEQ within 72 hours of such discovery. Consistent with **Section 5.3.4** below, the US Army will then work with USEPA, TCEQ, and the transferee to correct the problem(s) discovered. This reporting requirement does not preclude the US Army from taking immediate action pursuant to its CERCLA authorities to prevent any perceived risk(s) to human health or the environment.

5.3.4 Land Use Control Enforcement

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

5.3.5 Modification or Termination of Land Use Controls

The LUCs shall remain in effect until the US Army, TCEQ, and USEPA agree that the concentrations of COCs in groundwater have met cleanup levels in groundwater. The surface and subsurface soil concentrations allow unrestricted use. When this occurs, the LUCs will be terminated as needed. The decision to terminate the LUCs will be documented consistently with the NCP process for post-ROD changes, potentially including an ESD or a remedial action complete report. If the property has been transferred and a determination by the US Army, TCEQ, and USEPA has been made to terminate the LUCs, the US Army shall provide to the owner of the property an appropriate release for recordation about the Site and will also timely advise other local stakeholders of the action.

6 REMEDIAL CONSTRUCTION SCHEDULE

This section provides a preliminary schedule for the activities necessary to complete Phases I and II of RD. The Contractor will determine the actual sequence and shall be included in the individual work plan that will be submitted prior to commencing the work.

6.1 Construction Sequence

A preliminary sequence of the activities necessary to implement the RA is provided below. The RA is proposed to be performed in two phases. The contractor shall include the sequence in their RAWP that will be submitted for approval prior to commencing their work.

Remedial action Phase I activities will be completed as follows:

1. Site preparation
 - Locate and mark all underground utilities and verify existing site conditions in the vicinity of the work areas. The contractor shall use a third-party locate service if required.
 - Mobilize equipment and trailers to the site. Set up staging areas.
 - Conduct pre-construction photographic and video documentation.
 - Identify and clearly mark all monitoring wells in the vicinity of the work areas for protection.
 - Set up air monitoring stations.
 - Perform site clearing as needed to access/perform the work.
 - Conduct a preliminary survey using global positioning system equipment.
 - Construct decontamination facilities and a stockpiling area.
 - Set up traffic control.
 - Installation of performance monitoring wells for the ISB field pilot test and additional monitoring wells for LTM and baseline groundwater sampling. Installation of LTM monitoring wells and sampling can be completed concurrently if feasible.
2. Soil excavation and disposal
 - Install erosion control measures.
 - Construct access roads, as required, for soil excavation.
 - Remove impermeable liner and soil cover previously installed in November 1999 and repaired in December 2015.
 - Excavate areas to the primary excavation limits as defined.
 - Visually inspect excavation and field-screen area for VOCs using a PID. If no impacts are observed, collect sidewall and bottom confirmation samples.
 - Based on results, proceed with secondary excavations, if required.
 - If results are less than the cleanup levels, with the approval of the contracting officer's representative, perform backfill and compaction.
 - Following backfill, restore with topsoil and seed.
 - Transport and dispose of contaminated material.

- Demobilize.
 - Remove temporary erosion control measures.
3. ISB field pilot tests
- Clear injection and monitoring well locations are required for conducting all four pilot tests.
 - Mobilize materials, equipment, and labor for installing injection wells and new monitoring wells to be used for performance monitoring.
 - Mobilize materials, equipment, mixing tanks, and labor for injections for the pilot tests.
 - Layout injection locations and clear DPT injection points.
 - Install permanent injection wells for ISB field pilot tests.
 - Core concrete/asphalt at injection points, if needed, and adjust any points if obstructions are found, and push rods to the desired injection interval.
 - Setup amendment, equipment, and materials onsite.
 - Begin preparing the amendment solution for injection a day before planned injections. Preparation of the amendment solution will be a continual activity.
 - Inject amendments following the sequencing described as per Specification Section 02 53 17 ISB Injection Procedures and Monitoring.
 - Record injection intervals and volumes during injections.
 - Once the injection is complete at a DPT injection point, abandon the point.
 - Record injection wells and DPT injection point locations with GPS.
 - Record field measurements from the observation wells following the list provided in Specification Section 02 53 17 - injection procedures and monitoring.
 - Submit a field pilot test report documenting the implementation, findings, results, and recommendations for implementing the full-scale remedy for the full-scale ISB to be implemented in phase II.
4. In-situ thermal desorption for DNAPL treatment:
- Clear areas required for the implementation of the ISTD treatment.
 - Secure power drop.
 - Install construction access roads, as required.
 - Install heater wells, vapor extraction wells, and infrastructure for the ISTD treatment system.
 - Start the ISTD system.
 - Operate the system until the performance goals for the ISTD treatment have been met by completing the verification sampling.
 - Following receipt of verification samples achieving the performance goals and with the approval, decommission the ISTD system.

- Restore the area to pre-existing conditions to the extent practicable following removal and demobilization of all equipment and materials from the site.
- Reinstall monitoring wells.
- Perform two rounds of groundwater sampling.

Remedial action Phase II activities (The contractor to complete the following activities under Phase II RA concurrently).

1. Site preparation and mobilization
2. Full-scale ISB implementation:
 - Provide site clearing.
 - Please see Phase I Section 3 above.
3. Demobilization
4. Conduct performance monitoring.

6.2 Preliminary Schedule

Please see **Figure 6-1** for the preliminary RA schedule.

7 SUMMARY OF PROJECT COSTS

A cost estimate for the proposed RA was developed as part of the RD and provided in **Appendix B**. The total estimated cost is approximately \$44.8 M. Additional investigation data collected in the PDI has resulted in changes to the remedial project, including the larger area requiring remedial treatment. A detailed basis for the cost estimate will be prepared and provided in the Draft Final RD submittal.

8 REFERENCES

Bhate, 2018. Final Installation-Wide Work Plan for Longhorn Army Ammunition Plant, Karnack, Texas. May.

Camp, Dresser & McKee (CDM) Smith, 2018. White Paper on Thermal Remediation Technologies for Treatment of Chlorinated Solvents. Contract No.: De-Em0001128, Delivery Order: De-Dt0003515, July 30.

Environmental Protection Systems, Inc. (EPS), 1984. Longhorn Army Ammunition Plant Contamination Survey. Prepared for Thiokol Corporation/Longhorn Division, and Commander Longhorn Army Ammunition Plant, U.S. Army Toxic and Hazardous Materials Agency. June 1984.

HDR, 2019a. Draft Final Post Screening Investigation Report, LHAAP-47, Longhorn Army Ammunition Plant, Karnack, Texas. March.

HDR, 2019b. Draft Final Addendum Post-Screening Investigation Report for LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production Longhorn Army Ammunition Plant Karnack, Texas. July.

HDR, 2021a. Draft Final Post Screening Investigation Addendum No. 2 Report, LHAAP-47, Longhorn Army Ammunition Plant, Karnack, Texas. January.

HDR, 2021b. Draft Final LHAAP-47 Building 46A, Plant 3 Area, Solid Rocket Motor Fuel Production Feasibility Study Addendum. March.

HDR, 2023. Draft Final Pre-Design Investigation Work Plan, LHAAP-47, Longhorn Army Ammunition Plant, Karnack, Texas. April.

HDR, 2024. Draft Final Pre-Design Investigation Report (approved as Final), LHAAP-47, Longhorn Army Ammunition Plant, Karnack, Texas. February.

HDR, 2025. Draft Final Pre-Design Investigation Report Addendum (approved as Final), LHAAP-47, Longhorn Army Ammunition Plant, Karnack, Texas. August.

Jacobs, 2002. Final Remedial Investigation Report for the Group 4 Sites, Sites 35A, 35B, 35C, 46, 47, 48, 50, 60, and Goose Prairie Creek, Longhorn Army Ammunition Plant, Karnack, Texas, Oak Ridge, Tennessee. January.

Maley, Don, 1988. Potential Hazardous Waste Site Preliminary Assessment, EPA Form 2070- 12, April.

Shaw, 2011. Final Feasibility Study for LHAAP-47, Plant Area 3, Group 4, Longhorn Army Ammunition Plant, Karnack, Harrison County, Texas. July.

Solutions To Environmental Problems, Inc. (STEP), 2005. Final Plant-Wide Perchlorate Investigation for the Longhorn Army Ammunition Plant (LHAAP), Karnack, Texas. Prepared for the U.S. Army Corps of Engineers, Tulsa District. April.

Texas Commission on Environmental Quality (TCEQ), 2006. Updated Examples of Standard No. 2, Appendix II, Medium-Specific Concentrations. March.

U.S. Army & USEPA, 2022. Revised Final Record of Decision for LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production, Longhorn Army Ammunition Plant, Karnack, Texas. June.

U.S. Army Environmental Hygiene Agency (USAEHA), 1987. Final Groundwater Contamination Survey No. 38-26-0851-89, Evaluation of Solid Waste Management Units, Longhorn Army Ammunition Plant, Karnack, Texas, May.

U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), 1980. Installation Assessment of Longhorn Army Ammunition Plant, Report No. 150, February.

U.S. Army, 2004. Memorandum of Agreement Between the Department of the Army and the Department of the Interior for the Interagency Transfer of Lands at the Longhorn Army Ammunition Plant for the Caddo Lake National Wildlife Refuge, Harrison County, Texas, Signed by the Department of the Interior on April 27, 2004, and the U.S. Army on April 29, 2004.

United States Environmental Protection Agency (USEPA), 2015. Engineering Paper. In Situ Thermal Treatment Technologies: Lessons Learned. Office of Superfund Remediation and Technology Innovation (OSRTI).

9 LIST OF ACRONYMS AND ABBREVIATIONS

APP	Accident Prevention Plan
bgs	below ground surface
°C	degrees Celsius
CDFR	Chemical Data Final Report
CDM	Camp, Dresser & McKee
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
COCs	Contaminants of Concern
CSM	Conceptual Site Model
cy	Cubic Yards
DNAPL	Dense Non-aqueous Phase Liquid
DO/ORP	Dissolved Oxygen (DO)/Oxidation-Reduction Potential (ORP)
DPT	Direct Push Technology
ECP	Environmental Condition of Property
EPS	Environmental Protection Systems
ERH	Electrical Resistance Heating
ESD	Explanation of Significant Difference
EVO	emulsified vegetable oil
FS	Feasibility Study
ft	feet
ft bgs	feet below ground surface
GAC	Granular Activated Carbon
GPS	Global Positioning System
GWP-Ind	Medium-Specific Concentration for Industrial Use based on groundwater protection
GWTP	Groundwater Treatment Plant
HASP	Health and Safety Plan
HDR	HDR Environmental, Operations and Construction, Inc.
ID	Identification
ISB	In-Situ Bioremediation
ISTD	In-Situ Thermal Desorption
IWWP	Final Installation-Wide Work Plan for Longhorn Army Ammunition Plant
LHAAP	Longhorn Army Ammunition Plant
LTM	Long-term monitoring
LUCs	Land Use Controls
MCL	Maximum Contaminant Level
MNA	Monitored Natural Attenuation
MOA	Memorandum of Agreement

MSCs	Medium-Specific Concentration
NA	Natural Attenuation
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEC	National Electrical Code
NFPA	National Fire Protection Association
NPL	National Priorities List
OSHA	Occupational Safety and Health Association
PCL	Protective Concentration Levels
PDI	Pre-Design Investigation
PID	Photoionization Detector
PSI	Post-Screening Investigation
QAPP	Quality Assurance Project Plan
RA	Remedial Action
RACR	Remedial Action Completion Report
RAOs	Remedial Action Objectives
RAWP	Remedial Action Work Plan
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
ROD	Record of Decision
ROI	Radius of Influence
SESCs	Soil Erosion and Sediment Controls
SRS®-SD	Slow-Release Substrate
STEP	Solutions to Environmental Problems, Inc.
SVE	Soil Vapor Extraction
TAC	Texas Administrative Code
TCE	trichloroethylene
TCEQ	Texas Commission on Environmental Quality
TRRP	Texas Risk Reduction Program
U.S. Army	U.S. Army Corps of Engineers
USACE	United States Army Corps of Engineers
USAEHA	U.S. Army Environmental Hygiene Agency
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
VC	Vinyl Chloride
VOCs	volatile organic compounds
µg/kg	micrograms per kilograms
µg/L	micrograms per liter



Tables

**Former Longhorn Army
Ammunition Plant (LHAAP)
Site 47**

Karnack, Texas

Table 1-1 Summary of Sampling Events
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Pre-Phase I (Jacobs, 2002)
<i>EPS, 1984</i>
· EPS installed 1 monitoring well and collected a groundwater sample.
Phases I-III (Jacobs, 2002)
<i>USACE, Phase I 1993</i>
· Collected sump content sample for laboratory analysis.
· Completed borings at sump locations and collected soil samples.
<i>USACE, Phase II 1994</i>
· Collected soil samples from monitoring well locations and from ditch and drainage ways.
· Installed monitoring wells and collected groundwater samples from each well.
<i>USACE, Pre-Phase III 1996</i>
· Determined locations for Phase III monitoring wells by delineating plume using site characterization and analysis penetrometer system (8 locations).
<i>Jacobs, Phase III 1998</i>
· Collected soil samples at waste process sump locations.
· Collected surface water and sediment samples.
· Collected soil samples from locations.
· Installed monitoring wells and collected groundwater samples from the new and existing wells.
Remedial Investigation (Jacobs, 2002)
· USACE collected 2 rounds of groundwater samples in 1996 (Jacobs, 2002).
· In 1999 and 2000, collected soil samples for perchlorate and total petroleum hydrocarbons (Jacobs, 2002).
· In 2000, installed and sampled 4 new monitoring wells and collected groundwater samples from existing wells (Jacobs, 2002).
· In 2001, collected groundwater samples for perchlorate (Jacobs, 2002).
· In 2001, collected soil samples for perchlorate investigation (Lynntech, 2001).
· In 2002, collected soil samples as part of the perchlorate investigation (STEP, 2005).
· In 2003, collected groundwater and soil samples at two locations as part of the Phase II Environmental Site Assessment (Plexus, 2005).
· In 2004, installed 4 monitoring wells and collected groundwater samples for VOC analysis (Shaw, 2007b).
· In 2006, collected additional soil samples from select sumps (Shaw, 2007a and 2008)
· In 2007, installed 1 monitoring well and collected samples for natural attenuation evaluation and for geochemistry evaluation.
· In 2008, installed 4 monitoring wells and collected groundwater samples for VOC analysis.
· In 2009, collected additional groundwater samples for VOC analysis.
· In 2010, installed 2 monitoring wells and 18 temporary monitoring wells, collected additional groundwater samples for VOC, perchlorate, metals, SVOC, and MNA analysis, and collected additional soil samples for perchlorate analysis.
Post-Screening Investigation Report (HDR, 2019a)
· Advancement of 11 direct push technology borings (DPT) into the intermediate zone and collection of groundwater grab samples for a combination of analyses that included VOCs, SVOCs, perchlorate, explosives, and/or metals.
· Installation of 24 new or replacement wells and collection of groundwater samples for a combination of analyses that included VOCs, SVOCs, perchlorate, explosives, and/or metals.
· Collection of synoptic water level measurements.
· Well surveying.
· Surveying of select creek bottom locations within Goose Prairie Creek and collection of surface water samples for VOC and perchlorate analyses.

**Table 1-1 Summary of Sampling Events
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

Addendum Post-Screening Investigation (HDR, 2019b)	
·	Collection of 4 surface water grab samples for a combination of analyses that included VOCs and perchlorate.
·	Collection of synoptic groundwater level measurements.
·	Survey of Goose Prairie Creek bottom elevations.
·	Collection of surface water quality parameters stopped.
Post-Screening Investigation No. 2 Report (HDR, 2021a)	
·	Advancement of 27 DPT borings near Building 46A to depths between 31 and 51 bgs, and collection of 4-6 soil samples per boring for VOC analysis.
·	Installation of temporary wells at 27 locations near Building 46A. Side-by-side wells were installed and completed in the Shallow and Upper Intermediate Zones at 16 locations, Shallow Zone only wells installed at 11 locations. Groundwater grab samples were collected from each well for VOC analysis.
·	Installation of 4 Shallow Zone, 3 Upper Intermediate Zone and 1 Intermediate Zone monitoring wells near Building 46A and collection of samples for VOC analysis.
·	Abandonment of monitoring well 47WW25R.
·	Elevation surveys for all newly installed monitoring wells.
Pre-Design Investigation Report (HDR, 2024)	
·	Soil cores were collected at each new monitoring well location to record lithology and determine transition between the Shallow Zone and the Shallow / Intermediate Zone.
·	Installed six monitoring wells and collected groundwater samples from the new and existing wells.
·	Water elevation measurements were collected from 63 existing wells and 6 new wells.
·	Completed a topographic survey of LHAAP-47 and a survey of new groundwater monitoring wells.
Pre-Design Investigation Report Addendum (HDR, 2025)	
·	Wells 47WW18, LHSMW49, 105 and 47WW05 were selected for replacement with 47WW62, 47WW63, 47WW64, and 47WW65.
·	Groundwater samples were collected for VOCs, perchlorate, and metals analysis after wells were developed and allowed to stabilize after 24 hours.
·	Completed surveys for all newly installed monitoring wells.

**Table 1-2 Cleanup Levels for Target COCs in Soil
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

Contaminant of Concerns (COCs) Targeted for Remediation	Cleanup Level ^a (mg/kg)
Perchlorate	7.2
TCE	0.5

Notes:

^a Unless otherwise noted, cleanup level applies to soil from surface to groundwater interface.

mg/kg - milligram per kilogram

TCE - trichloroethylene

GWP-Ind - Texas Commission on Environmental Quality (TCEQ) soil medium specific concentration (MSC) for industrial use based on groundwater protection (GWP-Ind) was used in accordance with 30 TAC 335.559(g)(2).

**Table 1-3 Cleanup Levels for Target COCs in Groundwater
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

COCs Targeted for Remediation	MCL (µg/L)	TRRP Tier 1 Residential Groundwater PCLs (µg/L)	Background (µg/L)	Cleanup Level (µg/L)
Perchlorate	--	17	--	17
1,1-Dichloroethene	7	--	--	7
1,2-Dichloroethane	5	--	--	5
Acetone	--	22,000	--	22,000
Chloroform	80	--	--	80
cis-1,2-Dichloroethene (cis-1,2-DCE)	70	--	--	70
Tetrachloroethene (PCE)	5	--	--	5
trans-1,2-Dichloroethene (trans-1,2- DCE) (daughter product)	100	--	--	100
Trichloroethene (TCE)	5	--	--	5
Vinyl Chloride (VC)	2	--	--	2
2,4,6-Trinitrotoluene	--	12	--	12
2,4-Dinitrotoluene	--	1.3	--	1.3
2,6-Dinitrotoluene	--	1.3	--	1.3
bis(2-Ethylhexyl)phthalate	6	--	--	6
Pentachlorophenol	1	--	--	1
Aluminum	--	24,000	2,680	24,000
Antimony	6	--	12.2	12.2
Arsenic	10	--	34.2	34.2
Cadmium	5	--	5.1	5.1
Chromium	100	--	15.8	100
Cobalt	--	240	187	240
Manganese	--	1,100	7,820	7,820
Nickel	--	490	229	490
Silver	--	120	1.92	120
Strontium	--	15,000	7,330	15,000
Thallium	2	--	--	2
Tin	--	15,000	--	15,000
Vanadium	--	44	3.99	44

Notes:

Source: the source of this table is the Final Feasibility Study, LHAAP-47, Plant 3, Group 4 (Shaw, 2011) Background concentration from Final Evaluation of Perimeter Well Data for Use as Groundwater Background (Shaw, 2007c).

COCs - Contaminant of Concerns

MCL - Maximum Contaminant Level

PCL - Protective Concentration Level

µg/L - micrograms per liter

TRRP - Texas Risk Reduction Program

PCLs - Protective Concentration Levels

TRRP Tier 1 - Residential Groundwater PCL

**Table 1-4 Monitoring Levels for Perchlorate and VOCs in Surface Water
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

Chemicals	Texas Surface Water Quality Standards^a (µg/L)
Perchlorate ^b	17 ^b
1,1-Dichloroethene	7
1,2-Dichloroethane	5
Acetone ^b	22,000 ^b
Chloroform	70
cis-1,2-Dichloroethene (cis-1,2-DCE) ^c	70 ^c
Tetrachloroethene (PCE)	5
trans-1,2-Dichloroethene (trans-1,2-DCE) (daughter product) ^c	100 ^c
Trichloroethene (TCE)	5
Vinyl Chloride (VC)	0.23

Notes:

^a Texas Surface Water Quality Standards are adopted from 30 Texas Administrative Code (TAC) §307.6(d)(1) (Human Health Protection for Water and Fish consumption).

^b There is no Texas surface water quality standard for this chemical. The value provided is the TRRP Tier 1 Residential Groundwater PCL for this chemical.

^c There is no Texas surface water quality standard for this chemical. The value provided is the MCL for this chemical.
µg/L - micrograms per liter

Table 2-1 Excavation Areas
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Area ID	Area			Depth Interval		Depth	Excavation Volume	Excavation Volume	Sloped Volume				Total Volume	Total Volume
	square feet			ft	ft	ft	cubic feet	cubic yards	cubic feet				cubic feet	cubic yards
Excavation Area 1	3,110			0	12	12	37,320	1,390	52,070				89,390	3,400
Excavation Area 2	1,310			0	12	12	15,720	590	29,280				45,000	1,700
Area ID	Length	Width	Area	Depth Interval		Depth	Excavation Volume	Excavation Volume	Sloped Length	Sloped Width	Sloped Area	Sloped Volume	Total Volume	Total Volume
	ft	ft	square feet	ft	ft	ft	cubic feet	cubic yards	ft	ft	square feet	cubic feet	cubic feet	cubic yards
Excavation Area 3	50	15	750	0	7	7	5,250	200	78	43	3,350	8,020	13,270	500
Excavation Area 4	25	20	500	0	4	4	2,000	80	41	36	1,472	1,780	3,780	140
Excavation Area 5	70	50	3,500	0	14	14	49,000	1,820	126	106	13,352	61,550	110,550	4,100
TOTAL							56,250	4,080					262,000	9,900

Notes:

ID - Identification

ft - feet

bgs - below ground surface

Volume includes soils removed as part of sloping required to complete excavations.

* = Rounded to Nearest 10

** = Rounded to Nearest 100

Table 3-1 Groundwater Seepage Velocity and Travel Time
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Calculate groundwater seepage velocity and travel time:

Assumptions:

Total Porosity 0.396 Average Porosity from Feasibility Study Report

Well ID	Water Elevations - June 2023*	Well ID	Water Elevations - June 2023*	Horizontal Distance between Wells	Hydraulic Gradient	Assumes Hydraulic conductivity of **	Assumes Hydraulic conductivity of **	Reference Monitoring Well ID	Groundwater Seepage Velocity	Groundwater Seepage Velocity	Average Seepage Velocity	Average Seepage Velocity
	ft amsl		ft amsl						ft	ft/ft		
SHALLOW/ ZONE												
DPT-031	178.00	DPT-030	177	63	0.0159	1.90E-03	5.39	LHSMW50	0.22	78.80	83.7	0.23
DPT-031	178	DPT-004	176	112	0.0179	1.90E-03	5.39	LHSMW50	0.24	88.65		
DPT-003	177	DPT-001	176	51.79	0.0193	1.90E-03	5.39	LHSMW50	0.26	95.85	72.3	0.20
DPT-003	177	DPT-009	176	101.77	0.0098	1.90E-03	5.39	LHSMW50	0.13	48.78		
DPT-012	177	DPT-006	176	119.45	0.0084	1.90E-03	5.39	LHSMW50	0.11	41.56	52.4	0.14
DPT-012	177	DPT-027	176	73.79	0.0136	1.90E-03	5.39	LHSMW50	0.18	67.27		
DPT-012	177	DPT-005	176	102.36	0.0098	1.90E-03	5.39	LHSMW50	0.13	48.50		
DPT-031	178	DPT-012	177	147.8	0.0068	1.90E-03	5.39	LHSMW50	0.09	33.59	40.9	0.11
DPT-012	177	DPT-005	176	102.82	0.0097	1.90E-03	5.39	LHSMW50	0.13	48.28		
DPT-003	177	DPT-004	176	42.02	0.0238	1.90E-03	5.39	LHSMW50	0.32	118.14	68.5	0.19
DPT-003	177	DPT-029	176	263.81	0.0038	1.90E-03	5.39	LHSMW50	0.05	18.82		
SHALLOW/INTERMEDIATE ZONE												
DPT-026	177	DPT-029	176	260.31	0.0038	3.20E-04	0.91	47WW14	0.01	3.21	3.4	0.01
DPT-026	177	DPT-028	176	285.26	0.0035	3.20E-04	0.91	47WW14	0.01	2.93		
DPT-026	177	DPT-018	176	209.69	0.0048	3.20E-04	0.91	47WW14	0.01	3.99		
DPT-011	177	DPT-010	176.5	57.33	0.0087	3.20E-04	0.91	47WW14	0.02	7.29	6.4	0.02
DPT-010	176.5	DPT-022	176	76.13	0.0066	3.20E-04	0.91	47WW14	0.02	5.49		

**Table 3-1 Groundwater Seepage Velocity and Travel Time
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

Well ID	Water Elevations - June 2023*	Well ID	Water Elevations - June 2023*	Horizontal Distance between Wells	Hydraulic Gradient	Assumes Hydraulic conductivity of **	Assumes Hydraulic conductivity of **	Reference Monitoring Well ID	Groundwater Seepage Velocity	Groundwater Seepage Velocity	Average Seepage Velocity	Average Seepage Velocity
	ft amsl		ft amsl						ft	ft/ft		
SHALLOW/INTERMEDIATE ZONE												
DPT-014	177	DPT-008	176.5	87	0.0057	3.20E-04	0.91	47WW14	0.01	4.81	4.4	0.01
DPT-014	177	DPT-036	176	208.4	0.0048	3.20E-04	0.91	47WW14	0.01	4.01		
DPT-013	177	DPT-008	176.5	61.71	0.0081	3.20E-04	0.91	47WW14	0.02	6.77	6.1	0.02
DPT-013	177	DPT-010	176.5	65.8	0.0076	3.20E-04	0.91	47WW14	0.02	6.35		
DPT-013	177	DPT-022	176	112.79	0.0089	3.20E-04	0.91	47WW14	0.02	7.41		
DPT-013	177	DPT-036	176	209.77	0.0048	3.20E-04	0.91	47WW14	0.01	3.99		
47WW37	177	47WW50	176.5	29.4	0.0170	3.20E-04	0.91	47WW14	0.04	14.22	9.0	0.02
47WW37	177	47WW51	176	222.35	0.0045	3.20E-04	0.91	47WW14	0.01	3.76		
DPT-007	177	DPT-008	176.5	55.82	0.0090	3.20E-04	0.91	47WW14	0.02	7.49	5.1	0.01
DPT-008	176.5	DPT-036	176	149.84	0.0033	3.20E-04	0.91	47WW14	0.01	2.79		

Notes:

* Water elevations are from PDI Report (August 2023)

** Hydraulic conductivity at Site 47 was estimated through Final Remedial Investigation Report Group 4 Sites - Jacobs

ft asml - feet above mean sea level

cm/sec - centimeters per second

ft - feet

ft/ft - feet per feet

ft/day - feet per day

ft/year - feet per year

ID - Identification

Table 3-2 ISTD Treatment Areas
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Area ID	Area	Thickness	Volume	Volume	Approximate Target Depth
	(square feet)	(feet)	(cubic feet)	(cubic yards)	(feet bgs)
ISTD Area 1	18,500	12	222,000	8,500	22 to 34
ISTD Area 2	34,000	26	884,000	33,000	21 to 47
TOTAL	52,500	12 to 26 feet	1,106,000	41,500	

Notes:

ID - Identification

ISTD - In-situ thermal desorption

bgs - Below ground surface

Table 3-3 ISTD Treatment System - Minimum Process Monitoring Reporting Requirements
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Process Monitoring	Location	Matrix	Parameter	Frequency
Temperature/ Vapor Pressure Monitoring	Temperature Monitoring Points	Soil and groundwater	Temperature/ Pressure	Daily
Heating Duration	Power Supply or Control Unit	Energy	Continuous operation	Continuously
Recovered Vapor Flow	Well-field Vapor Influent Manifold	Vapor	Vacuum-flow	Daily
	Blower inlet			
	Blower outlet			
Safety and Environmental Control	Treatment area subsurface and periphery	Soil and groundwater	Stray voltage	Minimum weekly
			Pressure	
			Noise	
		Peripheral Groundwater (four new downgradient wells)	VOC concentrations (Analytical) and temperature measurements	Minimum monthly
VOC Vapor Destruction Efficiency	Vapor Treatment Equipment influent/effluent	Vapor	VOC concentrations (Analytical)	Minimum weekly and in accordance with permit equivalent(s)
			VOC concentrations (PID)	Daily and in accordance with permit equivalent(s)
Shallow Vacuum Monitoring	Perimeter vacuum monitoring points	Vapor	Pressure	Minimum weekly
NAPL Analysis for VOCs	NAPL collection equipment	Liquid	VOC concentrations (Analytical)	As needed (additional analyses may be required for disposal)

Notes:

ISTD - In-situ thermal desorption

VOCs - Volatile Organic Compounds

NAPL - Non-aqueous phase liquid

PID - Photoionization Detector

Table 4-1 ISB Pilot Test Areas
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Area ID	Area	Injection Points	ROI	Target Depth Interval	Saturated Thickness	Nearby Existing Well ID	Perchlorate	TCE	Screen Depth	Depth to Water	Boring Depth
	square feet	no.	feet	feet bgs	feet		µg/L	µg/L	feet bgs	feet bgs	feet bgs
Pilot Test Area 1 (Shallow & Shallow/ Intermediate Zones)	6,570	Up to 9 DPT Points in a Grid Configuration	13.5	31-51	20	47WW52	<0.025 U	1610 J	23-33	31.63	33
						47WW53	<0.025 U	1,040	42-47	31.63	47
						47WW55	<0.025 U	1380 J	23-33	31.24	33
Pilot Test Area 2 (Shallow/ Intermediate)	6,570	Up to 9 DPT Points in a Grid Configuration	13.5	27-57	20	47WW09	<0.025 U	1230 J	28-38	27.72	39
						LHSMW43R	91	2970 J	24-34	26.53	35
Pilot Test Area 3 (Shallow/ Intermediate)	3,650	Up to 5 Permanent Injection Well Points	13.5	23-43	20	47WW39	<0.025 U	17.50 J+	29-39	23.05	40
Pilot Test Area 4 (Shallow)	4,060	Up to 24 DPT Points in a Grid Configuration	6.5	20-30	10	47WW58	<0.025 U	1890 J	15-25	20.47	32

Notes:

ID – Identification

ROI – Radius of Influence

ISB – In-Situ Bioremediation

bgs – below ground surface

µg/L – micrograms per liter

DPT – Direct Push Technology

TCE – trichloroethene

J+ – estimated value, possibly biased high

J – estimated value

U - Not Detected

< – less than

Table 4-2 ISB Grid Areas
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Area ID	Area	Injection Points	ROI	Target Depth Interval	Saturated Thickness	Nearby Existing Well ID	Perchlorate	TCE	Screen Depth	Depth to Water	Boring Depth
	square feet	no.	feet	feet bgs	feet		µg/L	µg/L	feet bgs	feet bgs	feet bgs
ISB Grid Area 1S	167,000	988	6.5	30-40	10	47WW48	0.0741 J	10,000 J*	22-32	31.13	32
						47WW49	<0.025 U	2760 J*	19-29.3	30.65	29.3
						47WW52	<0.025 U	1610 J	23-33	31.63	33
						47WW55	<0.025 U	1380 J	23-33	31.24	33
ISB Grid Area 2S	123,000	728	6.5	27-37	10	LHSMW45	<0.025 U	1,740	25.5-35.5	27.97	48
ISB Grid Area 3S	103,000	609	6.5	20-30	10	47WW58	<0.025 U	1890 J	15-25	20.47	32
ISB Grid Area 1SI	181,000	248	13.5	30-50	20	47WW51	<0.025 U	6950*	42-47	30.32	47
						47WW53	<0.025 U	1,040	42-47	31.63	47
						47WW56	0.0465 J	1070 J	27-37	29.18	40
						47WW54	<0.025 U	1940 J	46-51	31.37	51
ISB Grid Area 2SI	36,000	49	13.5	20-40	20	LHSMW60	23,600	2.79 J+	15.8-25.8	20.18	60
ISB Grid Area 3SI	94,000	129	13.5	27-57	20	LHSMW43R	91	2970 J	24-34	26.53	35
						47WW09	<0.025 U	1230 J	28-38	27.72	39
ISB Grid Area 4SI/5SI/6SI	762,000	1,045	13.5	20-40	20	LHSMW56R	<0.025 U	5,190	24.5-34.5	22.71	35
						47WW42	0.34	624**	30-40	19.57	40.5
						47WW45	<0.025 U	3700 J	38-48	17.12	48
TOTAL	1,466,000	3,797									

* TCE concentrations will be reduced by ISTD treatment at this location

** Total volatile organic compound (VOCs) concentration exceeds 1,000 µg/L

Notes:

ID – Identification

ROI – Radius of Influence

ISB – In-Situ Bioremediation

bgs – below ground surface

µg/L – micrograms per liter

DPT – Direct Push Technology

TCE – trichloroethene

J+ – estimated value, possibly biased high

J – estimated value

U - Not Detected

< – less than

**Table 4-3 Shallow/Intermediate ISB Biobarrier Areas
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

Area ID	Area		Injection Points	ROI	Target Depth Interval	Saturated Thickness	Nearby Existing Well ID	Perchlorate	TCE	Screen Depth	Depth to Water	Boring Depth
	square feet	Linear Feet	no.	feet	feet bgs	feet		µg/L	µg/L	feet bgs	feet bgs	feet bgs
ISB Biobarrier 1	32,400	1,200	45	13.5	23-43	20	LHSMW54	0.42	56	32.2-42.2	17.50	44
							LHSMW56R	<0.025 U	5,190	24.5-34.5	22.71	35
							47WW42	0.34	624**	30-40	19.57	40.5
ISB Biobarrier 2	27,000	1,000	35	13.5	30-50	20	47WW61	<0.025 U	<0.156 U	30-40	21.80	50
ISB Biobarrier 3	21,600	800	29	13.5	30-50	20	47WW40	59	6.74 J+	29-39	21.03	42.4
							47WW26R	0.01 J	2.39 J+	29.3-39.3	28.12	40
TOTAL	81,000	3,000	109									

**** Total volatile organic compound (VOCs) concentration exceeds 1,000 µg/L**

Notes:

ID – Identification

ROI – Radius of Influence

ISB – In-Situ Bioremediation

bgs – below ground surface

µg/L – micrograms per liter

TCE – trichloroethene

J+ – estimated value, possibly biased high

J – estimated value

< – less than

U - Not Detected

**Table 4-4 Baseline Sampling Plan for Pilot Test Areas
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

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
47WW51 (SI)	Upgradient to Pilot Test Area #1	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-01 (S)	Upgradient to Pilot Test Area #1	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW24 (S)	Sidegradient to Pilot Test Area #1	✓	✓							✓
47WW56 (SI)	Sidegradient to Pilot Test Area #1	✓	✓							✓
47WW55 (S)	Downgradient to Pilot Test Area #1	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW54 (SI)	Downgradient to Pilot Test Area #1	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW53 (SI)	Performance Data within Pilot Test Area #1	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW52 (S)	Performance Data within Pilot Test Area #1	✓		✓	✓	✓	✓	✓	✓	✓
PMW-02 (SI)	Upgradient to Pilot Test Area #2	✓	✓							✓
PMW-03 (SI)	Upgradient to Pilot Test Area #2	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-04 (SI)	Downgradient to Pilot Test Area #2	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW09 (SI)	Performance Data within Pilot Test Area #2	✓	✓	✓	✓	✓	✓	✓	✓	✓
LHSMW43R (SI)	Performance Data within Pilot Test Area #2	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW39 (SI)	Upgradient to Pilot Test Area #3	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-08 (SI)	Downgradient to Pilot Test Area #3	✓	✓							✓
PMW-09 (SI)	Downgradient to Pilot Test Area #3	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-06 (SI)	Performance Data within Pilot Test Area #3	✓	✓							✓
PMW-07 (SI)	Performance Data within Pilot Test Area #3	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-27 (SI)	Upgradient to Pilot Test Area #3	✓	✓							✓
PMW-10 (S)	Upgradient to Pilot Test Area #4	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-11 (S)	Upgradient to Pilot Test Area #4	✓	✓							✓
PMW-13 (S)	Downgradient to Pilot Test Area #4	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-14 (S)	Downgradient to Pilot Test Area #4	✓	✓							✓

**Table 4-4 Baseline Sampling Plan for Pilot Test Areas
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

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
PMW-12 (S)	Performance Data within Pilot Test Area #4	✓	✓							✓
47WW58 (S)	Performance Data within Pilot Test Area #4	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes:

^a VOCs include TCE; cis-1,2-DCE; 1,1-DCE; 1,2-DCA; 1,1,2-TCA; and VC.

^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)

TOC - total organic carbon

VOCs - volatile organic compounds

ISB – In-Situ Bioremediation

S - Shallow

SI - Shallow/Intermediate

Table 4-5 ISB Performance Monitoring Sampling Plan (Years 1 and 2) in the Pilot Test Areas
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Monitoring Locations	ISB Area	First Two Months (Up to Two Events ^a)					Year 1 (Quarterly)												Year 2 (Quarterly)												
		DO (field reading)	ORP (field reading)	pH (field reading)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs ^b (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions ^c (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	DHC (qPCR)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs ^b (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions ^c (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	Bromide (E300.0)	TOC (SW9060)
47WW51 (SI)	Upgradient to Pilot Test Area #1	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓							
PMW-01 (S)	Upgradient to Pilot Test Area #1	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓							
47WW24 (S)	Sidegradient to Pilot Test Area #1	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓							
47WW56 (SI)	Sidegradient to Pilot Test Area #1	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓							
47WW54 (SI)	Downgradient to Pilot Test Area #1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW55 (S)	Downgradient to Pilot Test Area #1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW53 (SI)	Performance Data within Pilot Test Area #1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW52 (S)	Performance Data within Pilot Test Area #1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-02 (SI)	Upgradient to Pilot Test Area #2	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓							
PMW-03 (SI)	Upgradient to Pilot Test Area #2	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓							
PMW-04 (SI)	Downgradient to Pilot Test Area #2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-05 (SI)	Downgradient to Pilot Test Area #2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW09 (SI)	Performance Data within Pilot Test Area #2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LHSMW43R (SI)	Performance Data within Pilot Test Area #2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW39 (SI)	Upgradient to Pilot Test Area #3	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓							
PMW-27 (SI)	Upgradient to Pilot Test Area #3	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓							

Table 4-5 ISB Performance Monitoring Sampling Plan (Years 1 and 2) in the Pilot Test Areas
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Monitoring Locations	ISB Area	First Two Months (Up to Two Events ^a)					Year 1 (Quarterly)										Year 2 (Quarterly)														
		DO (field reading)	ORP (field reading)	pH (field reading)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs ^b (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions ^c (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	DHC (qPCR)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs ^b (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions ^c (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	Bromide (E300.0)	TOC (SW9060)
PMW-08 (SI)	Downgradient to Pilot Test Area #3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-09 (SI)	Downgradient to Pilot Test Area #3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-06 (SI)	Performance Data within Pilot Test Area #3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-07 (SI)	Performance Data within Pilot Test Area #3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-10 (S)	Upgradient to Pilot Test Area #4	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓							
PMW-11 (S)	Upgradient to Pilot Test Area #4	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓							
PMW-13 (S)	Downgradient to Pilot Test Area #4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-14 (S)	Downgradient to Pilot Test Area #4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-12 (S)	Performance Data within Pilot Test Area #4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW58 (S)	Performance Data within Pilot Test Area #4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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 VOCs include TCE; cis-1,2-DCE; 1,1-DCE; 1,2-DCA; 1,1,2-TCA; and VC.

^c Anions include nitrate and sulfate.

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

S - Shallow

SI - Shallow/Intermediate

ISB - In-Situ Bioremediation

DO - Dissolved Oxygen

ORP - Oxidation–Reduction Potential

Table 4-6 Pre-ISB Implementation Groundwater Sampling Plan for ISB Grid Areas
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

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
47WW48 (S)	Performance Data within ISB Grid Area #1S	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW49 (S)	Performance Data within ISB Grid Area #1S	✓	✓							✓
47WW55 (S)	Performance Data within ISB Grid Area #1S	✓	✓							✓
PMW-15 (S)	Performance Data within ISB Grid Area #2S	✓	✓							✓
LHSMW45	Performance Data within ISB Grid Area #2S	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-10 (S)	Performance Data within ISB Grid Area #3S	✓	✓							✓
47WW58 (S)	Performance Data within ISB Grid Area #3S	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-14 (S)	Performance Data within ISB Grid Area #3S	✓	✓							✓
47WW51 (SI)	Performance Data within ISB Grid Area #1SI	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW56 (SI)	Performance Data within ISB Grid Area #1SI	✓	✓							✓
47WW54 (SI)	Performance Data within ISB Grid Area #1SI	✓	✓							✓
LHSMW60 (SI)	Performance Data within ISB Grid Area #2SI	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-48(SI)	Performance Data within ISB Grid Area #2SI	✓	✓							✓
47WW09 (SI)	Performance Data within ISB Grid Area #3SI	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-4 (SI)	Performance Data within ISB Grid Area #3SI	✓	✓							✓
PMW-5 (SI)	Performance Data within ISB Grid Area #3SI	✓	✓							✓
47WW42 (SI)	Performance Data within ISB Grid Area #4SI	✓	✓							✓
LHSMW56R (SI)	Performance Data within ISB Grid Area #4SI	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-16 (SI)	Performance Data within ISB Grid Area #4SI	✓	✓							✓
PMW-17 (SI)	Performance Data within ISB Grid Area #5SI	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-18 (SI)	Performance Data within ISB Grid Area #6SI	✓	✓							✓
PMW-19 (SI)	Performance Data within ISB Grid Area #6SI	✓	✓							✓
47WW45 (SI)	Performance Data within ISB Grid Area #6SI	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes:

^a VOCs include TCE; cis-1,2-DCE; 1,1-DCE; 1,2-DCA; 1,1,2-TCA; and VC.

^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)

TOC - total organic carbon

VOCs - volatile organic compounds

S - Shallow

SI - Shallow/Intermediate

Table 4-7 Pre-ISB Implementation Groundwater Sampling Plan for ISB Biobarriers
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

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
PMW-27 (SI)	Upgradient to Shallow/Intermediate ISB Biobarrier #1	✓	✓							✓
PMW-28 (SI)	Upgradient to Shallow/Intermediate ISB Biobarrier #1	✓	✓							✓
PMW-8 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #1	✓	✓							✓
PMW-33 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #1	✓	✓							✓
PMW-34 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #1	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-35 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #1	✓	✓							✓
PMW-06 (SI)	Performance Data within Shallow/Intermediate ISB Biobarrier #1	✓	✓							✓
PMW-29 (SI)	Performance Data within Shallow/Intermediate ISB Biobarrier #1	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-36 (SI)	Upgradient to Shallow/Intermediate ISB Biobarrier #2	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW61 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #2	✓	✓							✓
PMW-37 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #2	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-38 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #2	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-39 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #2	✓	✓							✓
PMW-20 (SI)	Performance Data within Shallow/Intermediate ISB Biobarrier #2	✓	✓							✓
PMW-21 (SI)	Performance Data within Shallow/Intermediate ISB Biobarrier #2	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-24 (SI)	Upgradient to Shallow/Intermediate ISB Biobarrier #3	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-25 (SI)	Upgradient to Shallow/Intermediate ISB Biobarrier #3	✓	✓							✓
47WW40 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #3	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-22 (SI)	Performance Data within Shallow/Intermediate ISB Biobarrier #3	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-23 (SI)	Performance Data within Shallow/Intermediate ISB Biobarrier #3	✓	✓							✓

Notes:

^a VOCs include TCE; cis-1,2-DCE; 1,1-DCE; 1,2-DCA; 1,1,2-TCA; and VC.

^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.

Table 4-7 Pre-ISB Implementation Groundwater Sampling Plan for ISB Biobarriers
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

DHC - Dehalococcoides (microbial analysis)
TOC - total organic carbon
VOCs - volatile organic compounds
S - Shallow
SI - Shallow/Intermediate

Table 4-8 ISB Performance Monitoring Sampling Plan (Years 1 and 2) in ISB Grid Areas
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Monitoring Locations	ISB Area	First Two Months (Up to Two Events ^a)					Year 1 (Quarterly)												Year 2 (Quarterly)												
		DO (field reading)	ORP (field reading)	pH (field reading)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs ^b (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions ^c (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	DHC (qPCR)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs ^b (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions ^c (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	Bromide (E300.0)	TOC (SW9060)
47WW48 (S)	Performance Data within ISB Grid Area #1S	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW49 (S)	Performance Data within ISB Grid Area #1S	✓	✓	✓	✓	✓																									
47WW55 (S)	Performance Data within ISB Grid Area #1S	✓	✓	✓	✓	✓																									
PMW-15 (S)	Performance Data within ISB Grid Area #2S	✓	✓	✓	✓	✓																									
LHSMW45 (S)	Performance Data within ISB Grid Area #2S	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-10 (S)	Performance Data within ISB Grid Area #3S	✓	✓	✓	✓	✓																									
47WW58 (S)	Performance Data within ISB Grid Area #3S	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-14 (S)	Performance Data within ISB Grid Area #3S	✓	✓	✓	✓	✓																									
47WW51 (SI)	Performance Data within ISB Grid Area #1SI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW56 (SI)	Performance Data within ISB Grid Area #1SI	✓	✓	✓	✓	✓																									
47WW54 (SI)	Performance Data within ISB Grid Area #1SI	✓	✓	✓	✓	✓																									
LHSMW60 (SI)	Performance Data within ISB Grid Area #2SI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-48(SI)	Performance Data within ISB Grid Area #2SI	✓	✓	✓	✓	✓																									
47WW09 (SI)	Performance Data within ISB Grid Area #3SI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-4 (SI)	Performance Data within ISB Grid Area #3SI	✓	✓	✓	✓	✓																									

Table 4-8 ISB Performance Monitoring Sampling Plan (Years 1 and 2) in ISB Grid Areas
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Monitoring Locations	ISB Area	First Two Months (Up to Two Events ^a)					Year 1 (Quarterly)										Year 2 (Quarterly)														
		DO (field reading)	ORP (field reading)	pH (field reading)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs ^b (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions ^c (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	DHC (qPCR)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs ^b (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions ^c (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	Bromide (E300.0)	TOC (SW9060)
PMW-5 (SI)	Performance Data within ISB Grid Area #3SI	✓	✓	✓	✓	✓																									
47WW42 (SI)	Performance Data within ISB Grid Area #4SI	✓	✓	✓	✓	✓																									
LHSMW56R (SI)	Performance Data within ISB Grid Area #4SI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-16 (SI)	Performance Data within ISB Grid Area #4SI	✓	✓	✓	✓	✓																									
PMW-17 (SI)	Performance Data within ISB Grid Area #5SI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-18 (SI)	Performance Data within ISB Grid Area #6SI	✓	✓	✓	✓	✓																									
PMW-19 (SI)	Performance Data within ISB Grid Area #6SI	✓	✓	✓	✓	✓																									
47WW45 (SI)	Performance Data within ISB Grid Area #6SI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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 VOCs include TCE; cis-1,2-DCE; 1,1-DCE; 1,2-DCA; 1,1,2-TCA; and VC.

^c Anions include nitrate and sulfate.

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

ISB - In-Situ Bioremediation

S - Shallow

SI - Shallow/Intermediate

DO - Dissolved Oxygen

ORP - Oxidation–Reduction Potential

Table 4-9 ISB Performance Monitoring Sampling Plan (Years 1 and 2) in ISB Biobarriers
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Monitoring Locations	ISB Area	First Two Months (Up to Two Events ^a)					Year 1 (Quarterly)										Year 2 (Quarterly)														
		DO (field reading)	ORP (field reading)	pH (field reading)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs ^b (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions ^c (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	DHC (qPCR)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs ^b (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions ^c (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	Bromide (E300.0)	TOC (SW9060)
PMW-27 (SI)	Upgradient to Shallow/Intermediate ISB Biobarrier #1	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓							
PMW-28 (SI)	Upgradient to Shallow/Intermediate ISB Biobarrier #1	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓							
PMW-8 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #1	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓
PMW-33 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #1	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓
PMW-34 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #1	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓
PMW-35 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #1	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓
PMW-06 (SI)	Performance Data within Shallow/Intermediate ISB Biobarrier #1	✓	✓	✓	✓	✓																									
PMW-29 (SI)	Performance Data within Shallow/Intermediate ISB Biobarrier #1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-36	Upgradient to Shallow/Intermediate ISB Biobarrier #2	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓							
47WW61 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #2	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓
PMW-37 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #2	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓
PMW-38 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #2	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓
PMW-39 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #2	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓
PMW-20 (SI)	Performance Data within Shallow/Intermediate ISB Biobarrier #2	✓	✓	✓	✓	✓																									
PMW-21 (SI)	Performance Data within Shallow/Intermediate ISB Biobarrier #2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 4-9 ISB Performance Monitoring Sampling Plan (Years 1 and 2) in ISB Biobarriers
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Monitoring Locations	ISB Area	First Two Months (Up to Two Events ^a)					Year 1 (Quarterly)										Year 2 (Quarterly)													
		DO (field reading)	ORP (field reading)	pH (field reading)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs ^b (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions ^c (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	DHC (qPCR)	Bromide (E300.0)	TOC (SW9060)	Perchlorate (6850)	VOCs ^b (SW8260B)	DO (field reading)	ORP (field reading)	pH (field reading)	Alkalinity (2320B)	Anions ^c (E300.0)	Ethene (RSK-175)	Ethane (RSK-175)	Methane (RSK-175)	Bromide (E300.0)
PMW-24 (SI)	Upgradient to Shallow/Intermediate ISB Biobarrier #3	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓						
PMW-25 (SI)	Upgradient to Shallow/Intermediate ISB Biobarrier #3	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓	✓	✓	✓	✓						
47WW40 (SI)	Downgradient to Shallow/Intermediate ISB Biobarrier #3	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓
PMW-22 (SI)	Performance Data within Shallow/Intermediate ISB Biobarrier #3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-23 (SI)	Performance Data within Shallow/Intermediate ISB Biobarrier #3	✓	✓	✓	✓	✓																								

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 VOCs include TCE; cis-1,2-DCE; 1,1-DCE; 1,2-DCA; 1,1,2-TCA; and VC.

^c Anions include nitrate and sulfate.

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

ISB - In-Situ Bioremediation

S - Shallow

SI - Shallow/Intermediate

DO- Dissolved Oxygen

ORP - Oxidation–Reduction Potential

**Table 4-10 MNA and LTM Performance Monitoring Plan
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

Monitoring Locations	Location of Well ^a	Groundwater Zone	Proposed Analyses									
			VOCs ^b (SW8260B)	Perchlorate (6850)	TAL Metals (EPA Method 6020A)	Anions ^c (E300.0)	Dissolved Gases ^d (RSK-175)	Alkalinity (2320B)	TOC (SW9060)	DHC (qPCR)	Bromide (E300.0)	Field Parameters ^e
47WW49	Inside ISB Grid Area #1S	Shallow Zone	✓	✓	✓							✓
LHSMW45	Inside ISB Grid Area #2S	Shallow Zone	✓	✓	✓							✓
47WW58	Inside ISB Grid Area #3S	Shallow Zone	✓	✓	✓							✓
47WW03	Northeastern portion outside LHAAP-47 boundary	Shallow Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW04	Northeastern portion outside LHAAP-47 boundary	Shallow Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW21	Northeastern portion outside LHAAP-47 boundary	Shallow Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW51	Inside ISB Grid Area #1SI	Shallow/Intermediate Zone	✓	✓	✓							✓
LHSMW60	Inside ISB Grid Area #2SI	Shallow/Intermediate Zone	✓	✓	✓							✓
PMW-04	Inside ISB Grid Area #3SI	Shallow/Intermediate Zone	✓	✓	✓							✓
LHSMW56R	Inside ISB Grid Area #4SI	Shallow/Intermediate Zone	✓	✓	✓							✓
PMW-17	Inside ISB Grid Area #5SI	Shallow/Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-19	Inside ISB Grid Area #6SI	Shallow/Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW39	Northeastern portion within LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓							✓
PMW-38	Downgradient to Shallow/Intermediate ISB Biobarrier #2	Shallow/Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
47WW40	Downgradient to Shallow/Intermediate ISB Biobarrier #3	Shallow/Intermediate Zone	✓	✓	✓							✓
PMW-26*	Northeastern portion within LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓						✓	✓

**Table 4-10 MNA and LTM Performance Monitoring Plan
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

Monitoring Locations	Location of Well ^a	Groundwater Zone	Proposed Analyses									
			VOCs ^b (SW8260B)	Perchlorate (6850)	TAL Metals (EPA Method 6020A)	Anions ^c (E300.0)	Dissolved Gases ^d (RSK-175)	Alkalinity (2320B)	TOC (SW9060)	DHC (qPCR)	Bromide (E300.0)	Field Parameters ^e
PMW-31*	Eastern portion outside LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-32*	Eastern portion outside LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-33*	Eastern portion outside LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-34	Eastern portion outside LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-40*	Northern portion within LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓						✓	✓
PMW-41*	Northern portion within LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓						✓	✓
PMW-42*	Northern portion within LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓						✓	✓
PMW-43*	Northern portion within LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓						✓	✓
PMW-44*	Northeastern portion outside LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-45*	Northeastern portion outside LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-46*	Northeastern portion outside LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-47*	Northeastern portion outside LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PMW-48*	Southern portion outside LHAAP-47 boundary	Shallow/Intermediate Zone	✓	✓	✓						✓	✓

**Table 4-10 MNA and LTM Performance Monitoring Plan
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

Notes:

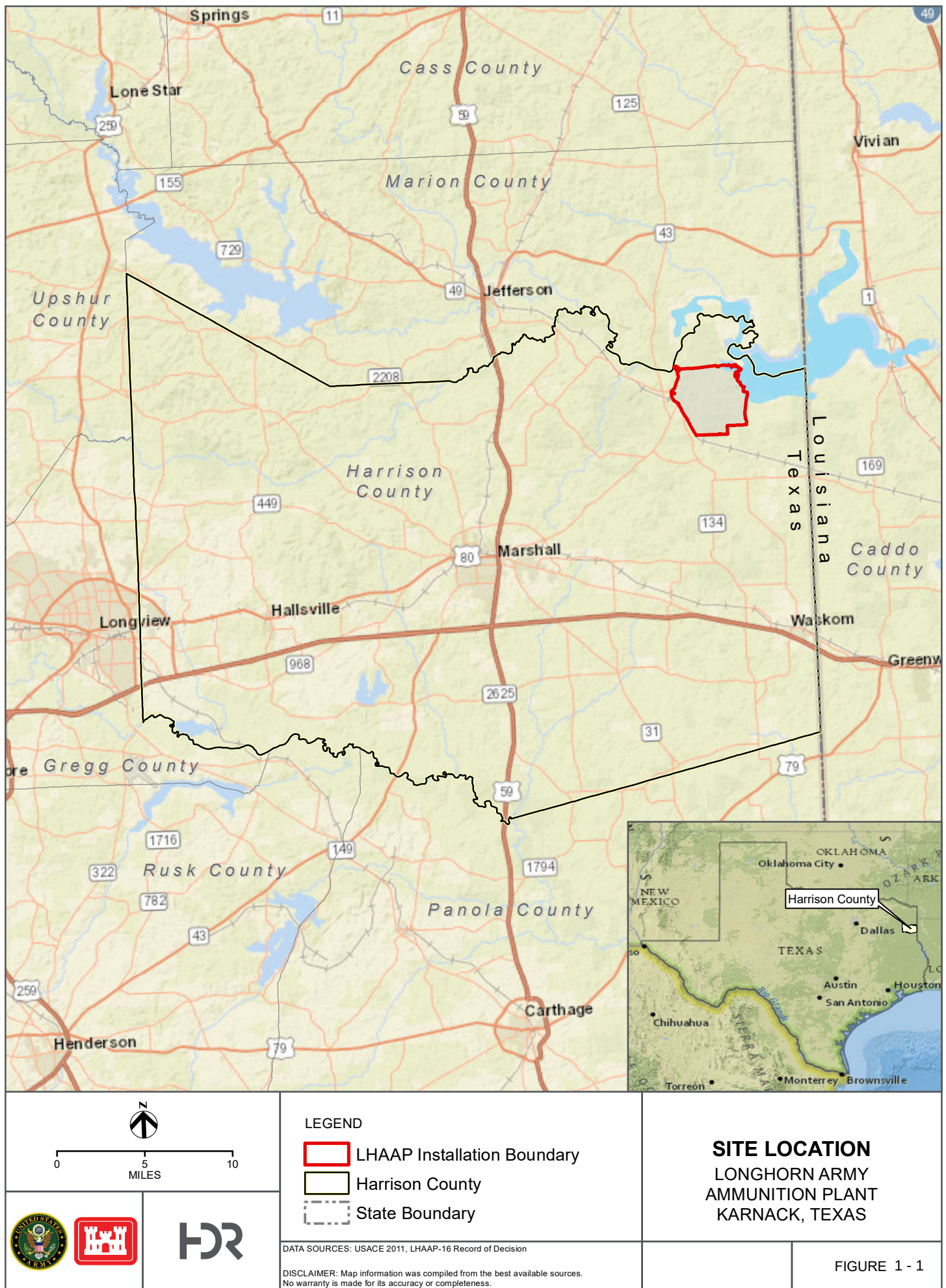
- ^a The MNA and LTM Sampling Plan for the Shallow Zone and Shallow/Intermediate are provided in Appendix A Sheets 04C100 and 04C101,
- ^b VOCs include TCE; cis-1,2-DCE; 1,1-DCE; 1,2-DCA; 1,1,2-TCA; and VC.
- ^c Anions include nitrate and sulfate.
- ^d Dissolved gasses include ethene, ethane, and methane.
- ^e Field Parameters include dissolved oxygen, oxidation reduction potential, and pH.
- ✓ Indicates that sample will be collected and analyzed for the listed analyte.
- * These wells will be sampled during Pilot Test Baseline, Pre-ISB Implementation Groundwater sampling and LTM Sampling.

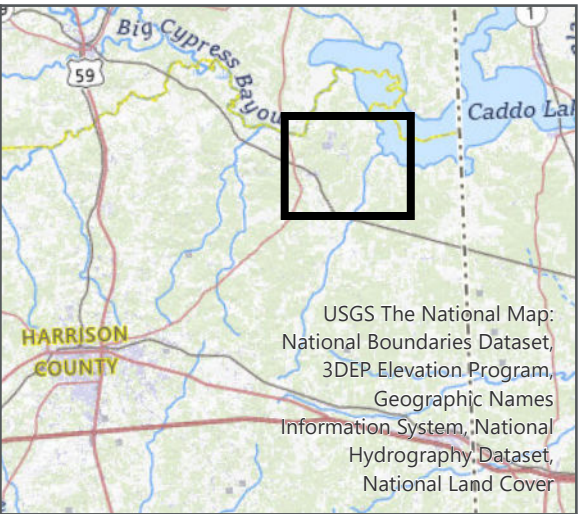
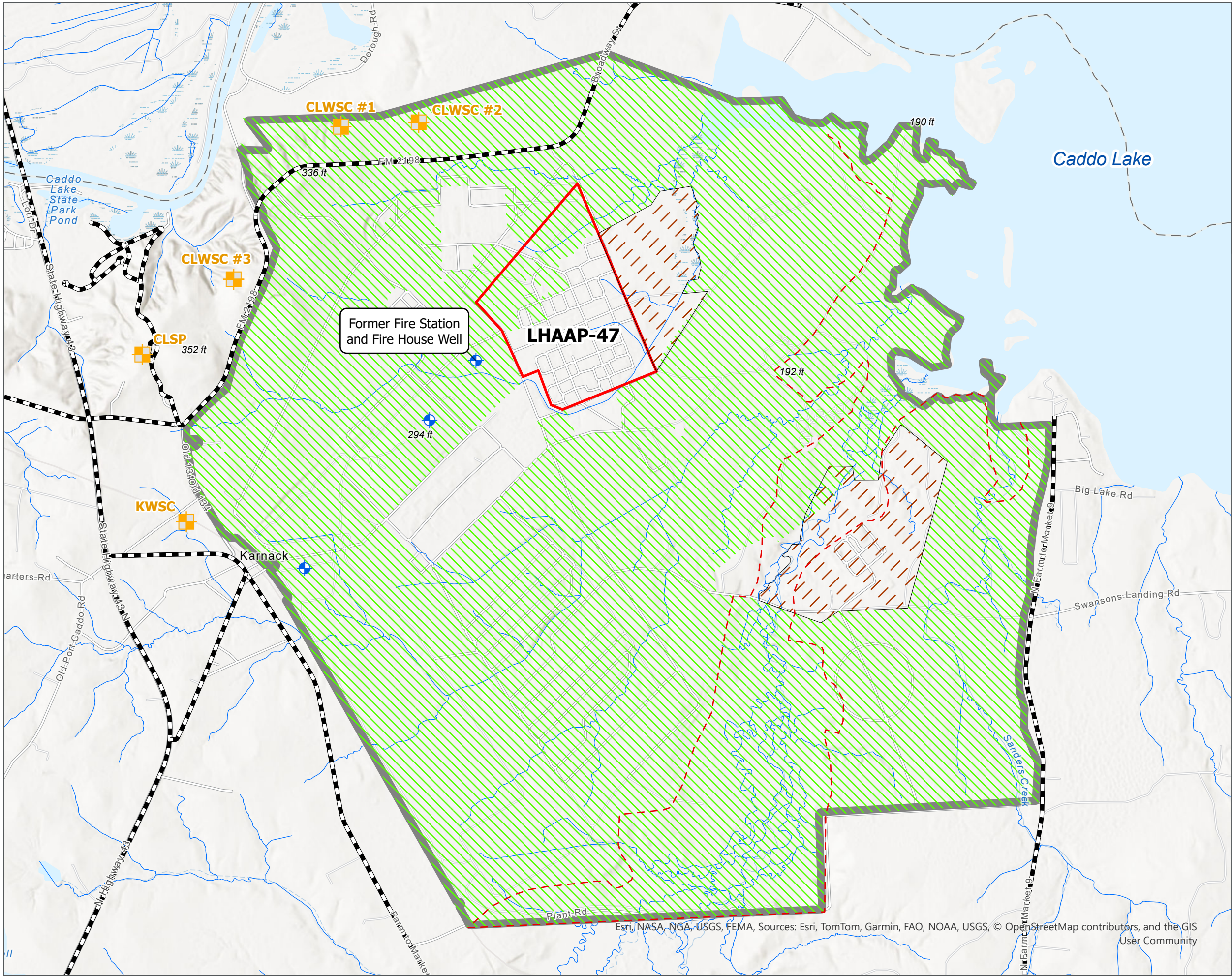


Figures

**Former Longhorn Army
Ammunition Plant (LHAAP)
Site 47**

Karnack, Texas





- LEGEND**
- Boundary of 1966 CLI Conservation Lease
 - MOA with Army
 - LHAAP-47 Site Boundary
 - USFWS Fee Lands
 - Streams
 - Acquisition Boundary
 - Non-Potable Water Wells
 - Public Water Supply Well Locations

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

LHAAP-47 AND SURROUNDING LAND STATUS
LHAAP-47
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

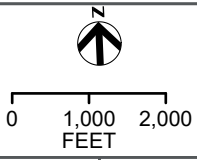
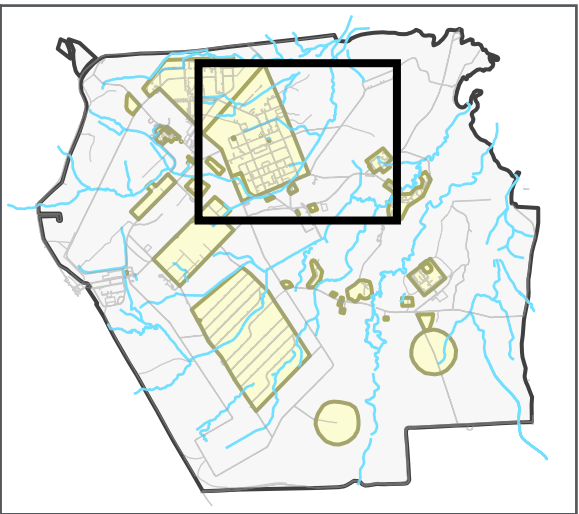
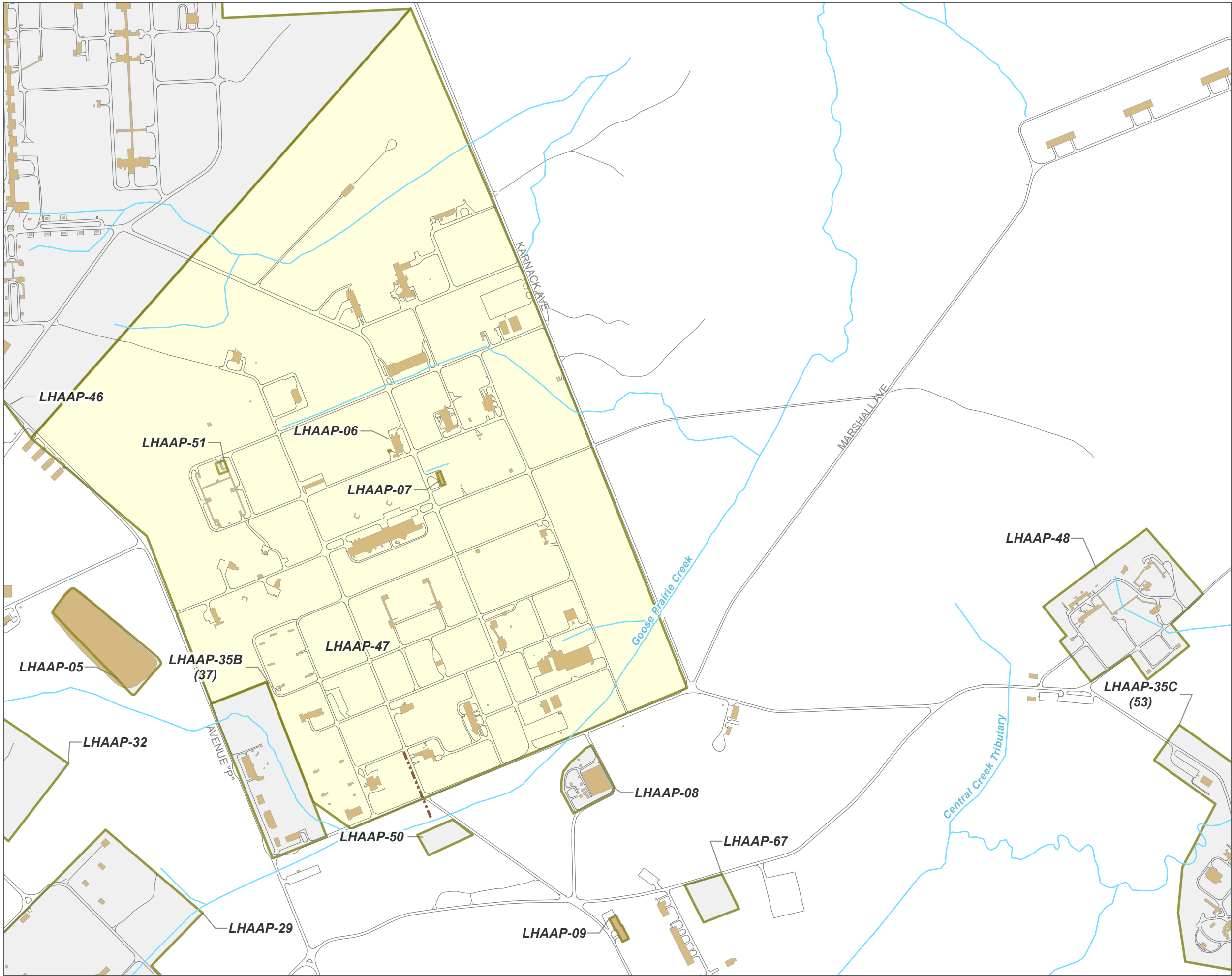


FIGURE 1-2



LEGEND

- Ditches
- Stream
- Roads
- LHAAP Site
- Buildings
- LHAAP-47 Site
- LHAAP Sites

DATA SOURCES: July 2011 Final Feasibility Study Report for LHAAP-47, Plant 3 Area, Group 4, Longhorn Army Ammunition Plant, Karnack, Harrison County, Texas (Shaw, 2011)

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

SITE PLAN

LHAAP 47
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

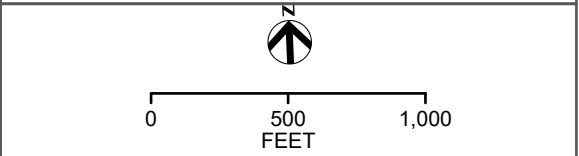






FIGURE 1-3

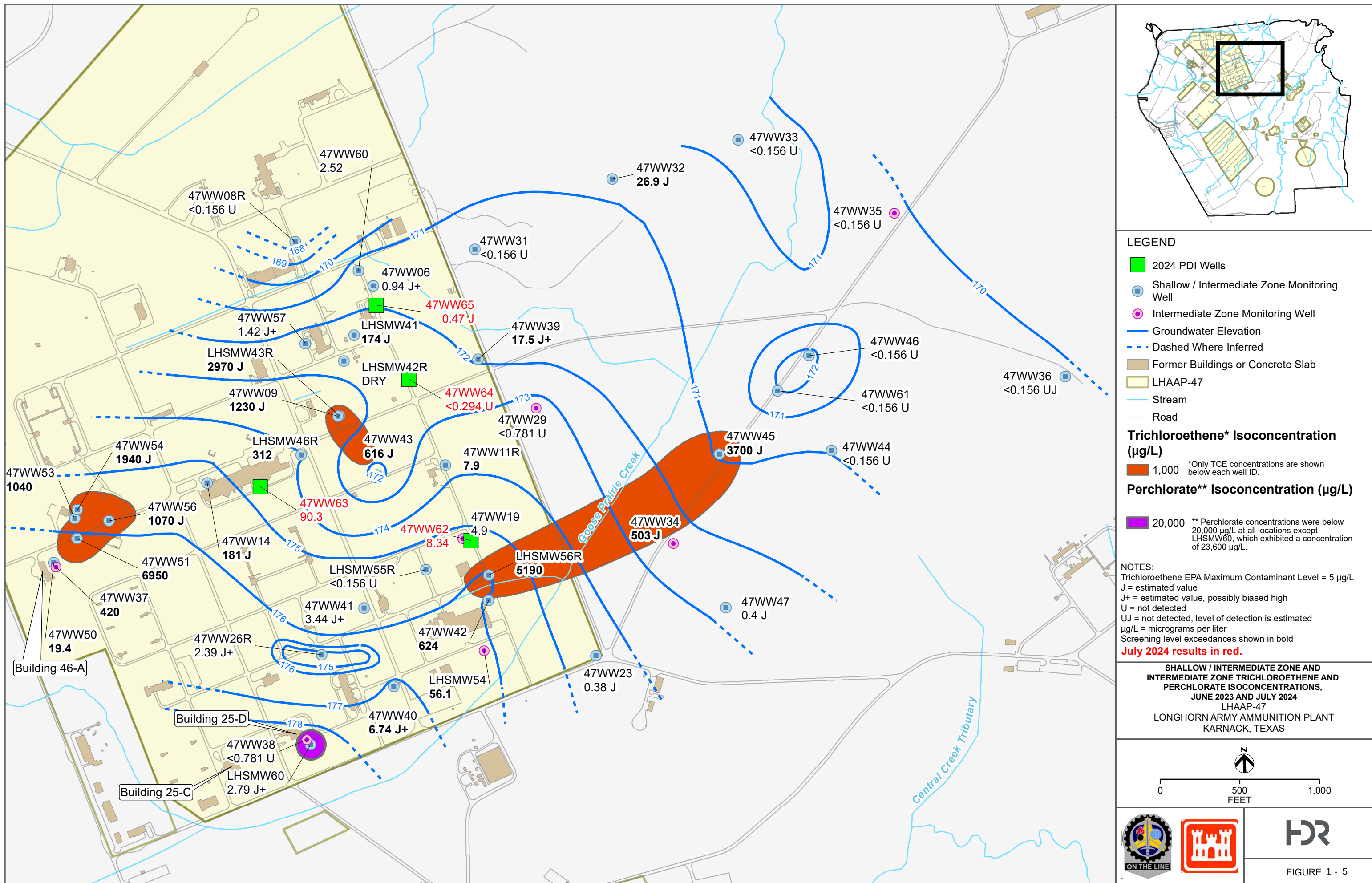
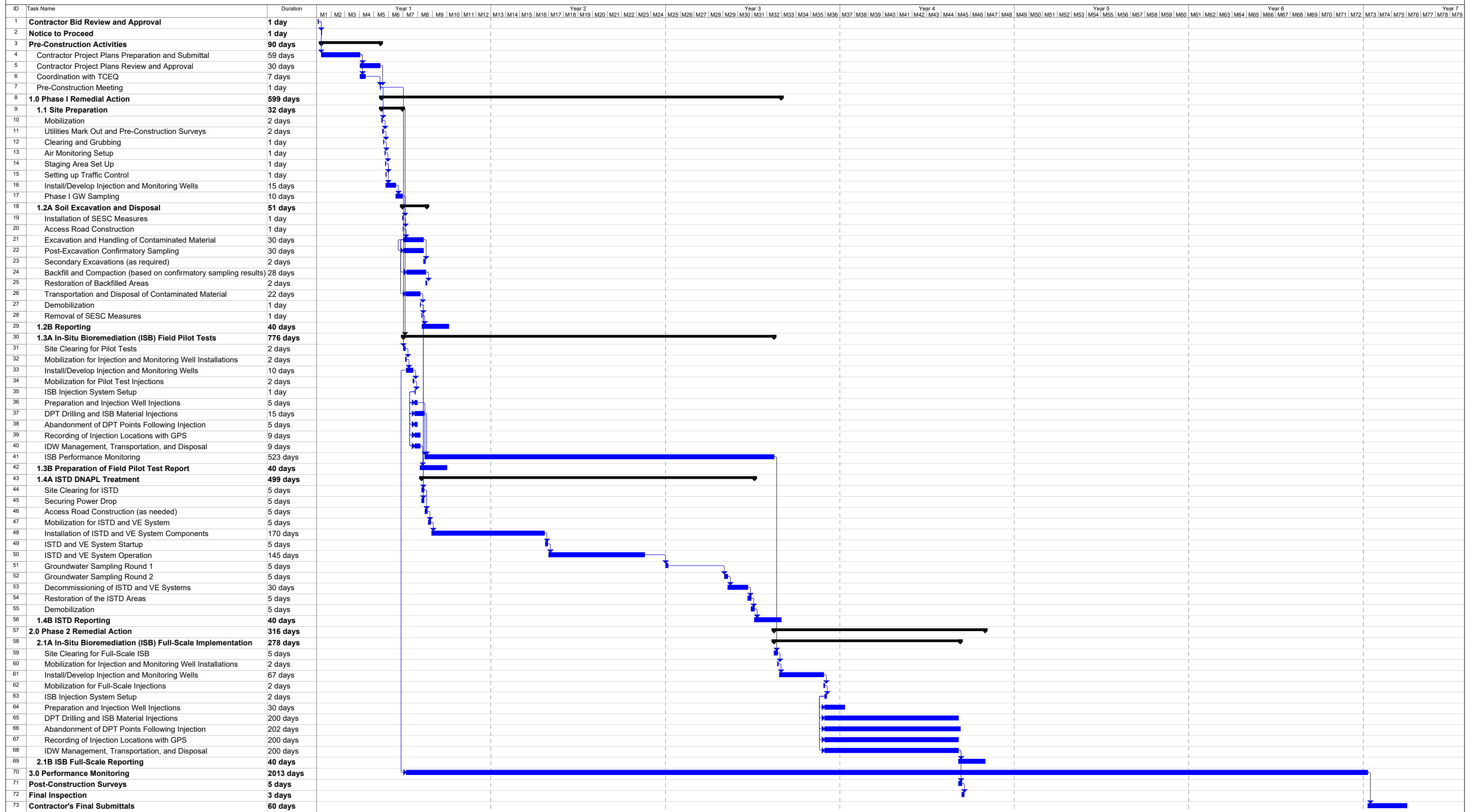


Figure 6-1 General Remedial Action Construction Schedule
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas





APPENDIX B

Final Remedial Design Cost Estimate

**Former Longhorn Army Ammunition Plant
(LHAAP) Site 47**

CONSTRUCTION COST ESTIMATE								
Site:		Former Longhorn Army Ammunition Plant (LHAAP) Site 47 - Plant 3 Area - Solid Rocket Motor Fuel Production				RA costs include: • Phase I - Implementation of additional wells and sampling, Excavation of unsaturated soil, implementation of ISTD treatment to remove DNAPL, implementation of four ISB field pilot tests, and implementation of LUCs. • Phase II - ISB treatment in grids and biobarriers. RA costs for MNA and LTM activities are not provided in this cost estimate.		
Location:		Karnack, Texas						
Phase:		Final (100%) Remedial Design						
Base Year:		2026						
Date:		June 18, 2026						
Item		Quantity	Unit	Unit Cost	Estimated Cost	Subtotal	Note	
Phase 1-1: Unsaturated Soil Excavation Remedial Action								
1.1.1 General								
1.1.1.1	Submittals/Implementation Plans	1	LS	\$80,000	\$80,000		Work Plan, QAPP, HASP, CQCP, etc.	
1.1.1.2	Coordinate with Regulators/Approvals	1	LS	\$15,000	\$15,000		Based on experience on similar projects.	
1.1.1.3	Pre-Construction Meetings	1	LS	\$15,000	\$15,000		Based on experience on similar projects.	
1.1.1.4	Post-Construction Submittals	1	LS	\$80,000	\$80,000		Manifests, as-builts, air monitoring results, verification sample results, boring logs, etc.	
Subtotal							\$190,000	
1.1.2 Mobilization/Demobilization for Excavation								
1.1.2.1	General Mobilization/Demobilization	1	LS	\$150,000	\$150,000		Excavators, loader, dozer, etc.	
Subtotal							\$150,000	
1.1.3 Site Preparation for Excavation								
1.1.3.1	Pre-Construction Survey	1	acre	\$2,000	\$2,000		Existing conditions survey and stakeout.	
1.1.3.2	Clearing and Grubbing	0.3	acre	\$3,180	\$954		Based on task-based estimate.	
1.1.3.3	Silt Fence	1,600	LF	\$1.70	\$2,720		Assume silt fence around excavation perimeters and stockpile area.	
1.1.3.4	Erosion Control Measures	1	LS	\$10,000	\$10,000		Based on experience on similar projects.	
1.1.3.5	Access Roads	700	SY	\$11	\$7,700		8" Gravel depth, 20-ft wide.	
1.1.3.6	Equipment Staging Areas	1	EA	\$13,100	\$13,100		Based on experience on similar projects.	
1.1.3.7	Decontamination Pad	1	EA	\$17,800	\$17,800		Lined stone decon pad with sump.	
1.1.3.8	Truck Loading Area	3	EA	\$800	\$2,400		Bermed loading area with geo-membrane liner.	
1.1.3.9	Utility Mark-Out	3	Day	\$2,430	\$7,290		Based on experience on similar projects.	
1.1.3.10	Temporary Facilities Rentals	3	Mo	\$600	\$1,800		Based on experience on similar projects.	
1.1.3.11	Construction Fence	1,600	LF	\$1.80	\$2,880		Orange construction fence to signify excavation area.	
Subtotal							\$69,000	
1.1.4 Health and Safety for Excavation								
1.1.4.1	Perimeter Air Monitoring	28	Day	\$960	\$26,880		Based on task-based estimate.	
1.1.4.2	H&S Monitoring	6	Week	\$1,280	\$7,168		Based on task-based estimate.	
1.1.4.3	PPE and Field Supplies	6	Week	\$200	\$1,120		Based on experience on similar projects.	
1.1.4.4	H&S Superintendent	280	Hr	\$200	\$56,000		Based on task-based estimate.	
Subtotal							\$91,000	
1.1.5 Excavation								
1.1.5.1	Excavation, Stockpiling, & Handling	9,900	BCY	\$18	\$178,200		Excavate soil and loading of trucks for off-site disposal.	
1.1.5.2	Survey Work	30	Day	\$2,430	\$72,900		1 day field per excavation; 3 days office per excavation.	
1.1.5.3	Confirmation Sample Collection	240	HR	\$170	\$40,800		VOCs and perchlorate analysis.	
1.1.5.4	Confirmation Sample Analysis - Perchlorate	55	EA	\$260	\$14,300		48 hr TAT (primary excavations).	
Subtotal							\$306,000	
1.1.6 Waste Disposal for Excavation								
1.1.6.1	Non-Hazardous Waste Transport & Disposal	9,900	LCY	\$245.53	\$2,430,729		Assumes 1.10 conversion from BCY to LCY.	
1.1.6.2	Hazardous Waste Transport	1,100	LCY	\$223.94	\$246,330		Assumes 1.10 conversion from BCY to LCY.	
1.1.6.3	Hazardous Waste Disposal	1,700	TN	\$501.48	\$852,516		Assumes 1.5 conversion from LCY to tons.	
1.1.6.4	Truck Liners	1,000	EA	\$60	\$60,000		Based on experience on similar projects.	
1.1.6.5	Waste Characterization Samples	40	EA	\$1,880	\$75,200		1 test per 250 CY; Based on experience on similar projects.	
Subtotal							\$3,665,000	
1.1.7 Post-Excavation Restoration								
1.1.7.1	Backfill (Imported Common Fill)	12,100	CCY	\$81	\$980,100		Importing certified clean soil; includes placement, hauling, compaction.	
1.1.7.2	Backfill Source Sampling	49	EA	\$520	\$25,480		1 sample per 250 cy (for both reused shallow soil and imported common fill).	
1.1.7.3	Seeding	9,200	SF	\$0.20	\$1,840		Based on experience on similar projects.	
Subtotal							\$1,007,000	
Subtotal for Phase 1-1: Unsaturated Soil Excavation Remedial Action						\$5,478,000		
Phase 1-2: In-Situ Thermal Desorption (ISTD) Remedial Action								
1.2.1 Pre-Construction								
1.2.1.1	Submittals/Implementation Plans	1	LS	\$104,800	\$104,800		QAPP, HASP, shop drawings, and work plans.	
1.2.1.2	Detailed Design and Permit Equivalency	1	LS	\$70,000	\$70,000		2026 Quote from TerraTherm.	
1.2.1.3	Procurement	1	LS	\$120,000	\$120,000		2026 Quote from TerraTherm.	
1.2.1.4	Coordinate with Regulators/Approvals	1	LS	\$14,400	\$14,400		Based on experience on similar projects.	
1.2.1.5	Pre-Construction Meetings	1	LS	\$5,000	\$5,000		Based on experience on similar projects.	
1.2.1.6	Post-Construction Submittals	1	LS	\$50,000	\$50,000		ISTD Completion Report.	
Subtotal							\$364,200	
1.2.2 Mobilization/Demobilization for ISTD								
1.2.2.1	General Mobilization	1	LS	\$3,000	\$3,000		General Mobilization for oversight sampling.	
1.2.2.2	Mobilization and Site Setup	1	LS	\$310,000	\$310,000		2026 Quote from TerraTherm.	
1.2.2.3	Decomissioning	1	LS	\$190,000	\$190,000		2026 Quote from TerraTherm.	
1.2.2.4	Site Clearance and Demobilization	1	LS	\$150,000	\$150,000		2026 Quote from TerraTherm.	
1.2.2.5	Reporting	1	LS	\$30,000	\$30,000		2026 Quote from TerraTherm.	
Subtotal							\$683,000	
1.2.3 Site Preparation for ISTD								
1.2.3.1	Perimeter Fence	1,245	LF	\$40	\$50,148		Perimeter fence around the ISTD areas.	
1.2.3.2	Clearing and Grubbing	1.3	acre	\$3,180	\$4,134		Based on experience on similar projects.	
1.2.3.3	Erosion Control Measures	1	LS	\$10,000	\$10,000		Based on experience on similar projects.	
1.2.3.4	Equipment Staging Area	1	EA	\$13,100	\$13,100		Based on experience on similar projects.	
1.2.3.5	Utility Mark-Out	2	Day	\$2,430	\$4,860		Based on experience on similar projects.	
1.2.3.6	New Well Installation - Mob/Demob	1	LS	\$11,940	\$11,940		Based on task-based estimate.	
1.2.3.7	New Well Installation (up to 50 ft)	6	EA	\$15,400	\$92,400		Well Installation + Development	
1.2.3.8	Temporary Facilities Rentals	17	Mo	\$3,352	\$56,976		Based on task-based estimate.	
Subtotal							\$244,000	

CONSTRUCTION COST ESTIMATE							
Site:		Former Longhorn Army Ammunition Plant (LHAAP) Site 47 - Plant 3 Area - Solid Rocket Motor Fuel Production				RA costs include: • Phase I - Implementation of additional wells and sampling, Excavation of unsaturated soil, implementation of ISTD treatment to remove DNAPL, implementation of four ISB field pilot tests, and implementation of LUCs. • Phase II - ISB treatment in grids and biobarriers. RA costs for MNA and LTM activities are not provided in this cost estimate.	
Location:		Karnack, Texas					
Phase:		Final (100%) Remedial Design					
Base Year:		2026					
Date:		June 18, 2026					
Item		Quantity	Unit	Unit Cost	Estimated Cost	Subtotal	Note
1.2.4 Health and Safety for ISTD							
1.2.4.1	Perimeter Air Monitoring	30	Week	\$4,780	\$143,400		VOCs monitoring.
1.2.4.2	H&S Monitoring	68	Week	\$1,280	\$87,040		VOCs monitoring.
1.2.4.3	PPE and Field Supplies	68	Week	\$200	\$13,600		Based on experience on similar projects.
1.2.4.4	H&S Superintendent	300	Hr	\$200	\$60,000		Based on task-based estimate.
Subtotal						\$304,000	
1.2.5 Power Drop for ISTD							
1.2.5.1	Power Drop and Transformer Installation	1	LS	\$150,000	\$150,000		Requires actual quote when RA is being implemented.
1.2.5.2	Utilities - Power	1	LS	\$1,712,920	\$1,712,920		2026 Quote from Ark-La-Tex-Electric.
Subtotal						\$1,863,000	
1.2.6 ISTD - System Installations and Operations							
1.2.6.1	Drilling and Well Installation	1	LS	\$2,760,000	\$2,760,000		2026 Quote from TerraTherm. 100 ft/day drilling production is assumed.
1.2.6.2	Wellfield Piping	1	LS	\$600,000	\$600,000		2026 Quote from TerraTherm.
1.2.6.3	Power System Installation (ERH)	1	LS	\$80,000	\$80,000		2026 Quote from TerraTherm.
1.2.6.4	Power System Rental (ERH)	1	LS	\$540,000	\$540,000		2026 Quote from TerraTherm.
1.2.6.5	Treatment System Installation	1	LS	\$540,000	\$540,000		2026 Quote from TerraTherm.
1.2.6.6	Effluent Treatment System Rental	1	LS	\$180,000	\$180,000		2026 Quote from TerraTherm.
1.2.6.7	GAC and Water	1	LS	\$610,000	\$610,000		2026 Quote from TerraTherm.
1.2.6.8	Electrical Installation, Wellfield and Process	1	LS	\$220,000	\$220,000		2026 Quote from TerraTherm.
1.2.6.9	Instrument and Monitoring System Installation	1	LS	\$100,000	\$100,000		2026 Quote from TerraTherm.
1.2.6.10	Pre-Startup and Shakedown	1	LS	\$60,000	\$60,000		2026 Quote from TerraTherm.
1.2.6.11	System Operation Labor and Per Diem	1	LS	\$660,000	\$660,000		2026 Quote from TerraTherm. Field Crew (3 persons on average) housed within a 30-minute drive to the site.
1.2.6.12	Field and Technical Support during Operation	1	LS	\$590,000	\$590,000		2026 Quote from TerraTherm.
1.2.6.13	Process Monitoring, Sampling and Analysis	1	LS	\$140,000	\$140,000		2026 Quote from TerraTherm.
1.2.3.14	Condensate/Discharge Storage, Sampling and Analysis	1	LS	\$18,800	\$18,800		Assumes once a month sampling for 8 months.
1.2.6.15	Repair/Maintenance	1	LS	\$110,000	\$110,000		2026 Quote from TerraTherm.
1.2.6.16	Tools, Rentals and Fees	1	LS	\$40,000	\$40,000		2026 Quote from TerraTherm.
Subtotal						\$7,249,000	
1.2.7 Post-ISTD Restoration							
1.2.7.1	Seeding	52,500	SF	\$0.20	\$10,500		
1.2.7.2	Groundwater Sampling and Analysis	1	LS	\$39,800	\$39,800		Assumes one pre and two post-ISTD events for 7 wells.
Subtotal						\$50,000	
Subtotal for Phase 1-2: In-Situ Thermal Desorption (ISTD) Remedial Action						\$10,757,000	
Phase 1-3: In-Situ Bioremediation (ISB) Pilot Tests							
1.3.1 Pre-Pilot Tests							
1.3.1.1	Submittals/Implementation Plans	1	LS	\$49,140	\$49,140		QAPP, HASP, shop drawings, and work plans.
1.3.1.2	Coordinate with Regulators/Approvals	1	LS	\$14,400	\$14,400		Based on experience on similar projects.
1.3.1.3	Pre-Pilot Tests Meetings	1	LS	\$5,000	\$5,000		Based on experience on similar projects.
1.3.1.4	Post Pilot Test Submittals	1	LS	\$50,000	\$50,000		ISB Pilot Test and Recommendation Report.
1.3.1.5	Pre-Test and Performance Monitoring Sampling Labor	104	Day	\$2,160	\$224,640		Based on task-based estimate.
1.3.1.6	Pre-Test and Performance Monitoring Sampling Analysis	1	LS	\$251,740	\$251,740		
1.3.1.7	Field Parameters Monitoring Labor and Equipment	12	Day	\$1,350	\$15,525		Field Parameters Monitoring.
1.3.1.8	LTM Sampling (Year 1 to 2)	40	Day	\$2,160	\$86,400		Assumes two-person crew; 2 sampling events/year; total 4 events.
1.3.1.9	LTM Sampling Analyses (Laboratory) (Year 1 to 2)	1	LS	\$120,680	\$120,680		Assumes two-person crew; 2 sampling events/year; total 4 events.
Subtotal						\$818,000	
1.3.2 Mobilization/Demobilization for ISB Pilot Tests		1	LS	\$23,000	\$23,000		Drill Rig and Organic Substrate Materials Mobilization.
Subtotal						\$23,000	
1.3.3 Site Preparation for ISB Pilot Tests							
1.3.3.1	Clearing and Grubbing	0.5	acre	\$3,180	\$1,590		Based on task-based estimate.
1.3.3.2	Equipment Staging Area	1	EA	\$5,000	\$5,000		Based on experience on similar projects.
1.3.3.3	Utility Mark-Out	2	Day	\$2,430	\$4,860		Assumes half day for each area.
1.3.3.4	New Well Installation - Mob/Demob	1	LS	\$11,940	\$11,940		Based on task-based estimate.
1.3.3.5	New Well Installation (up to 50 ft)	28	EA	\$15,400	\$431,200		Well Installation + Development. 15 for the Pilot Test and 13 for LTM.
1.3.3.6	Temporary Facilities Rentals	12	Mo	\$3,360	\$40,320		
Subtotal						\$495,000	
1.3.4 Health and Safety for ISB Pilot							
1.3.4.1	H&S Monitoring	4	Week	\$1,280	\$5,120		VOCs monitoring.
1.3.4.2	PPE and Field Supplies	4	Week	\$200	\$800		Based on experience on similar projects.
1.3.4.3	H&S Superintendent	40	Hr	\$200	\$8,000		Based on task-based estimate.
Subtotal						\$14,000	
1.3.5 ISB Pilot Tests Substrate Material and Delivery							
1.3.5.1	ISB Substrate Material and Delivery	1	LS	\$52,100	\$52,100		Material cost plus estimated freight + Tax; From Terrasystems Quote.
Subtotal						\$53,000	
1.3.6 ISB Pilot Tests Injections							
1.3.6.1	DPT Drilling and Injection for Temporary Injections	11	Day	\$3,430	\$36,015		Probe/Drill Rig Daily Rental W/ Operator.
1.3.6.2	Decontamination Equipment	11	Day	\$220	\$2,310		Based on experience on similar projects.
1.3.6.3	Injection Labor and Equipment	11	Day	\$2,868	\$30,114		Based on task-based estimate.
1.3.6.4	IDW Management	1	LS	\$400	\$400		Based on experience on similar projects.
Subtotal						\$69,000	

CONSTRUCTION COST ESTIMATE						
Site: Former Longhorn Army Ammunition Plant (LHAAP) Site 47 - Plant 3 Area - Solid Rocket Motor Fuel Production Location: Karnack, Texas Phase: Final (100%) Remedial Design Base Year: 2026 Date: June 18, 2026 RA costs include: • Phase I - Implementation of additional wells and sampling, Excavation of unsaturated soil, implementation of ISTD treatment to remove DNAPL, implementation of four ISB field pilot tests, and implementation of LUCs. • Phase II - ISB treatment in grids and biobarriers. RA costs for MNA and LTM activities are not provided in this cost estimate.						
Item	Quantity	Unit	Unit Cost	Estimated Cost	Subtotal	Note
1.3.7 ISB Pilot Tests 2 - IW Installation and Injections						
1.3.7.1 IW Well Installation Mob/Demob	1	LS	\$11,940	\$11,940		Probe/Drill Rig Daily Rental W/ Operator; Based on task-based estimate.
1.3.7.2 IW Well Installation	5	EA	\$15,400	\$77,000		Well Installation + Development; Based on task-based estimate.
1.3.7.3 Decontamination Equipment	1	Day	\$220	\$220		Based on experience on similar projects.
1.3.7.4 Decontamination of Drilling Equipment	6	Day	\$110	\$660		Based on experience on similar projects.
1.3.7.5 Injection Labor and Equipment	1	Day	\$2,868	\$2,868		Based on task-based estimate.
1.3.7.6 IDW Management	1	LS	\$100	\$100		Based on experience on similar projects.
Subtotal					\$93,000	
Subtotal for Phase 1-3: In-Situ Bioremediation (ISB) Pilot Tests						
					\$1,565,000	
Phase 1-4: Implementation of LUCs						
1.4.1 Implementation of LUCs						
1.4.1.1 Preliminary LUCs Review	1	LS	\$10,000	\$10,000		Based on experience on similar projects.
1.4.1.2 LUC Updates and Revision	1	LS	\$15,000	\$15,000		Based on experience on similar projects.
1.4.1.3 LUC Submittals	1	LS	\$5,000	\$5,000		Based on experience on similar projects.
Subtotal					\$30,000	
Subtotal for 1.4.1 Implementation of LUCs						
					\$30,000	
Subtotal for Phase I Remedial Actions:						
					\$17,830,000	
Contingency: 30%						
					\$5,349,000	
Subtotal for Remedial Actions:						
					\$23,179,000	
Construction Oversight: 6%						
					\$1,070,000	
Construction Management: 8%						
					\$1,426,000	
TOTAL PHASE I - REMEDIAL ACTION COST						
					\$ 25,675,000	
Phase 2: In-Situ Bioremediation Grids and Biobarriers						
2.1 Pre-Construction						
2.1.1 Submittals/Implementation Plans	1	LS	\$229,320	\$229,320		QAPP, HASP, shop drawings, and work plans.
2.1.2 Coordinate with Regulators/Approvals	1	LS	\$14,400	\$14,400		Based on experience on similar projects.
2.1.3 Pre-Construction Meetings	1	LS	\$5,000	\$5,000		Based on experience on similar projects.
2.1.4 Post-Construction Submittals	1	LS	\$150,000	\$150,000		ISB Completion Report.
Subtotal					\$399,000	
2.2 Mobilization/Demobilization for ISB						
2.2.1 General Mobilization/Demobilization	1	LS	\$29,000	\$29,000		Drill Rigs & Organic Substrate Materials Mobilization.
Subtotal					\$29,000	
2.3 Site Preparation for ISB						
2.3.1 Clearing and Grubbing	35.6	acre	\$3,180	\$113,300		Based on experience on similar projects.
2.3.2 Equipment Staging Area	1	EA	\$10,000	\$10,000		Based on experience on similar projects.
2.3.3 Utility Mark-Out	12	Day	\$2,430	\$28,836		Assumes 3 acre per day.
2.3.4 New Well Installation - Mob/Demob	1	LS	\$11,940	\$11,940		
2.3.5 New Well Installation (up to 50 ft)	20	EA	\$15,400	\$308,000		Well Installation + Development for 20 wells
2.3.6 Temporary Facilities Rentals	12	Mo	\$3,352	\$40,218		Based on experience on similar projects.
Subtotal					\$512,000	
2.4 Health and Safety for ISB Drilling						
2.4.1 H&S Monitoring	108	Week	\$1,200	\$129,600		VOCs monitoring.
2.4.2 PPE and Field Supplies	108	Week	\$200	\$21,600		Based on experience on similar projects.
2.4.3 H&S Superintendent	1,080	Hr	\$120	\$129,600		Assumes 2 hours per day.
Subtotal					\$281,000	
2.5 ISB Injections Substrate Material and Delivery - 1st Event						
2.5.1 ISB Substrate Material and Delivery	1	LS	\$2,374,100	\$2,374,100		Material cost plus estimated fright + Tax for both Biobarriers and Grid Areas.
Subtotal					\$2,374,000	
2.6 ISB Grid System DPT Installation & Injections - 1st Event						
2.6.1 DPT Drilling for Temporary Injections (Two Rigs)	328	Day	\$6,860	\$2,247,019		Probe/Drill Rig Daily Rental W/ Operator (Two Rigs).
2.6.2 Decontamination Equipment (Two Crews)	328	Day	\$440	\$144,124		Based on experience on similar projects.
2.6.3 Decontamination of Drilling Equipment (Two crews)	328	Day	\$220	\$72,062		Based on experience on similar projects.
2.6.4 Injection Labor and Equipment (Two crews)	328	Day	\$5,736	\$1,878,855		
2.6.5 IDW Management	1	LS	\$30,000	\$30,000		Based on experience on similar projects.
Subtotal					\$4,372,000	
2.7 ISB Biobarrier IW Injection - 1st Event						
2.7.1 IW Well Installation Mob/Demob	1	LS	\$11,940	\$11,940		Probe/Drill Rig Daily Rental W/ Operator.
2.7.2 IW Well Installation	16	EA	\$15,400	\$246,400		Well Installation + Development.
2.7.3 Decontamination Equipment	5	Day	\$220	\$1,100		Based on experience on similar projects.
2.7.4 Decontamination of Drilling Equipment	16	Day	\$110	\$1,760		Based on experience on similar projects.
2.7.5 Injection Labor and Equipment	5	Day	\$5,736	\$28,680		
2.7.6 IDW Management	1	LS	\$1,000	\$1,000		
Subtotal					\$291,000	

CONSTRUCTION COST ESTIMATE							
Site:		Former Longhorn Army Ammunition Plant (LHAAP) Site 47 - Plant 3 Area - Solid Rocket Motor Fuel Production				RA costs include:	
Location:		Karnack, Texas				• Phase I - Implementation of additional wells and sampling, Excavation of unsaturated soil, implementation of ISTD treatment to remove DNAPL, implementation of four ISB field pilot tests, and implementation of LUCs.	
Phase:		Final (100%) Remedial Design				• Phase II - ISB treatment in grids and biobarriers.	
Base Year:		2026				RA costs for MNA and LTM activities are not provided in this cost estimate.	
Date:		June 18, 2026					
Item		Quantity	Unit	Unit Cost	Estimated Cost	Subtotal	Note
2.8 ISB Biobarrier DPT Injections - 1st Event							
2.8.1	DPT Drilling and Injection for Temporary Injections	25	Day	\$3,430	\$85,750		Probe/Drill Rig Daily Rental W/ Operator.
2.8.2	Decontamination Equipment	25	Day	\$220	\$5,500		Based on experience on similar projects.
2.8.3	Decontamination of Drilling Equipment	25	Day	\$110	\$2,750		Based on experience on similar projects.
2.8.4	Injection Labor and Equipment	25	Day	\$2,868	\$71,700		
2.8.5	IDW Management	1	LS	\$2,000	\$2,000		
Subtotal						\$168,000	
2.9 ISB Injections Substrate Material and Delivery - 2nd Event (Assumes 33% of 1st Event)							
2.9.1	ISB Substrate Material and Delivery	1	LS	\$792,000	\$792,000		Material cost plus estimated fright + Tax; from Terrasystems.
Subtotal						\$792,000	
2.10 ISB Grid System DPT Installation & Injections - 2nd Event (Assumes 33% of the 1st Event)							
2.10.1	DPT Drilling for Temporary Injections (Two Rigs)	162	Day	\$6,860	\$1,108,748		Probe/Drill Rig Daily Rental W/ Operator.
2.10.2	Decontamination Equipment (Two crews)	162	Day	\$440	\$71,115		Based on experience on similar projects.
2.10.3	Decontamination of Drilling Equipment (Two crews)	162	Day	\$220	\$35,558		Based on experience on similar projects.
2.10.4	Injection Labor and Equipment (Two crews)	162	Day	\$5,736	\$927,084		
2.10.5	IDW Management	1	LS	\$10,000	\$10,000		
Subtotal						\$2,153,000	
2.11 ISB Biobarrier IW Injection - 2nd Event							
2.11.1	Decontamination Equipment	5	Day	\$220	\$1,100		Based on experience on similar projects.
2.11.2	Decontamination of Injection Equipment	5	Day	\$110	\$550		Based on experience on similar projects.
2.11.3	Injection Labor and Equipment	5	Day	\$2,868	\$14,340		
Subtotal						\$16,000	
2.12 Post-ISB Restoration							
2.12.1	Field Parameters Monitoring	1	LS	\$564,300	\$564,300		Field Parameters Monitoring.
2.12.2	Evaluation Of Design Effectiveness Sampling Labor (Year 1 & 2)	149	Day	\$2,160	\$321,840		Assumes two-person crew; total 8 events as Quarterly for Year 1& 2 and surface water sampling.
2.12.3	Evaluation Of Design Effectiveness Sample Analyses (Laboratory) (Year 1 & 2)	1	LS	\$244,020	\$244,020		Assumes two-person crew; total 8 events as Quarterly for Year 1& 2 and surface water sampling.
2.12.4	LTM Sampling (Year 3 to 5)	60	Day	\$2,160	\$129,600		Assumes two-person crew; 2 sampling events/year; total 6 events.
2.12.5	LTM Sampling Analyses (Laboratory)(Year 3 to 5)	1	LS	\$181,020	\$181,020		Assumes two-person crew; 2 sampling events/year; total 6 events.
2.12.6	Reporting	4	EA	\$25,000	\$100,000		
2.12.7	Hydroseed	1,550,736	SF	\$0.20	\$310,147		Based on experience on similar projects.
2.12.8	Demobilization	1	LS	\$20,000	\$20,000		Labor, equipment and disposal.
Subtotal						\$1,871,000	
Subtotal for Phase II Remedial Actions:						\$13,258,000	
Contingency:						30%	\$3,977,400
Subtotal for Remedial Actions:						\$17,235,000	
Construction Oversight:						6%	\$795,000
Construction Management:						8%	\$1,061,000
TOTAL PHASE II - REMEDIAL ACTION COST						\$ 19,091,000	
TOTAL COST						\$ 44,766,000	

Longhorn 47

Task-Based Estimate Backup Calculations

Task #	Description	Type	Item	Total Rate	Unit	Bid Qty	Bid Unit	Prod	Prod Unit	Qty	±	Qty ±	Qty Unit	Task Cost	Direct Unit Cost	HOOH (6%)	JOOH (10%)	Profit (8%)	Bond (2%)	Total Unit Price
1	Excavation, Stockpiling, and Handling					9,900.0	BCY							\$134,502.51	\$13.59	\$0.82	\$1.36	\$1.09	\$0.27	\$17.12
	Excavate and Stockpile Fill	Crew	EXC1	\$848.86	hour	9,900.0	BCY	100.0	cy/hr	99.0	4.0	100.0	hour	\$84,886.28	\$8.57					
	Load Fill into Trucks for Disposal	Crew	LOAD1	\$775.25	hour	6,200.0	BCY	100.0	cy/hr	62.0	4.0	64.0	hour	\$49,616.23	\$8.00					
2	Haul Disposal, Non-Hazardous					9,900.0	CCY							\$1,409,400.00	\$142.36	\$8.54	\$14.24	\$11.39	\$2.85	\$179.38
	Haul to disposal	Haul	Haul_Dispose_WC	\$1,566.00	load	9,900.0	BCY	11.0	cy/load	900.0	1.0	900.0	load	\$1,409,400.00	\$142.36					
3	Disposal Fee, Non-Hazardous					9,900.0	CCY							\$519,750.00	\$52.50	\$3.15	\$5.25	\$4.20	\$1.05	\$66.15
	Disposal Fee	MatFee	Fee_WC	\$52.50	cy	9,900.0	BCY	n/a	n/a	9,900.0	10.0	9,900.0	cy	\$519,750.00	\$52.50					
4	Haul Disposal, Hazardous					1,100.0	CCY							\$195,500.00	\$177.73	\$10.66	\$17.77	\$14.22	\$3.55	\$223.94
	Haul to disposal	Haul	Haul_Dispose_Republic	\$1,955.00	load	1,100.0	BCY	11.0	cy/load	100.0	1.0	100.0	load	\$195,500.00	\$177.73					
5	Disposal Fee, Hazardous					1,100.0	TON							\$437,800.00	\$398.00	\$23.88	\$39.80	\$31.84	\$7.96	\$501.48
	Disposal Fee	MatFee	Fee_Republic	\$398.00	tn	1,100.0	TON	n/a	n/a	1,100.0	10.0	1,100.0	tn	\$437,800.00	\$398.00					
6	Survey Crew per Day					1.0	DAY							\$1,927.39	\$1,927.39	\$115.64	\$192.74	\$154.19	\$38.55	\$2,428.51
	Survey	Crew	Survey	\$240.92	hour	1.0	DAY	0.13	hr/day	8.0	4.0	8.0	hour	\$1,927.39	\$1,927.39					
7	Sampling					8.0	HR							\$1,075.36	\$134.42	\$8.07	\$13.44	\$10.75	\$2.69	\$169.37
	Collect and Log Samples	Crew	Sampling	\$134.42	hour	8.0	HR	1.00	HR	8.0	4.0	8.0	hour	\$1,075.36	\$134.42					
8	Injection Well Eq and Labor					10.5	DAY							\$23,900.08	\$2,276.20	\$136.57	\$227.62	\$182.10	\$45.52	\$2,868.01
	Injection Well Crew	Crew	InjWell	\$227.62	hour	10.5	DAY	0.10	HR	105.0	1.0	105.0	hour	\$23,900.08	\$2,276.20					
9	Security Guard					3,024.0	HR							\$161,129.15	\$53.28	\$3.20	\$5.33	\$4.26	\$1.07	\$67.14
	Guard 1	Crew	Guard1	\$53.28	hour	3,024.0	HR	1.00	HR	3,024.0	4.0	3,024.0	hour	\$161,129.15	\$53.28					
10	Monitoring Costs																			
	Air Quality Monitor (DAY)	Crew	EnvMonitor	\$94.68	hour	28.0	day	0.13	HR	224.0	4.0	224.0	hour	\$21,207.74	\$757.42	\$45.45	\$75.74	\$60.59	\$15.15	\$954.35
	Air Quality Monitor (WK)	Crew	EnvMonitor	\$94.68	hour	4.0	wk	0.03	wk/hr	160.0	4.0	160.0	hour	\$15,148.38	\$3,787.10	\$227.23	\$378.71	\$302.97	\$75.74	\$4,771.74
11	Health and Safety																			
	Health and Safety Officer	Crew	HSOfficer	\$156.34	hour	300.0	hr	1.00	HR	300.0	4.0	300.0	hour	\$46,901.69	\$156.34	\$9.38	\$15.63	\$12.51	\$3.13	\$196.99
	Health and Safety Monitor (10 hr/wk)	Crew	HSMonitor	\$101.24	hour	68.0	wk	0.10	wk/hr	680.0	4.0	680.0	hour	\$68,844.80	\$1,012.42	\$60.75	\$101.24	\$80.99	\$20.25	\$1,275.65
12	Dispose Excavation					9,900.0	tn							\$3,940,200.00	\$398.00	\$23.88	\$39.80	\$31.84	\$7.96	\$501.48
	Disposal at Charles Lake CWM	MatFee	FEE_Republic	\$398.00	tn	9,900.0	tn	n/a	n/a	9,900.0	10.0	9,900.0	tn	\$3,940,200.00	\$398.00					
13	DPT Drilling					10.5	day							\$28,562.38	\$2,720.23	\$163.21	\$272.02	\$217.62	\$54.40	\$3,427.49
	Direct Push Rig, Labor, Decon, Sampling	MatFee	DirectPushRig	\$2,596.58	day	10.5	day	n/a	n/a	10.5	1.0	11.0	day	\$28,562.38	\$2,720.23					
14	Clearing and Grubbing (assume 6-in deep)					30,411.3	CCY							\$6,408,426.93	\$210.72	\$12.64	\$21.07	\$16.86	\$4.21	\$265.51
					0.8	37.7	AC							\$6,408,426.93	\$169,984.80	\$10,199.09	\$16,998.48	\$13,598.78	\$3,399.70	\$214,180.85
													No disposal	\$94,848.93	\$2,515.89	\$150.95	\$251.59	\$201.27	\$50.32	\$3,170.02
	Excavate surface material	Crew	CG1	\$307.95	hour	30,411.3	CCY	100.0	cy/hr	304.1	4.0	308.0	hour	\$94,848.93	\$3.12	\$0.19	\$0.31	\$0.25	\$0.06	\$3.93
	Haul to disposal	Haul	Haul_Dispose_WC	\$1,566.00	load	36,493.6	BCY	13.0	cy/load	2,807.2	1.0	2,808.0	load	\$4,397,328.00	\$120.50					
	Disposal Fee	MatFee	Fee_WC	\$52.50	cy	36,493.6	BCY	n/a	n/a	36,493.6	10.0	36,500.0	cy	\$1,916,250.00	\$52.51					
15	Drill MW + Development					10	ea							\$122,054.35	\$12,205.44	\$732.33	\$1,220.54	\$976.43	\$244.11	\$15,378.85
						500.0	LF							\$122,054.35	\$244.11	\$14.65	\$24.41	\$19.53	\$4.88	\$307.58
	Drill Well	Crew	Drilling	\$592.26	hour	500.0	LF	12.5	lf/hr	40.0	4.0	40.0	hour	\$23,690.29	\$47.38					
	Casing	MatFee	MW_Casing	\$26.39	lf	500.0	lf	n/a	n/a	500.0	10.0	500.0	lf	\$13,195.46	\$26.39					
	Well Screen	MatFee	MW_Screen	\$44.79	lf	500.0	lf	n/a	n/a	500.0	10.0	500.0	lf	\$22,395.00	\$44.79					
	Gravel Filter	MatFee	MW_GravelPack	\$309.79	lf	200.0	lf	n/a	n/a	200.0	10.0	200.0	lf	\$61,958.00	\$309.79					
	Well Cap	MatFee	MW_Cap	\$81.56	ea	10.0	ea	n/a	n/a	10.0	10.0	10.0	ea	\$815.60	\$81.56					
16	Drill MW - Mob/Demob					1	ls							\$9,476.12	\$9,476.12	\$568.57	\$947.61	\$758.09	\$189.52	\$11,939.91
	Drill Well	Crew	Drilling	\$592.26	hour	1.0	ls	16.0	hr/ea	16.0	4.0	16.0	hour	\$9,476.12	\$9,476.12					
17	Temporary Facilities Rentals					12.0	mo							\$31,919.30	\$2,659.94	\$159.60	\$265.99	\$212.80	\$53.20	\$3,351.53
	Office Trailer	MatFee	OfficeTrailer_MO	\$549.12	mo	12.0	mo	n/a	n/a	12.0	10.0	20.0	mo	\$10,982.40	\$915.20					
	Field Storage	MatFee	StorageBox_MO	\$162.07	mo	12.0	mo	n/a	n/a	12.0	10.0	20.0	mo	\$3,241.40	\$270.12					

Longhorn 47

Summary of Task-Based Estimate Haul

Description	Segment	Distance	Speed	Time (min)	Haul (Min)	Haul (Hr)	Crew	Rate	Total Rate	Unit	Notes
Haul_Commercial	Load	n/a	n/a	4.5	99	1.7	Haul2	\$183.61	\$303.00	load	20-ft flatbed, haul from commercial supplier
	Assumed haul	n/a	n/a	45.0							
	Dump	n/a	n/a	4.5							
Haul_Exc_Stock	Load	n/a	n/a	4.0	22	0.4	Haul1	\$177.73	\$67.00	load	Haul to nearby disposal areas northeast of site.
	Surface Road Haul	0.5	25	1.2							
	On site	0.5	5	6.0							
	Dump	n/a	n/a	4.0							
Haul_Dispose_Republic	Load	n/a	n/a	30.0	660	11.0	Haul1	\$177.73	\$1,955.00	load	Hazardous Disposal to Tulsa Facility (Republic Service)
	307-mi 1-way haul	n/a	n/a	300.0							Tulsa Facility
	Dump	n/a	n/a	30.0							2700 South 25th West Avenue Tulsa, OK 74107
Haul_Dispose_WC	Load	n/a	n/a	12.0	529	8.8	Haul1	\$177.73	\$1,566.00	load	Non-hazardous disposal, Turkey Creek Landfill (Waste Connections)
	Surface Road Haul	204.0	50	244.8							Turkey Creek Landfill Disposal Dump
	On site	0.5	5	6.0							9100 I-35W, Alvarado, TX 76009
	Dump	n/a	n/a	15.0							

Longhorn 47

Summary of Task-Based Estimate Crews

Crew	Eq & Labor	Category	Unit Rate	Unit	Num	Rate	Total Rate	Notes
CG1	Excavator_4.0cy	Equip	\$183.04	hour	1	\$183.04	\$307.95	Hauling calculated separately.
	Operator4	Labor	\$124.91	hour	1	\$124.91		
	Teamster	Labor	\$118.50	hour	0	\$0.00		
	Laborer	Labor	\$94.87	hour	0	\$0.00		
Survey	Truck_Conventional	Equip	\$39.55	hour	1	\$39.55	\$240.92	Survey crew, 1 chief + 2 aide + 2 technicians + work truck
	SurveyChief	Labor	\$51.59	hour	1	\$51.59		
	SurveyingAide	Labor	\$31.58	hour	2	\$63.16		
	SurveyingTechnician	Labor	\$43.31	hour	2	\$86.62		
InjWell	6inPump	Equip	\$37.54	hour	1	\$37.54	\$227.62	IW labor, pump + 2 lab + truck
	6inPumpHose40ft	Equip	\$0.35	hour	1	\$0.35		
	Laborer	Labor	\$94.87	hour	2	\$189.73		
Sampling	Truck_Conventional	Equip	\$39.55	hour	1	\$39.55	\$134.42	Survey crew, 1 chief + 2 aide + 2 technicians + work truck
	Laborer	Labor	\$94.87	hour	1	\$94.87		
EnvMonitor	Truck_Conventional	Equip	\$39.55	hour	1	\$39.55	\$94.68	Environmental monitor + truck
	EnviroTech	Labor	\$55.13	hour	1	\$55.13		
HSEOfficer	HealthSafetyOfficer	Labor	\$156.34	hour	1	\$156.34	\$156.34	
HSMonitor	HealthSafetyMonitor	Labor	\$101.24	hour	1	\$101.24	\$101.24	
Guard1	Guard1	Labor	\$53.28	hour	1	\$53.28	\$53.28	
EXC1	Excavator_4.0cy	Equip	\$183.04	hour	1	\$183.04	\$848.86	Excavator to dump material to be pushed to sotckpile by dozer.
	Dozer_D6	Equip	\$216.18	hour	1	\$216.18		
	Truck_45klb_4x2	Equip	\$61.71	hour	1	\$61.71		
	WaterTank	Equip	\$19.61	hour	1	\$19.61		
	Operator4	Labor	\$124.91	hour	2	\$249.81		
EXC1	Teamster	Labor	\$118.50	hour	1	\$118.50		
EXC2	Excavator_4.0cy	Equip	\$183.04	hour	1	\$183.04	\$1,083.20	Excavator to dump material to be handled by dozer and loaded by loader, water truck for dust
	Dozer_D6	Equip	\$216.18	hour	1	\$216.18		
	Loader_FE_3.5cy	Equip	\$109.44	hour	1	\$109.44		
	Truck_45klb_4x2	Equip	\$61.71	hour	1	\$61.71		
	WaterTank	Equip	\$19.61	hour	1	\$19.61		
	Operator4	Labor	\$124.91	hour	3	\$374.72		
	Teamster	Labor	\$118.50	hour	1	\$118.50		
LOAD1	Excavator_4.0cy	Equip	\$183.04	hour	0	\$0.00	\$775.25	Material handling - loader + dozer
	Dozer_D6	Equip	\$216.18	hour	1	\$216.18		
	Loader_FE_3.5cy	Equip	\$109.44	hour	1	\$109.44		
	Truck_45klb_4x2	Equip	\$61.71	hour	1	\$61.71		
	WaterTank	Equip	\$19.61	hour	1	\$19.61		
	Operator4	Labor	\$124.91	hour	2	\$249.81		
	Teamster	Labor	\$118.50	hour	1	\$118.50		
FILL1	Dozer_D6	Equip	\$216.18	hour	1	\$216.18	\$1,015.66	Assume material dumped from import, dozer to push material in place for compactor, water truck included for dust control and moisture conditioning, water tank for water storage on site.
	Loader_FE_3.5cy	Equip	\$109.44	hour	0	\$0.00		
	Grader	Equip	\$119.94	hour	0.1	\$11.99		
	Roller_Vib_ShpFt_5.5ft	Equip	\$62.93	hour	1	\$62.93		

Longhorn 47**Summary of Task-Based Estimate Crews**

FILL1	Truck_45klb_4x2	Equip	\$61.71	hour	1	\$61.71		
	WaterTank	Equip	\$19.61	hour	1	\$19.61		
	Pump_Water_6in	Equip	\$17.09	hour	1	\$17.09		
	Tank_10kGal	Equip	\$16.75	hour	1	\$16.75		
	Truck_Pickup	Equip	\$38.86	hour	1	\$38.86		
	Operator4	Labor	\$124.91	hour	2.1	\$262.30		
	Teamster	Labor	\$118.50	hour	1	\$118.50		
FILL1	Laborer	Labor	\$94.87	hour	2	\$189.73		
Drilling	8inAuger	Equip	\$173.24	hour	1	\$173.24	\$592.26	8-in auger
	Truck_Conventional	Equip	\$39.55	hour	1	\$39.55		
	Laborer	Labor	\$94.87	hour	4	\$379.47		
SEED1	Hydroseeder	Equip	\$86.57	hour	1	\$86.57	\$361.65	
	Truck_45klb_4x2	Equip	\$61.71	hour	1	\$61.71		
	Teamster	Labor	\$118.50	hour	1	\$118.50		
	Laborer	Labor	\$94.87	hour	1	\$94.87		
HAUL1	Dump_Highway	Equip	\$59.23	hour	1	\$59.23	\$177.73	
	Teamster	Labor	\$118.50	hour	1	\$118.50		
HAUL2	Flatbed	Equip	\$3.40	hour	1	\$3.40	\$183.61	
	Truck_45klb_4x2	Equip	\$61.71	hour	1	\$61.71		
	Teamster	Labor	\$118.50	hour	1	\$118.50		

Longhorn 47

Summary of Labor Rates and Markups

Labor	Base Rate		Adjusted Base Rate	Fringes	Payroll Tax	WCI	Overtime	Productivity	Escalation	Total Rate	Unit	Notes
	Natl	Adjustment										
Operator2	\$58.29	0.98	\$56.99	\$25.57	\$11.34	\$12.81	\$6.48	\$19.98	\$18.32	\$133.17	hour	Heavy, USACE 2021 National Labor Library, adjusted to TX, escalated to 2022 + 20% for HTRW
Operator4	\$53.42	0.98	\$52.23	\$25.57	\$10.69	\$11.74	\$5.94	\$18.74	\$17.18	\$124.91	hour	Medium, USACE 2021 National Labor Library, adjusted to TX, escalated to 2022 + 20% for HTRW
Teamster	\$50.63	0.98	\$49.50	\$24.32	\$10.14	\$11.12	\$5.63	\$17.77	\$16.30	\$118.50	hour	Heavy, USACE 2021 National Labor Library, adjusted to TX, escalated to 2022
Laborer	\$44.53	0.98	\$43.54	\$14.40	\$7.96	\$9.78	\$4.95	\$14.23	\$13.05	\$94.87	hour	Semi-skilled, USACE 2021 National Labor Library, adjusted to TX, escalated to 2022 + 20% for HTRW
SurveyChief	\$24.68	0.98	\$24.13	\$7.24	\$4.31	\$5.42	\$2.74	\$7.74	\$0.00	\$51.59	hour	SCA code 99830, present cost
SurveyingAide	\$15.11	0.98	\$14.77	\$4.43	\$2.64	\$3.32	\$1.68	\$4.74	\$0.00	\$31.58	hour	SCA code 99831, present cost
SurveyingTechnician	\$20.72	0.98	\$20.26	\$6.08	\$3.62	\$4.55	\$2.30	\$6.50	\$0.00	\$43.31	hour	SCA code 99832, present cost
EnviroTech	\$26.37	0.98	\$25.78	\$7.74	\$4.61	\$5.79	\$2.93	\$8.27	\$0.00	\$55.13	hour	SCA code 30090, present cost
HealthSafetyOfficer	\$65.75	0.98	\$64.29	\$19.29	\$11.48	\$14.45	\$7.31	\$20.62	\$18.90	\$156.34	hour	USACE 2021 National Labor Library, adjusted to TX, escalated to 2022
HealthSafetyMonitor	\$42.58	0.98	\$41.63	\$12.49	\$7.44	\$9.36	\$4.74	\$13.35	\$12.24	\$101.24	hour	USACE 2021 National Labor Library, adjusted to TX, escalated to 2022
Guard1	\$25.49	0.98	\$24.92	\$7.48	\$4.45	\$5.60	\$2.83	\$7.99	\$0.00	\$53.28	hour	SCA code 27131, present cost
Factors			Rate									
Payroll Tax			13.74%									
WCI Rate			22.47%									
Overtime			10.00%		Mon-Fri, 12 hours/day							
Productivity			85.00%									
Factors			Rate									
HTRW Adjustment			20.00%		Increase							
Esc 2020 to 2022			24.86%									
Esc 2021 to 2022			13.75%									
State Adjustment Factor			81.48%		USACE National Labor Library adjustment from Seattle to TX							

Note 1: payroll tax is calculated on base rate + fringe benefits, workmans comp insurance is calculated only on base rate, overtime markup applies to base rate + payroll tax

Note 2: service and professional labor assumes fringe = 30% of base rate

Longhorn 47
Summary of Material Pricing

Material	Base Rate	Rate	Unit	
Fill_Import	\$25.00	\$25.00	cy	Quoted by A&T Sand and Gravel, 2 February 2026
Fill_HaulLoad	\$250.00	\$250.00	ea	11 CY loads. Quoted by A&T Sand and Gravel, 2 February 2026
Fee_WC	\$52.50	\$52.50	cy	Online rate for special handling waste
Fee_Republic	\$398.00	\$398.00	tn	Hazardous disposal at Charles Lake CWM
Fee_Water	\$0.40	\$0.43	cy	
MW_Casing	\$24.75	\$26.39	lf	2025 MCACES Cost Book, 4-in DIA well casing
MW_Screen	\$44.79	\$44.79	lf	2025 MCACES Cost Book, 4-in DIA well casing
MW_GravelPack	\$309.79	\$309.79	lf	2025 MCACES Cost Book, 4-in DIA well casing
MW_Cap	\$81.56	\$81.56	ea	2025 MCACES Cost Book, 4-in DIA well casing
OfficeTrailer_MO	\$549.12	\$549.12	mo	2025 MCACES Cost Book, 50' x 12' trailer
StorageBox_MO	\$162.07	\$162.07	mo	2025 MCACES Cost Book, 40' x 8' storage box
ToiletPortable_MO	\$198.89	\$198.89	mo	2025 MCACES Cost Book
FieldExpense_MO	\$586.44	\$586.44	mo	2025 MCACES Cost Book, office equipment, supplies, field office lights
TempPowerConnection	\$1,404.21	\$1,404.21	ea	2025 MCACES Cost Book
DirectPushRig	\$2,596.58	\$2,596.58	day	Vendor quote from 2025 MCACES Cost Book, Direct Push Rig, Truck Mounted, non Hydraulic, Incl. Labor, Sampling, Decon
Factors	Rate			
Sales Tax + Market Allowance	1.0663	Sales tax		
Escalation 2022 to 2026	1.11			USACE EM 1110-2-1304, September 2025 Update

Non-hazardous disposal, Turkey Creek Landfill (Waste Connections)

[Turkey Creek Landfill | Disposal | Dump](#)

9100 I-35W, Alvarado, TX 76009

End dump transportation to Turkey Creek is \$1,650 per load for 20-22 tons average per load and the disposal cost is \$35/ton for Class 1

1 LCY to Ton conversion	1.5	Tons/LCY	\$35	\$per ton	\$52.50
-------------------------	-----	----------	------	-----------	---------

Longhorn 47

Summary of Material Pricing

Hazardous Disposal to Tulsa Facility (Republic Service)

[Tulsa Facility](#)

2700 South 25th West Avenue Tulsa, OK 74107

Transportation and Disposal				
Description	Quantity	Unit	Rate	Estimated Total
Transportation per trip	65	Trip	\$3,000.00	\$195,000.00
Per Diem	65	EA	\$250.00	\$16,250.00
20 - 20 YD Roll-off Boxes for 90 days ea	1800	Day	\$20.00	\$36,000.00
Disposal - Perchlorate contaminated soil (10 ton min)	1700	Ton	\$398.00	\$676,600.00
			Subtotal:	\$923,850.00

Longhorn 47

Summary of Equipment Rates and Markups

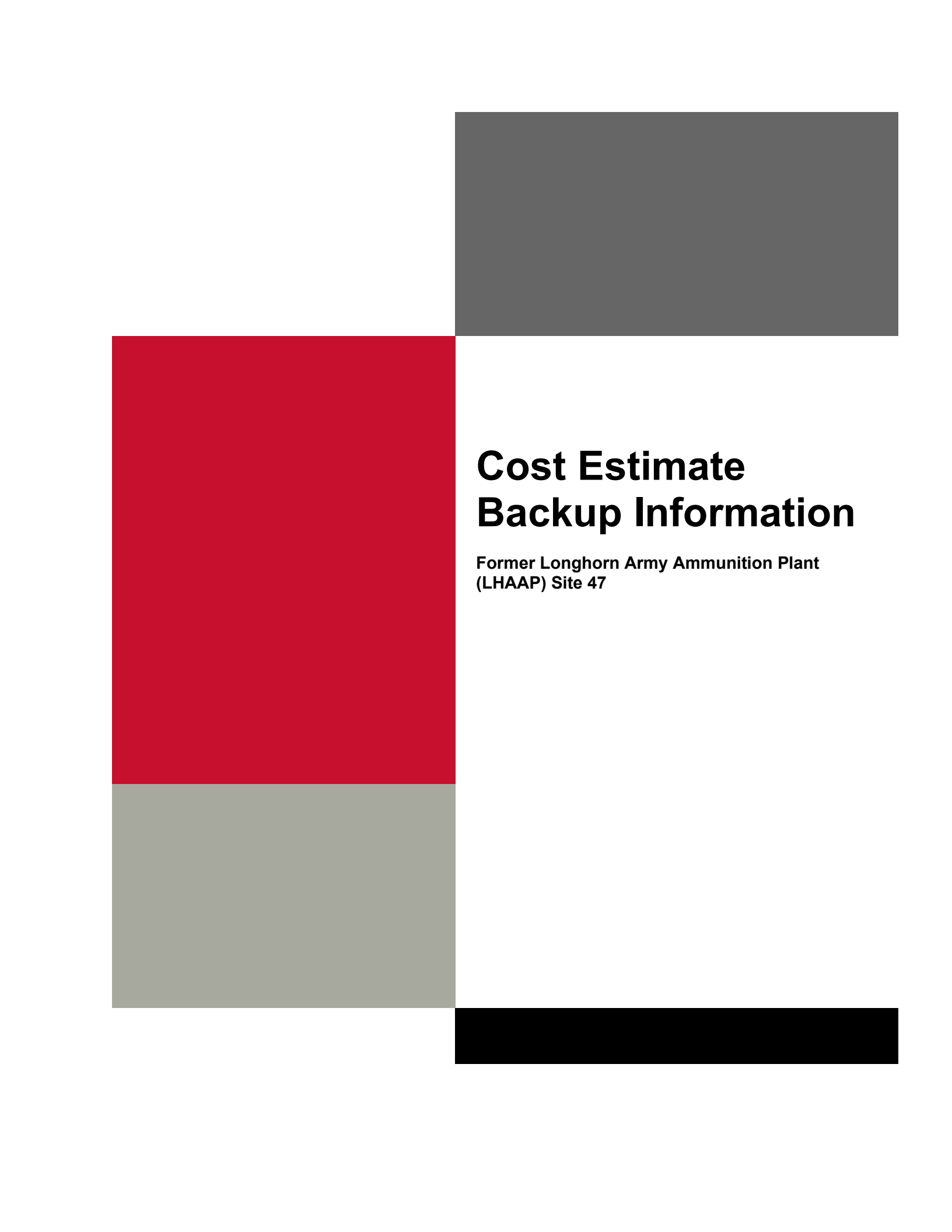
Equipment	Model	Depreciation	FCCM	FCCM Discount	Operating Cost	Productivity	Subtotal	Escalation FY20 to FY22	Total Rate	Unit	Notes
Loader_FE_3.5cy	930M	\$22.85	\$4.63	-\$0.93	\$54.98	\$14.39	\$95.92	\$13.51	\$109.44	hour	LOADER, FRONT END, WHEEL, ARTICULATED, 3.50 CY (2.7 M3) BUCKET, 4X4
Truck_Conventional	4X4 3/4 TON CONV GAS	\$3.85	\$0.61	-\$0.12	\$25.13	\$5.20	\$34.67	\$4.88	\$39.55	hour	TRUCK, HIGHWAY, CONVENTIONAL, 3/4 TON PICKUP, 4X4
Truck_45klb_4x2	4X2 37KGVW DSL	\$3.91	\$1.00	-\$0.20	\$41.27	\$8.11	\$54.09	\$7.62	\$61.71	hour	TRUCK, HIGHWAY, 37 KGVW (16.8 MT), 2 AXLE, 4X2 (CHASSIS ONLY-ADD OPTIONS)
Dump_Highway	4X2 28KGVW DSL	\$7.02	\$1.46	-\$0.29	\$35.94	\$7.79	\$51.92	\$7.31	\$59.23	hour	10wh Dump
Flatbed	PVMXT-203C	\$1.29	\$0.20	-\$0.04	\$1.08	\$0.45	\$2.98	\$0.42	\$3.40	hour	20-ft
Hydroseeder	T330	\$18.10	\$1.71	-\$0.34	\$45.03	\$11.38	\$75.88	\$10.69	\$86.57	hour	3,000 gal truck mounted hydroseeder, add truck
WaterTank	4K GAL, WATER TRLR	\$5.51	\$1.34	-\$0.27	\$8.03	\$2.58	\$17.19	\$2.42	\$19.61	hour	TRUCK TRAILER, WATER TANKER, 4,000 GAL (ADD TOWING TRUCK)
WaterTruck	KT-80	\$66.72	\$15.80	-\$3.16	\$151.95	\$40.82	\$272.13	\$38.34	\$310.47	hour	TRUCK, WATER, OFF-HIGHWAY, 8,000 GAL, W/CAT 621K TRACTOR
Dozer_D6	D6T XW	\$39.79	\$9.18	-\$1.84	\$113.93	\$28.42	\$189.49	\$26.69	\$216.18	hour	TRACTOR, CRAWLER (DOZER), 181-250 HP (135-186 KW), POWERSHIFT, LGP, W/UNIVERSAL BLADE
Excavator_4.0cy	349	\$28.02	\$7.47	-\$1.49	\$102.38	\$24.07	\$160.44	\$22.60	\$183.04	hour	HYDRAULIC EXCAVATOR, CRAWLER, 105,00 LBS, 3.52 CY BUCKET, 27' MAX DIGGING DEPTH
Grader	140-M3	\$23.59	\$6.56	-\$1.31	\$60.52	\$15.77	\$105.13	\$14.81	\$119.94	hour	GRADER, MOTOR, ARTICULATED, 6X4, 14' BLADE W/5 RIPPER/SCARIFIERS
Roller_Vib_ShpFt_5.5 ft	BW11RH-5	\$15.97	\$2.34	-\$0.47	\$29.04	\$8.27	\$55.16	\$7.77	\$62.93	hour	ROLLER, STATIC, SELF-PROPELLED, PNEUMATIC, 12 TON, 68" WIDE, 9 TIRE, ASPHALT COMPACTOR
Pump_Water_6in	S6A1-E60 460/3	\$2.76	\$0.39	-\$0.08	\$9.66	\$2.25	\$14.98	\$2.11	\$17.09	hour	PUMP, WATER, SUBMERSIBLE, ELECTRIC, 6" DIA, 1,950 GPM @ 40' HEAD (ADD HOSES)
Pump_Hose_20ft	C354-90	\$0.15	\$0.01	\$0.00	\$0.29	\$0.08	\$0.53	\$0.07	\$0.60	hour	PUMP HOSE, SUCTION, 6" (153 MM) DIA x 20' (6.1 M) LENGTH, W/COUPLING/SECTION
Tank_10kGal	KPT-100	\$4.77	\$1.07	-\$0.21	\$6.85	\$2.20	\$14.68	\$2.07	\$16.75	hour	WATER TANK, PORTABLE, TRAILER MTD, SELF ELEVATING, 10,000 GAL, 10" PIPE
Truck_Pickup	4x2	\$3.61	\$0.57	-\$0.11	\$24.89	\$5.11	\$34.07	\$4.80	\$38.86	hour	TRUCK, HIGHWAY, CONVENTIONAL, 3/4 TON PICKUP, 4X2
Dump_740	740GC	\$66.55	\$11.86	-\$2.37	\$152.30	\$40.29	\$268.63	\$37.84	\$306.48	hour	TRUCK, OFF-HIGHWAY, ARTICULATED FRAME, 31.4 CY, 43.5 TON, 6X6, REAR DUMP
Generator_30KW	30KW Trailer	\$4.38	\$0.57	-\$0.11	\$9.98	\$2.61	\$17.43	\$2.46	\$19.89	hour	GENERATOR SET, SKID MTD, 30 KW
8inAuger	B-60 Truck	\$38.02	\$8.06	-\$1.61	\$84.60	\$22.78	\$151.84	\$21.39	\$173.24	hour	DRILL, EARTH / AUGER, MULTI-PURPOSE, 8" (20CM) DIA, 250' (76.2M) DEPTH, 7,000 FT-LBS (9.5KNM) TORQUE W/45KGVW (20.4MT) TRUCK (ADD COST FOR DRILL STEEL AND CUTTING EDGE WEAR)
6inPump	04MH & 250HPND	\$4.85	\$0.76	-\$0.15	\$22.51	\$4.94	\$32.90	\$4.64	\$37.54	hour	PUMP, WATER, SUBMERSIBLE, 4"(10 CM) DIA, 455 GPM (1.7 M3M) MAX FLOW, 59' (18 M) MAX HEAD (INCLUDES TRAILER MTD POWER UNIT MODEL 250)(ADD HOSES)
6inPumpHose40ft	C357-90	\$0.09	\$0.01	\$0.00	\$0.16	\$0.05	\$0.30	\$0.04	\$0.35	hour	2X PUMP HOSE, SUCTION, 4" (102 MM) DIA x 20' (6.1 M)LENGTH, W/COUPLING/SECTION
Factors											
Escalation	14.09%										
Productivity	85.00%										
Overtime FCCM Discou	-20.00%										

Longhorn 47

Summary of Equipment Rates and Markups

Fuel (via internet search, Shell Station on Lafayette, taken 12 May 2022)

Diesel:	\$6.90	/gal
Regular:	\$6.30	/gal
Intermediate:	\$6.50	/gal
Premium:	\$6.70	/gal



Cost Estimate Backup Information

**Former Longhorn Army Ammunition Plant
(LHAAP) Site 47**



TERRATHERM

a Cascade Company

www.terratherm.com

PRELIMINARY SITE EVALUATION

HDR Longhorn Army Ammunition Plant, Site 47 *Revision 2*

Karnack, TX
February 25, 2026





About TerraTherm

Based in MA and offering all major methods of subsurface heating

- Thermal Conduction Heating (TCH)
- Electric Resistance Heating (ERH)
- Steam Enhanced Extraction (SEE)

Over 25 years of experience implementing all three thermal technologies

First thermal company in the industry to gain UL electrical safety certification of heaters

Our staff has played key roles in the technical development of TCH and ERH, and have an unparalleled knowledge about how to successfully deploy each technology

TerraTherm has successfully completed more than:

- 75 TCH projects
- 55 ERH projects
- 15 SEE projects

70 dedicated staff members with over 450 years of collective thermal experience

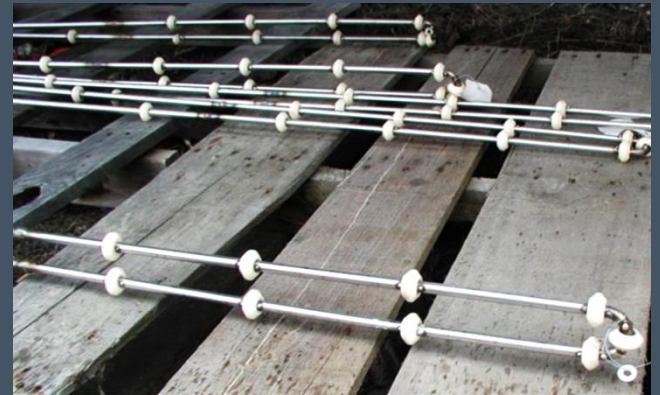
Site Background

SITE NAME:
Longhorn Army Ammunition Plant, Site 47

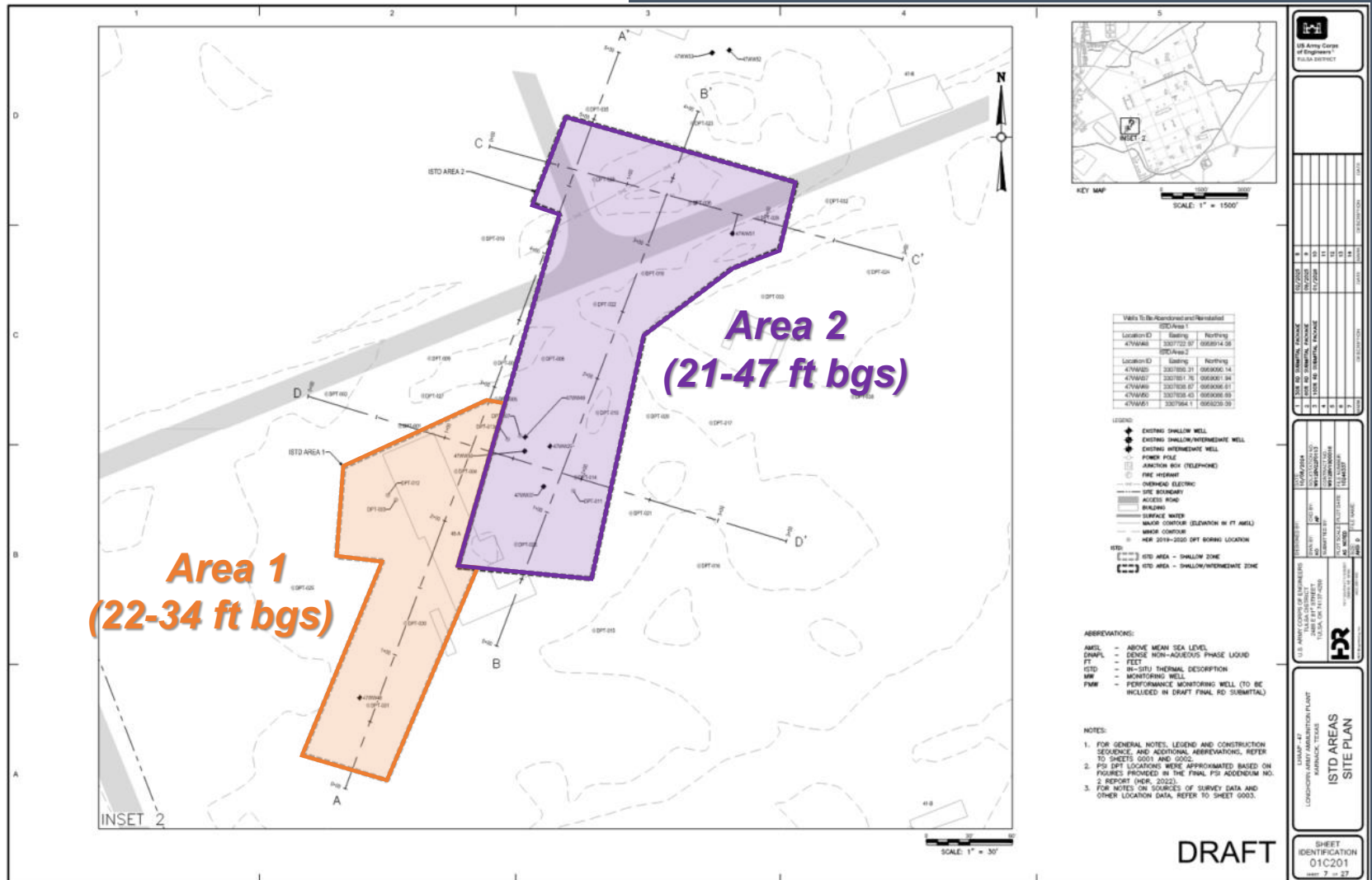
SITE LOCATION:
Karnack, Texas

SITE/ENVIRONMENTAL CONSULTANT:
HDR

OBJECTIVE:
Obtain a conceptual cost to implement thermal remediation at the site



Treatment Areas Map



Geology and Hydrogeology

Geology:

- 0 to ~35 ft bgs: Shallow Zone (Clay/Sand laminations)
- ~35 to ~55 ft bgs: Upper Intermediate Zone (Sand/Silty Sand)

Hydrogeology:

- Per the information provided, water surface elevation is found as follows,
 - Shallow Zone (Clay/Sand laminations): 25 – 32 ft bgs
 - Upper Intermediate Zone (Sand/Silty Sand): 35 – 55 ft bgs
- A representative water surface elevation at 27 ft bgs was used for this evaluation.
- The following hydraulic conductivity values were provided,
 - Shallow Zone (Clay/Sand laminations): 1.9×10^{-3} cm/sec
 - Upper Intermediate Zone (Sand/Silty Sand): 3.2×10^{-4} cm/sec
- The following groundwater velocities were provided,
 - Shallow Zone (Clay/Sand laminations): 0.032 to 0.23 ft/day
 - Upper Intermediate Zone (Sand/Silty Sand): 0.009 to 0.025 ft/day

Hydraulic gradient:

- The following hydraulic gradients were provided,
 - Shallow Zone (Clay/Sand laminations): 0.0023 to 0.018 ft/ft
 - Upper Intermediate Zone (Sand/Silty Sand): 0.0033 to 0.017 ft/ft

Treatment Scenarios

Treatment Scenarios	Treatment Zones (ft ²)		Treatment Depth (ft bgs)	Treatment Volume (CY)	
T. Scenario 1 (TCH)	Area 1	18,500	21.6 – 34.0	8,500	41,500
	Area 2	34,000	20.8 – 47.0	33,000	
T. Scenario 2 (ERH)	Area 1	18,500	21.6 – 34.0	8,500	41,500
	Area 2	34,000	20.8 – 47.0	33,000	

Notes:

- Natural surface – mostly vegetated/wooded
- No cover, no structures present
- Some concrete walls/deteriorated concrete/asphalt, mostly wooded/vegetated w/no structures
- No utilities present on site
- No current operations
- Remote site, may be able to tie into power from existing power lines up to 2,500 feet away
- TerraTherm assumes full access to the site during construction and operation

COCs, Mass Estimate and Remediation Goals

Contaminants of Concern (COC): TCE

Mass Estimate: Not provided. A total mass estimate of approximately 11,894 lbs was estimated for the treatment volume using an average concentration of 100 mg/kg.

The estimated total mass present within the target treatment zone (TTZ) should be further evaluated at a later stage of the project.

Remediation Goals:

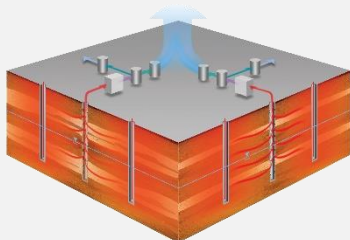
“The residual TCE DNAPL in groundwater and TCE in soil near Building 46A will be treated using ISTD”

Chemical Name	Groundwater (µg/L)		Soil (mg/kg)	
	Max Level Detected	Target Level	Max Level Detected	Target Level
TCE	140,000	0.005	59.6	0.5



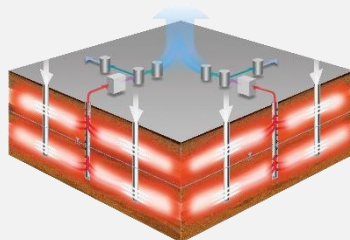
Thermal Technologies

Thermal Conduction Heating (TCH / ISTD)



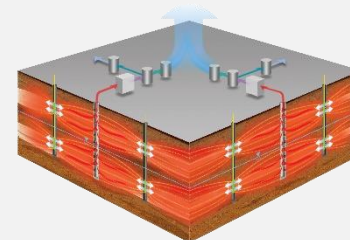
For all sites with low to moderate groundwater flow rates and either Volatile Organic Compounds (VOCs) or Semi-Volatile Organic Compounds (SVOCs).

Steam Enhanced Extraction (SEE)



For permeable sites with significant groundwater flow rates and for sites with either volatile or moderately volatile contaminants.

Electrical Resistance Heating (ERH)



For all sites with low to moderate groundwater flow rates and either volatile or moderately volatile contaminants.

TEMPERATURE RANGE

Lower

Below 100°C

(Free Product Recovery)

Moderate

~100°C

VOCs/CVOCs

Higher

Above 100°C

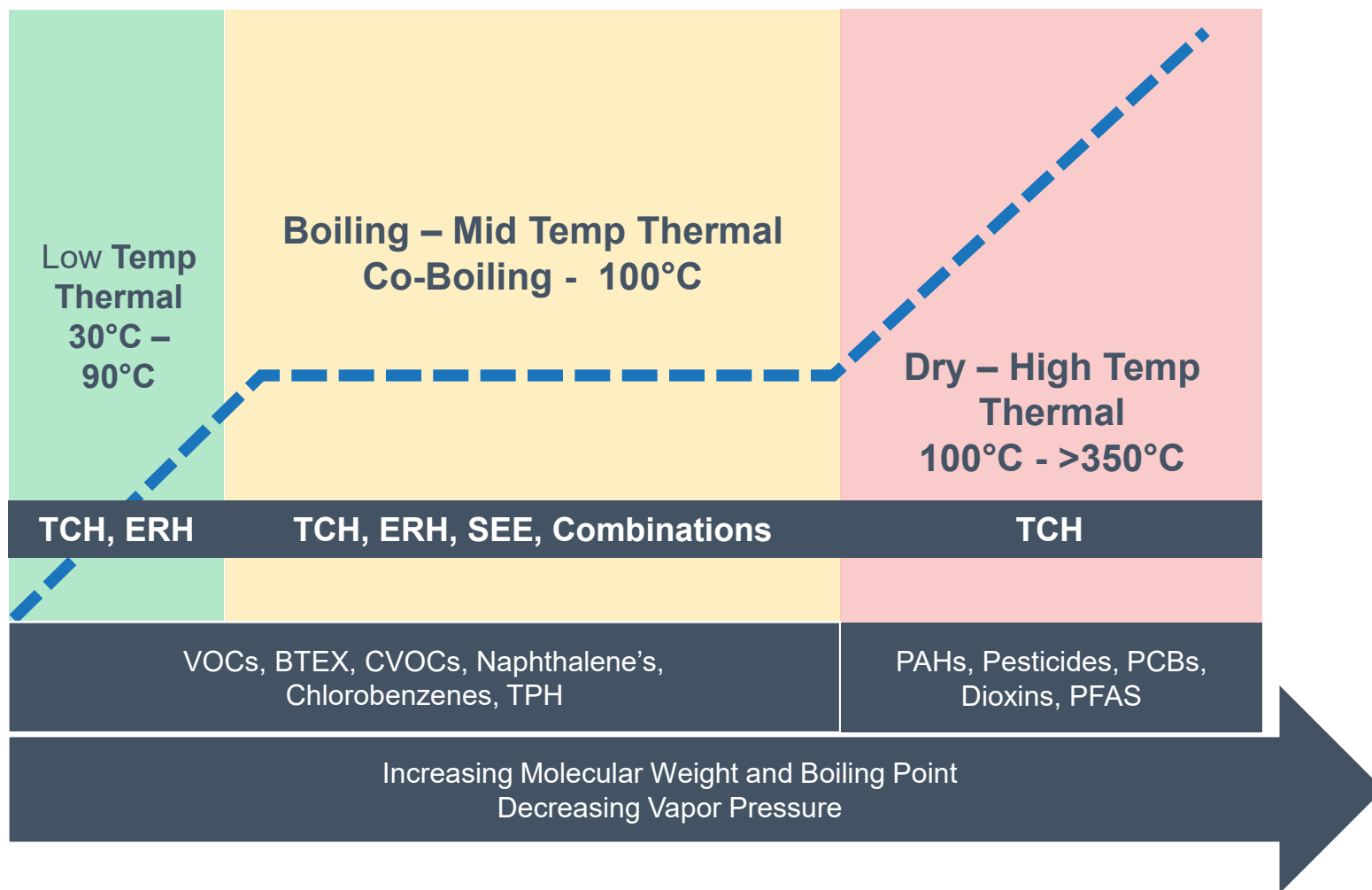
SVOCs

Steam

Electrical Resistance

Thermal Conduction

COCs, Target Temperatures and Applicable Technologies



Thermal Technologies Evaluated

Characteristics	TCH	SEE	ERH
Heating Method	Conduction	Steam Injection, Convection	Electrical Resistance
Factors Governing Heating	- Thermal conductivity of the soil matrix. - Groundwater flow rate.	Injection rates and pressure are determined by the permeability of the soil matrix which can be too tight for SEE applications.	- Electrical resistivity of the soil matrix. - Groundwater flow rate. - Minimum electrode length is 10-feet
Maximum Temperature	- Low Temp TCH = 100°C (boiling point) - High Temp TCH = 325-400°C (once dewatered)	100°C (boiling point)	100°C (boiling point)
Sensitivity to Water Content and Flow	- Works in saturated and dry conditions. - High water flow can remove heat faster than it is added.	Not Sensitive	- Difficulty in dry Vadose Zone conditions. - High water flow can remove heat faster than it is added.
Sensitivity to Contrasts between Layers	Heating rates may be affected by differences in water content and flow rates between layers.	Aquitards not heated directly	Resistivity contrasts between layers require multi-element electrodes – long electrodes may be less efficient.
Sensitivity to Buried Objects	Not sensitive	Low-permeable layers may interfere with steam migration.	Metal debris and pipes may prevent uniform heating.
Heat Input Governed By	Soil thermal conductivity - which varies only by a factor of 1 to 3 between most common geologies.	Hydraulic conductivity of soil layers	Soil resistivity – which varies by large factors (over 200 X) between most common geologies.
Fluids Added to Ground	None	Steam	Water to keep electrodes saturated
General Safety Issues	High temperatures and steam	High temperatures and steam	- High temperatures and steam - Surface voltages

Note: Thermal Conductive Heating (TCH) and Electrical Resistance Heating (ERH) have been selected as the preferred ISTR technologies for this preliminary evaluation.

Conceptual Treatment Approach/Methodology

Conceptual Treatment Approach:

Treatment Scenario 1

- TCH using a heater spacing of approximately 15 feet to target the boiling point of water.
- Soil vapor and steam extraction from vertical extraction wells used to extract the vaporized contaminants and steam, and to maintain pneumatic and hydraulic control.

Treatment Scenario 2

- ERH using an electrode spacing of approximately 17 feet to target the boiling point of water.
- Soil vapor and steam extraction from co-located vertical extraction wells used to extract the vaporized contaminants and steam, and to maintain pneumatic and hydraulic control.

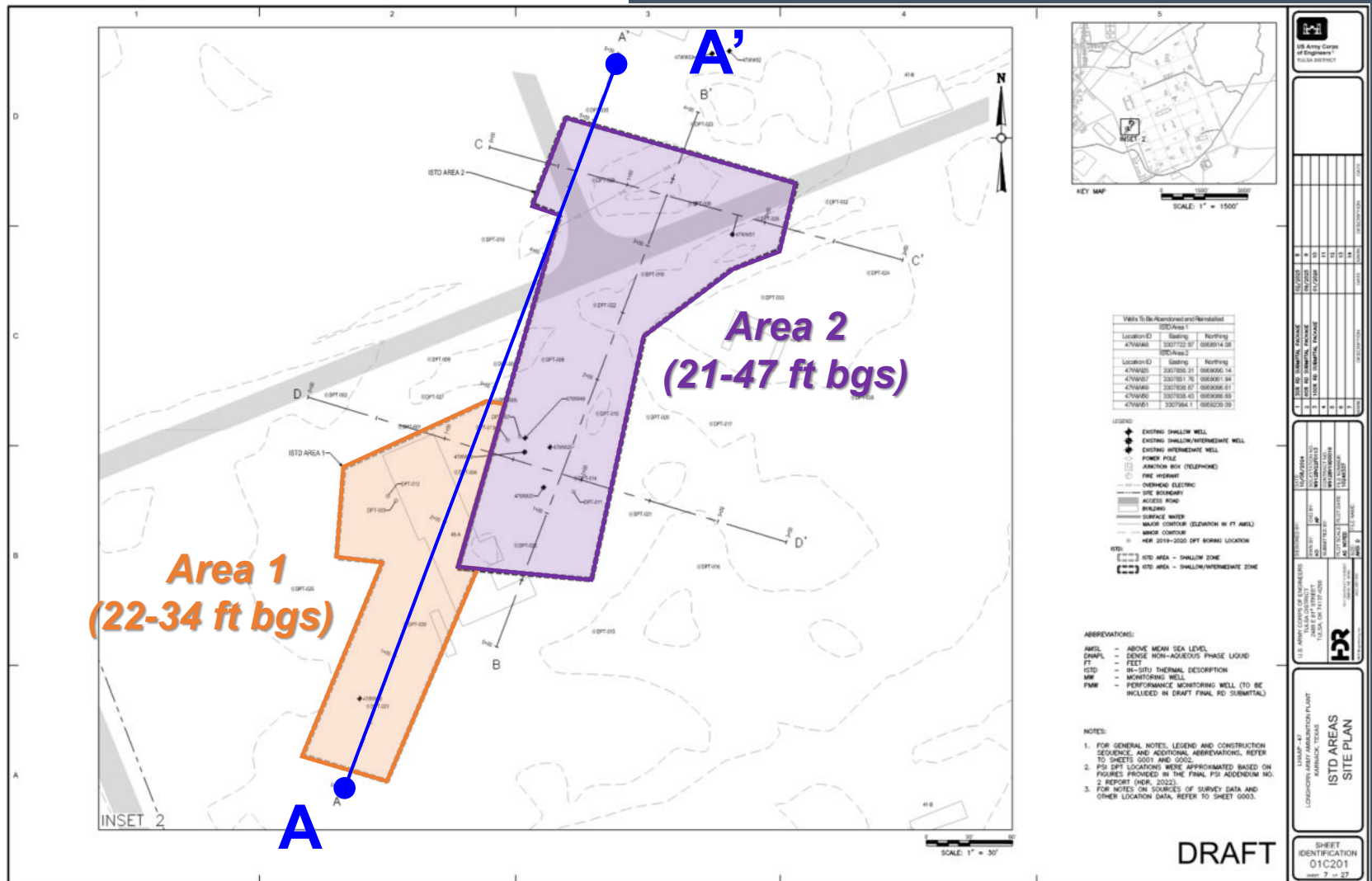
Vapor and Liquid Treatment Approach:

- Extracted vapors and liquids (condensate) treated using Granular Activated Carbon (GAC).

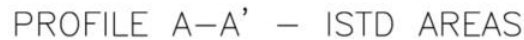
Monitoring:

- Temperature and pressure monitoring to track subsurface heating, pneumatic, and hydraulic control.
- Vapor and liquid treatment system monitoring for mass removal and discharge compliance

Treatment Areas and Cross Section A-A'

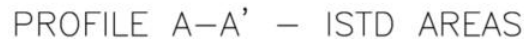


PROFILE A-A' – ISTD AREAS



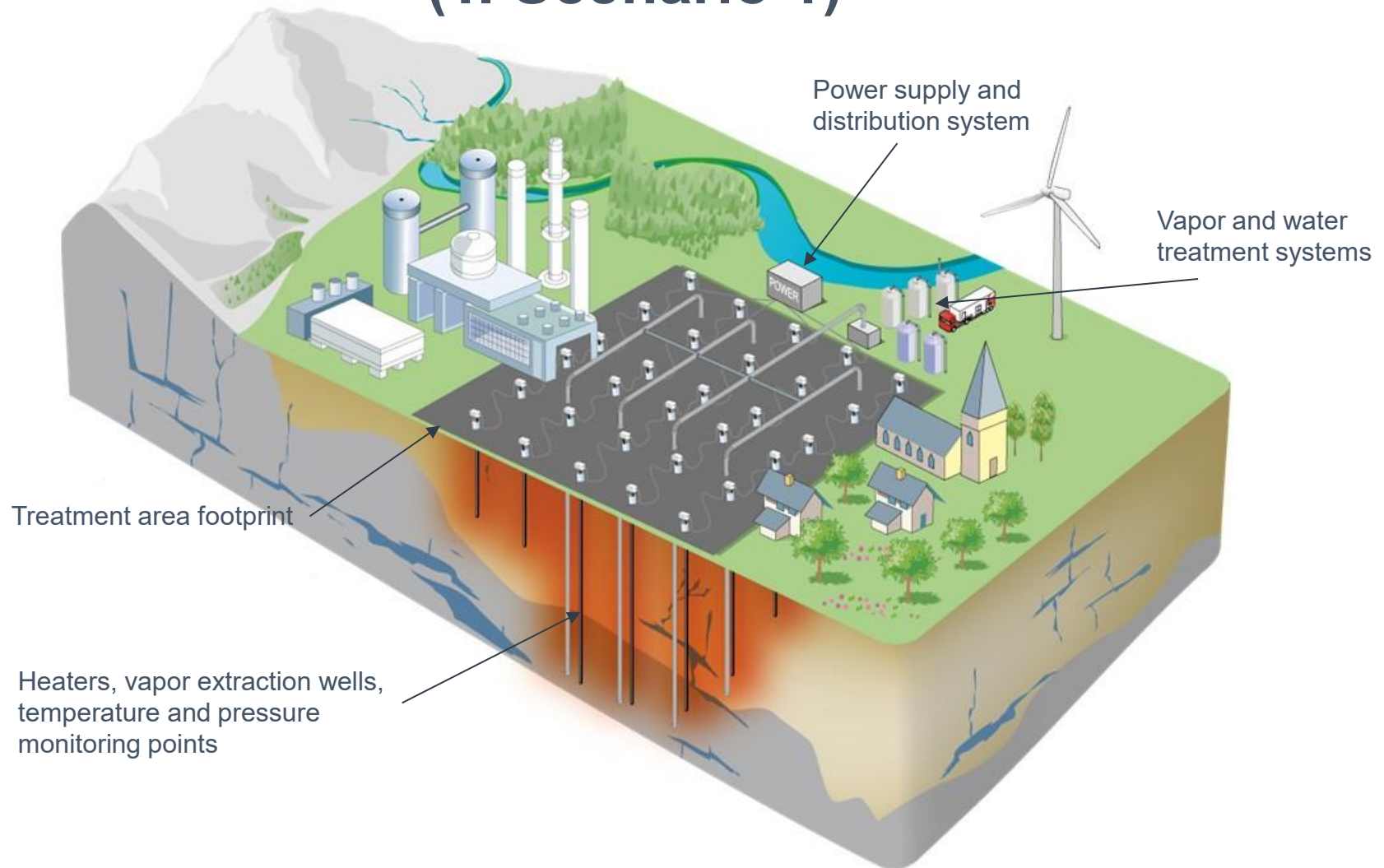
NOT TO SCALE

PROFILE A-A' – ISTD AREAS

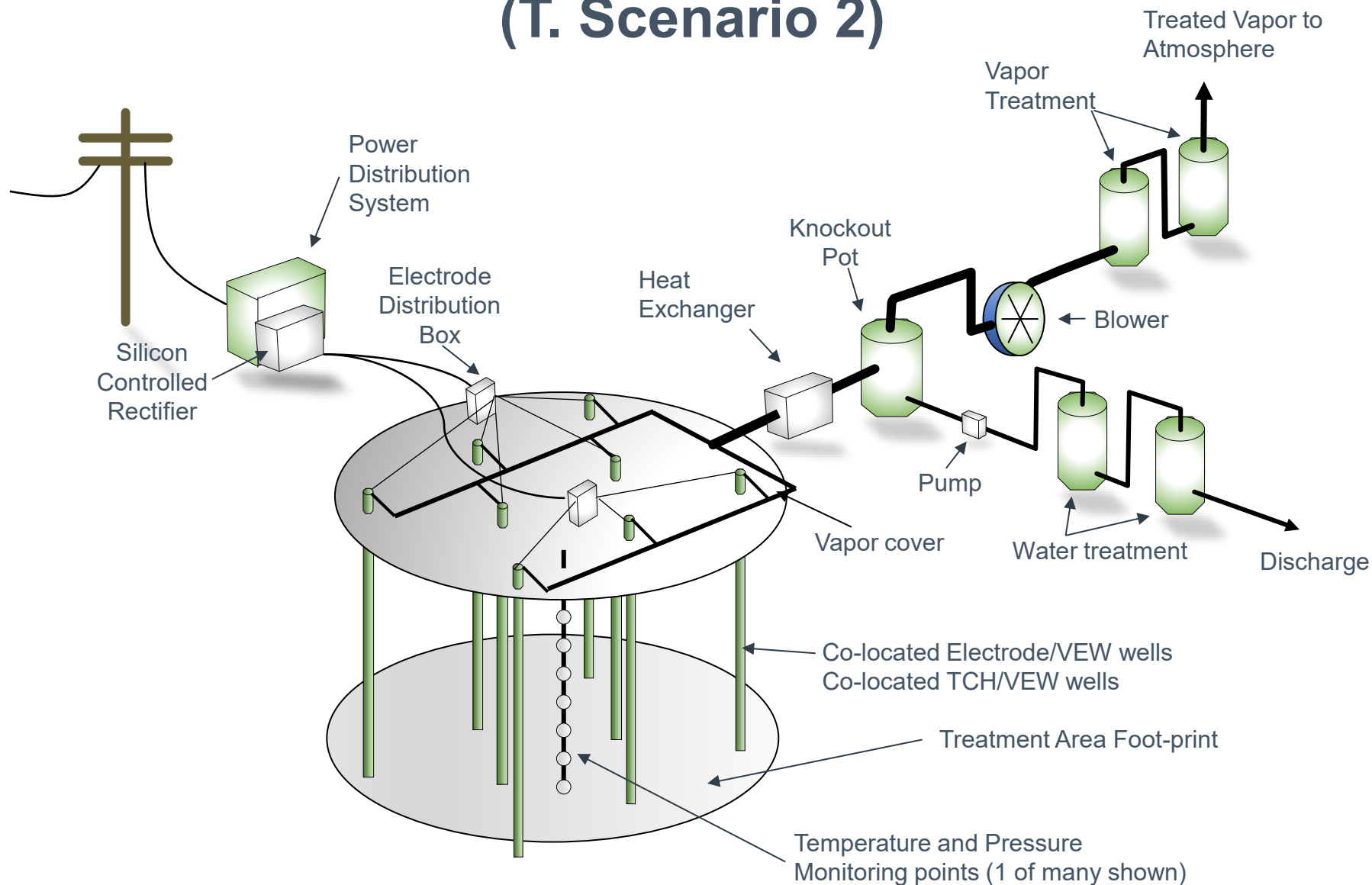


NOT TO SCALE

Schematic of Typical TCH Site (T. Scenario 1)

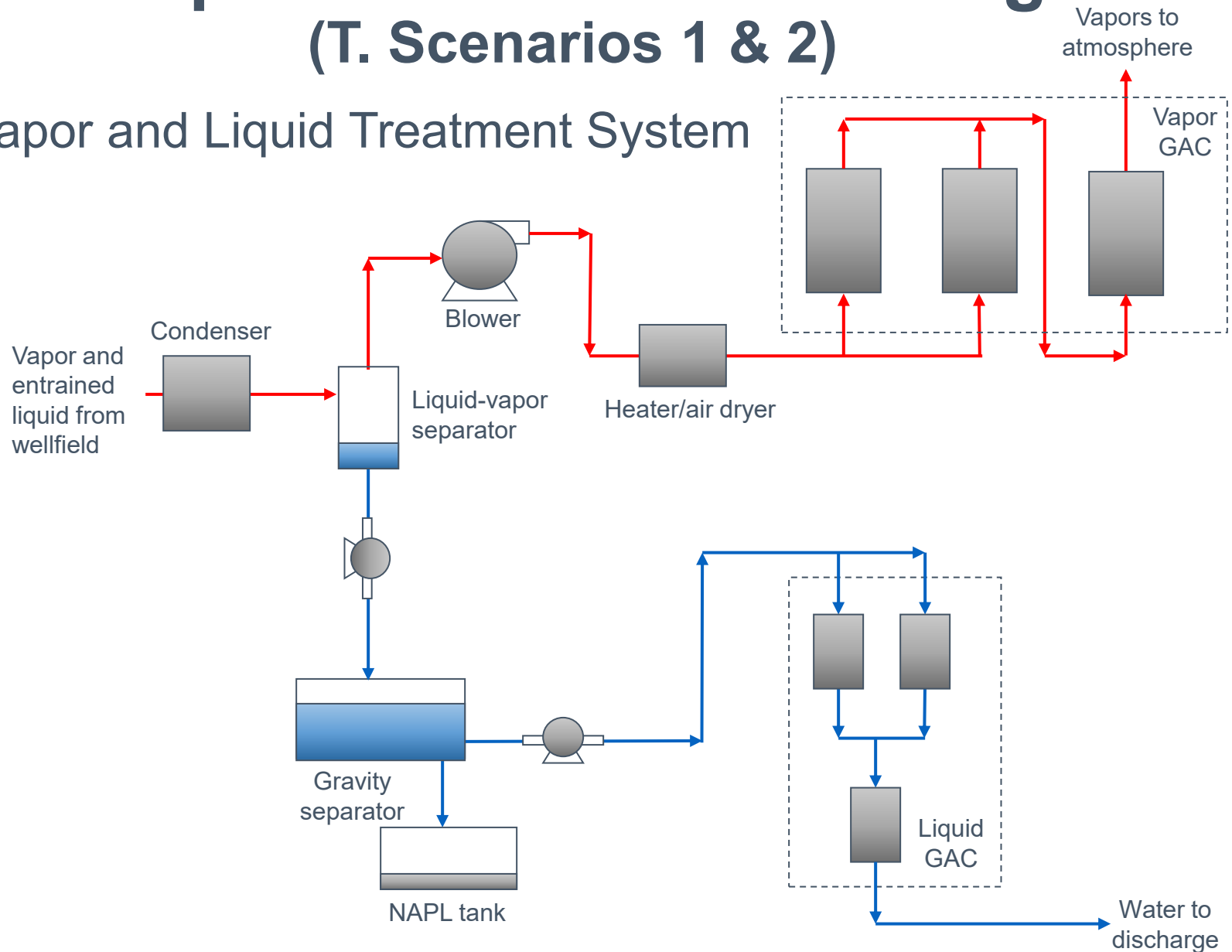


Schematic of Typical ERH Site (T. Scenario 2)



Conceptual Process Flow Diagram (T. Scenarios 1 & 2)

Vapor and Liquid Treatment System



Treatment Scenario 1

(TCH)

Conceptual Design Parameters

LHAAP - Site 47 (T. Scenario 1)				HDR
<i>Volume and heat capacity</i>	<i>Area 1</i>	<i>Area 2</i>	<i>Total</i>	<i>Unit</i>
Treatment area	18,500	34,000	52,500	ft ²
Upper depth of treatment	21.6	20.8		ft bgs
Lower depth of treatment	34.0	47.0		ft bgs
Volume, TTZ	8,500	33,000	41,500	yd ³
Solids volume	5,525	21,450	26,975	yd ³
Porosity	0.35	0.35	0.70	-
Porosity volume	2,975	11,550	14,525	yd ³
Initial saturation	87	93		percent
Soil weight	24,670,829	95,780,865	120,451,693	lbs soil
Water weight	4,363,697	18,104,422	22,468,119	lbs water
Soil heat capacity	6,167,707	23,945,216	30,112,923	BTU/F
Water heat capacity	4,363,697	18,104,422	22,468,119	BTU/F
Total heat capacity, whole TTZ	10,531,404	42,049,638	52,581,043	BTU/F

Conceptual Design Parameters

LHAAP - Site 47 (T. Scenario 1)				HDR
<i>Energy balance</i>	<i>Area 1</i>	<i>Area 2</i>	<i>Total</i>	<i>Unit</i>
TCH power input rate	776	2,151	2,927	kW
Water extraction rate during heatup	0	0	1	gpm
Average extracted water temperature	190	190		F
Percent of injected energy extracted as steam	30	30		%
Steam extracted, average	818	2,267	3,085	lbs/hr
Energy flux into treatment volume	2,648,441	7,336,685	9,985,127	BTU/hr
Energy flux in extracted groundwater	26,779	17,535	44,313	BTU/hr
Energy flux in extracted steam	794,532	2,201,006	2,995,538	BTU/hr
Net energy flux into treatment volume	1,827,130	5,118,145	6,945,283	BTU/hr
Heating per day	4	3		F/day
Start temperature	64	64		F
Target temperature	218	228		F
Estimated heat loss, worst case	98	62		%
<i>Operating time</i>				
Heater ramp up	3	3		days
Heating to target temperature	70	82		days
Maintaining target temperature	78	95		days
Sampling/analysis phase	3	3		days
Post treatment vapor extraction	7	7		days
Total operating time	190			days

Conceptual Design Parameters

LHAAP - Site 47 (T. Scenario 1)	HDR		
<i>Numbers of wells</i>	<i>Area 1</i>	<i>Area 2</i>	<i>Total</i>
Heater borings, regular application	126	216	342
Vertical Vapor Extraction well, regular application	35	63	98
Temperature monitoring holes	8	13	21

LHAAP - Site 47 (T. Scenario 1)	HDR	
<i>Process equipment</i>	<i>Value</i>	<i>Unit</i>
ISTD power supply	2,930	kW
Treatment system power supply	330	kW
Total power need to site	4,080	kW
Estimated total electric load	5,100	kVA
Estimated total amperage	6,100	Amps
Vapor extraction rate, total	2,420	scfm
Non-condensable vapor	1,320	scfm
Estimated steam extraction	1,100	scfm
Liquid extraction rate	0.63	gpm
Condensed liquid rate	6.18	gpm
Water treatment rate	6.81	gpm
Vapor treatment type	GAC w/ gas conditioning	-
Dominant contaminant of concern	Trichloroethene (TCE)	-
Estimated COC mass	11,894	lbs
Estimated COC mass treated by vapor system	11,656	lbs
Estimated COC mass treated by water system	238	lbs
Estimated max mass removal rate, vapor system	139	lbs/day

Conceptual Utility Requirements

LHAAP - Site 47 (T. Scenario 1)		HDR
<i>Utility estimates</i>	<i>Value</i>	<i>Unit</i>
Power usage, in ground	12,183,000	kWh
Power usage, treatment system	1,262,000	kWh
Power usage, total	13,445,000	kWh

Budgetary Costs

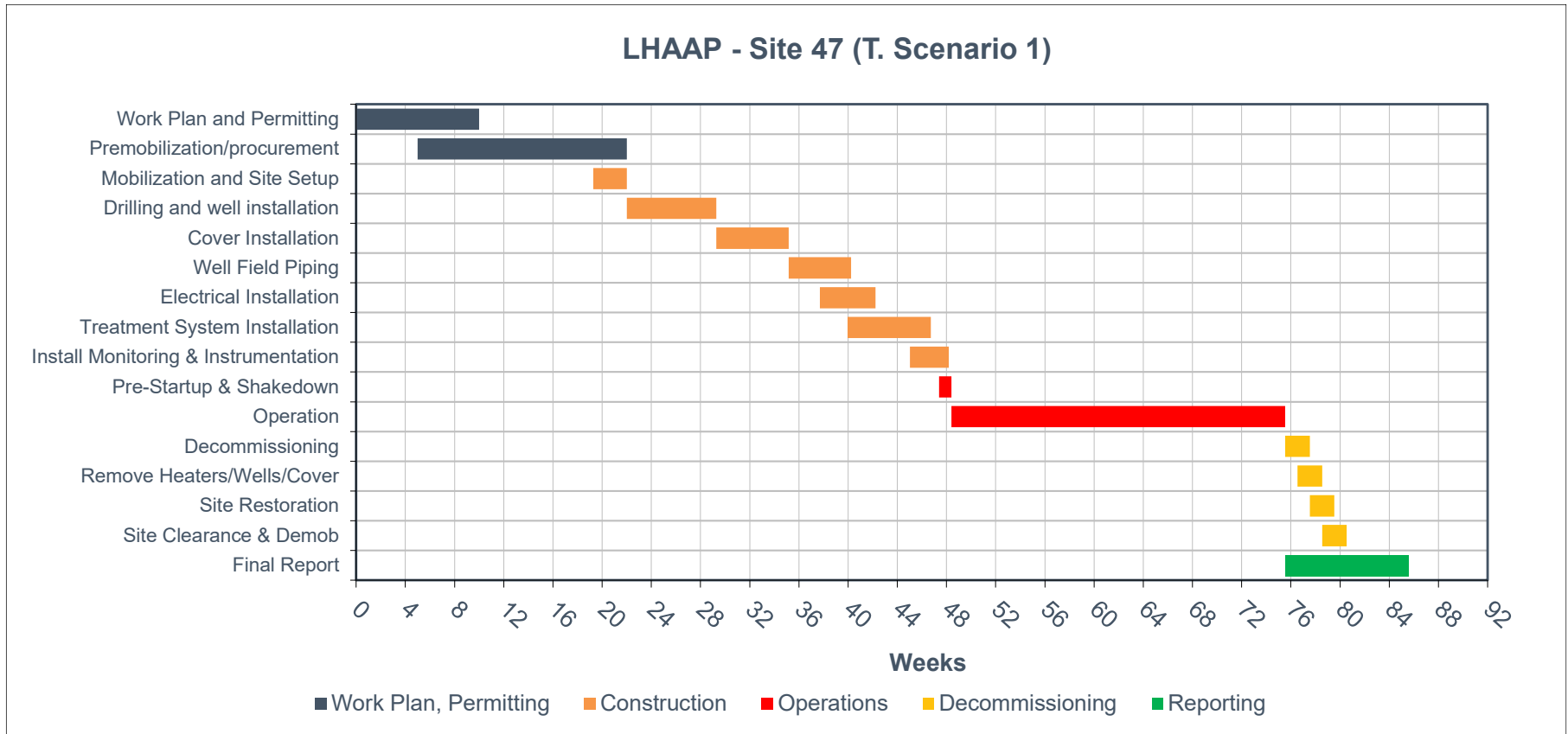
HDR LHAAP - Site 47 (T. Scenario 1)		
Task	Subtask	Cost (\$)
Design and Procurement	Detailed design, permitting	\$60,000
	Procurement	\$130,000
Mobilization and Construction	Mobilization and site setup	\$310,000
	Power drop and transformer	Not included
	Drilling and well installation	\$3,260,000
	Vapor cover installation	\$370,000
	Wellfield piping	\$310,000
	Power equipment installation (TCH)	\$120,000
	Treatment system installation	\$520,000
	Electrical installation, wellfield and process	\$150,000
	Instrument and monitoring system installation	\$70,000
	Pre-startup and shakedown	\$60,000
Operation	Power equipment rental (TCH)	\$150,000
	Effluent treatment system rental	\$170,000
	Labor, travel, per diem	\$580,000
	Process monitoring, sampling and analysis	\$60,000
	GAC and water	\$420,000
	Repair/maintenance	\$100,000
	Tools, rentals and fees	\$40,000
Demob and other	Decommissioning	\$170,000
	Site Clearance & Demob	\$150,000
	Reporting	\$30,000
Indirect costs	Field support	\$250,000
	Home office support	\$290,000
Subtotal (without utilities)		\$7,770,000
Utilities, paid by client	Power	\$1,320,000
Total (with utilities)		\$9,090,000

HDR LHAAP - Site 47 (T. Scenario 1)	
219	\$/CY with utilities
187	\$/CY without utilities

Note:

Overall cost reduction is due to the effect of combining treatment areas and reduced number of perimeter heaters.

Preliminary Schedule



Note: Preliminary schedule shown above is flexible and can be adjusted if required to meet project specific requirements.

Treatment Scenario 2

(ERH)

Conceptual Design Parameters

LHAAP - Site 47 (T. Scenario 2)				HDR
<i>Volume and heat capacity</i>	<i>Area 1</i>	<i>Area 2</i>	<i>Total</i>	<i>Unit</i>
Treatment area	18,500	34,000	52,500	ft ²
Upper depth of treatment	21.6	20.8		ft bgs
Lower depth of treatment	34.0	47.0		ft bgs
Volume, TTZ	8,500	33,000	41,500	yd ³
Solids volume	5,525	21,450	26,975	yd ³
Porosity	0.35	0.35	0.70	-
Porosity volume	2,975	11,550	14,525	yd ³
Initial saturation	87	93		percent
Soil weight	24,670,829	95,780,865	120,451,693	lbs soil
Water weight	4,363,697	18,104,422	22,468,119	lbs water
Soil heat capacity	6,167,707	23,945,216	30,112,923	BTU/F
Water heat capacity	4,363,697	18,104,422	22,468,119	BTU/F
Total heat capacity, whole TTZ	10,531,404	42,049,638	52,581,043	BTU/F

Conceptual Design Parameters

LHAAP - Site 47 (T. Scenario 2)				HDR
Energy balance	Area 1	Area 2	Total	Unit
TCH power input rate	684	1,973	2,658	kW
ERH power input rate	684	1,973	2,658	kW
ERH water injection rate	9	14	23	gpm
Water extraction rate during heatup	9	15	23	gpm
Average extracted water temperature	190	190		F
Percent of injected energy extracted as steam	30	30		%
Steam extracted, average	721	2,080	2,801	lbs/hr
Energy flux into treatment volume	2,334,259	6,732,083	9,066,342	BTU/hr
Energy flux in extracted groundwater	622,953	1,020,510	1,643,463	BTU/hr
Energy flux in extracted steam	700,278	2,019,625	2,719,903	BTU/hr
Net energy flux into treatment volume	1,011,028	3,691,948	4,702,984	BTU/hr
Heating per day	2	2		F/day
Start temperature	64	64		F
Target temperature	218	228		F
Estimated heat loss, worst case	53	35		%
Operating time				
Heater ramp up	3	3		days
Heating to target temperature	98	95		days
Maintaining target temperature	105	107		days
Sampling/analysis phase	3	3		days
Post treatment vapor extraction	7	7		days
Total operating time	216			days

Conceptual Design Parameters

LHAAP - Site 47 (T. Scenario 2)	HDR		
<i>Numbers of wells</i>	<i>Area 1</i>	<i>Area 2</i>	<i>Total</i>
Vertical Vapor Extraction well (Co-located)	85	143	228
Electrode borings	85	143	228
Temperature monitoring holes	11	17	28

LHAAP - Site 47 (T. Scenario 2)	HDR	
<i>Process equipment</i>	<i>Value</i>	<i>Unit</i>
ERH power supply	2,660	kW
Treatment system power supply	330	kW
Total power need to site	3,740	kW
Estimated total electric load	4,700	kVA
Estimated total amperage	5,700	Amps
Vapor extraction rate, total	2,170	scfm
Non-condensable vapor	1,170	scfm
Estimated steam extraction	1,000	scfm
Liquid extraction rate	23.43	gpm
Condensed liquid rate	5.61	gpm
Water treatment rate	29.04	gpm
Vapor treatment type	GAC w/ gas conditioning	-
Dominant contaminant of concern	Trichloroethene (TCE)	-
Estimated COC mass	11,894	lbs
Estimated COC mass treated by vapor system	11,656	lbs
Estimated COC mass treated by water system	238	lbs
Estimated max mass removal rate, vapor system	122	lbs/day

Conceptual Utility Requirements

LHAAP - Site 47 (T. Scenario 2)		HDR
<i>Utility estimates</i>	<i>Value</i>	<i>Unit</i>
Power usage, in ground	12,948,000	kWh
Power usage, treatment system	1,690,000	kWh
Power usage, total	14,638,000	kWh

Budgetary Costs

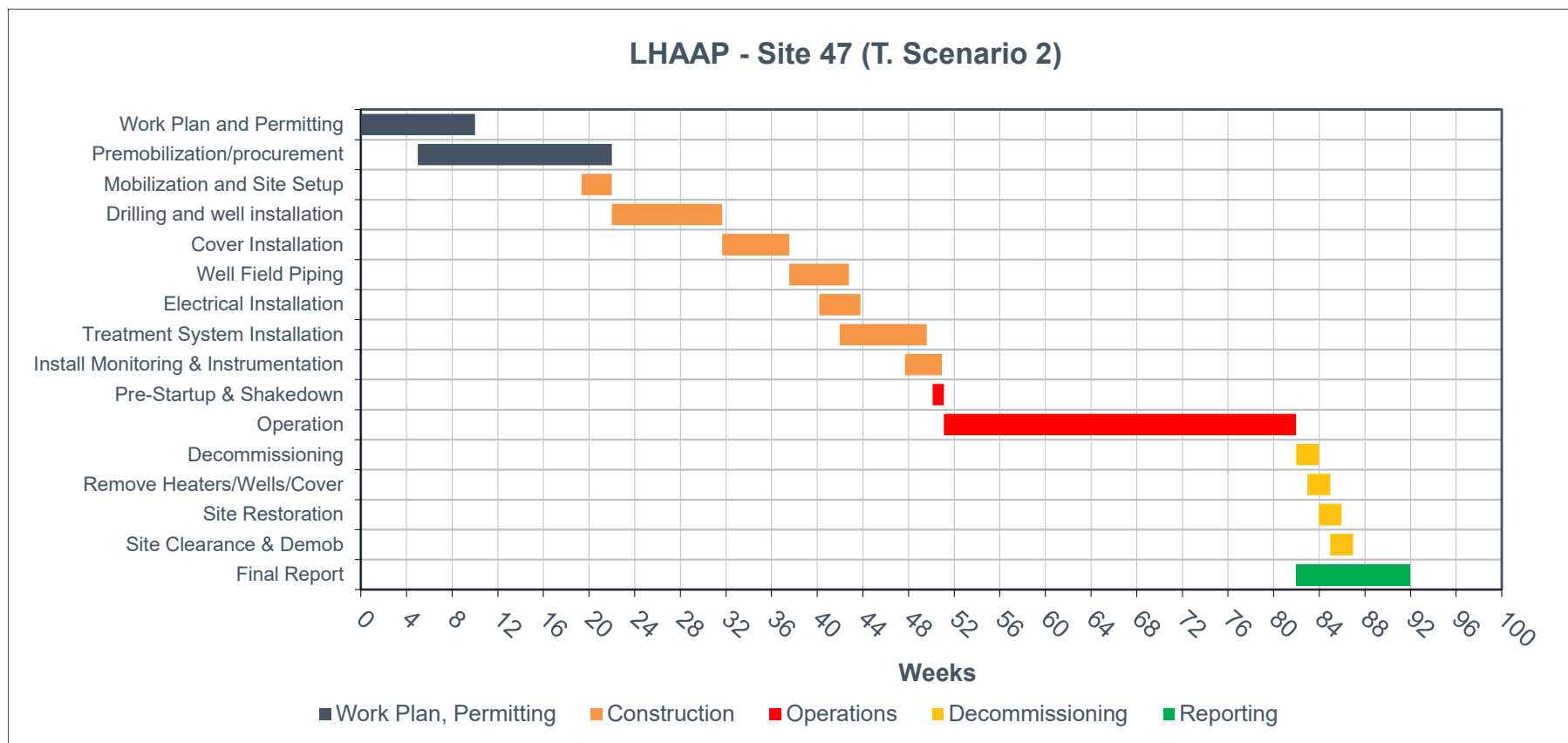
HDR LHAAP - Site 47 (T. Scenario 2)		
Task	Subtask	Cost (\$)
Design and Procurement	Detailed design, permitting	\$70,000
	Procurement	\$120,000
Mobilization and Construction	Mobilization and site setup	\$310,000
	Power drop and transformer	Not included
	Drilling and well installation	\$2,760,000
	Vapor cover installation	\$370,000
	Wellfield piping	\$600,000
	Power system installation (ERH)	\$80,000
	Treatment system installation	\$540,000
	Electrical installation, wellfield and process	\$220,000
	Instrument and monitoring system installation	\$100,000
	Pre-startup and shakedown	\$60,000
Operation	Power system rental (ERH)	\$540,000
	Effluent treatment system rental	\$180,000
	Labor, travel, per diem	\$660,000
	Process monitoring, sampling and analysis	\$140,000
	GAC and water	\$610,000
	Repair/maintenance	\$110,000
	Tools, rentals and fees	\$40,000
Demob and other	Decommissioning	\$190,000
	Site Clearance & Demob	\$150,000
	Reporting	\$30,000
Indirect costs	Field support	\$270,000
	Home office support	\$320,000
Subtotal (without utilities)		\$8,470,000
Utilities, paid by client	Power	\$1,430,000
Total (with utilities)		\$9,900,000

HDR LHAAP - Site 47 (T. Scenario 2)	
239	\$/CY with utilities
204	\$/CY without utilities

Note:

Overall cost increase is due to the increase of the treatment areas and increased number of electrodes.

Preliminary Schedule



Note: Preliminary schedule shown above is flexible and can be adjusted if required to meet project specific requirements.

Cost Summary

Treatment Scenarios	Treatment Zones	Treatment Volume (CY)		Cost (\$)
T. Scenario 1 (TCH)	Area 1	8,500	41,500	\$9,090,000
	Area 2	33,000		
T. Scenario 2 (ERH)	Area 1	8,500	41,500	\$9,900,000
	Area 2	33,000		

For Treatment Scenario 1 (TCH), overall cost reduction is due to the effect of combining treatment areas and reduced number of perimeter heaters

For Treatment Scenario 2 (ERH), overall cost increase is due to the increase of the treatment areas and increased number of electrodes

Assumptions

Price:

- +/- 30% price accuracy based on current understanding of preliminary Conceptual Site Model (CSM) as stated in this treatment concept
- Unit power cost assumed: \$0.10/kWh (Source: <https://www.eia.gov/electricity/state/>)
- Evaluation assumes: (a) full access to the site during construction and operation; (b) that all utilities will be protected at the boundary of the Treatment Area; and (c) that all electrical and mechanical connections to be done above grade.

Turn-Key services:

- Design/procurement/permitting (permitting managed by HDR, TerraTherm supports the process)
- Construction
- Operations (site and office support)
- Demobilization
- Reporting

Assumptions

Construction:

- 150 ft/day drilling production assumed for Treatment Scenario 1 (TCH)
- 100 ft/day drilling production assumed for Treatment Scenario 2 (ERH)
- Electrical and mechanical connections above grade

Operations

- Standard:
 - Field Crew (3 persons on average) housed within a 30-minute drive to the site for All Treatment Scenarios
 - Office support: Project Management and Engineering

Demobilization

- Bringing site back to as near to starting conditions as possible:
 - Well abandonment is not included
 - Removal of all equipment
 - Overdrilling of wells is excluded

Possible Next Steps

Basis of Design Report (BODR):

TerraTherm would be pleased to provide a proposal for preparation of the BODR (or alternatively for preparation of the detailed design effort) as described below for the project.

The BODR includes the following:

- Site visit and meeting
- Thermal modeling and refinement of thermal treatment concept(s)
- Evaluation of data gaps
- Risk/uncertainty evaluation
- Definition of exact scope of work for key project tasks (responsibility matrix)
- Comparison of multiple treatment scenarios (if applicable)
- Updated cost estimate

The price for this deliverable can range from \$20,000 to \$25,000

For further information, please contact Nicole Bryson at (805) 402-2982

Ark-La-Tex Electric, Inc.

PO Box 708
Waskom, TX 75692
(903) 687-4005

mikki@arklatexelectric.com

Estimate

Date	Estimate #
3/5/2026	3599
Exp Date	
	3/16/2026

Name / Address
HDR 50 Tice Blvd., Ste 210 Woodcliff Lake, NJ 07677

Description	Qty	Rate	Total
HDR- LHAAP- 47 Electrical Service * Note: This is only a rough budgetary estimate. No details or electrical engineering has been provided. Customer will need to apply for service with SWEPCO to determine feasibility and point of demarcation. We were not provided with electrical distribution gear requirements or an exact location. This is not to be considered an accurate cost for the installation. * Trench from the wildlife refuge headquarters approx. 2 miles to area 47 and install 4/0 copper, 15K primary underground cable * Supply and install (1) 6000 KVA, 7200/12470y to 277/480y three phase sub station * Supply and install (1) 277/480v, 5000 amp 3 R switchgear at sub station (5000 amp is the largest single piece of switchgear available) Budgetary Estimate \$ 1,712,920.00 Note*** Draw schedule will be included with formal proposal***		1,712,920.00	1,712,920.00
Subtotal			\$1712920.00
Sales Tax (6.25%)			\$0.00
Total			\$1712920.00

Permit fees and /or sales tax may apply.

Thank you for the opportunity to bid!



Preliminary Proposal

Company: HDR Inc
Contact: Sanji Sangani
Phone: 201-335-9552
Email: Sanji.Sangani@hdrinc.com

March 18, 2026

Dear Sanji,

Republic Services Environmental Solutions is pleased to provide the following preliminary proposal for services described below. We appreciate this opportunity and look forward to working with Peterbilt Motors Co.

Republic Services offers our customers the unmatched ability to use one comprehensive provider to internally manage all your waste management and industrial service needs. Republic Services is an environmental services industry leader with the vision to partner with customers to create a more sustainable world. Republic’s vast nationwide service footprint, waste management assets, field industrial services, and emergency response expertise, enables us to offer you the most turnkey waste management solution in the marketplace.

Republic is committed to ensuring the health and safety of our employees in the performance of assigned work, giving full regard to evolving industry practices and regulatory requirements. We continuously strive to achieve excellence in health and safety performance and to be recognized as a leader in accident prevention. All employees have the responsibility and accountability for safety performance through active involvement in safety initiatives. Employees are encouraged to raise safety issues and are empowered to make changes. Our target is ZERO injuries.

Location: Longhorn Army Ammunition Plant - Karnack, TX

Scope of Work:

Republic Services to load 1300 Cubic Yards of Perchlorate contaminated soil into roll-off boxes for transportation and disposal at Republic Services - Tulsa OK. Work would consist of transporting 10 boxes per week for disposal. The project would be completed over a 1 month period. Disposal pricing is an estimate based on the information provided. Final pricing will be determined on sampling prior to project.

Transportation and Disposal				
Description	Quantity	Unit	Rate	Estimated Total
Transportation per trip	65	Trip	\$3,000.00	\$195,000.00
Per Diem	65	EA	\$250.00	\$16,250.00
20 - 20 YD Roll-off Boxes for 90 days ea	1800	Day	\$20.00	\$36,000.00
Disposal - Perchlorate contaminated soil (10 ton min)	1700	Ton	\$398.00	\$676,600.00
			Subtotal:	\$923,850.00

Labor				
Description	Quantity	Unit	Rate	Estimated Total
Supervisor (ST)	80	hour	\$75.00	\$6,000.00
Supervisor (OT)	26	hour	\$112.50	\$2,925.00
Equipment Operator	80	hour	\$65.00	\$5,200.00
Equipment Operator (OT)	26	hour	\$97.50	\$2,535.00
Technician x1 (ST)	80	hour	\$60.00	\$4,800.00
Technician x1 (OT)	26	hour	\$90.00	\$2,340.00
			Subtotal:	\$16,660.00

Supplies/Equipment				
Description	Quantity	Unit	Rate	Sales Total
Crew Truck (x2)	15	day	\$300.00	\$4,500.00
Skidsteer	15	day	\$800.00	\$12,000.00
Delivery of Roll-off Boxes	10	Trips	\$1,350.00	\$13,500.00
Various Hand/Power Tools	15	day	\$300.00	\$4,500.00
Level C PPE (2 per man per day)	90	EA	\$148.00	\$13,320.00
			Subtotal:	\$47,820.00

Totals				
--------	--	--	--	--

Description	Quantity	Unit	Rate	Sales Total
Labor	1	EA	\$16,660.00	\$16,660.00
Supplies/Equipment	1	EA	\$47,820.00	\$47,820.00
Transportation and Disposal	1	EA	\$923,850.00	\$923,850.00
EEC Fee	1	EA	16.85%	\$166,533.61
Subtotal:				\$1,154,863.61

*Does not include any taxes, state waste fees, or manifest fees

Miranda Pachulo

Regional Account Executive

e: MPachulo@republicservices.com

c: 831-776-3963

Division Entity: US Ecology Houston, Inc.

Approved by:	Title:
(Authorized Signature)	
Customer Name (Print)	Date

GENERAL PROPOSAL CONDITIONS:

- Prices and services are contingent upon credit approval and waste acceptance approval from the receiving facility. Approval of waste materials will be based on a completed and signed waste profile, an MSDS or analytical report, and an evaluation of a representative sample (if required) for a treatability study.
- Surcharges may apply if waste varies from its original profile or is re-characterized or reclassified on site at the TSDF.
- Additional fees may apply at the time of delivery for assistance with off-loading or due to non-conforming waste.
- Improperly classified and/or rejected waste will be returned to the customer, or managed in an alternative manner, at the customer's expense.
- Quoted bulk disposal charges for solid materials will be billed by the cubic yard if the truckload density is less than 2,000 pounds per cubic yard. If the truckload density is greater than 2,000 pounds per cubic yard, then bulk charges will be billed by the ton, regardless of the approved container. Republic Services' personnel will monitor all shipments.
- Due to the U.S. EPA's e-manifest regulations, a fee will be assessed to all customers for shipments utilizing a hazardous waste manifest.
- An EEC fee will be added to your services. EEC is an environmental, energy & compliance fee. The EEC fluctuates monthly and will be charged as a percentage of all invoiced charges, excluding taxes. For more information about this fee, please visit www.republicservices.com/customer-support/fee-disclosures.
- Fees will be charged for waste approvals. A Profile Submission Fee of \$125 will be charged for each initial profile approval, and a Profile Renewal Fee of \$10 will be charged for each profile renewal.

TRANSPORTATION CONDITIONS:

- In the event that the scope of work changes from that specified above, out-of-scope work shall be charged at cost plus 15% or at rates mutually agreed upon in writing before work continues. The work site must be accessible for the size and type of truck ordered.
- Washout/cleanout charges for tankers and/or containers shall be billed at Republic Services' Standard Rates, unless previously quoted.
- Expenses related to waiting time at the work site or work stoppage outside of Republic Services' control will be the responsibility of the customer and will be billed at quoted rates, or at cost plus 15% if not quoted.
- All shipping containers must be non-leaking and D.O.T. approved.

Customer Initials:

Date:



Outlook

Re: Quote for backfill material

From jesse thompson <jesseleethompson76@gmail.com>

Date Wed 2/11/2026 4:25 PM

To Sangani, Sanji <Sanji.Sangani@hdrinc.com>

CAUTION: [EXTERNAL] This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Backfill material is \$25yd

12,750yds@\$25=\$318,750

1,159 loads@\$250=\$289,750

Total for everything = \$608,500

If you have any questions feel free to call me 903-758-8939

Sent from my iPhone

On Feb 10, 2026, at 2:14 PM, Sangani, Sanji <Sanji.Sangani@hdrinc.com> wrote:

Hello,

I am Sanji from HDR Engineering. Currently we are working on project Longhorn Army Ammunition Plant (LHAAP) 47 remedial design. Please provide quote for backfill material with transportation cost.

Backfill delivery location: 51st St, Karnack, TX 75661

Please provide quote for following information:

- Cost for Sandy fill dirt Backfill material for 12,750 cubic yards.
- Cost for total transportation. Please provide cost per load.

Thanks,
Sanji

Sanji Sangani

Environmental Designer

HDR

50 Tice Blvd , Suite 210

Woodcliff Lake, NJ 07677

4/10/26, 2:09 PM

Re: Quote for backfill material - Sangani, Sanji - Outlook

D 201.335.9552

Sanji.Sangani@hdrinc.com

hdrinc.com/follow-us



Outlook

Re: LHAAP-47

From Michael Templin <michael.templin@wasteconnections.com>**Date** Tue 3/3/2026 1:49 PM**To** Sangani, Sanji <Sanji.Sangani@hdrinc.com>**CAUTION: [EXTERNAL] This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.**

End dump transportation to Turkey Creek is \$1,650 per load for 20-22 tons average per load and the disposal cost is \$35/ton for Class 1

Mike Templin

Special Waste Account Manager

Waste Connections

9100 South I-35W

Alvarado, TX 76009

Cell: 817-600-9017

Landfill Main: 817-790-0311

www.wasteconnections.comcid:image001.jpg@01D1C240.9D0EBFA0***A cleaner community is our business.******A greener environment is our goal.....*****Special Waste Portal****<https://specialwaste.wasteconnections.com>**

On Mar 3, 2026, at 12:26 PM, Sangani, Sanji <Sanji.Sangani@hdrinc.com> wrote:

Hello,

How much will be total transportation cost for Class 1 waste? How much volume will be in one load? What is disposal cost for class 1?

Thanks,
Sanji
Sanji Sangani
D 201.335.9552

hdrinc.com/follow-us

From: Michael Templin <michael.templin@wasteconnections.com>
Sent: Tuesday, March 3, 2026 1:21 PM
To: Sangani, Sanji <Sanji.Sangani@hdrinc.com>
Subject: Re: LHAAP-47

CAUTION: [EXTERNAL] This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

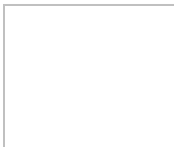
Hello Sanji,

Your transportation to my Class 2 landfill in Henderson will be \$600/load if the soil is Class 2 and \$1,650/load for Class 1 loads going to Turkey Creek. These are transportation rates only

Please let me know if you have any questions

Mike Templin
Special Waste Account Manager
Waste Connections
9100 South I-35W
Alvarado, TX 76009
Cell: 817-600-9017
Landfill Main: 817-790-0311

www.wasteconnections.com



***A cleaner community is our business.
A greener environment is our goal.....***

Special Waste Portal

<https://specialwaste.wasteconnections.com>

On Mar 2, 2026, at 12:43 PM, Sangani, Sanji <Sanji.Sangani@hdrinc.com> wrote:

Hello,

I am Sanji from HDR Engineering. Currently we are working on project Longhorn Army Ammunition Plant (LHAAP) 47 remedial design.

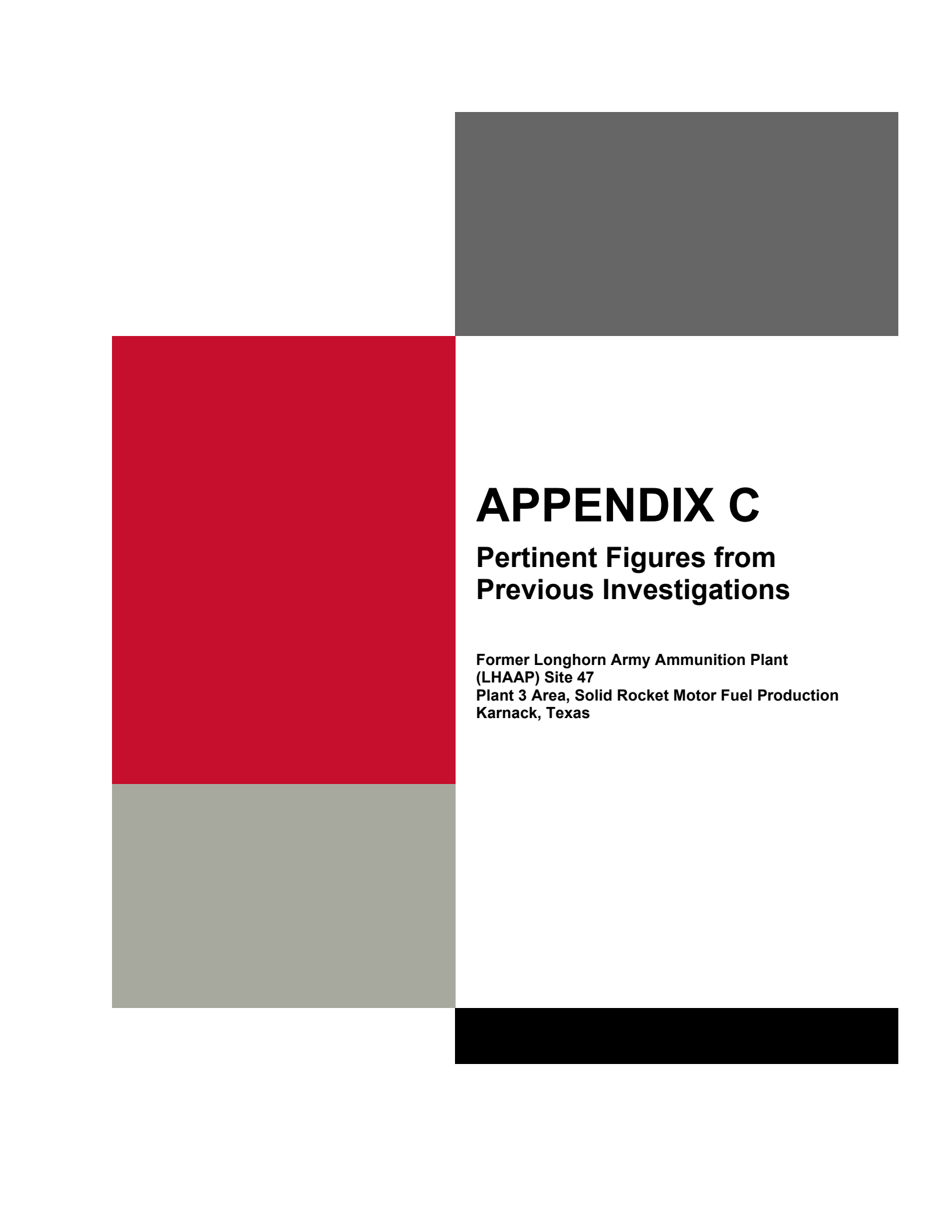
I am following up on our phone conversation. Would you be able to provide transportation and disposal pricing for the below waste?

1. 11,500 Cubic Yard of non-hazardous soil.
2. This waste will be generated at the Site 47 Former Longhorn Army Ammunition Plant (LHAAP) in Karnack, Texas.

Please use dump hauler for transportation. Please provide price for total transportation and cost per load. Please let me know if you need any additional information to prepare a quote. I appreciate your help.

Thanks,
Sanji

Get [Outlook for iOS](#)



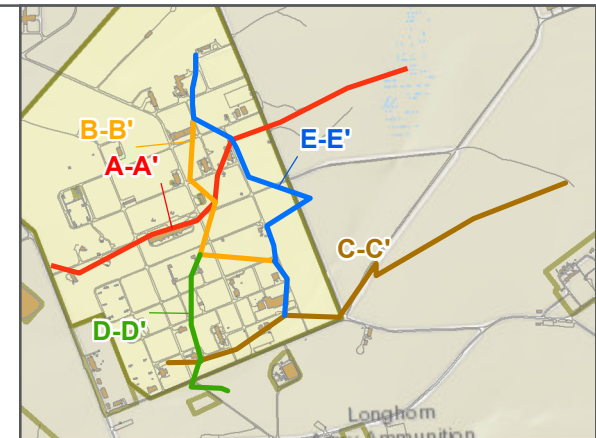
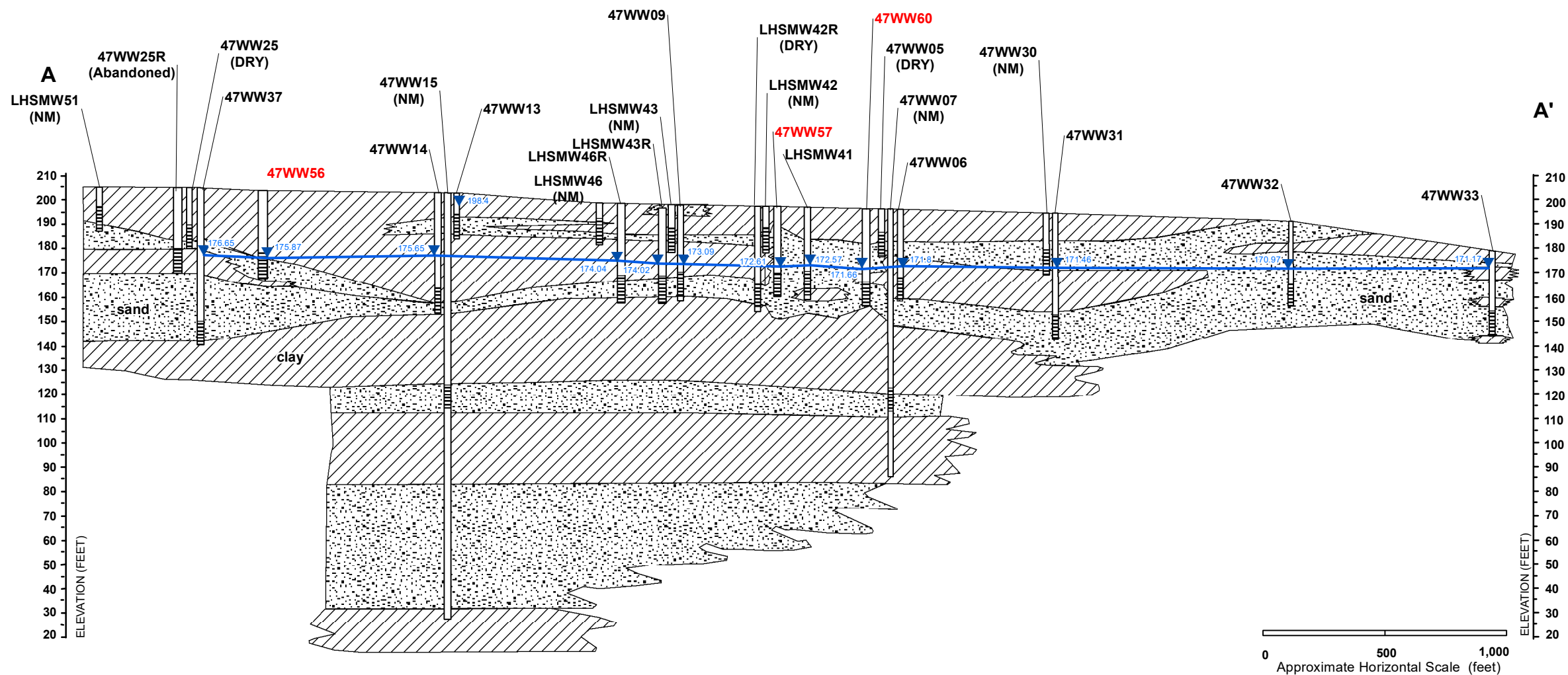
APPENDIX C

Pertinent Figures from Previous Investigations

**Former Longhorn Army Ammunition Plant
(LHAAP) Site 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

LIST OF FIGURES

PDI Appendix C	Geological Cross-Section A-A'
PDI Appendix C	Geological Cross-Section B-B'
PDI Appendix C	Geological Cross-Section C-C'
PDI Appendix C	Geological Cross-Section D-D'
PDI Appendix C	Geological Cross-Section E-E'
Figure 2-2	Site Vicinity
Figure 2-7	Perchlorate in Soil at Building 25C
Figure 2-10	Modified Alternative 2 ISB Bioarrier, Soil Excavation, and ERH Target Areas
Figure 2-11	Preliminary Land Use Control Boundary
Figure 5-1	Proposed Soil Excavation Area
Figure 6	2010 and 2018 Shallow Zone TCE and Perchlorate Plumes
Figure 7	2010 and 2018 Intermediate Zone TCE and Perchlorate Plumes
Figure 10	PSI No. 2 DPT Soil Results Building 46A Area
Figure 13	Geologic Cross Sections LHAAP-47 Building 46A Area
Figure 14	Geological Cross Section A-A'
Figure 15	Geological Cross Section AA-AA'
Figure 16	Geological Cross Section BB-BB'
Figure 19	PSI 2020 Shallow Zone Groundwater TCE Iso-Concentration Contours Building 46A Area
Figure 20	PSI 2020 Shallow/intermediate Groundwater TCE Iso-concentration Contours Building 46A Area
Figure 27	PDI Shallow Zone VOCs Extent
Figure 28	PDI Shallow / Intermediate Zone and Intermediate Zone VOCs and Perchlorate Extent



- Legend**
- Screen
 - Well
 - Clay
 - Sand
 - Groundwater Level
 - Measured Groundwater Elevation (May 2023)
 - 2023 PDI Wells

NOTES:
NM = Not Measured
Cross-sections digitized from 2011 Shaw Feasibility Study
New PDI Wells projected onto existing cross-section
Red font indicates 2023 PDI wells

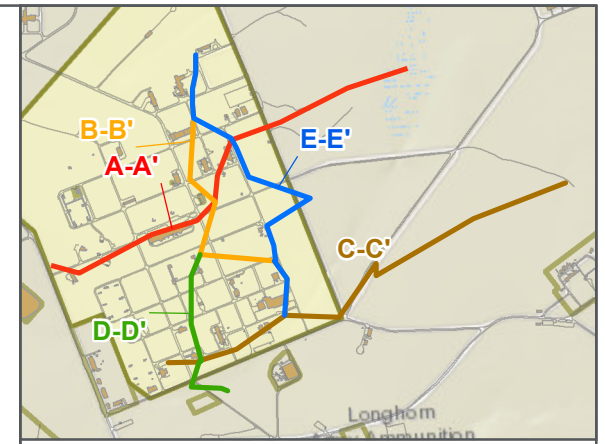
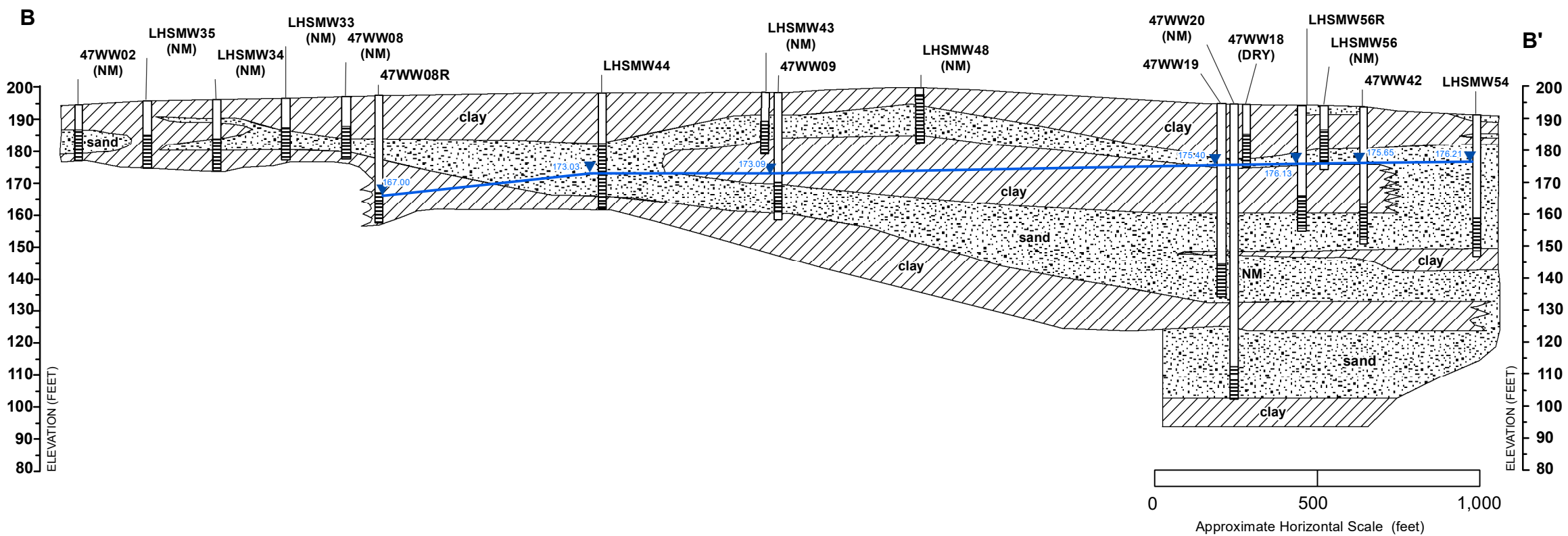
DISCLAIMER: Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.

GEOLOGICAL CROSS-SECTION A-A'

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS



PDI Appendix C



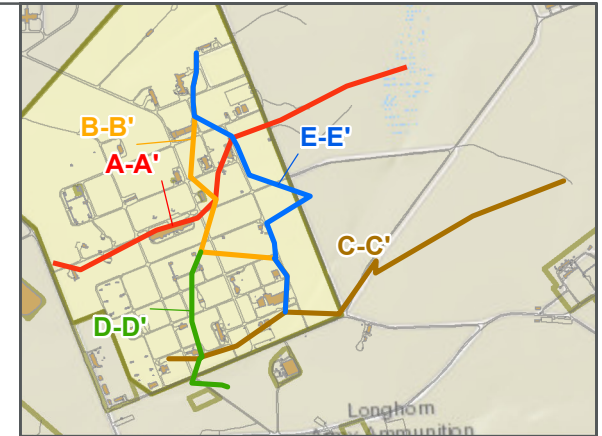
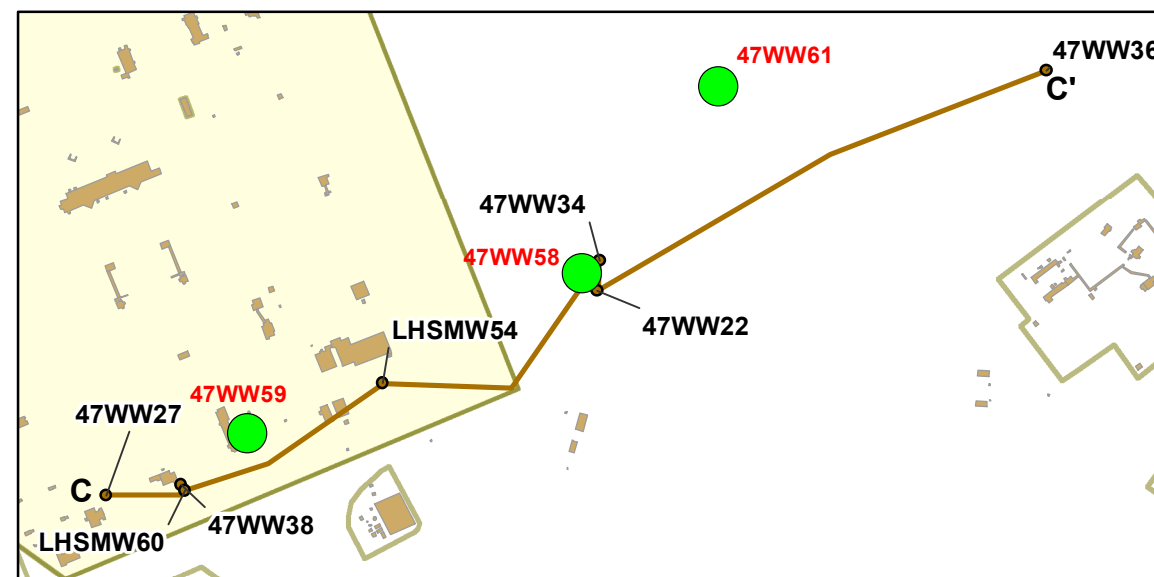
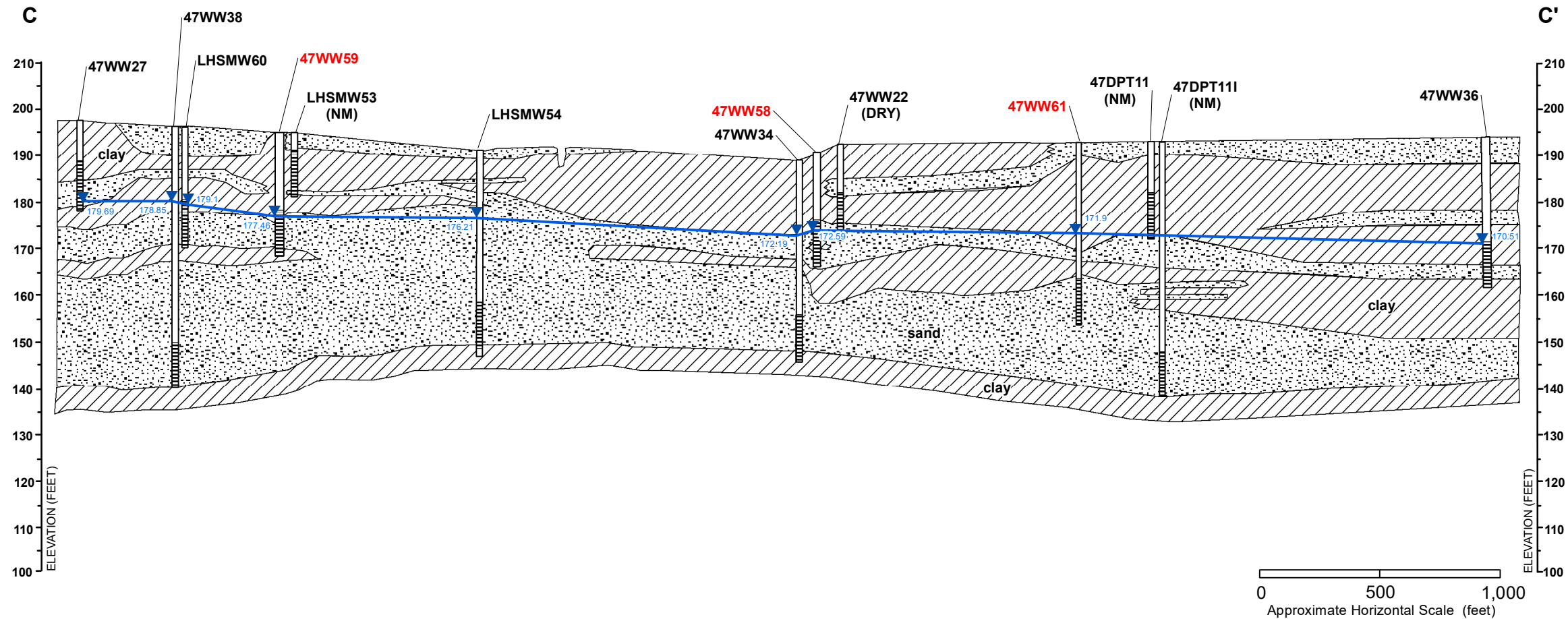
- Legend**
- Screen
 - Well
 - Clay
 - Sand
 - Groundwater Level
 - Measured Groundwater Elevation (May 2023)

NOTES:
NM = Not Measured
Cross-sections digitized from 2011 Shaw Feasibility Study
New PDI Wells projected onto existing cross-section

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

**GEOLOGICAL CROSS-SECTION
B-B'**
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

PDI Appendix C



Legend

- Screen
- Well
- Clay
- Sand
- Groundwater Level
- Measured Groundwater Elevation (May 2023)
- 2023 PDI Wells

NOTES:
 NM = Not Measured
 Cross-sections digitized from 2011 Shaw Feasibility Study
 New PDI Wells projected onto existing cross-section
 Red font indicates 2023 PDI wells

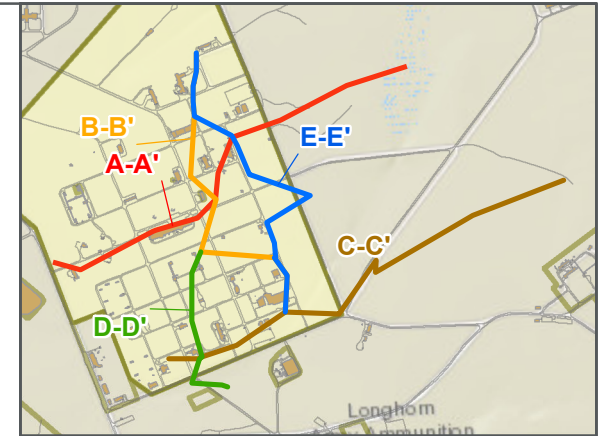
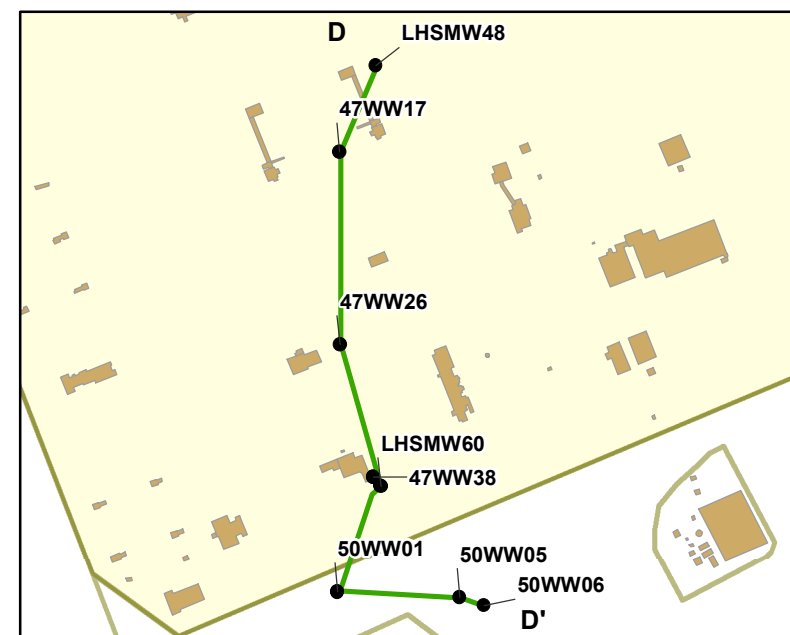
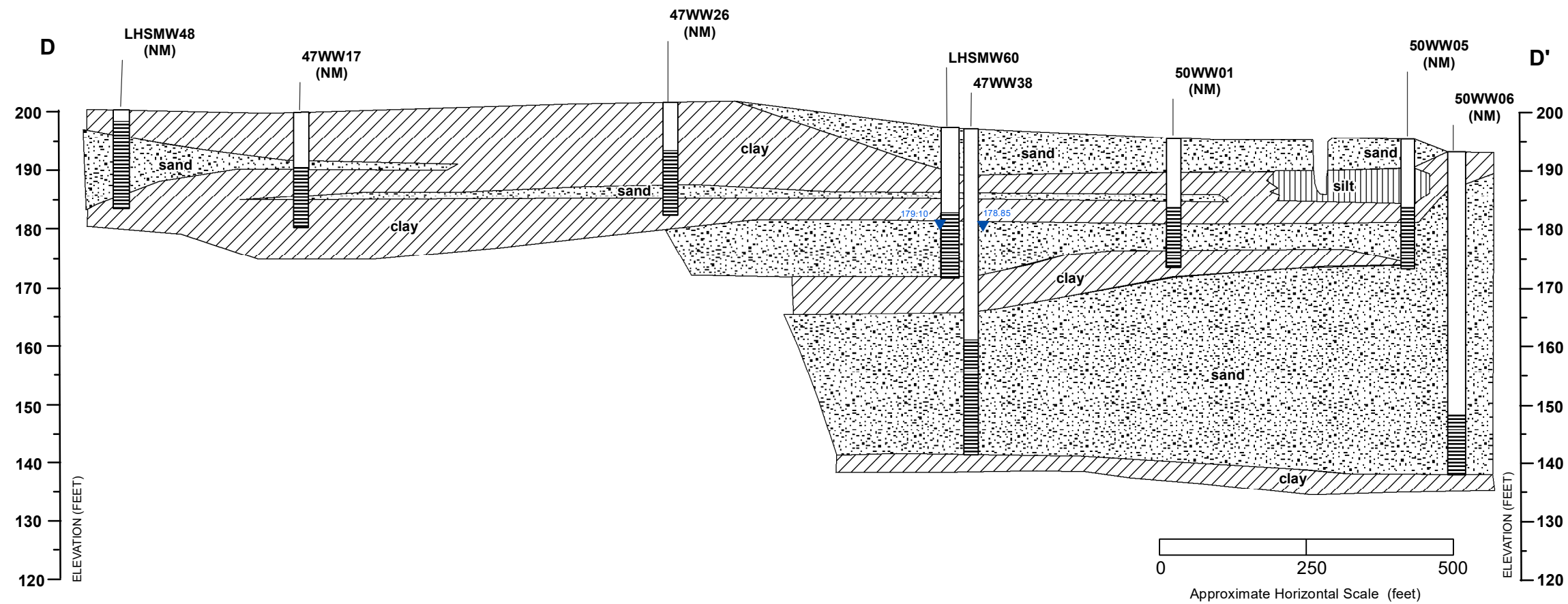
DISCLAIMER: Map information was compiled from the best available sources. No warranty is made for its accuracy or completeness.

GEOLOGICAL CROSS-SECTION C-C'

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS



PDI Appendix C



Legend

- Screen
- Well
- Clay
- Sand
- Silt
- Measured Groundwater Elevation (May 2023)

NOTES:
NM = Not Measured
Cross-sections digitized from 2011 Shaw Feasibility Study
New PDI Wells projected onto existing cross-section

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

GEOLOGICAL CROSS-SECTION D-D'

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

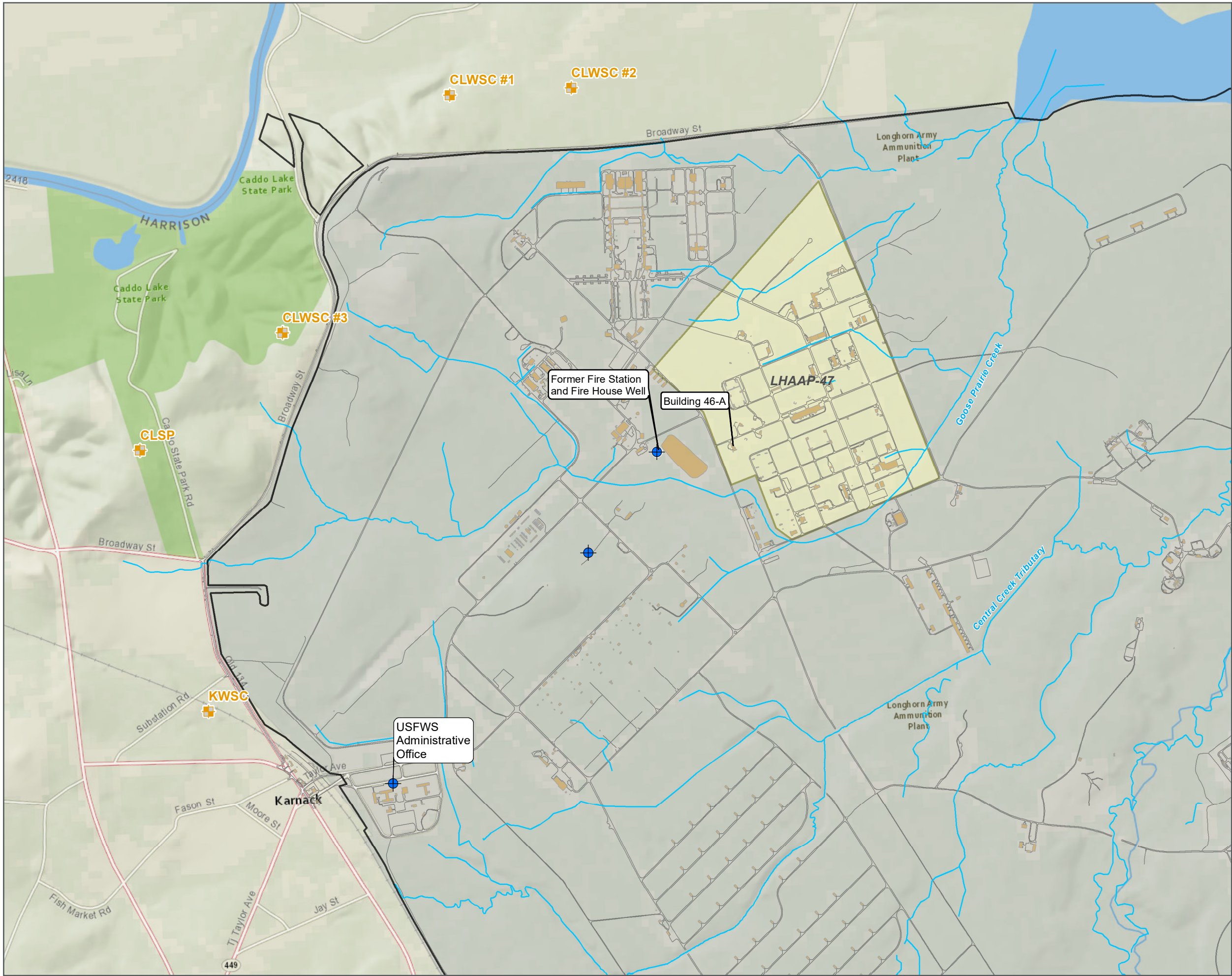


HR

PDI Appendix C



PDI Appendix C



LEGEND

- Public Water Supply Well Locations
- Potable Water Wells
- Stream
- Roads
- Buildings
- LHAAP-47 Site

DATA SOURCES: July 2011 Final Feasibility Study Report for LHAAP-47, Plant 3 Area, Group 4, Longhorn Army Ammunition Plant, Karnack, Harrison County, Texas (Shaw, 2011)

Surface Water and Sediment Sampling Locations are taken from the Remedial Investigation RI Report (Jacobs, 2002).

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

SITE VICINITY

LHAAP 47

LONGHORN ARMY AMMUNITION PLANT

KARNACK, TEXAS

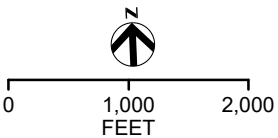
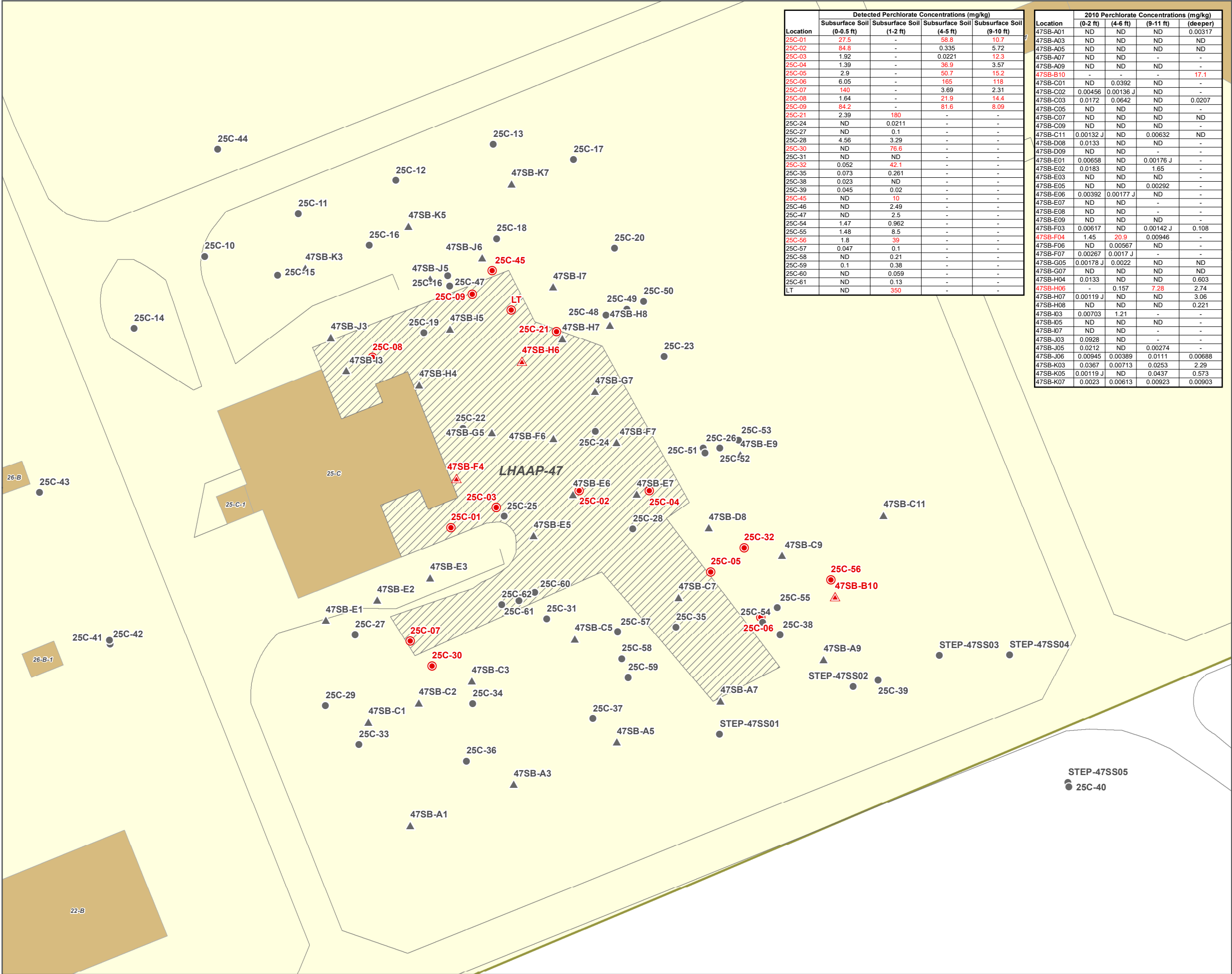
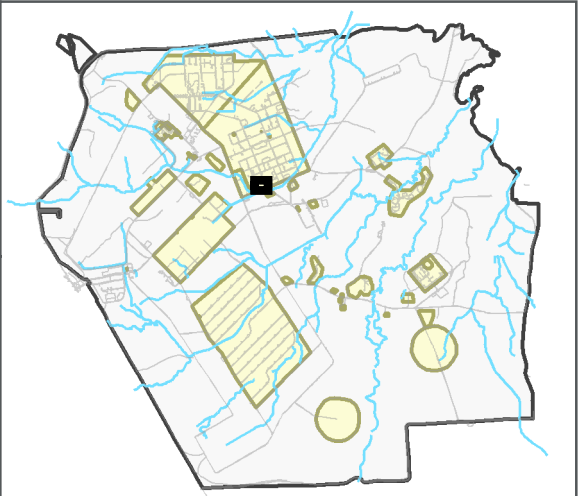


FIGURE 2-2



Location	Detected Perchlorate Concentrations (mg/kg)			
	Subsurface Soil (0-0.5 ft)	Subsurface Soil (1-2 ft)	Subsurface Soil (4-6 ft)	Subsurface Soil (9-10 ft)
25C-01	27.5	-	58.8	10.7
25C-02	84.8	-	0.335	5.72
25C-03	1.92	-	0.0221	12.3
25C-04	1.39	-	36.9	3.57
25C-05	2.9	-	50.7	15.2
25C-06	6.05	-	165	118
25C-07	140	-	3.69	2.31
25C-08	1.64	-	21.9	14.4
25C-09	84.2	-	81.6	8.09
25C-21	2.39	180	-	-
25C-24	ND	0.0211	-	-
25C-27	ND	0.1	-	-
25C-28	4.56	3.29	-	-
25C-30	ND	76.6	-	-
25C-31	ND	ND	-	-
25C-32	0.052	42.1	-	-
25C-35	0.073	0.261	-	-
25C-38	0.023	ND	-	-
25C-39	0.045	0.02	-	-
25C-45	ND	10	-	-
25C-46	ND	2.49	-	-
25C-47	ND	2.5	-	-
25C-54	1.47	0.962	-	-
25C-55	1.48	8.5	-	-
25C-56	1.8	39	-	-
25C-57	0.047	0.1	-	-
25C-58	ND	0.21	-	-
25C-59	0.1	0.38	-	-
25C-60	ND	0.059	-	-
25C-61	ND	0.13	-	-
LT	ND	350	-	-

Location	2010 Perchlorate Concentrations (mg/kg)			
	(0-2 ft)	(4-6 ft)	(9-11 ft)	(deeper)
47SB-A01	ND	ND	ND	0.00317
47SB-A03	ND	ND	ND	ND
47SB-A05	ND	ND	ND	ND
47SB-A07	ND	ND	-	-
47SB-A09	ND	ND	ND	-
47SB-B10	-	-	-	17.1
47SB-C01	ND	0.0392	ND	-
47SB-C02	0.00456	0.00136 J	ND	-
47SB-C03	0.0172	0.0642	ND	0.0207
47SB-C05	ND	ND	ND	-
47SB-C07	ND	ND	ND	ND
47SB-C09	ND	ND	ND	-
47SB-C11	0.00132 J	ND	0.00632	ND
47SB-D08	0.0133	ND	ND	-
47SB-D09	ND	ND	-	-
47SB-E01	0.00658	ND	0.00176 J	-
47SB-E02	0.0183	ND	1.65	-
47SB-E03	ND	ND	ND	-
47SB-E05	ND	ND	0.00292	-
47SB-E06	0.00392	0.00177 J	ND	-
47SB-E07	ND	ND	-	-
47SB-E08	ND	ND	-	-
47SB-E09	ND	ND	ND	-
47SB-F03	0.00617	ND	0.00142 J	0.108
47SB-F04	1.45	20.9	0.00946	-
47SB-F06	ND	0.00567	ND	-
47SB-F07	0.00267	0.0017 J	-	-
47SB-G05	0.00178 J	0.0022	ND	ND
47SB-G07	ND	ND	ND	ND
47SB-H04	0.0133	ND	ND	0.603
47SB-H06	-	0.157	7.28	2.74
47SB-H07	0.00119 J	ND	ND	3.06
47SB-H08	ND	ND	ND	0.221
47SB-I03	0.00703	1.21	-	-
47SB-I05	ND	ND	ND	-
47SB-I07	ND	ND	-	-
47SB-J03	0.0928	ND	-	-
47SB-J05	0.0212	ND	0.00274	-
47SB-J06	0.00945	0.00389	0.0111	0.00688
47SB-K03	0.0367	0.00713	0.0253	2.29
47SB-K05	0.00119 J	ND	0.0437	0.573
47SB-K07	0.0023	0.00613	0.00923	0.00903



- LEGEND**
- Perchlorate Sample Locations
- ▲ 2010 <7.2 mg/kg
 - ▲ 2010 >7.2 mg/kg
 - Previous <7.2 mg/kg
 - Previous >7.2 mg/kg
 - Approximate Extent of Liner
 - Stream
 - Roads
 - Buildings
 - LHAAP-47 Site
 - LHAAP Site

DATA SOURCES: Shaw 2011 Feasibility Study Report

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

**PERCHLORATE IN SOIL AT BUILDING 25C
(FEASIBILITY STUDY, 2011)**

LHAAP 47
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

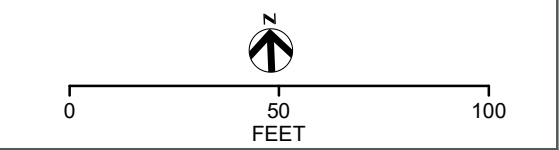
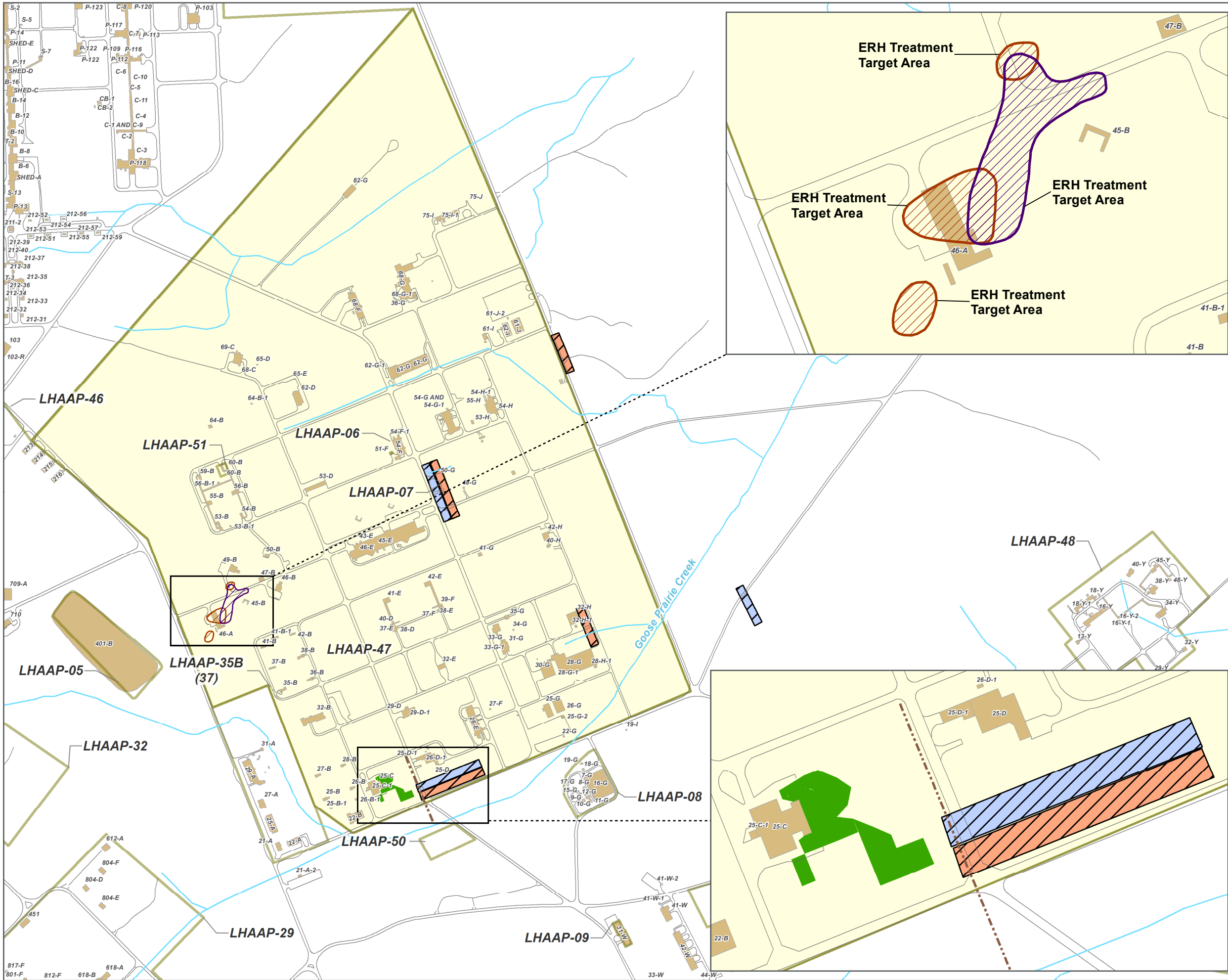






FIGURE 2-7



LEGEND

Shallow Groundwater Zone TCE Iso-Concentration Contours

TCE > 10,000 µg/L

Upper Intermediate Groundwater Zone TCE Iso-Concentration Contours

TCE > 10,000 µg/L

ISB Biobarrier Intermediate

ISB Biobarrier Shallow

Building 25C - Proposed Excavation

Ditches

Stream

Roads

Buildings

LHAAP-47 Site

LHAAP Site

Biobarrier locations are based on the FS and the extent of contaminated groundwater has changed since 2010. The final locations and design will be presented in the Remedial Design.

DATA SOURCES: July 2011 Final Feasability Study Report for LHAAP-47, Plant 3 Area, Group 4, Longhorn Army Ammunition Plant, Karnack, Harrison County, Texas (Shaw, 2011)

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

MODIFIED ALTERNATIVE 2 ISB BIOARRIER, SOIL EXCAVATION, AND ERH TARGET AREAS

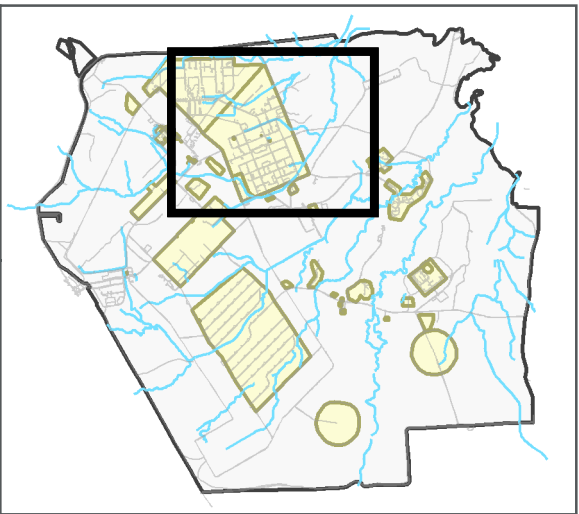
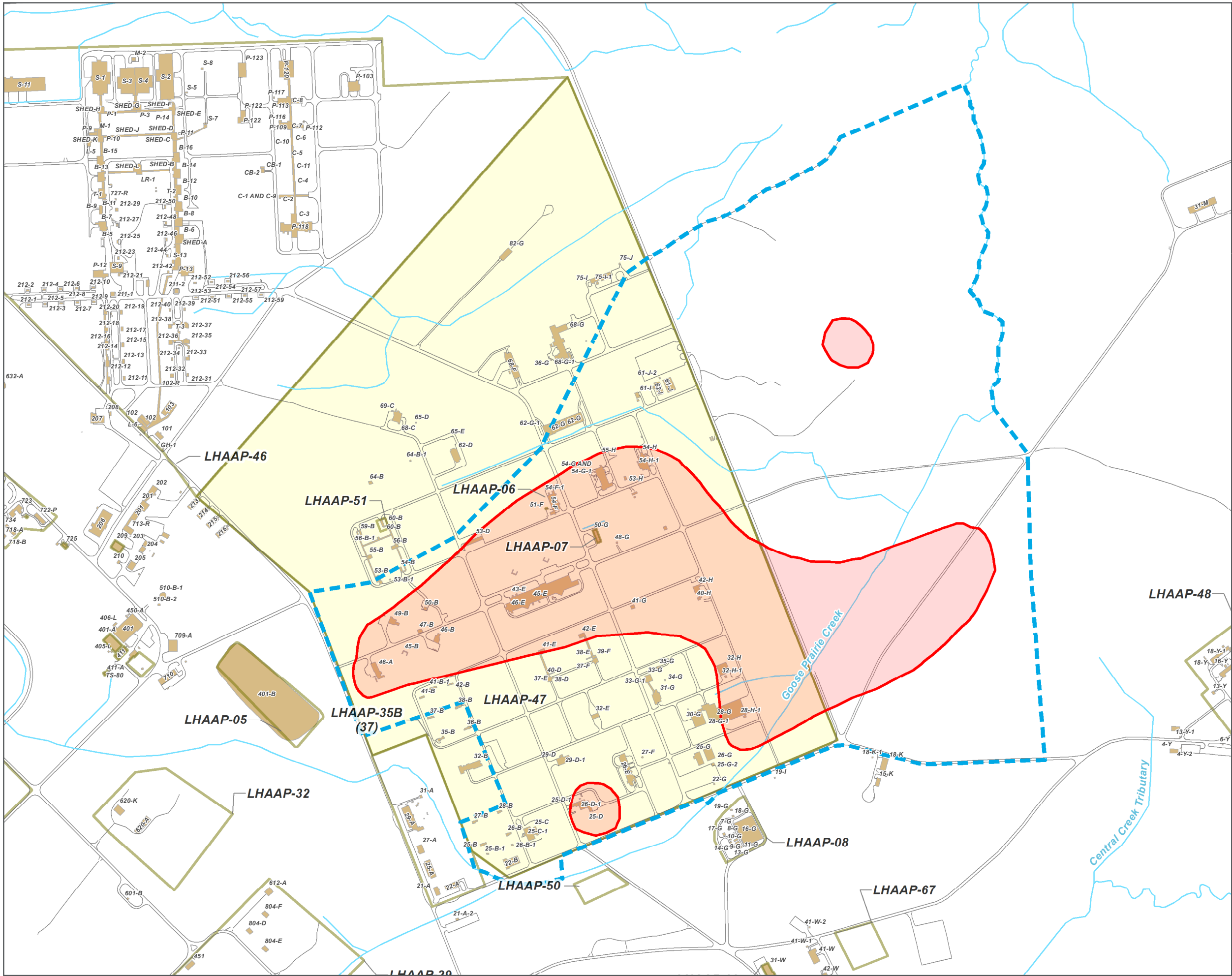
LHAAP 47

LONGHORN ARMY AMMUNITION PLANT

KARNACK, TEXAS

0 500 1,000
FEET

FIGURE 2-10



- LEGEND**
- Contamination Extent
 - Preliminary Land Use Control Boundary
 - Stream
 - Roads
 - Building
 - LHAAP-47
 - Site LHAAP

SOURCES: Revised Final Record of Decision, 2022
NOTES: Maximum extent of contamination is based on the MCL for TCE (5 ug/L) and PCL for perchlorate (17 ug/L) .
DISCLAIMER: Map information was compiled from the best available sources. No warranty is made for its accuracy or completeness.

PRELIMINARY LAND USE CONTROL BOUNDARY
LHAAP 47
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

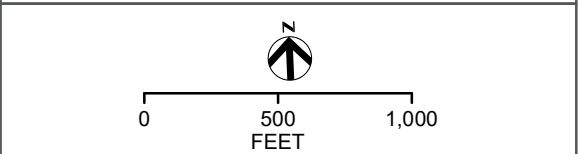
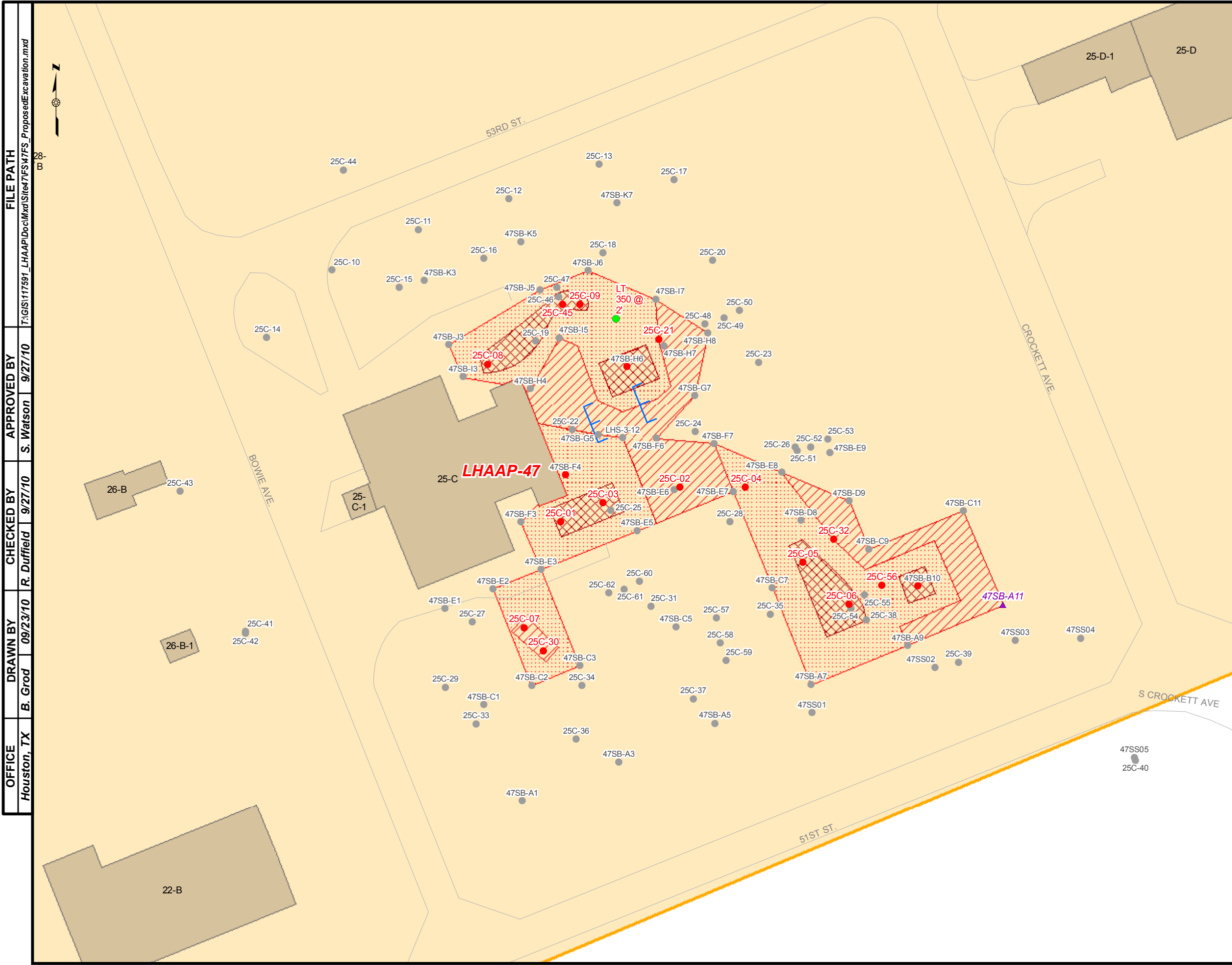






FIGURE 2-11



LEGEND

- Proposed Sample Location
- Perchlorate Sample Location above 7.2 mg/kg
- Perchlorate Sample Location

Road

Proposed Excavation Area

Slope or Step

4'

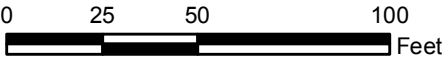
12'

Building or Concrete Slab

Site

Notes:

1. LT: Lyntech sampled 5 individual samples within a span of 35 feet.
2. Perchlorate concentrations are in milligrams per kilogram (mg/kg).
3. 25C series soil boring locations were placed at locations provided by Cliff Murray.
4. Excavation side slopes 1.5 to 10.

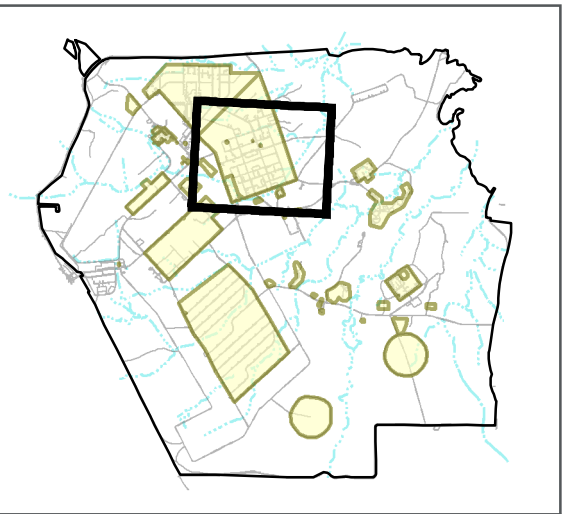
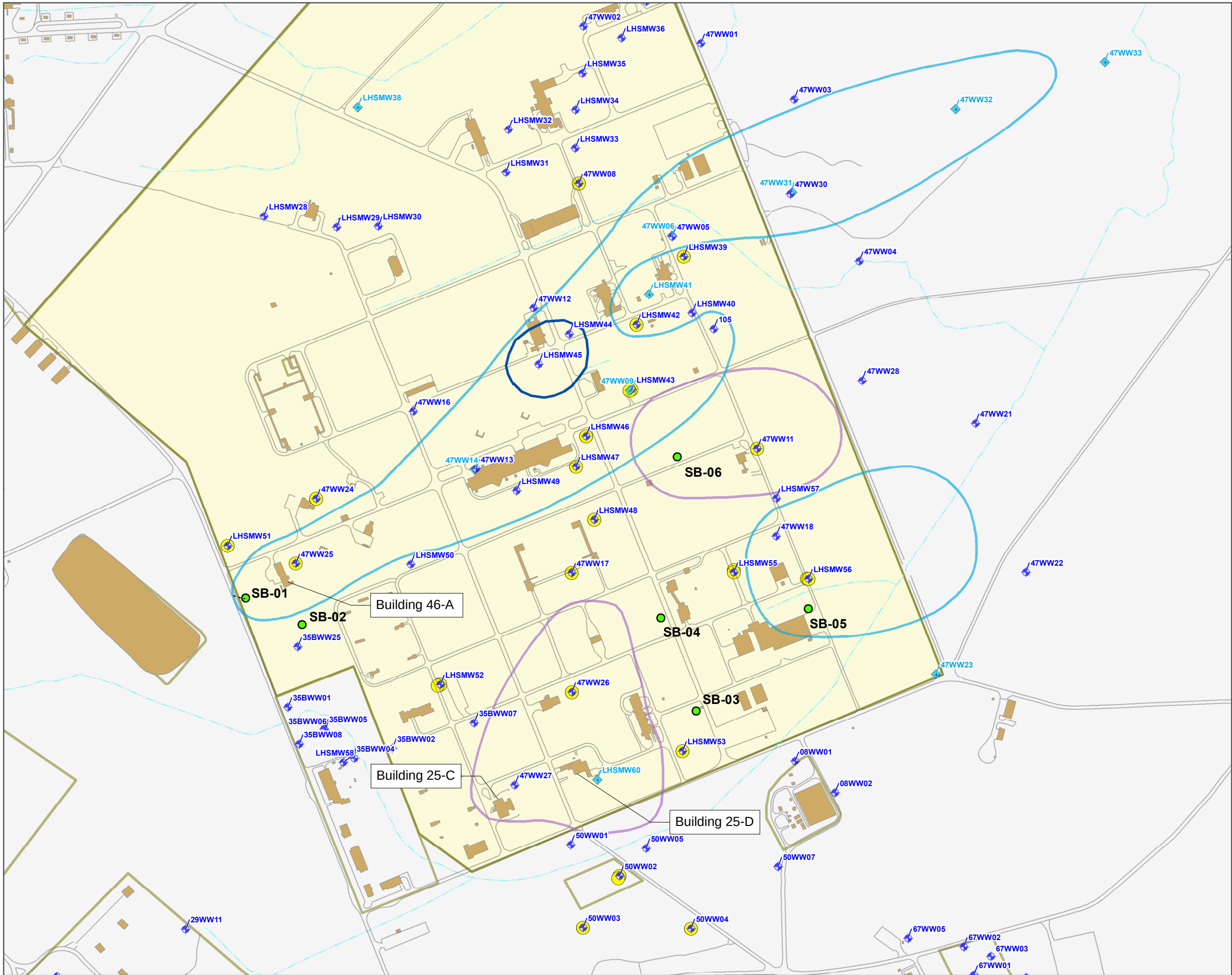


U.S. ARMY CORPS OF ENGINEERS
TULSA DISTRICT
TULSA, OKLAHOMA

FIGURE 5-1

PROPOSED SOIL EXCAVATION AREA
LHAAP-47 FEASIBILITY STUDY

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS



LEGEND

- Soil Boring Location, Sampled 2018
- ◆ Shallow Monitoring Well
- ◆ Shallow/Intermediate Monitoring Well
- Well Dry in 2010
- Trichloroethene Exceeding Shallow Zone USEPA MCL (5 µg/L), July 2018
- Perchlorate Exceeding Shallow Zone TRRP PCL (17 µg/L), 2010 and prior
- Trichloroethene Exceeding Shallow Zone MCL (5 µg/L), 2010 and prior
- Road
- Stream
- Building
- LHAAP-47
- LHAAP Site

SOURCES: Feasibility Study Report, 2011 and Draft Final Post Screening Investigation Addendum No. 2 Report, 2021
NOTE: Soil boring data blocks apply to groundwater grab samples. Map data and plume boundaries apply to previous sampling results through 2010.

**2010 AND 2018 SHALLOW ZONE
TCE AND PERCHLORATE PLUMES**
LHAAP-47
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

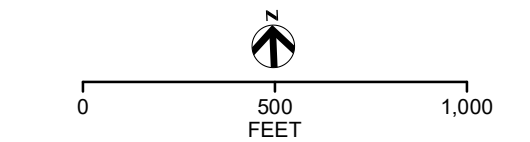
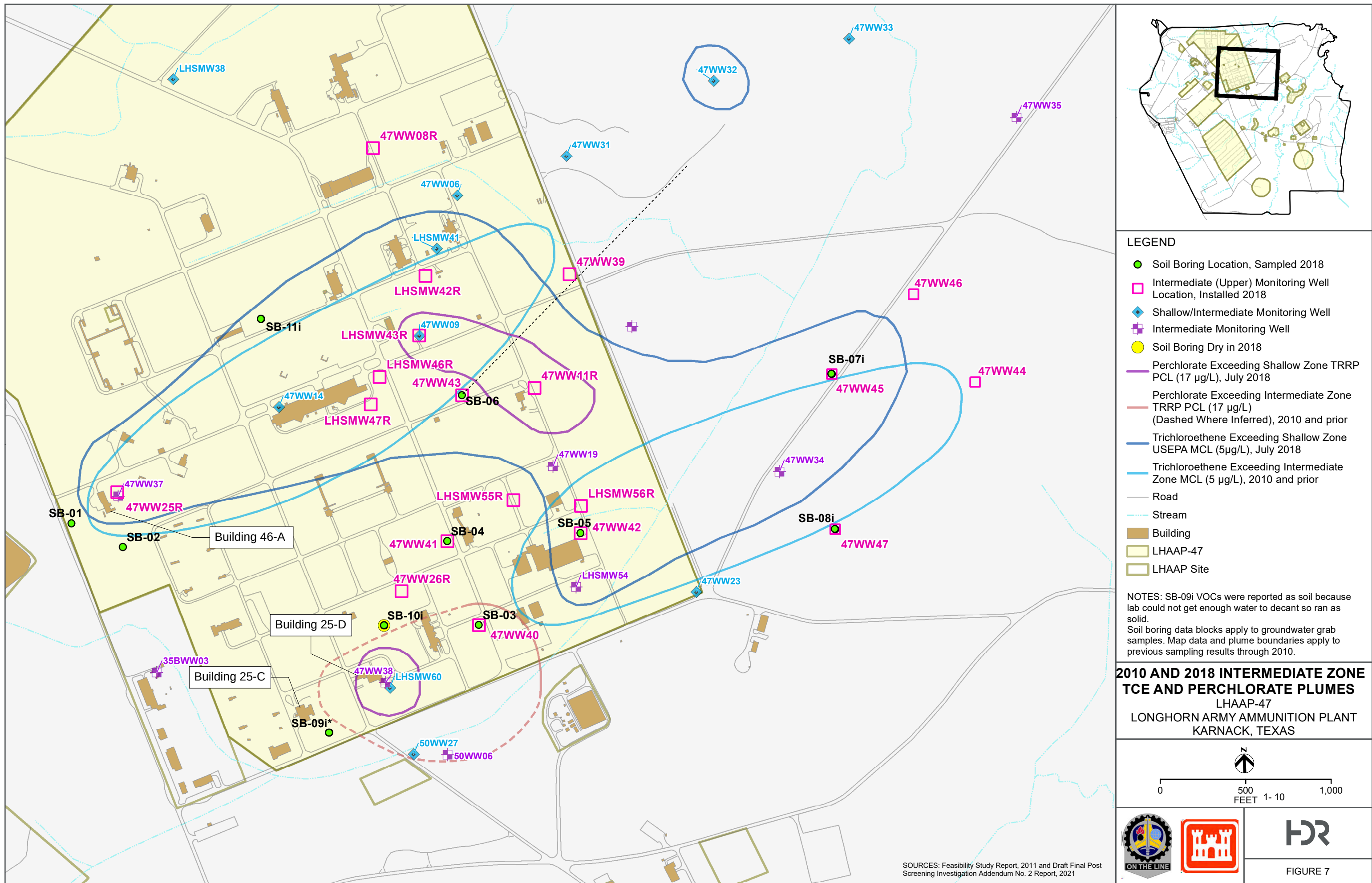


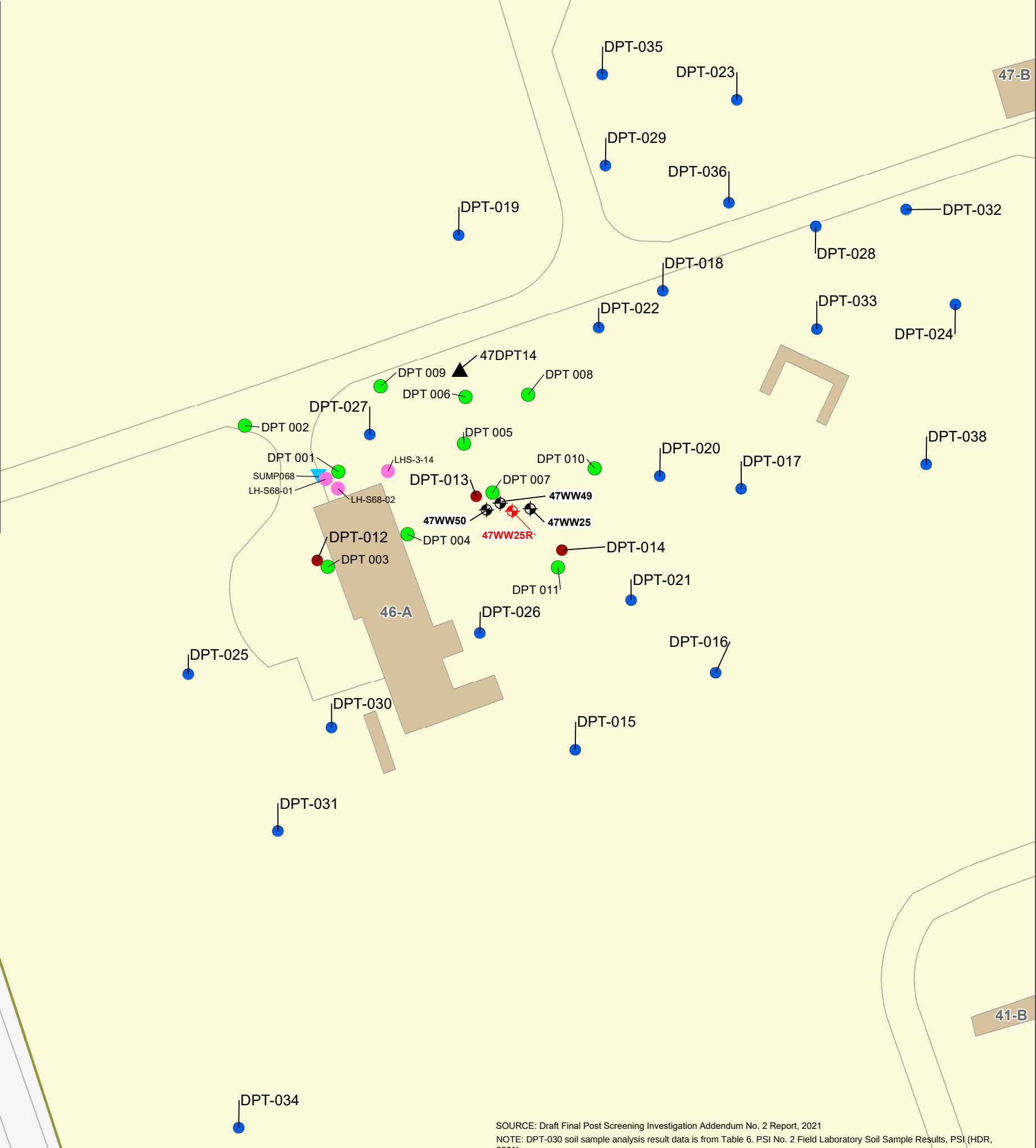
FIGURE 6



Location ID	Collection Date	Depth Interval (ft bgs)	TCE Result (mg/kg)	Qual
DPT-001	11/5/2019	27-28	11.8	
		31-32	0.00162	J
		38-39	ND	U
DPT-002	11/4/2019	26-27	0.0165	
		32-33	0.0039	
		40-41	ND	U
DPT-003	11/4/2019	29-30	15.8	
		35-36	ND	U
		39-40	0.00148	J
DPT-004	11/6/2019	28-29	8.37	
		30-31	0.0187	
		32-33	0.00089	J
DPT-005	11/5/2019	24-25	1.62	
		27-28	0.957	
		31-32	0.271	
DPT-006	11/5/2019	20-21	0.0684	
		27-28	0.191	
		30-31	0.00124	J
DPT-007	11/5/2019	27-28	6.21	
		29-30	1.76	
		31-32	15.6	
DPT-008	11/6/2019	26-27	1.34	
		27-28	0.497	
		29-30	1.42	
DPT-009	11/5/2019	24-25	0.295	
		28-29	0.00105	J
		31-32	ND	U
DPT-010	11/6/2019	23-24	1.24	
		28-29	3.18	
		32-33	4.1	
DPT-011	11/6/2019	22-23	1.1	
		27-28	3.81	
		31-32	3.08	
DPT-012	6/4/2020	3-4	0.026	U
		7-8	0.036	U
		11-12	0.025	U
DPT-013	6/4/2020	17-18	0.032	UJ
		1-2	0.03	U
		11-12	0.056	
DPT-014	6/3/2020	17-18	0.041	J-
		20-21	0.5	
		3-4	0.037	U
DPT-015	6/3/2020	10-11	0.03	U
		19-20	0.027	U
		25-26	0.63	
DPT-016	6/2/2020	3-4	0.1	
		15-16	0.028	U
		19-20	0.028	U
DPT-017	6/3/2020	23-24	0.21	
		7-8	0.026	U
		13-14	0.028	U
DPT-018	6/1/2020	21-22	0.026	U
		24-25	0.027	U
		10-11	0.028	U
DPT-019	6/1/2020	17-18	0.027	U
		19-20	0.028	U
		23-24	0.73	
DPT-020	6/4/2020	7-8	0.21	J-
		15-16	0.47	J-
		21-22	0.058	J-
DPT-021	6/4/2020	32-33	15	
		4-5	0.03	J-
		8-9	0.048	J-
DPT-022	6/5/2020	14-15	0.07	J-
		22-23	0.032	UJ
		5-6	0.032	UJ
DPT-023	6/8/2020	11-12	0.029	UJ
		14-15	0.028	UJ
		18-19	0.026	UJ
DPT-024	6/8/2020	6-7	0.029	U
		10-11	0.029	U
		11-12	0.029	UJ
DPT-025	6/9/2020	17-18	0.031	U
		22-23	0.052	
		4-5	0.035	U
DPT-026	6/7/2020	16-17	0.027	U
		17-18	0.033	UJ
		26-27	0.069	
DPT-027	6/11/2020	2-3	0.027	UJ
		5-6	0.03	U
		8-9	0.035	U
DPT-028	6/10/2020	11-12	0.034	U
		17-18	0.1	
		22-23	0.032	U
DPT-029	6/11/2020	10-11	0.41	
		13-14	0.22	
		16-17	1.3	
DPT-030	6/11/2020	28-29	0.00105	J
		7-8	0.029	U
		13-14	0.028	U
DPT-031	6/12/2020	17-18	0.028	U
		21-22	0.031	U
		10-11	16	
DPT-032	6/13/2020	15-16	7.9	
		17-18	0.032	U
		19-20	0.03	U
DPT-033	6/13/2020	3-4	0.065	
		12-13	0.027	J
		16-17	0.56	
DPT-034	6/13/2020	21-22	2	
		12-13	0.026	U
		15-16	0.028	U
DPT-035	6/13/2020	19-20	0.026	U
		21-22	0.032	U
		8-9	0.029	U
DPT-036	6/14/2020	12-13	0.025	U
		19-20	0.52	
		22-23	1.7	
DPT-037	6/14/2020	8-9	0.025	U
		15-16	0.034	U
		18-19	0.028	U
DPT-038	6/15/2020	22-23	0.03	U
		10-11	0.028	U
		15-16	0.034	U
DPT-039	6/15/2020	18-19	0.028	U
		21-22	0.033	U
		11-12	0.028	U
DPT-040	6/15/2020	15-16	0.029	U
		18-19	0.031	U
		21-22	0.029	U
DPT-041	6/15/2020	11-12	0.026	U
		14-15	0.029	U
		18-19	0.023	U
DPT-042	6/15/2020	21-22	0.025	U
		11-12	0.024	U
		15-16	0.027	U
DPT-043	6/15/2020	18-19	0.027	U
		22-23	0.024	U
		5-6	0.026	U
DPT-044	6/5/2020	8-9	0.029	
		14-15	0.029	U
		21-21	0.1	

Location ID	Collection Date	Depth Interval (ft bgs)	TCE Result (mg/kg)	Qual
DPT-023	6/8/2020	2-3	0.026	U
		4-5	0.027	U
		7-8	0.033	U
DPT-024	6/8/2020	9-10	0.031	U
		9-10	0.029	U
		13-14	0.028	U
DPT-025	6/9/2020	17-18	0.033	U
		21-22	0.031	U
		6-7	0.026	U
DPT-026	6/9/2020	11-12	0.031	U
		17-18	0.038	
		22-23	0.052	
DPT-027	6/7/2020	4-5	0.035	U
		16-17	0.027	U
		17-18	0.033	UJ
DPT-028	6/11/2020	26-27	0.069	
		2-3	0.027	UJ
		5-6	0.03	U
DPT-029	6/11/2020	8-9	0.035	U
		11-12	0.034	U
		17-18	0.1	
DPT-030	6/11/2020	22-23	0.032	U
		10-11	0.41	
		13-14	0.22	
DPT-031	6/10/2020	16-17	1.3	
		21-22	3.3	
DPT-032	6/11/2020	7-8	0.029	U
		13-14	0.028	U
		17-18	0.028	U
DPT-033	6/11/2020	21-22	0.031	U
		10-11	16	
		15-16	7.9	
DPT-034	6/11/2020	17-18	0.032	U
		19-20	0.03	U
DPT-035	6/12/2020	3-4	0.065	
		12-13	0.027	J
		16-17	0.56	
DPT-036	6/13/2020	21-22	2	
		12-13	0.026	U
		15-16	0.028	U
DPT-037	6/13/2020	19-20	0.026	U
		21-22	0.032	U
		8-9	0.029	U
DPT-038	6/13/2020	12-13	0.025	U
		19-20	0.52	
		22-23	1.7	
DPT-039	6/14/2020	8-9	0.025	U
		15-16	0.034	U
		18-19	0.028	U
DPT-040	6/14/2020	22-23	0.03	U
		10-11	0.028	U
		15-16	0.034	U
DPT-041	6/14/2020	18-19	0.028	U
		21-22	0.033	U
		11-12	0.028	U
DPT-042	6/15/2020	15-16	0.029	U
		18-19	0.031	U
		21-22	0.029	U
DPT-043	6/15/2020	11-12	0.026	U
		14-15	0.029	U
		18-19	0.023	U
DPT-044	6/15/2020	21-22	0.025	U
		11-12	0.024	U
		15-16	0.027	U
DPT-045	6/15/2020	18-19	0.027	U
		22-23	0.024	U
		5-6	0.026	U
DPT-046	6/5/2020	8-9	0.029	
		14-15	0.029	U
		21-21	0.1	

NS - Not Sampled
ND - Not Detected
Shading indicates unsaturated zone
Samples



Map Extent

LEGEND

- HDR PSI November 2019 DPT Boring Locations (up to 40bgs)
- HDR PSI 2020 Shallow DPT Boring Locations
- HDR PSI 2020 Deep and Shallow DPT Boring Locations
- Inter./Upper Inter. MW
- Shallow MW
- DPT (DPT Boring Shaw, FS 2011)
- SB (Soil Boring Shaw, FS 2011)
- SUMP
- Road
- Stream
- Building
- LHAAP-47
- LHAAP Site

Uniform depth of 23 ft below ground surface based on historical data is used to define the depth of the Unsaturated Zone.

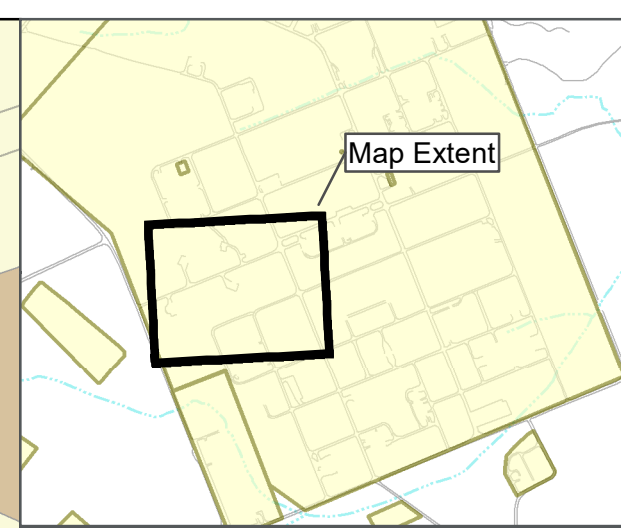
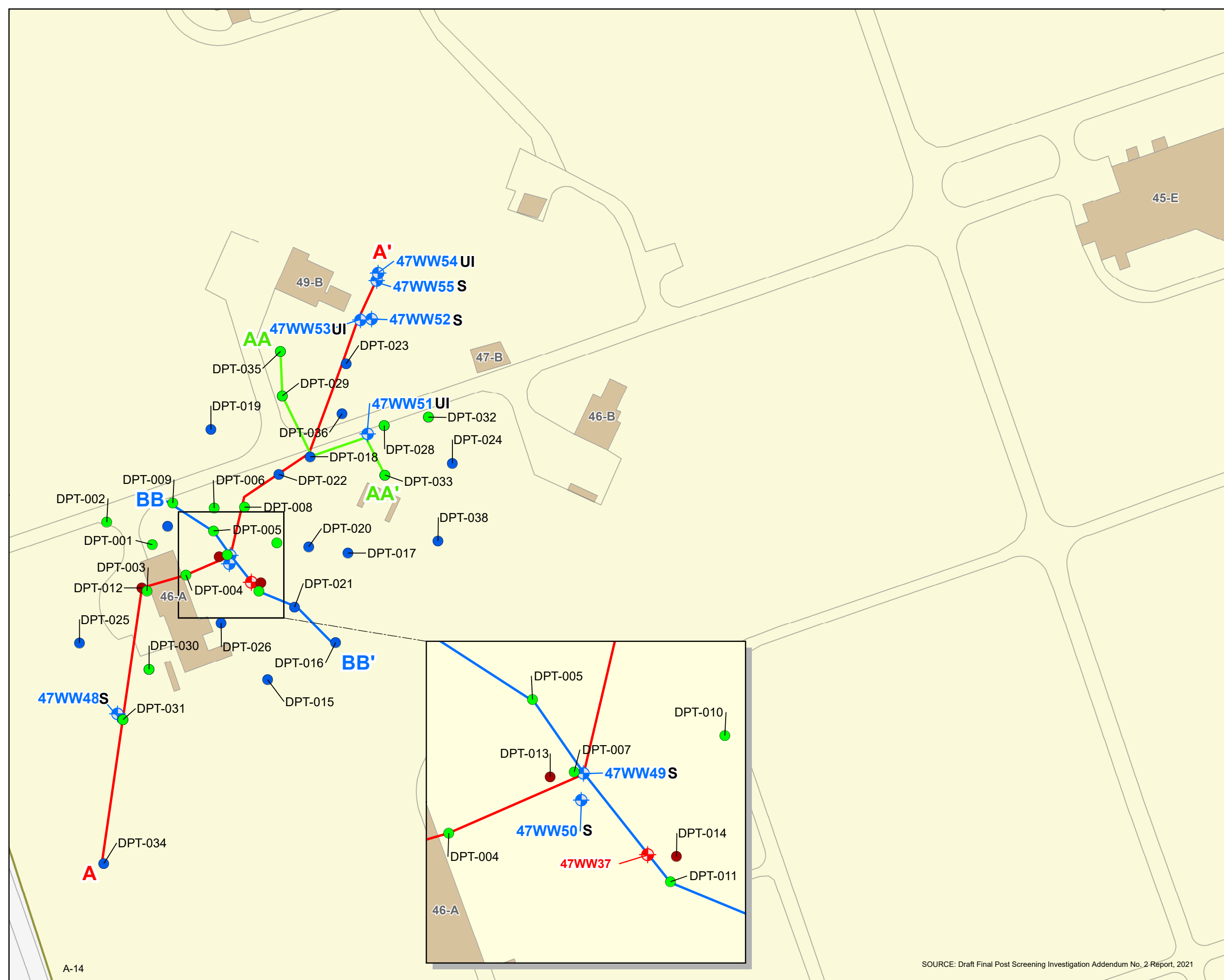
NOTES:
Bold Results indicate concentration greater than GWP-Ind MSC of 0.5 mg/kg.
All units are in milligrams per kilogram (mg/kg)
TCE = ND indicates TCE was not detected at all depths
ft bgs = feet below ground surface NS = not sampled

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

PSI NO. 2 DPT SOIL RESULTS BUILDING 46A AREA

LHAAP-47 LONGHORN ARMY
AMMUNITION PLANT

FIGURE 10



LEGEND

- New Well Location
- HDR November 2019 DPT Boring
- HDR 2020 Shallow DPT Boring Locations
- HDR 2020 Deep and Shallow DPT Boring Locations
- UI Monitoring Well
- Existing Shallow MW
- Road
- Stream
- Building
- LHAAP-47
- LHAAP Site

Cross Sections

- A-A'
- AA-AA'
- BB-BB'

NOTES: S- Shallow monitoring well
 UI- Upper intermediate monitoring well
 DISCLAIMER: Map information was compiled from the best available sources. No warranty is made for its accuracy or completeness.

**GEOLOGIC CROSS SECTIONS
 LHAAP-47 BUILDING 46A AREA**

LHAAP-47 LONGHORN ARMY
 AMMUNITION PLANT

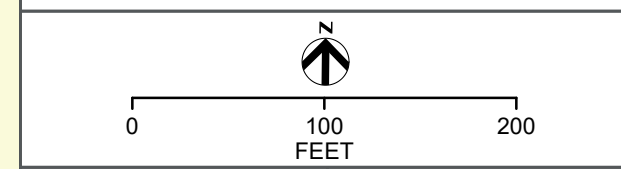
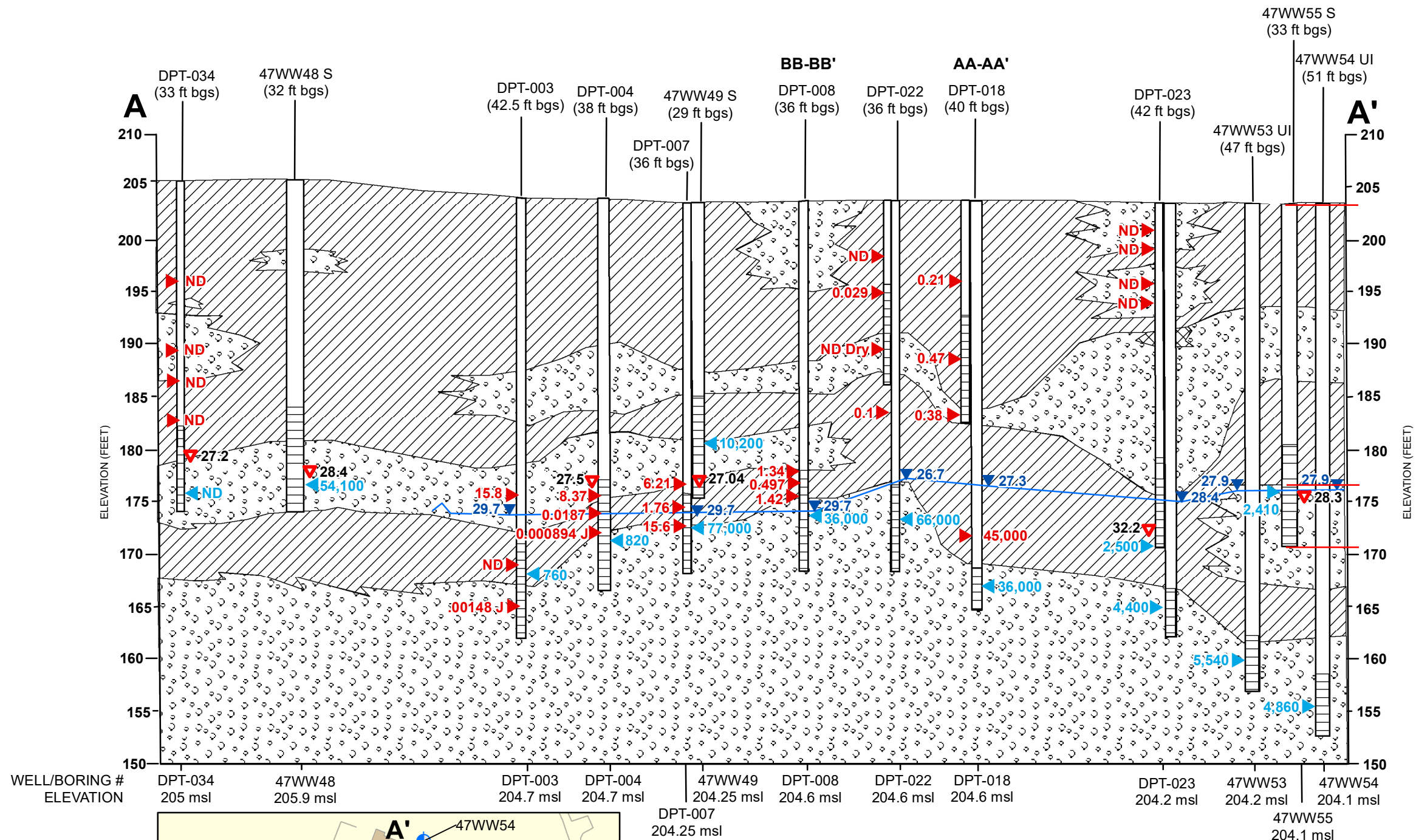


FIGURE 13



SCALE: HORIZONTAL 1 cm = 27'
VERTICAL AS SHOWN



LEGEND

- Clay, Clay with Fine Sand, Silt and Sand/Silty Lenses
- Silty Sands, Sand Silt Mixtures
- Well
- Screen
- No Recovery
- UI Groundwater Elevation (ft bgs)
- Shallow Groundwater Elevation (ft bgs)
- Groundwater TCE Sample Interval and Results
- Soil TCE Sample Interval and Results
- 2019 DPT Boring
- 2020 Deep and Shallow DPT Boring
- 2020 Newly Installed Wells
- Groundwater Table Line

Cross Sections

- A-A'
- AA-AA'
- BB-BB'

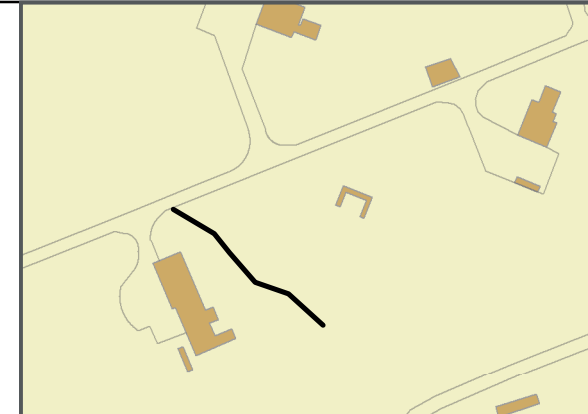
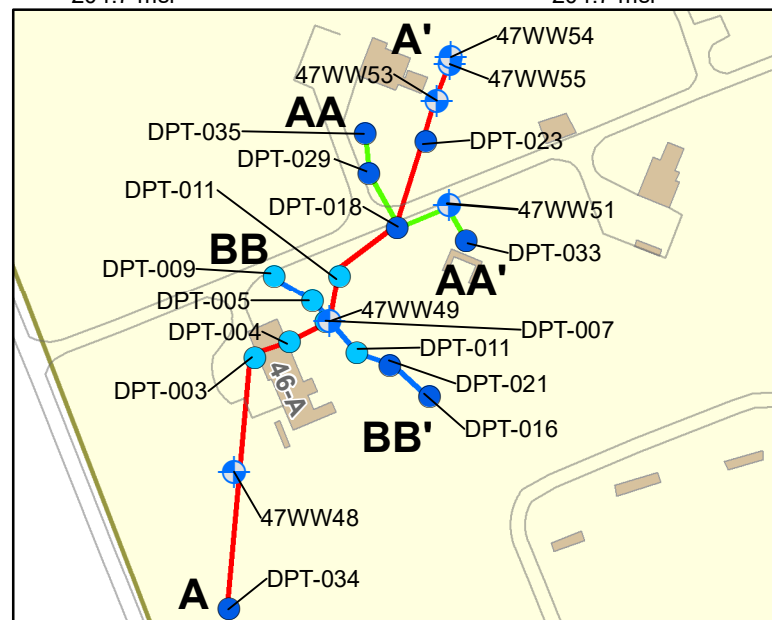
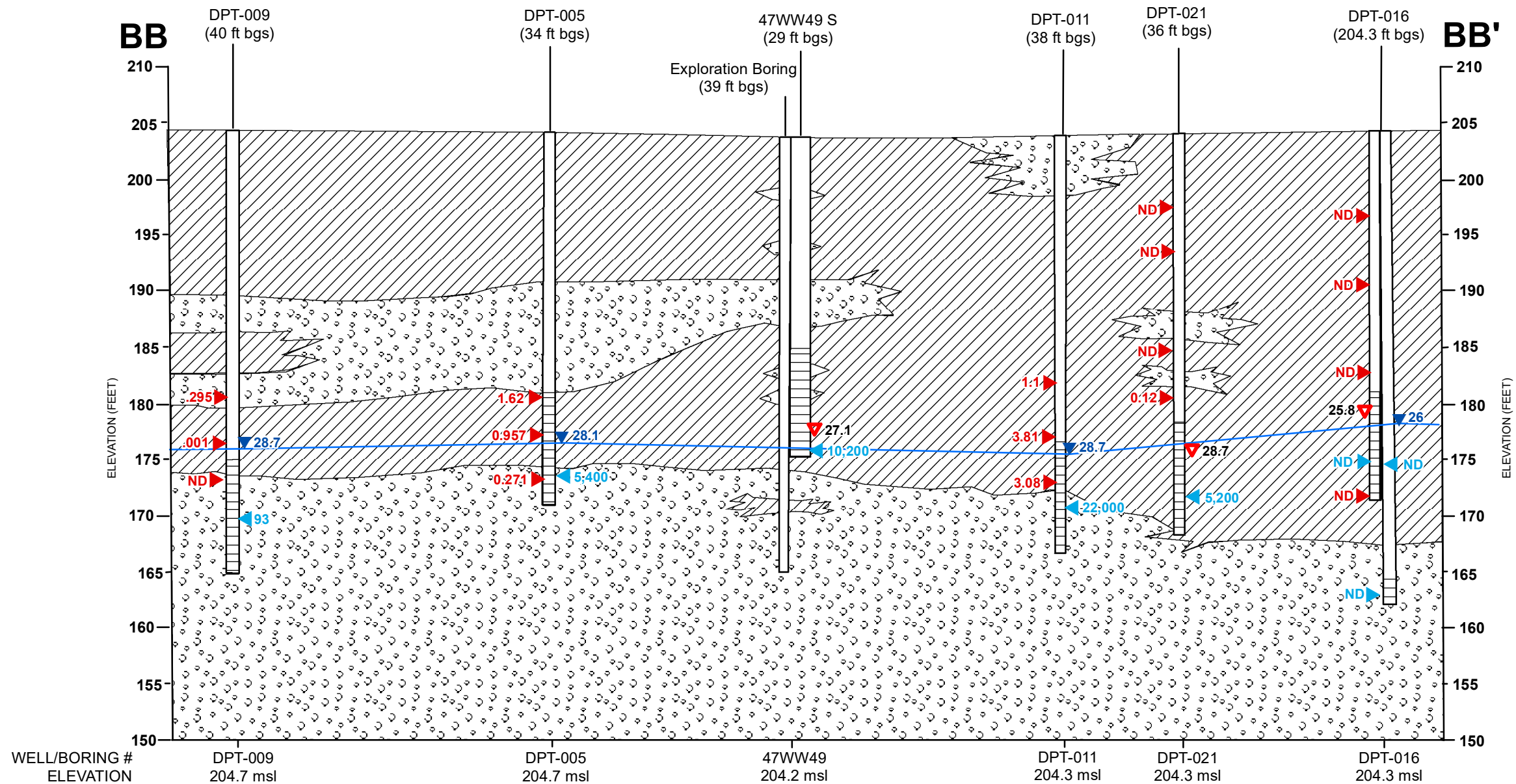
NOTES: Groundwater results reported in micrograms per liter
Soil results reported in milligrams per kilogram
ND- Nondetect
J- Estimated
S- Shallow monitoring well
UI- Upper Intermediate monitoring well
DATA SOURCES: HDR
DISCLAIMER: Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.

GEOLOGIC CROSS SECTION A-A'

LHAAP-47 POST SCREENING
INVESTIGATION ADDENDUM 2 REPORT

FIGURE 14



LEGEND

- Clay, Clay with Fine Sand, Silt and Sand/Silty Lenses
- Silty Sands, Sand Silt Mixtures
- Well
- Screen
- UI Groundwater Elevation (ft bgs)
- Shallow Groundwater Elevation (ft bgs)
- Groundwater TCE Sample Interval and Results
- Soil TCE Sample Interval and Results
- 2019 DPT Boring
- 2020 Deep and Shallow DPT Boring
- 2020 Newly Installed Wells
- Groundwater Table Line
- Cross Sections**
 - A-A'
 - AA-AA'
 - BB-BB'

NOTES: Groundwater results reported in micrograms per liter
Soil results reported in milligrams per kilogram
ND- Nondetect
J- Estimated
S- Shallow monitoring well
DATA SOURCES: HDR
DISCLAIMER: Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.

GEOLOGIC CROSS SECTION BB-BB'

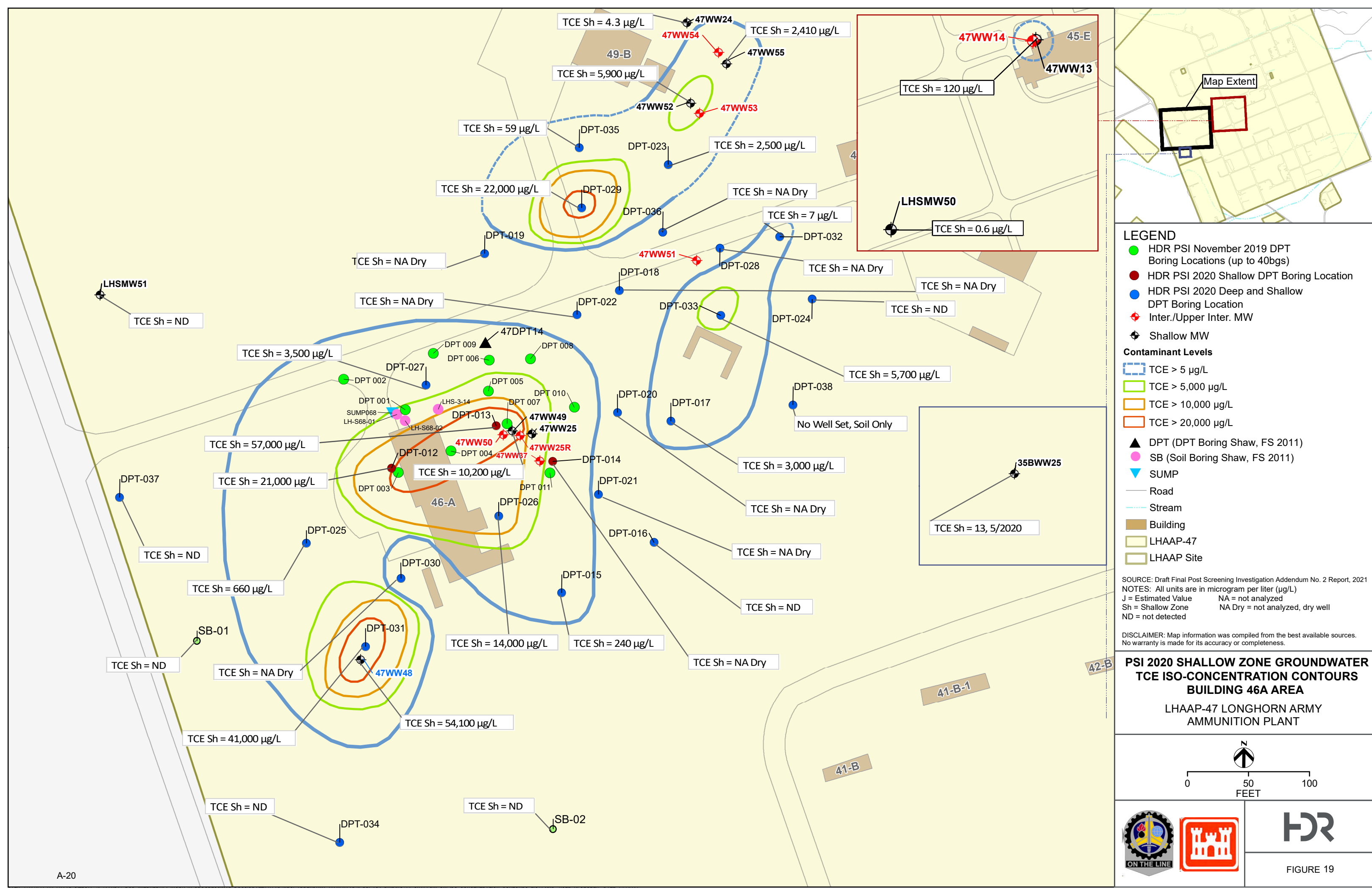
LHAAP-47 POST SCREENING
INVESTIGATION ADDENDUM 2 REPORT



HDR

FIGURE 16

SOURCE: Draft Final Post Screening Investigation Addendum No. 2 Report, 2021



LEGEND

- HDR PSI November 2019 DPT Boring Locations (up to 40bgs)
- HDR PSI 2020 Shallow DPT Boring Location
- HDR PSI 2020 Deep and Shallow DPT Boring Location
- Inter./Upper Inter. MW
- Shallow MW

Contaminant Levels

- TCE > 5 µg/L
- TCE > 5,000 µg/L
- TCE > 10,000 µg/L
- TCE > 20,000 µg/L

- DPT (DPT Boring Shaw, FS 2011)
- SB (Soil Boring Shaw, FS 2011)
- SUMP
- Road
- Stream
- Building
- LHAAP-47
- LHAAP Site

SOURCE: Draft Final Post Screening Investigation Addendum No. 2 Report, 2021
NOTES: All units are in microgram per liter (µg/L)
J = Estimated Value NA = not analyzed
Sh = Shallow Zone NA Dry = not analyzed, dry well
ND = not detected

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

PSI 2020 SHALLOW ZONE GROUNDWATER TCE ISO-CONCENTRATION CONTOURS BUILDING 46A AREA

LHAAP-47 LONGHORN ARMY AMMUNITION PLANT

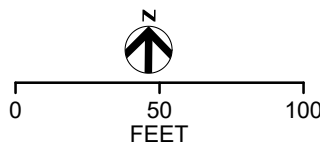
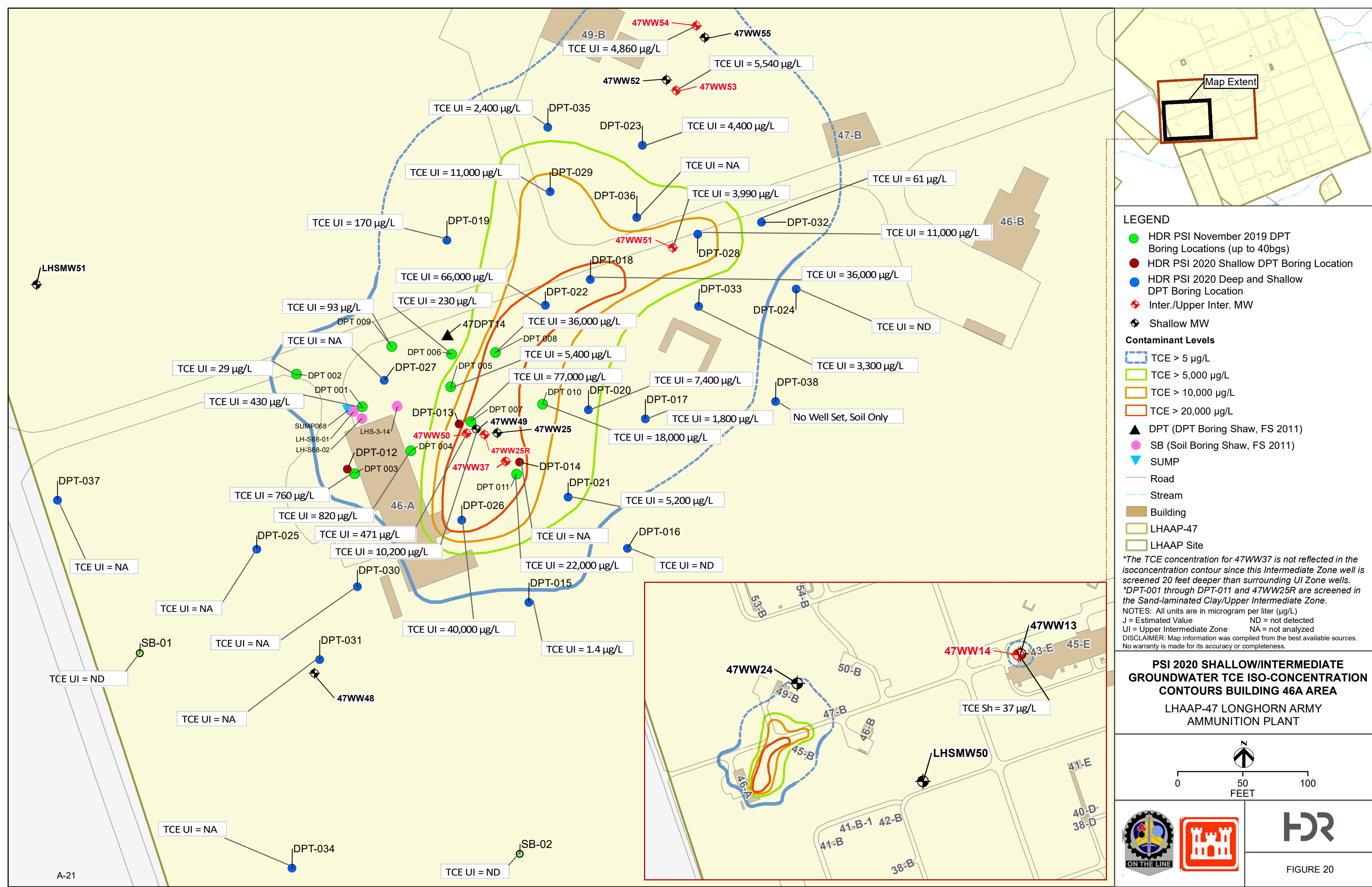
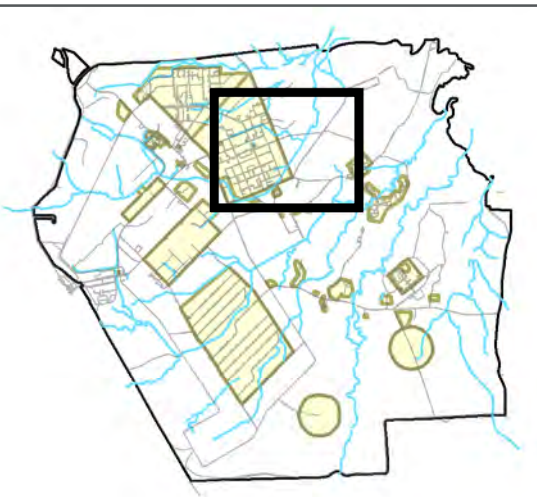
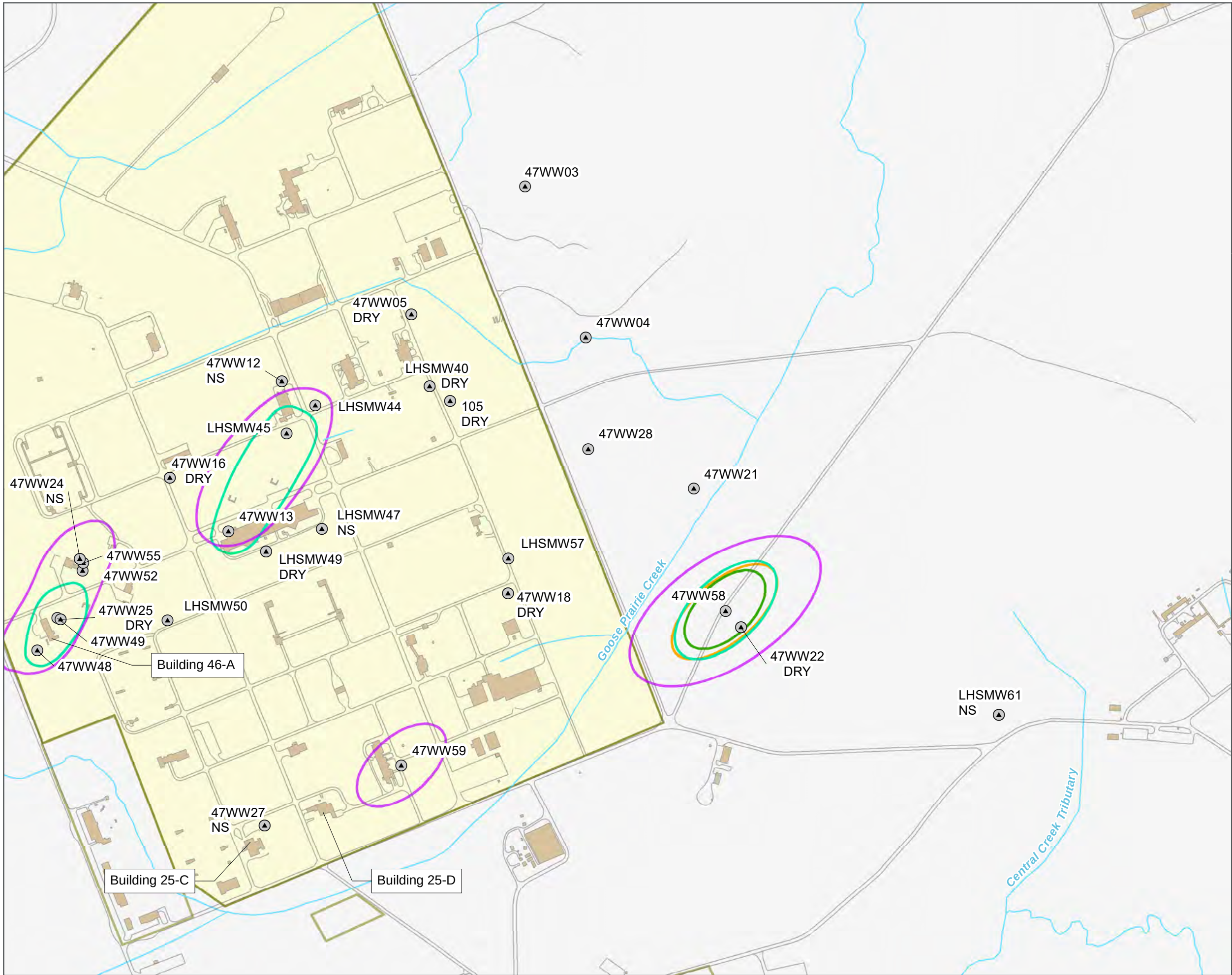


FIGURE 19





LEGEND

- Shallow Zone Monitoring Well
- Former Buildings or Concrete Slab
- LHAAP-47
- Stream
- Road
- Trichloroethene Isoconcentration ($\mu\text{g/L}$)**
 - 5-EPA Maximum Contaminant Level
- 1,1-Dichloroethene Isoconcentration ($\mu\text{g/L}$)**
 - 7-EPA Maximum Contaminant Level
- cis-1,2-Dichloroethene Isoconcentration ($\mu\text{g/L}$)**
 - 70-EPA Maximum Contaminant Level
- Vinyl Chloride Isoconcentration ($\mu\text{g/L}$)**
 - 2-EPA Maximum Contaminant Level

NOTES:
NS = not sampled
 $\mu\text{g/L}$ = micrograms per liter
SOURCE: Draft Final Pre-Design Investigation Report, 2024

**PDI SHALLOW ZONE
VOCs EXTENT**

LHAAP-47
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

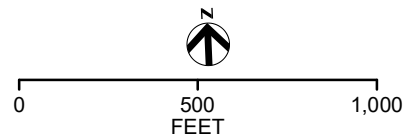
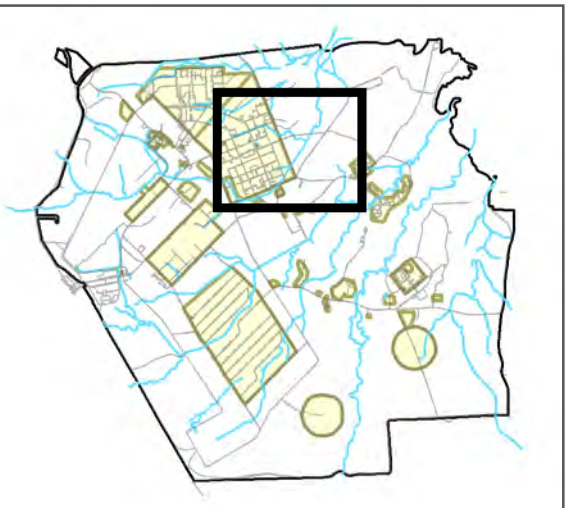
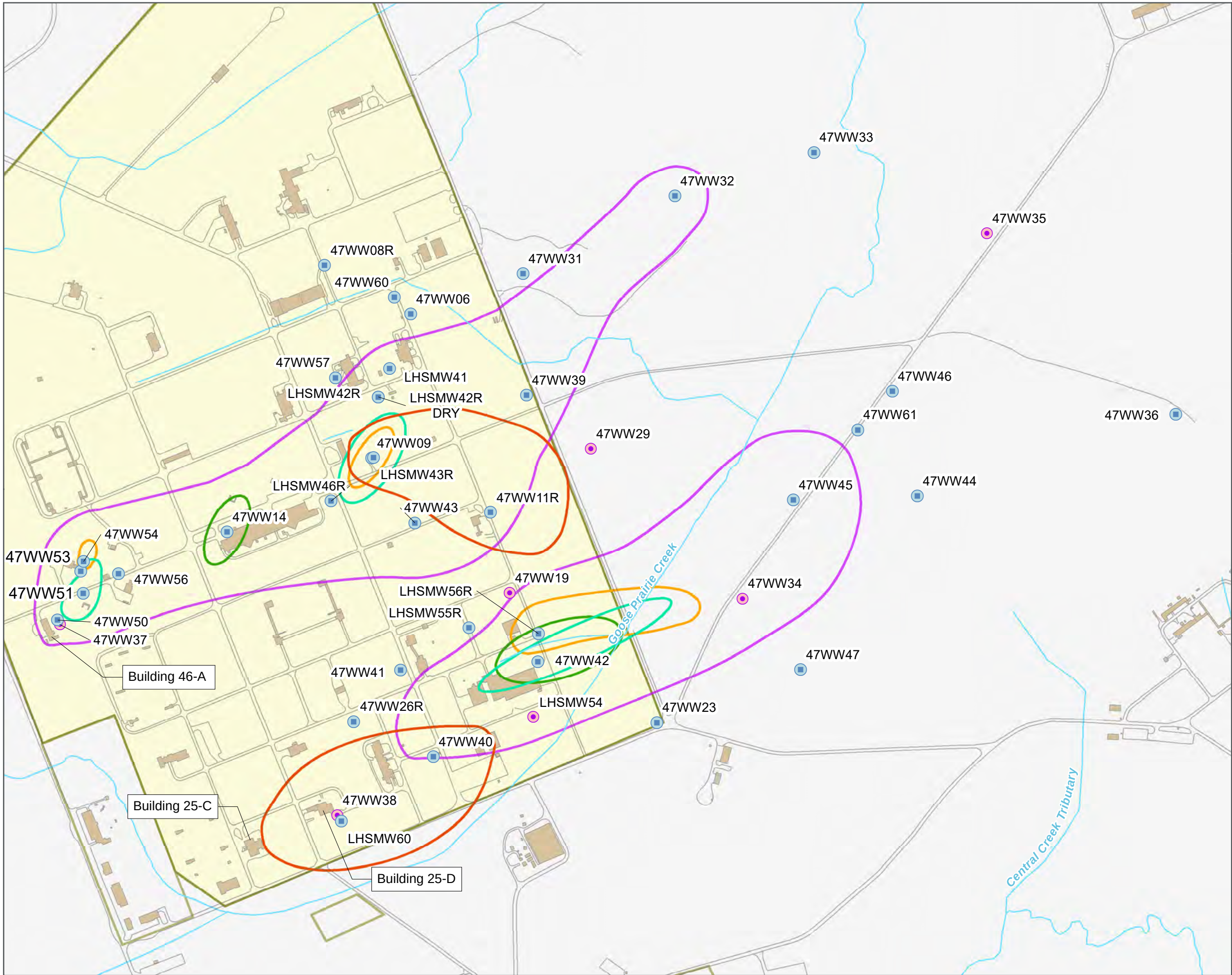


FIGURE 27



LEGEND

- Shallow / Intermediate Zone Monitoring Well
- Intermediate Zone Monitoring Well
- Former Buildings or Concrete Slab
- LHAAP-47
- Stream
- Road

Trichloroethene Isoconcentration (µg/L)

- 5-EPA Maximum Contaminant Level

1,1-Dichloroethene Isoconcentration (µg/L)

- 7-EPA Maximum Contaminant Level

cis-1,2-Dichloroethene Isoconcentration (µg/L)

- 70-EPA Maximum Contaminant Level

Vinyl Chloride Isoconcentration (µg/L)

- 2-EPA Maximum Contaminant Level

Perchlorate Isoconcentration (µg/L)

- 17-TRRP Protective Concentration Level

NOTES:
µg/L = micrograms per liter

SOURCE: Draft Final Pre-Design Investigation Report, 2024

PDI SHALLOW / INTERMEDIATE ZONE AND INTERMEDIATE ZONE VOCs AND PERCHLORATE EXTENT

LHAAP-47
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

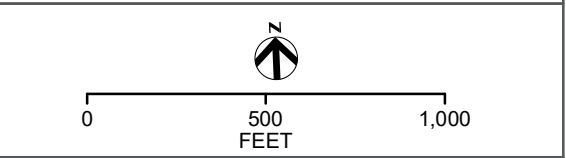
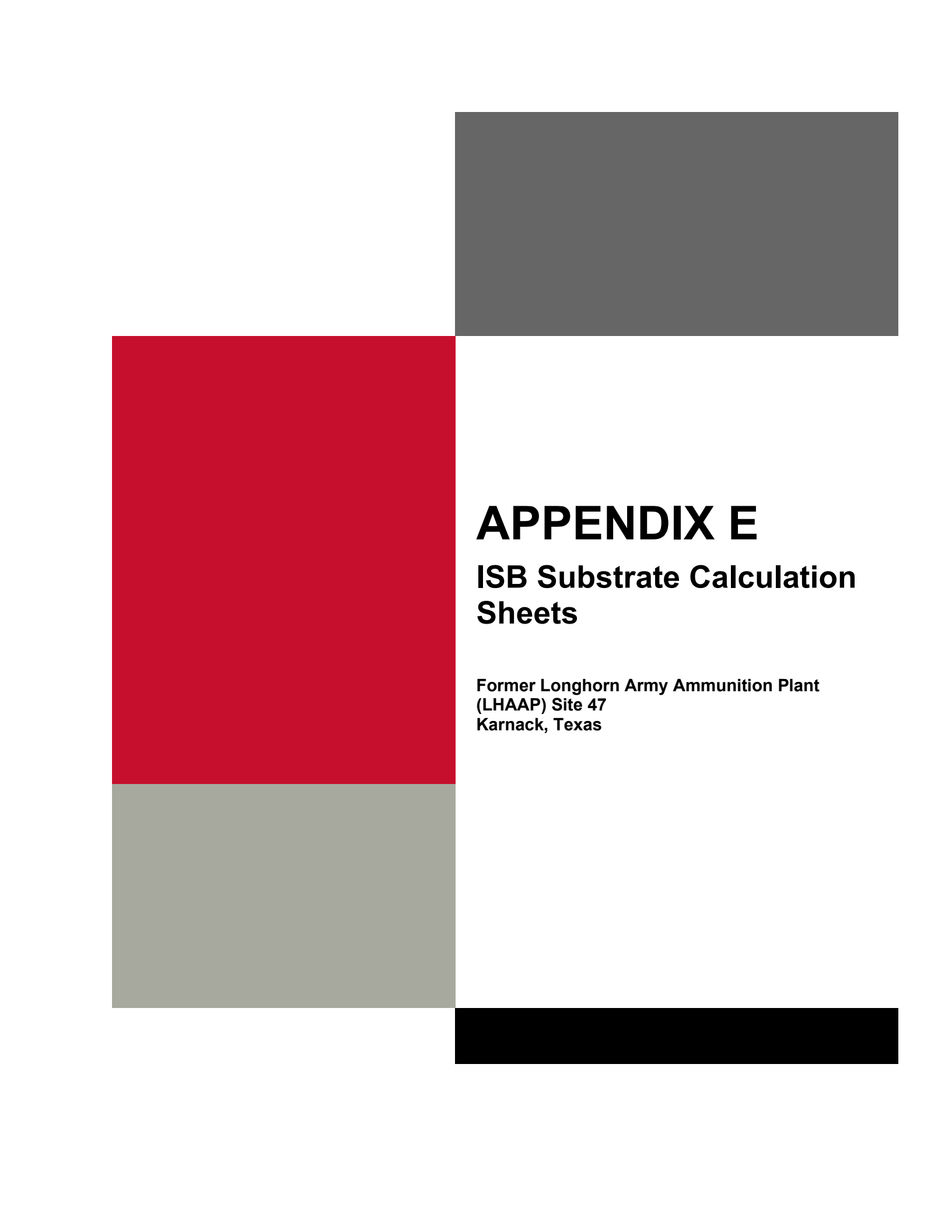


FIGURE 28



APPENDIX E

ISB Substrate Calculation Sheets

**Former Longhorn Army Ammunition Plant
(LHAAP) Site 47
Karnack, Texas**

**Example Calculation for ISB Pilot Test Area 1
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

Calculation for Pilot Test Area 1

Description	Units	Quantity	Notes
Injection Area ID	-	ISB Pilot Test Area 1	
Area Length	feet	81	
Area Width	feet	81	
Treatment Thickness	feet	20	
Approximate Target Area	Square Feet	6570	Rounded up to nearest 10
Volume	Cubic Feet	131,400	(Area x Treatment Thickness)
Number of Points	#	9	Based on 13.5 feet Radius of Influence
Soil Density (pb)	grams per cubic centimeters	1.37	Assumed
Porosity (n)	%	28%	Assumed
Effective Porosity (n_{eff})	%	25%	Assumed
Hydraulic Conductivity	feet/day	1.43	Previous Reports
Hydraulic Gradient	feet/feet	0.0014	Calculated

Description	Units	Quantity	Notes
Total Pore Volume (PV) in Pilot Test Area 1	cubic feet	32,850	
Total Pore Volume (PV) in Pilot Test Area 1	gallons	245,736	(x 7.48 gallons/cubic feet), rounded to nearest 0
Total Pore Volume (PV) in Pilot Test Area 1	liters	930,212	(x 3.79 liters/gallons), rounded to nearest 0

Bioaugmentation Culture Quantity Requirement

If KB-1 is used:

Description	Units	Quantity	Notes
KB-1 Plus Volume per Point	liter/point	4	Based on SiREM Quote
Total KB-1 Plus Volume	liters	36	(KB-1 Plus volume per point x number of points)

**Example Calculation for ISB Pilot Test Area 1
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

Description	Units	Quantity	Notes
KB-1 Primer	gallons/point	128	Based on SiREM Quote
Total KB-1 Primer	gallons	1,152	(KB-1 Primer volume per point x number of points)
Total KB-1 Primer Material needed	pounds	9	7 pounds of KB-1 Primer makes 1,000 gallons of anaerobic water

If TSI DC Dehalococcoides mccartyi Bioaugmentation Culture® is used:

Description	Units	Quantity	Notes
TSI DC Volume per Point	liter/point	5.2	Based on TSD Quote
Total TSI-DC Volume	liters	47	(TSI DC Volume per point x number of points)
Available Quantity/Units	liter/keg	19	
Required Quantities	keg	3	(Total liters / liters per keg)
Shipped Quantities	liters	57	(number of kegs x liters per pail)

Organic Substrate - Electron Donor Solution – Extended Release (60% SRS®-SD) & pH Buffering Quantities Requirement

SRS®-SD Allocation per Point

Description	Units	Quantity	Notes
60% SRS®-SD Recommended Dosage per Area	pounds	2,460	To treat approximately 245736 gallons pore volume
Density of SRS®-SD	pounds/gallons	8.09	Based on TSD Quote
Total SRS®-SD Injection Volume	gallons	305	Recommended Dosage / Density, rounded to nearest 0
SRS®-SD Injection Volume per Point	gallons	34	Total Volume / Number of Points
Total Volume of Dilution Water	gallons	2745	9:1 dilution ratio based on TSD Quote
SRS®-SD Injection Volume per Point	gallons	305	Total Volume / Number of Points
Total Injection Volume for Pilot Test Area 1	gallons	3050	SRS®-SD + Dilution Water
Injection Solution Percent of Effective Pore Volume	%	1.2%	Injection Solution / Total Pore Volume
Injection Volume per Point	gallons	339	Total Volume / Number of Points

**Example Calculation for ISB Pilot Test Area 1
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

Sodium Ascorbate Allocation per Point

Description	Units	Quantity	Notes
Sodium Ascorbate Recommended Dosage	grams per liter	1	Based on TSD Quote
Sodium Ascorbate Recommended Dosage	pounds per gallons	0.00835	Converting grams per liter to pounds per gallons (x 0.0083454)
Total Quantity of Sodium Ascorbate	pounds	26	Recommended Dosage x Total Injection Volume
Sodium Ascorbate per Point	pounds	2.89	Total Weight / Number of Points

Sodium Bicarbonate Allocation per Point

Sodium Bicarbonate Recommended Dosage	grams per liter	6	Based on TSD Quote
Sodium Bicarbonate Recommended Dosage	pounds per gallons	0.0501	Converting grams per liter to pounds per gallons (x 0.0083454)
Total Quantity of Sodium Bicarbonate	pounds	153	Recommended Dosage x Total Injection Volume
Sodium Bicarbonate per Point	pounds	17	Total Weight / Number of Points

Radius of Influence Confirmation

Injection Area ID	Units	Pilot Test Area 1
Approximate Target Area	square feet	6561
Number of Points	#	9
Treatment Area per Point	square feet	729
Estimated Radius of Influence (ROI)	feet	15.2

Summary of ISB Loading/Injection - Pilot Tests
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Assumptions:

Description	Units	
Effective Porosity ^(n_{eff})	%	25%
Density of SRS®-SD	pounds to gallons	8.09
Water Dilution Ratio Based on TSD Quote	Constant	9
grams per liter to pounds per gallons	Constant	0.0083454
gallons to liter	Constant	3.78541
Bicarbonate Bag Size (lb/bag)		50
Cubic feet of water to gallons	Constant	7.48052

Injection Area ID	Area	Injection Points	Depth Interval	Saturated Thickness	Pore Volume
	Square Feet	no.	ft bgs	ft	gallons
Pilot Test Area 1	6,570	9	31-51	20	245,736
Pilot Test Area 2	6,570	9	27-57	20	245,736
Pilot Test Area 3	3,650	5	23-43	20	136,520
Pilot Test Area 4	4,060	24	20-30	10	75,928

Injection Area ID	60% SRS®-SD Recommended Dosage per Area (per TSD Quote)	Total SRS®-SD Injection Volume	Total Volume of Dilution Water	Total Volume (SRS®-SD+Water)	Sodium Ascorbate Recommended Dosage	Total Quantity of Sodium Ascorbate	Sodium Bicarbonate Recommended Dosage	Total Quantity of Sodium Bicarbonate	TSI DC
	pounds	gallons	gallons	gallons	g/L	pounds	g/L	pounds	liters
Pilot Test Area 1	2,460	305	2,745	3,050	1	26	6	153	47
Pilot Test Area 2	2,460	305	2,745	3,050	1	26	6	153	47
Pilot Test Area 3	1,309	162	1,458	1,620	1	14	8	109	26
Pilot Test Area 4	1,748	217	1,953	2,170	1	19	6	109	29
Total Phase 1: Pilot Study		989	8,901	9,890		85		524	149

Summary of ISB Loading/Injection - Pilot Tests
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Injection Area ID	60% SRS®-SD Recommended Dosage per Area (per TSD Quote)	Total SRS®-SD Injection Volume	Total Volume of Dilution Water	Total Volume (SRS®- SD+Water)	Sodium Ascorbate Recommended Dosage	Total Quantity of Sodium Ascorbate	Sodium Bicarbonate Recommended Dosage	Total Quantity of Sodium Bicarbonate	TSI DC
Available Quantity/Units		4,800				55		55	19
Units		gallons/truck				pounds/box		pounds/bag	liters/keg
Required Quantities		1				2		10	8
Units		trucks				boxes		bags	kegs
Shipped Quantities		990				110		550	152
Units		gallons				pounds		pounds	liters
Material Costs		\$ 15.00	\$ 0.15			\$ 18.00		\$ 50.00	\$ 135.00
Units		per gallons	per gallons			per pounds		per bag	per liter
Shipping/Transportation		7,000	-			-		-	275
Units		per truck	per truck			per box		per load	per keg
Total Costs		\$ 21,850.00	\$ 1,335.15			\$ 1,980.00		\$ 500.00	\$ 22,720.00
Dry Good Truck Delivery						\$ 3,700.00			
Rounded up to 100								\$ 52,100.00	

Notes:
% - Percent
ft - feet
bgs - below ground surface
g/L - grams per liter
lb - pound

Summary of ISB Loading/Injection - Grid Areas
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Assumptions:

Description	Units	
Effective Porosity ^(n_{eff})	%	25%
Density of SRS®-SD	pounds/gallons	8.09
Water Dilution Ratio Based on TSD Quote	Constant	9
grams per liter to pounds per gallons	Constant	0.0083454
gallons to liter	Constant	3.78541
Bicarbonate Bag Size (lb/bag)		50
Cubic feet of water to gallons	Constant	7.48052

Injection Area ID	Area	Injection Points	Depth Interval	Saturated Thickness	Pore Volume
	Square Feet	no.	ft bgs	ft	gallons
ISB Grid Area 1S	167,000	988	30-40	10	3,123,118
ISB Grid Area 2S	123,000	728	27-37	10	2,300,260
ISB Grid Area 3S	103,000	609	20-30	10	1,926,234
ISB Grid Area 1SI	181,000	248	30-50	20	6,769,871
ISB Grid Area 2SI	36,000	49	20-40	20	1,346,494
ISB Grid Area 3SI	94,000	129	27-57	20	3,515,845
ISB Grid Area 4SI/5SI/6SI	762000	1045	20-40	20	28,500,782

Injection Area ID	60% SRS®-SD Recommended Dosage per Area (per TSD Quote)	Total SRS®-SD Injection Volume	Total Volume of Dilution Water	Total Volume (SRS®-SD+Water)	Sodium Ascorbate Recommended Dosage	Total Quantity of Sodium Ascorbate	Sodium Bicarbonate Recommended Dosage	Total Quantity of Sodium Bicarbonate	TSI DC
	pounds	gallons	gallons	gallons	g/L	pounds	g/L	pounds	liters
ISB Grid Area 1S	56,700	7,009	63,081	70,090	1	585	5	2,925	1168
ISB Grid Area 2S	41,179	5,091	45,819	50,910	1	425	5	2,125	839
ISB Grid Area 3S	34,541	4,270	38,430	42,700	1	357	9	3,208	703
ISB Grid Area 1SI	59,671	7,376	66,384	73,760	1	616	5	3,078	1233
ISB Grid Area 2SI	11,921	1,474	13,266	14,740	1	124	5	616	240

Summary of ISB Loading/Injection - Grid Areas
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Injection Area ID	60% SRS®-SD Recommended Dosage per Area (per TSD Quote)	Total SRS®- SD Injection Volume	Total Volume of Dilution Water	Total Volume (SRS®- SD+Water)	Sodium Ascorbate Recommend ed Dosage	Total Quantity of Sodium Ascorbate	Sodium Bicarbonate Recommended Dosage	Total Quantity of Sodium Bicarbonate	TSI DC
ISB Grid Area 3SI	30,696	3,795	34,155	37,950	1	317	5	1,584	620
ISB Grid Area 4SI/5SI/6SI	90,077	11,135	100,215	111,350	1	930	9	8,364	1856
	27,520	3,402	30,618	34,020	1	284	5	1,420	558
	145,510	17,987	161,883	179,870	1	1,502	9	13,510	3,031
Total Phase 2: Grid Areas		61,539	553,851	615,390		5,140		36,830	10,248
Available Quantity/Units		4,800	4800			55		55	19
Units		gallons/truck	gallons/truck			pounds/box		pounds/bag	liters/keg
Required Quantities		13	116			94		670	540
Units		trucks	trucks			boxes		bags	kegs
Shipped Quantities		62,400	556,800			5,170		36,850	10,260
Units		gallons	gallons			pounds		pounds	liters
Material Costs		\$ 12.00	\$ 0.15			\$ 10.00		\$ 50.00	\$ 105.00
Units		per gallons	per gallons			per pounds		per bag	per liter
Shipping/Transportation		\$ 7,000.00	\$ -			\$ -		\$ -	\$ 275.00
Units		per truck	per truck			per box		per load	per keg
Total Costs		\$ 839,800.00	\$ 83,077.65			\$ 51,700.00		\$ 33,500.00	\$ 1,225,800.00
				Dry Good Truck Delivery		\$ 7,000.00			
Rounded up to 100									\$ 2,240,900.00

Notes:
% - Percent
ft - feet
bgs - below ground surface
g/L - grams per liter
lb - pound

Summary of ISB Loading/Injection - ISB Biobarriers
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Assumptions:

Description	Units	
Effective Porosity ^(n_{eff})	%	25%
Density of SRS®-SD	pounds/gallons	8.09
Water Dilution Ratio Based on TSD Quote	Constant	9
grams per liter to pounds per gallons	Constant	0.0083454
gallons to liter	Constant	3.78541
Bicarbonate Bag Size (lb/bag)		50
Cubic feet of water to gallons	Constant	7.48052

Injection Area ID	Area	Injection Points	Depth Interval	Saturated Thickness	Pore Volume
	Square Feet	no.	ft bgs	ft	gallons
ISB Biobarrier 1	32,400	45	23-43	20	1,211,845
ISB Biobarrier 2	27,000	35	30-50	20	1,009,871
ISB Biobarrier 3	21,600	29	30-50	20	807,897

Injection Area ID	60% SRS®-SD Recommended Dosage per Area (per TSD Quote)	Total SRS®-SD Injection Volume	Total Volume of Dilution Water	Total Volume (SRS®-SD+Water)	Sodium Ascorbate Recommended Dosage	Total Quantity of Sodium Ascorbate	Sodium Bicarbonate Recommended Dosage	Total Quantity of Sodium Bicarbonate	TSI DC
	pounds	gallons	gallons	gallons	g/L	pounds	g/L	pounds	liters
ISB Biobarrier 1	14,930	1,846	16,614	18,460	1	155	5	771	194
ISB Biobarrier 2	12,101	1,496	13,464	14,960	1	125	5	625	192
ISB Biobarrier 3	5,808	718	6,462	7,180	1	60	5	300	93
Total Phase 2: Biobarriers		4,060	36,540	40,600		340		1,696	479
Available Quantity/Units		4,800	4,800			55		55	19
Units		gallons/truck	allons/truck			pounds/box		pounds/bag	liters/keg

Summary of ISB Loading/Injection - ISB Biobarriers
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Injection Area ID	60% SRS®-SD Recommended Dosage per Area (per TSD Quote)	Total SRS®- SD Injection Volume	Total Volume of Dilution Water	Total Volume (SRS®- SD+Water)	Sodium Ascorbate Recommended Dosage	Total Quantity of Sodium Ascorbate	Sodium Bicarbonate Recommended Dosage	Total Quantity of Sodium Bicarbonate	TSI DC
Required Quantities		1	8			7		31	26
Units		trucks	trucks			boxes		bags	kegs
Shipped Quantities		4,100	38,400			385		1,705	494
Units		gallons	gallons			pounds		pounds	liters
Material Costs		12	0			10		50	105
Units		per gallons	per gallons			per pounds		per bag	per liter
Shipping/Transportation Cost		7,000	-			-		-	275
Units		per truck	per truck			per box		per load	per keg
Total Costs		56,200	5,481			3,850		1,550	59,020
Dry Good Truck Delivery						\$	7,000.00		
								Rounded up to 100	\$ 133,200.00

Notes:
% - Percent
ft - feet
bgs - below ground surface
g/L - grams per liter
lb - pound

Injection Duration Calculation Worksheet - DPT Wells
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Injection Parameters	Units	Pilot tests			ISB Grid Injection									ISB Biobarrier Injection		
		Pilot Test Area 1	Pilot Test Area 2	Pilot Test Area 4	ISB Grid 1S	ISB Grid 2S	ISB Grid 3S	ISB Grid 1SI	ISB Grid 2SI	ISB Grid 3SI	ISB Grid 4SI	ISB Grid 5SI	ISB Grid 6SI	ISB Biobarrier 1	ISB Biobarrier 2	ISB Biobarrier 3
		DPT	DPT	DPT	DPT	DPT	DPT	DPT	DPT	DPT	DPT	DPT	DPT	DPT	DPT	DPT
Injection Spacing	feet	27	27	13	13	13	13	27	27	27	27	27	27	27	27	27
Target Depth (feet below ground surface)	feet below ground surface	51	57	30	40	37	30	50	40	57	40	40	40	43	50	50
Thickness	feet	20	20	10	10	10	10	20	20	20	20	20	20	20	20	20
Number of Points	#	9	9	24	988	728	609	248	49	129	356	103	586	24	35	29
Substrate Loading/Injection																
Total Weight of Concentrated Substrate	pounds	2460	2460	1748	56700	41179	34541	59671	11921	30696	90077	27520	145510	7960	12101	5808
Total Volume of Concentrated Substrate	gallons	305	305	217	7009	5091	4270	7376	1474	3795	11135	3402	17987	984	1496	718
Dilution Ratio of Substrate with Water	By Volume	9:1	9:1	9:1	9:1	9:1	9:1	9:1	9:1	9:1	9:1	9:1	9:1	9:1	9:1	9:1
Volume of Diluted Substrate (with water)	gallons	3050	3050	2170	70090	50910	42700	73760	14740	37950	111350	34020	179870	9840	14960	7180
Culture/Anaerobic Water																
TSI DC	liters	47	47	29	1168	839	703	1233	240	620	1856	558	3031	103	192	93
Sodium Ascorbate	pounds	26	26	19	585	425	357	616	124	317	930	284	1502	83	125	60
Sodium Bicarbonate	pounds	153	153	109	2925	2125	3208	3078	616	1584	8364	1420	13510	411	625	300
Total Volume of Substrate + Culture/Anaerobic Water	gallons	3063	3063	2178	70,399	51,132	42,886	74,086	14,804	38,114	111,841	34,168	180,671	9,868	15,011	7,205
Total Volume per Point	gallons	340	340	91	71	70	70	298	300	296	314	332	308	411	429	248
Volume per foot	gallons	17	17	9	7	7	7	15	15	15	16	17	15	21	21	12
Injection Rate	gallons per minute (gpm)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Injection Pressure (not to exceed)	pounds per square inch	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Injection Time per Point	hours	1.2	1.2	0.4	0.3	0.3	0.3	1.0	1.0	1.0	1.1	1.2	1.1	1.4	1.5	0.9
Drilling Rate per Rig	feet/hours	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Drilling Time per Point	hours	1.5	1.6	0.9	1.1	1.1	0.9	1.4	1.1	1.6	1.1	1.1	1.1	1.2	1.4	1.4
Total Drilling & Injection Time per Point	hours	2.7	2.8	1.3	1.4	1.4	1.2	2.4	2.1	2.6	2.2	2.3	2.2	2.6	2.9	2.3
Hours per day	hours	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Total points per day	#	4	4	8	7	7	8	4	5	4	5	4	5	4	3	4
Number of Crew	#	1	1	1	2	2	2	2	2	2	2	2	2	1	1	1
Days of Drilling & Injection - DPT (rounded up to nearest full day)	days	3	3	4	70	51	37	30	6	17	40	12	65	7	11	7
TOTAL	Days	10			328									25		

Injection Duration Calculation Worksheet - Permanent Injection Wells
Former Longhorn Army Ammunition Plant (LHAAP) 47
Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas

Injection Parameters	Units	Pilot Test Area 3	ISB Biobarrier 1
		IW	IW
Injection Spacing	feet	27	27
Target Depth (feet below ground surface)	feet below ground surface	43	43
Thickness	feet	20	20
Number of Points	#	5	21
<i>Substrate Loading/Injection</i>			
Total Weight of Concentrated Substrate	pounds	1309	6965
Total Volume of Concentrated Substrate	gallons	162	861
Dilution Ratio of Substrate with Water	By Volume	9:1	9:1
Volume of Diluted Substrate (with water)	gallons	1620	8610
<i>Culture/Anaerobic Water</i>			
TSI DC	liters	26	90
Sodium Ascorbate	pounds	14	72
Sodium Bicarbonate	pounds	109	360
Total Volume of Substrate + Culture/Anaerobic Water	gallons	1627	8,634
Total Volume per Point	gallons	325	411
Volume per foot	gallons	16	21
Injection Rate	gallons per minute (gpm)	3	3
Injection Pressure (not to exceed)	pounds per square inch (psi)	10	10
Injection Time per Point	hours	1.9	2.3
Simultaneous Injection per Points	#	4	4
Total Injection Time	Days	1	5
Drilling Rate per Rig	feet/hours	10.0	10.0
Drilling Time per Point	hours	4.3	4.3
Hours per day	hours	10	10
Total Drilling Time	Days	3	10
Days of Drilling & Injection - IW (rounded up to nearest full day)	days	4	15
TOTAL	Days	4	15



ISB Backup Information

**Former Longhorn Army
Ammunition Plant (LHAAP)
Site 47**

Karnack, Texas





August 1, 2025

TSD Proposal No. 251120

Jessenia Guzman Peralta
Environmental Designer
HDR
50 Tice Blvd, Suite 210
Woodcliff Lake, NJ 07677

RE: Proposal for Enhanced In-Situ Dechlorination (EISD)
Longhorn Army Ammunition Plant
Site 47
15600 Highway 134
Karnack, TX 75661

Dear Ms. Guzman-Peralta

Thank you for contacting Terra Systems of Delaware (TSD) about the above-referenced site (the Site). Our technical team reviewed the project files sent via electronic mail (e-mail) on July 24, 2025. The following provides a conceptual level budgetary estimate for the completion of EISD at four pilot area at the Site as shown on **Figures 1 (Shallow) and 2 (Shallow Intermediate)**:

- Pilot 1 – 6,561 square feet near wells 47WW52, 47WW53, and 47WW55
- Pilot 2– 6,561 square feet near wells 47WW09 and LHSMW43R
- Pilot 3 – 3,645 square feet near well 47WW39
- Pilot 4 – 4,056 square feet near well 47WW58

Full scale grid injections will be conducted at the following areas in the shallow plume. Several other wells in this vicinity were dry at the last sampling point and were not included in the calculations. TSD estimated the treatment width (perpendicular to groundwater flow) and treatment length (in the direction of groundwater) from the site maps.

- 1S – 164,000 square feet near wells 47WW48, 47WW49, 47WW52, 47WW55,

and 47WW50

- 2S – 164,000 square feet near wells LSHMW45, 47WW13, and LSHMW44
- 3S – 99,000 square feet near wells 47WW58, 47WW57, 47WW21, and 47WW26

Full scale grid injections will be conducted at the following areas in the shallow intermediate plume:

- 1SI – 173,000 square feet near wells 47MWW50, 47WW37, 47WW51, 47WW53, 47WW56, 47WW54, and 47MW14
- 2SI – 33,600 square feet near wells 47WW38 and LSHMW60
- 3SI – 67,600 square feet near wells LSHMW46R, LSHMW43R, 47MWWO9, 47WW43, and 47MW11R
- 4SI – 261,000 square feet near wells 47WW42, LSHMW56R, 47WW19, 47WW41, LSHMW55R, and LSHMW54
- 5SI – 78,480 square feet near wells 47MW23 and LSHMW56R
- 6SI – 426,300 square feet near wells 47MW34, 47MW45, 47MW61, and 47WW47

Four biobarriers will be conducted in the shallow intermediate plume:

- ISB Biobarrier 1-South – 2,200 feet wide and 594,000 square feet near wells LSHMW54, 47MW23, and 47WW39
- ISB Biobarrier 2 – 1,000 feet wide 27,000 square feet near well 47MW61
- ISB Biobarrier 1-North – 550 feet wide 14,850 square feet near wells 47WWO6, 47WW57, LSHMW41, 47MWO8R, 47WW31, and 47WW60
- ISB Biobarrier 4 – 1480 feet wide 21,060 square feet near wells 47MW40 and 47WW26R

Remediation Considerations

Two aquifers were identified (**Figure 1**). Key hydrogeological and contaminant data are summarized below for each area:

Shallow Plume

- Saturated impacted thickness is 20 feet.
- Lithology is clayey sand with total porosity (n) of 0.28, and effective porosity (n_{eff}) of 0.25.
- Average hydraulic conductivity (K) 1.70 feet/day with a shallow gradient of 0.0020.

- Groundwater is impacted by perchlorate, trichloroethene (TCE), dichloroethene (DCE), and vinyl chloride (VC) in soil and groundwater.

Shallow Intermediate Plume

- Saturated impacted thickness is 20 feet.
- Lithology is clayey sand with total porosity (n) of 0.28, and effective porosity (n_{eff}) of 0.25.
- Average hydraulic conductivity (K) 1.43 feet/day with a shallow gradient of 0.0014.
- Groundwater is impacted by perchlorate, TCE, DCE, and VC in soil and groundwater.

Using our substrate estimating tool, TSD reviewed various EISED approaches and estimated the EVO demands. This tool uses the dimensions and parameters identified to assess the substrate requirements, including any additional reagents and bioaugmentation cultures recommended. Estimates of additional electron acceptors are input to perform these calculations.

Shallow Plume –

- The calculated average values for perchlorate and VOCs from July 2024 and dissolved oxygen from May 2023 were used. Nitrate, sulfate, and carbon dioxide were 0.5, 291, and 10 mg/L based upon the average concentrations in the 2011 natural attenuation evaluation by Shaw.
- Native aqueous phase electron acceptors exert a demand for ESID. The calculated average values from May 2023 for dissolved oxygen were used. Nitrate, sulfate, and carbon dioxide were 0.5, 291, and 10 mg/L based upon the average concentrations in the 2011 natural attenuation evaluation by Shaw.
- Native solid phase electron acceptors also exert a demand in EISD. Estimated values for Manganese Oxide (Mn^{IV}) and Ferrous Iron (Fe^{III}) included were 5 and 20 mg/L, respectively. These values are based upon our experience after EVO injections at other sites.
- All calculations used 3 years of performance and a 3 times (3X) safety factor.

Shallow Intermediate Plume –

- The calculated average values for perchlorate and VOCs from July 2024 and dissolved oxygen from May 2023 were used. Nitrate, sulfate, and

carbon dioxide were 0.5, 291, and 10 mg/L based upon the average concentrations in the 2011 natural attenuation evaluation by Shaw.

- Estimated values for Manganese Oxide (Mn^{IV}) and Ferrous Iron (Fe^{III}) were 5 and 20 mg/L, respectively. These values are based upon our experience after EVO injections at other sites.
- All calculations used 3 years of performance and a 3 times (3X) safety factor.

TSD has assumed injections will be completed using direct-push technology and permanent wells. Replenishment may be required after 2 to 5 years. **Table 1 – Terra Systems Substrate Input Data Pilots Grid Summary** summarizes the input data used for the Pilots. **Table 2 – Terra Systems Pilots Recommended Volumes of SRS®-SD, Dilution Water, Sodium Ascorbate, Sodium Bicarbonate, and TSI-DC** summarizes the recommended volumes. **Table 3 – Terra Systems Data Input Shallow Full Scale 1S–3S Summary** and **Table 4 – Terra Systems Shallow Full Scale Grid 1S –3S Recommended Volumes of SRS®-SD, Dilution Water, Sodium Ascorbate, Sodium Bicarbonate, and TSI-DC** summarizes the input data used for the three shallow grid areas and the recommended volumes. **Table 5 Terra Systems Shallow Intermediate 1SI – 3SI Grid Substrate Demand**. **Table 6 – Terra Systems Recommended Volumes of SRS®-SD, Dilution Water, Sodium Ascorbate, Sodium Bicarbonate, and TSI-DC**, **Table 7 – Terra Systems Shallow Intermediate Grid 4SI – 6SI Substrate Demand** and **Table 8 – Terra Systems Shallow Intermediate Full Scale Grid 4SI– 6SI Recommended Volumes of SRS®-SD, Dilution Water, Sodium Ascorbate, Sodium Bicarbonate, and TSI-DC** summarizes the input data and recommended volumes used for the six shallow intermediate grid areas. **Table 9 – Terra Systems Shallow Intermediate Biobarrier Substrate Demand** and **Table 10 Terra Systems Shallow Intermediate Biobarrier Recommended Volumes of SRS®-SD, Dilution Water, Sodium Ascorbate, Sodium Bicarbonate, and TSI-DC** summarizes the input data used for the four shallow intermediate grid areas.

Recommended EISD Products

TSD selected products based on the site-specific contaminant and hydrogeology, as well as remediation successes on other sites, to provide a cost-effective remediation approach for achieving the Site objectives. Descriptions of each of the recommended components are provided in **Table 5 – Terra Systems Recommended Application** and summarized below. Applicable Technical Data Sheets and Safety Data Sheets (SDSs) are provided in **Attachment A— Technical Information**.

SRS®-SD

Terra Systems' Slow-Release Substrate (SRS®-SD) small droplet - SRS®-SD is an emulsified vegetable oil (EVO) substrate with a nonionic emulsifier (has no charge), which is recommended for this application, considering the groundwater velocity of 2.9 to 5.0 feet per year. The other advantages that SRS®-SD provides are as follows:

- SRS®-SD includes a small volume of sodium lactate (5.5%) to provide a quick-release carbon substrate electron donor that accelerates the generation of anaerobic conditions and in-situ bioremediation.
- SRS®-SD also contains nutrients and Vitamin B12 to enhance the activity and growth of dechlorinating bacteria.
- SRS®-SD has been shown to provide dissolved organic carbon and reducing conditions favorable to reductive dechlorination 5 to 7+ years post-injection in sandy soils with groundwater seepage velocities estimated from 50 to 150 feet per year.

Sodium Bicarbonate pH Buffer

Adding a pH buffer is necessary to:

- Increase the native pH (average for the treatments area range from 5.7 to 9.3 SIU) with most below 7.0, and
- Offset the pH decrease associated with the fermentation of carbon substrates.
- Biotic dechlorination rates have been higher at pH 7 than at pH 6.

Bioaugmentation

To promote biotic dechlorination of the chlorinated ethenes, a consortium of microorganisms containing multiple strains of *Dehalococcoides mccartyi* (DHC) is recommended.

- TSD will supply TSI-DC with >1E11 DHC/L.
- Typically, TSI-DC is supplied in 19 L kegs shipped overnight on blue ice
- TSD also included sodium ascorbate to condition the injectate for the bioaugmentation culture. DHC is a strict anaerobe and requires low dissolved oxygen (<1.0 mg/L) and a negative ORP to survive.

Lead Time

TSD is one of the only EISD reagent manufacturers that operates its own facility. Reagents are made on a site-specific basis. A lead time of 4 weeks is recommended, but shorter lead times may be accommodated.

Pricing

The volumes of the EISD components recommended by TSD for the pilot are 986 gallons of SRS®-SD, 84 pounds of sodium ascorbate, 500 pounds of sodium bicarbonate, and 149 L of the TSI-DC *Dehalococcoides mccartyi* cultures (Table 11). The attached quote (**Attachment A—Pilot Quote**) for \$38,799.31 is suitable for conceptual costing.

The total volumes of the EISD components recommended by TSD for the full scale injections are 67,863 gallons of SRS®-SD, 5,640 pounds of sodium ascorbate, 34,100 pounds of sodium bicarbonate, and 11,062 L of the TSI-DC *Dehalococcoides mccartyi* cultures (Table 11). The attached quote (**Attachment B—Quote**) is suitable for conceptual costing.

TSD's total cost estimate for this remedial application is **\$2.4 M**.

This quote includes sales taxes and shipping costs, assuming full truckloads are shipped to the Site. LTL shipments are subject to scheduling delays and market pricing that are out of TSD's control. The actual freight will be charged at the time of shipment. Due to volatility in the commodities and chemicals markets, TSD can only hold these prices for 90 days.

Alternative Costs

The pricing listed above is for the traditional delivery of TSD products – mixing at our facility in Delaware and direct shipping to the Site on full truckloads. This provides premixed substrates ready to be diluted and injected, eliminating much onsite infrastructure for emplacement. While this is often the most efficient and cost-effective, given the size and scope of this project, TSD considered two alternative approaches that, with careful planning, would be more cost-effective.

Alternative 1 – Local Procurement and Onsite Mixing

As an alternative to TSD directly providing premixed substrates, TSD can arrange for components of SRS® to be shipped directly to the site for on-site mixing. SRS®-SE is a self-emulsifying material that minimizes the shipment of water but necessitates on-site mixing, providing a cost-effective alternative. To estimate this approach, TSD assumes:

- A mixing plant capable of offloading, storing, handling, and mixing the components into a stable emulsion is provided at the Site (by others, e.g., the

Consultant / Contractor):

- TSD will provide one high shear mixer, and
 - TSD will provide one person for two days to assist in the initial setup.
- TSD assumed others will provide:
 - Sufficient quantity and quality of dilution water,
 - All utilities required (e.g., electrical drop and wiring hookup for 230/460 volt, three-phase, 30-amp service), lighting, convenience electrical, secure dry storage and work area, and material handling equipment,
 - Tankage for emulsion storage (nominally 7000-gallon capacity for neat oil and sufficient capacity for mixed material), and
 - All transfer pumps, tankage, and piping.
- TSD will provide:
 - Tanker quantities of locally sourced soybean oil for direct delivery to the Site, and
 - Remaining components (e.g., emulsifier) shipped in complete truckloads directly to the Site
- The Site plant will then prepare all mixtures using a high shear mixer, and develop a stable emulsion suitable for injection on the Site

This approach's advantages include complete local control of mixed volumes and minimizing trucking expenses at the Site. Non-TSD equipment and staff will complete all costs associated with handling, storage, dilution, mixing, and emulsion transfer.

To provide an equivalent volume estimate of mixed product, the total costs for Alternative 1 (**Attachment B – Quote**) is **\$2.3 M**; the significant difference being the provision of onsite mixing.

Alternative 2 – TSD Establish Local Mixing Plant

As an alternative to directly providing premixed substrates, TSD can create a satellite mixing plant closer to the Site. In this manner, TSD will offer the same quality premixed substrates from a plant closer to the field Site, thus maintaining TSD's Quality Assurance/Quality Control (QA/QC) standards, whilst minimizing the costs associated with trucking SRS®-SD. In this approach, TSD assumes:

- TSD will construct a temporary/permanent mixing plant capable of preparing SRS®-SD, certified to TSD QA/QC standards
- This location will prepare injection-ready SRS®-SD, warehouse finished product for just-in-time delivery (JIT) direct to the Site

This approach's advantages include maintaining SRS®-SD's QA/QC while minimizing trucking costs and site needs for warehousing and utilities. Overall, this alternative ensures the project is completed in a greener, more sustainable manner.

To provide an equivalent volume estimate of mixed product, the total costs for Alternative 1 (**Attachment C – Quote**) for this remedial application is **\$2.4 M**; the major difference being the decreased trucking.

Final Consideration

Irrespective of the remedial approach, the costs associated with EISD in dilute plume remain significant.

Thank you for the opportunity to provide estimated costs for your project needs. If you have any questions or comments, please feel free to contact us as soon as possible.

Sincerely,



Dick Raymond, Jr.

President



Michael Lee, Ph. D
Vice President, R&D

Attachments

- Attachment A – Quote
- Attachment B – Quote – Alternative 1
- Attachment C – Quote – Alternative 2

Tables

Table 1. Terra Systems Substrate Demand Pilots Grid Data Summary

Remediation Area	Site Data						
	Length (feet)	Width (feet)	Thickness (feet)	Area (feet ²)	Volume (feet ³)	Lithology	Soil Density (ρ_b , g/cm ³)
Pilot 1	81	81	20	6561	131220	Clayey Sand	1.37
Pilot 2	81	81	20	6561	131220	Clayey Sand	1.37
Pilot 3	146	25	20	3650	73000	Clayey Sand	1.37
Pilot 4	54	75	20	4050	81000	Clayey Sand	1.37
Remediation Area	Hydrogeologic data						
	Porosity (n)	Effective Porosity (n _{eff})	Hydraulic Conductivity (feet/day)	Hydraulic Gradient (feet/feet)	Total Pore Volume (PV) (gallons)	Average Seepage Velocity (V _s) (feet/day)	Fraction Organic Carbon (Foc)
Pilot 1	28%	25%	1.43	0.0014	269,992	0.01	0.0390
Pilot 2	28%	25%	1.43	0.0014	245,447	0.01	0.0390
Pilot 3	28%	25%	1.43	0.0014	150,201	0.01	0.0390
Pilot 4	28%	25%	1.70	0.0020	136,547	0.01	0.0390
Remediation Area	Native Electron Acceptors						
	Oxygen (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Carbon Dioxide (mg/L)	Manganese (IV) (mg/L)	Iron (III) (mg/L)	
Pilot 1	1.60	0.50	291.0	10.00	5.000	20.000	
Pilot 2	1.40	0.50	291.0	10.00	5.000	20.000	
Pilot 3	1.00	0.50	291.0	10.00	5.000	20.000	
Pilot 4	3.40	0.50	291.0	10.00	5.000	20.000	
Remediation Area	Aqueous Geochemistry						
	ORP (mV)	pH (SU)	Specific Conductivity (μ S/cm)	Temperature (°C)	Alkalinity (mg/L)	TDS, or salinity (mg/L)	Chloride (mg/L)
Pilot 1	-28	6.10	200	15.0	325	10	100
Pilot 2	-65	7.20	200	15.0	325	10	100
Pilot 3	367	6.60	200	15.0	325	10	100
Pilot 4	35	6.20	200	15.0	325	10	100

Table 2. Terra Systems Pilots Grid Recommended Volumes of SRS®-SD, Dilution Water, Sodium Ascorbate, Sodium Bicarbonate, and TSI-DC

Recommended Application - Total							
Remediation Area	Recommended Injection Volume, Conditioners, and Culture						
	Terra Systems Recommended Injection Product			Dilution Water at Recommended Dilution	Sodium Ascorbate ⁽¹⁾	Sodium Bicarbonate ⁽²⁾	TSI DC ⁽³⁾
	(pounds)	(gallons)	(gallons per well)	(gallons) (dilution)	(pounds) (concentration)	(pounds) (concentration)	<i>Dehalococcoides mccartyi</i> Bioaugmentation Culture* (L) (concentration)
Pilot 1	2,460	304	34	2,737	26	150	47
	60% SRS®-SD			9 : 1 dilution	2 g/L	6 g/L	0.003%
Pilot 2	2,460	304	34	2,737	26	150	47
	60% SRS®-SD			9 : 1 dilution	2 g/L	6 g/L	0.003%
Pilot 3	1,309	162	32	1,456	14	100	26
	60% SRS®-SD			9 : 1 dilution	2 g/L	8 g/L	0.003%
	1,748			1,945	18	100	29
	60% SRS®-SD			9 : 1 dilution	1 g/L	6 g/L	0.003%
Pilot 4	60% SRS®-SD			9 : 1 dilution	1 g/L	6 g/L	0.003%
TOTAL	7923	986		315,373	2,910	11,750	2,239
Recommended Application - Each Well							
Remediation Area	Number Injection Wells	Total Volume Injection Solution Per Well (gallons)	Dilution Water Volume per Well (gallons)	Injection Solution Percent of Effective Pore Volume (%)	Sodium Ascorbate Per Well (pounds)	Sodium Bicarbonate Per Well (pounds)	TSI DC <i>Dehalococcoides mccartyi</i> Bioaugmentation Culture* Per Well (L)
Pilot 1	9	337.9	304.1	1.2%	2.9	16.7	5.2
Pilot 2	9	337.9	304.1	1.2%	2.9	16.7	5.2
Pilot 3	5	323.6	291.2	1.2%	2.8	20.0	5.2
Pilot 4	24	90.0	81.0	1.4%	0.8	4.2	1.2
TOTAL	47						

Table 3. Terra Systems Substrate Demand Shallow Full Scale Grid 1S-3S Summary

Remediation Area	Site Data						
	Length (feet)	Width (feet)	Thickness (feet)	Area (feet ²)	Volume (feet ³)	Lithology	Soil Density (ρ_b , g/cm ³)
1S	730	225	20	164250	3285000	Clayey Sand	1.37
2S	472	250	20	118000	2360000	Clayey Sand	1.37
3S	460	215	20	98900	1978000	Clayey Sand	1.37
Remediation Area	Hydrogeologic data						
	Porosity (n)	Effective Porosity (n_{eff})	Hydraulic Conductivity (feet/day)	Hydraulic Gradient (feet/feet)	Total Pore Volume (PV) (gallons)	Average Seepage Velocity (V_s) (feet/day)	Fraction Organic Carbon (F_{oc})
1S	28%	25%	1.70	0.0020	6,759,052	0.01	0.0390
2S	28%	25%	1.70	0.0020	6,144,593	0.01	0.0390
3S	28%	25%	1.70	0.0020	4,069,834	0.01	0.0390
Remediation Area	Native Electron Acceptors						
	Oxygen (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Carbon Dioxide (mg/L)	Manganese (IV) (mg/L)	Iron (III) (mg/L)	
1S	2.30	0.50	291.0	10.00	5.000	20.000	
2S	1.90	0.50	291.0	10.00	5.000	20.000	
3S	2.30	0.50	291.0	10.00	5.000	20.000	
Remediation Area	Aqueous Geochemistry						
	ORP (mV)	pH (SU)	Specific Conductivity (μ S/cm)	Temperature (°C)	Alkalinity (mg/L)	TDS, or salinity (mg/L)	Chloride (mg/L)
1S	121	6.60	200	15.0	325	10	100
2S	190	6.10	200	15.0	325	10	100
3S	29	5.70	200	15.0	325	10	100

Table 4. Terra Systems Substrate Demand Shallow Full Scale Grid 1S- 3S Recommended Volumes of SRS®-SD, Dilution Water, Sodium Ascorbate, Sodium Bicarbonate, and TSI-DC

Recommended Application - Total							
Remediation Area	Recommended Injection Volume, Conditioners, and Culture						
	Terra Systems Recommended Injection Product			Dilution Water at Recommended Dilution	Sodium Ascorbate ⁽¹⁾	Sodium Bicarbonate ⁽²⁾	TSI DC ⁽³⁾
	(pounds)	(gallons)	(gallons per well)	(gallons) (dilution)	(pounds) (concentration)	(pounds) (concentration)	<i>Dehalococcoides mccartyi</i> Bioaugmentation Culture* (L) (concentration)
1S	56,700	7,009	5	63,078	582	2,350	1168
	60% SRS®-SD			9 : 1 dilution	1 g/L	5 g/L	0.003%
2S	41,179	5,090	7	45,811	423	1,750	839
	60% SRS®-SD			9 : 1 dilution	1 g/L	5 g/L	0.003%
3S	34,541	4,270	7	38,427	355	2,900	703
	60% SRS®-SD			9 : 1 dilution	1 g/L	9 g/L	0.003%
TOTAL	132,420	16,369		147,316	1,360	7,000	2,800
Recommended Application - Each Well							
Remediation Area	Number Injection Wells	Total Volume Injection Solution Per Well	Dilution Water Volume per Well	Injection Solution Percent of Effective Pore Volume	Sodium Ascorbate Per Well	Sodium Bicarbonate Per Well	TSI DC <i>Dehalococcoides mccartyi</i> Bioaugmentation Culture* Per Well
		(gallons)	(gallons)	(%)	(pounds)	(pounds)	(L)
1S	1298	54.0	48.6	1.1%	0.4	1.8	0.9
2S	722	70.5	63.5	1.2%	0.6	2.4	1.2
3S	608	70.2	63.2	1.2%	0.6	4.8	1.2
TOTAL	2,628						

Table 5. Terra Systems Substrate Demand Shallow Intermediate 1SI-3SI Full Scale Grid Summary

Remediation Area	Site Data						
	Length (feet)	Width (feet)	Thickness (feet)	Area (feet ²)	Volume (feet ³)	Lithology	Soil Density (ρ_b , g/cm ³)
1SI	510	340	20	173400	3468000	Clayey Sand	1.37
2SI	187	180	20	33660	673200		1.37
3SI	212	411	20	87132	1742640	Clayey Sand	1.37
Remediation Area	Hydrogeologic data						
	Porosity (n)	Effective Porosity (n_{eff})	Hydraulic Conductivity (feet/day)	Hydraulic Gradient (feet/feet)	Total Pore Volume (PV) (gallons)	Average Seepage Velocity (V_s) (feet/day)	Fraction Organic Carbon (Foc)
1SI	28%	25%	1.43	0.0014	3,699,849	0.01	0.0390
2SI	28%	25%	1.43	0.0014	1,385,143	0.01	0.0390
3SI	28%	25%	1.43	0.0014	1,259,221	0.01	0.0390
Remediation Area	Native Electron Acceptors						
	Oxygen (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Carbon Dioxide (mg/L)	Manganese (IV) (mg/L)	Iron (III) (mg/L)	
1SI	2.10	0.50	291.0	10.00	5.000	20.000	
2SI	2.00	0.50	291.0	10.00	5.000	20.000	
3SI	4.90	0.50	291.0	10.00	5.000	20.000	
Remediation Area	Aqueous Geochemistry						
	ORP (mV)	pH (SU)	Specific Conductivity (μ S/cm)	Temperature (°C)	Alkalinity (mg/L)	TDS, or salinity (mg/L)	Chloride (mg/L)
1SI	29	7.40	200	15.0	325	10	100
2SI	46	6.00	200	15.0	325	10	100
3SI	165	7.10	200	15.0	325	10	100

**Table 6. Terra Systems Shallow Intermediate Full Scale Grid 1SI- 3SI
Recommended Volumes of SRS®-SD, Dilution Water, Sodium Ascorbate, Sodium
Bicarbonate, and TSI-DC**

Recommended Application - Total							
Remediation Area	Recommended Injection Volume, Conditioners, and Culture						
	Terra Systems Recommended Injection Product			Dilution Water at Recommended Dilution	Sodium Ascorbate ⁽¹⁾	Sodium Bicarbonate ⁽²⁾	TSI DC ⁽³⁾
	(pounds)	(gallons)	(gallons per well)	(gallons) (dilution)	(pounds) (concentration)	(pounds) (concentration)	<i>Dehalococcoides mccartyi</i> Bioaugmentation Culture* (L) (concentration)
1SI	59,671	7,376	28	66,383	613	2,500	1233
	60% SRS®-SD			9 : 1 dilution	1 g/L	5 g/L	0.003%
2SI	11,921	1,474	26	13,262	123	500	240
	60% SRS®-SD			9 : 1 dilution	2 g/L	5 g/L	0.003%
	30,696	3,794	30	34,149	315	1,300	620
3SI	60% SRS®-SD			9 : 1 dilution	1 g/L	5 g/L	0.003%
TOTAL	102,288	12,644		113,794	1,051	4,300	2,093
Recommended Application - Each Well							
Remediation Area	Number Injection Wells	Total Volume Injection Solution Per Well	Dilution Water Volume per Well	Injection Solution Percent of Effective Pore Volume	Sodium Ascorbate Per Well	Sodium Bicarbonate Per Well	TSI DC <i>Dehalococcoides mccartyi</i> Bioaugmentation Culture* Per Well
		(gallons)	(gallons)	(%)	(pounds)	(pounds)	(L)
1SI	260	283.7	255.3	1.1%	2.4	9.6	4.7
2SI	56	263.1	236.8	1.2%	2.2	8.9	4.3
3SI	128	296.4	266.8	1.2%	2.5	10.2	4.8
TOTAL	444						

Table 7. Terra Systems Substrate Demand Shallow Intermediate 4SI-6SI Full Scale Grid Summary

Remediation Area	Site Data						
	Length (feet)	Width (feet)	Thickness (feet)	Area (feet ²)	Volume (feet ³)	Lithology	Soil Density (ρ_b , g/cm ³)
4SI	435	600	20	261000	5220000	Clayey Sand	1.37
5SI	240	327	20	78480	1569600	Clayey Sand	1.37
6SI	980	435	20	426300	8526000	Clayey Sand	1.37
Remediation Area	Hydrogeologic data						
	Porosity (n)	Effective Porosity (n_{eff})	Hydraulic Conductivity (feet/day)	Hydraulic Gradient (feet/feet)	Total Pore Volume (PV) (gallons)	Average Seepage Velocity (V_s) (feet/day)	Fraction Organic Carbon (Foc)
4SI	28%	25%	1.43	0.0014	10,740,411	0.01	0.0390
5SI	28%	25%	1.43	0.0014	9,764,010	0.01	0.0390
6SI	28%	25%	1.43	0.0014	17,542,671	0.01	0.0390
Remediation Area	Native Electron Acceptors						
	Oxygen (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Carbon Dioxide (mg/L)	Manganese (IV) (mg/L)	Iron (III) (mg/L)	
4SI	1.40	0.50	291.0	10.00	5.000	20.000	
5SI	1.80	0.50	291.0	10.00	5.000	20.000	
6SI	5.80	0.50	291.0	10.00	5.000	20.000	
Remediation Area	Aqueous Geochemistry						
	ORP (mV)	pH (SU)	Specific Conductivity (μ S/cm)	Temperature (°C)	Alkalinity (mg/L)	TDS, or salinity (mg/L)	Chloride (mg/L)
4SI	-7	5.70	200	15.0	325	10	100
5SI	140	6.20	200	15.0	325	10	100
6SI	47	5.80	200	15.0	325	10	100

**Table 8. Terra Systems Shallow Intermediate Full Scale Grid 4SI- 6SI
Recommended Volumes of SRS®-SD, Dilution Water, Sodium Ascorbate, Sodium
Bicarbonate, and TSI-DC**

Recommended Application - Total							
Remediation Area	Recommended Injection Volume, Conditioners, and Culture						
	Terra Systems Recommended Injection Product			Dilution Water at Recommended Dilution	Sodium Ascorbate ⁽¹⁾	Sodium Bicarbonate ⁽²⁾	TSI DC ⁽³⁾ <i>Dehalococcoides mccartyi</i> Bioaugmentation Culture*
	(pounds)	(gallons)	(gallons per well)	(gallons) (dilution)	(pounds) (concentration)	(pounds) (concentration)	(L) (concentration)
4SI	90,077	11,134	27	100,210	925	7,450	1856
	60% SRS®-SD			9 : 1 dilution	1 g/L	9 g/L	0.003%
5SI	27,520	3,402	27	30,616	283	1,150	558
	60% SRS®-SD			9 : 1 dilution	1 g/L	5 g/L	0.003%
	145,510	17,986	26	161,877	1,493	12,050	3031
6SI	60% SRS®-SD			9 : 1 dilution	1 g/L	9 g/L	0.003%
TOTAL	132,107	32,522		294,703	2,701	20,650	5,445
Recommended Application - Each Well							
Remediation Area	Number Injection Wells	Total Volume Injection Solution Per Well (gallons)	Dilution Water Volume per Well (gallons)	Injection Solution Percent of Effective Pore Volume (%)	Sodium Ascorbate Per Well (pounds)	Sodium Bicarbonate Per Well (pounds)	TSI DC <i>Dehalococcoides mccartyi</i> Bioaugmentation Culture* Per Well (L)
4SI	418	266.4	239.7	1.1%	2.2	17.8	4.4
5Si	125	272.1	244.9	1.2%	2.3	9.2	4.5
6SI	681	264.1	237.7	1.1%	2.2	17.7	4.5
TOTAL	1,224						

Table 9. Terra Systems Substrate Demand Shallow Intermediate Biobarrier Summary

Remediation Area	Site Data						
	Length (feet)	Width (feet)	Thickness (feet)	Area (feet ²)	Volume (feet ³)	Lithology	Soil Density (ρ_b , g/cm ³)
PRB 1 South	27	2200	20	59400	1188000	Clayey Sand	1.37
PRB 2	27	1000	20	27000	540000		1.37
PRB 1 North	27	550	20	14850	297000	Clayey Sand	1.37
PRB 3	28%	25%	1.43	0.0014	533,317	0.01	0.0390
Remediation Area	Hydrogeologic data						
	Porosity (<i>n</i>)	Effective Porosity (<i>n_{eff}</i>)	Hydraulic Conductivity (feet/day)	Hydraulic Gradient (feet/feet)	Total Pore Volume (PV) (gallons)	Average Seepage Velocity (<i>V_s</i>) (feet/day)	Fraction Organic Carbon (<i>F_{oc}</i>)
PRB 1 South	28%	25%	1.43	0.0014	15,947,883	0.01	0.0390
PRB 2	28%	25%	1.43	0.0014	1,111,077	0.01	0.0390
PRB 1 North	28%	25%	1.43	0.0014	1,010,070	0.01	0.0390
PRB 3	2.50	0.50	291.0	10.00	5.000	20.000	Area 1 PRB 3
Remediation Area	Native Electron Acceptors						
	Oxygen (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Carbon Dioxide (mg/L)	Manganese (IV) (mg/L)	Iron (III) (mg/L)	
PRB 1 South	1.30	0.50	291.0	10.00	5.000	20.000	
PRB 2	3.10	0.50	291.0	10.00	5.000	20.000	
PRB 1 North	1.90	0.50	291.0	10.00	5.000	20.000	
PRB 3	2.50	0.50	291.0	10.00	5.000	20.000	
Remediation Area	Aqueous Geochemistry						
	ORP (mV)	pH (SU)	Specific Conductivity (μ S/cm)	Temperature (°C)	Alkalinity (mg/L)	TDS, or salinity (mg/L)	Chloride (mg/L)
PRB 1 South	191	6.40	200	15.0	325	10	100
PRB 2	214	6.80	200	15.0	325	10	100
PRB 1 North	326	6.60	200	15.0	325	10	100
PRB 3	214	6.80	200	15.0	325	10	100

**Table 10. Terra Systems Shallow Intermediate Biobarrier Summary
Recommended Volumes of SRS®-SD, Dilution Water, Sodium Ascorbate, Sodium Bicarbonate, and TSI-DC**

Recommended Application - Total							
Remediation Area	Recommended Injection Volume, Conditioners, and Culture						
	Terra Systems Recommended Injection Product			Dilution Water at Recommended Dilution	Sodium Ascorbate ⁽¹⁾	Sodium Bicarbonate ⁽²⁾	TSI DC ⁽³⁾ <i>Dehalococcoides mccartyi</i> Bioaugmentation Culture*
	(pounds)	(gallons)	(gallons per well)	(gallons) (dilution)	(pounds) (concentration)	(pounds) (concentration)	(L) (concentration)
PRB 1 South	26,622	3,291	41	29,616	274	1,100	423
	60% SRS®-SD			9 : 1 dilution	1 g/L	5 g/L	0.003%
PRB 2	12,101	1,496	42	13,462	125	500	192
	60% SRS®-SD			9 : 1 dilution	2 g/L	5 g/L	0.003%
PRB 1 North	6,655	823	39	7,404	69	300	106
	60% SRS®-SD			9 : 1 dilution	2 g/L	5 g/L	0.003%
	5,808	718	25	6,462	60	250	93
PRB 3	60% SRS®-SD			9 : 1 dilution	2 g/L	5 g/L	0.003%
TOTAL	51,186	6,328		56,580	528	2,150	814
Recommended Application - Each Well							
Remediation Area	Number Injection Wells	Total Volume Injection Solution Per Well	Dilution Water Volume per Well	Injection Solution Percent of Effective Pore Volume	Sodium Ascorbate Per Well	Sodium Bicarbonate Per Well	TSI DC <i>Dehalococcoides mccartyi</i> Bioaugmentation Culture* Per Well
		(gallons)	(gallons)	(%)	(pounds)	(pounds)	(L)
PRB 1 South	81	406.3	366.6	1.5%	3.4	13.6	4.3
PRB 2	36	415.5	373.9	1.5%	3.5	13.9	5.3
PRB 1 North	21	391.7	352.6	1.5%	3.3	14.3	5.0
PRB 3	29	247.6	222.8	1.5%	2.1	8.6	3.2
TOTAL	167						

Figures

August 1, 2025

Longhorn Army Ammunition Plant Site 47
TSD Proposal No. 251120

Figure 2. Shallow Intermediate Plume Pilot and Treatment Areas



Attachment A – Technical/Safety Data



Patented *Injection Ready* 60% SRS® –SD Small Droplet Emulsified Vegetable Oil (EVO) Substrate for Maximum Radius of Influence

SAFETY DATA SHEET

1. Product Identification

Synonyms:	60% Small Droplet Slow-Release Substrate (SRS® –SD) Emulsified Vegetable Oil Substrate (EVO)
Recommended Use:	Treatment of groundwater contaminated with chlorinated solvents and other anaerobically degradable compounds.
Supplier:	Terra Systems 130 Hickman Road, Suite 1 Claymont, Delaware 19703 Telephone (302) 798-9553 Fax (302) 798-9554 www.terrasystems.net

2. Hazards Identification

Emergency Overview

Caution:	May cause eye irritation.
Health Rating:	1 – Slight
Flammability Rating:	1 – Slight
Reactivity Rating:	1 – Slight
Contact Rating:	1 – Slight
Protective Equipment:	Goggles; Proper Gloves
Storage Color Code:	Green (General Storage)
Potential Health Effects	
Inhalation:	Not expected to be a health hazard. If heated, may produce vapors or mists that irritate the mucous membranes and cause irritation, dizziness, and nausea. Remove to fresh air.
Ingestion:	Not expected to be a health hazard via ingestion. Large doses may produce abdominal spasms or diarrhea.



Skin Contact: No adverse effects expected. May cause irritation or sensitization in sensitive individuals.

Eye Contact: May cause mild irritation, possible reddening.

Chronic Exposure: No information found.

Aggravation of Pre-existing Conditions: No information found.

3. Composition/Information on Ingredients

Ingredient	Synonyms	CAS #	Percent	Hazardous
Soybean oil	Soya oil	8001-22-7	60%	No
Emulsifiers and proprietary nutrient package containing nitrogen, phosphorus and vitamin B ₁₂		Mixture	7.5 – 10%	No
a quick release food grade soluble substrate sodium lactate or glycerol	2-hydroxypropionic acid sodium salt or glycerol or 1,2,2-propanetriol	72-17-3 or 56-81-5	10%	Yes
Water		7732-18-5	Difference	No

The emulsifiers and nutrient package mixture is a trade secret and consists of ingredients of unknown acute toxicity.

4. First Aid Measures

Inhalation: Not expected to require first aid measures. Remove to fresh air. Get medical attention for any breathing difficulty.

Ingestion: If large amounts are swallowed, give water to drink and get medical advice.

Skin Contact: Not expected to require first aid measures. Wash exposed area with soap and water. Get medical advice if irritation develops.

Eye Contact: Immediately flush eyes with plenty of water for at least 15 minutes, lifting upper and lower eyelids occasionally. Get medical attention if irritation persists.



5. Fire Fighting Measures

Fire:	Flash point: >200 C (>392 F). Not considered to be a fire hazard. Isolate from heat and open flame.
Explosion:	Not considered to be an explosion hazard. Closed containers may explode if exposed to extreme heat.
Fire Extinguishing Media:	Dry chemical, foam, or carbon dioxide. Water spray may be ineffective on fire but can protect fire-fighters and cool closed containers. Use fog nozzles if water is used.
Special Information:	In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode.

6. Accidental Release Measures

Clean-up personnel may require protective clothing. Absorb in sand, paper towels, "Oil Dry", or other inert material. Scoop up and containerize for disposal. Flush trace residues to sewer with soap and water. Containerized waste may be sent to an approved waste disposal facility.

7. Handling and Storage

Store in a cool, dry, ventilated area. Do not store in sunlight or above 32 C (90 F). Keep container tightly closed and upright when not in use to prevent leakage. Observe all warnings and precautions listed for the product. Protect against physical damage.

If container begins to bulge, open cap slowly to release carbon dioxide from biological activity on the SRS-SD and call TS.

Containers of this material are not hazardous when empty since they do not contain vapors or harmful substances; if drum or tote is observed to bulge, keep cap off as pressurization can occur on empty container with caps in place unless container is thoroughly rinsed.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:	None established.
Ventilation System:	Not expected to require any special ventilation.



Personal Respirators (NIOSH

Approved):	Not expected to require personal respirator usage.
Skin Protection:	Wear protective gloves and clean body-covering clothing.
Eye Protection:	Use chemical safety goggles and/or a full-face shield where splashing is possible. Provide readily accessible eye wash stations and safety showers.
Slips, Trips, and Falls:	Material is slippery when spilled. Clean up with sand, paper towels, "Oil Dry", or other inert material.

9. Physical and Chemical Properties

Appearance:	White liquid.
Odor:	Vegetable oil.
Solubility:	Miscible in water.
Specific Gravity (water=1):	0.95–0.98. 8.09 pounds per gallon.
pH:	6–7 (40% aqueous solution)
% Volatiles by volume	
@ 21C (70F):	Negligible.
Boiling Point:	≥ 100C (≥ 212F)
Melting Point:	No information found.
Flash Point (F):	No information found.
Autoignition Temperature:	No information found.
Decomposition Temperature:	No information found.
Vapor Density (Air=1):	No information found.
Vapor Pressure (mm Hg):	< 1.0 @ 20C (68F).
Evaporation Rate (BuAc=1):	No information found.
Viscosity @23 C (73 F):	213 centipoises (1.2 centipoises diluted 1:10)
Partition Coefficient	
(octanol/water):	No information found.

10. Stability and Reactivity

Stability:	Stable under ordinary conditions of use and storage.
Reactivity:	Not reactive under ordinary conditions.
Hazardous Decomposition Products:	Carbon dioxide and carbon monoxide may form when heated to decomposition.
Hazardous Polymerization:	Will not occur.
Incompatibilities:	Strong oxidizers, acids.



Conditions to Avoid: Incompatibles. Isolate from heat and open flame.

11. Toxicological Information

Soybean Oil:	No information found on toxicology. It is not a carcinogen listed by IARC, NTP, NIOSH, OSHA, or ACGIH.
Emulsifier/Nutrient Mixture:	No information found on toxicology. It is not a carcinogen listed by IARC, NTP, NIOSH, OSHA, or ACGIH.
Sodium Lactate:	Oral rat LD50: 2,000 mg/kg. 100 mg caused mild irritation to rabbit eye in Draize test. This compound is not listed as a carcinogen by IARC, NTP, NIOSH, OSHA, or ACGIH.
Glycerol	Oral rat LD50: 25,000 mg/kg.
SRS-SD:	The toxicity of the mixture has not been measured.

12. Ecological Information

Environmental Fate:	No information found.
Environmental Toxicity:	No information found.
Degradability:	This product is completely biodegradable under both aerobic and anaerobic conditions.
Soil Mobility:	This compound will move with groundwater until the adsorbed onto the soil. Degradation products may be mobile.
Bioaccumulation Potential:	No information found.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be managed in an appropriate and approved waste disposal facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of containers and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Not regulated.



15. Regulatory Information

OSHA STATUS: This product is not hazardous under the criteria of the Federal OSHA hazard Communication Standard 29 CFR 1910.1200. However, thermal processing and decomposition fumes from this product may be hazardous as noted in Section 10.

TSCA STATUS: No component of this product is listed on the TSCA inventory.

CERCLA (Comprehensive Response Compensation, and Liability Act): Not reportable.

SARA TITLE III (Superfund Amendments and Reauthorization Act)

Section 312 Extremely Hazardous Substances: None

Section 311/312 Hazard Categories: Non-hazardous Under Section 311/312

Section 313 Toxic Chemicals: None

RCRA STATUS: If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as hazardous waste. (40 CFR 261.20-24)

CALIFORNIA PROPOSITION 65: The following statement is made in order to comply with the California safe Drinking Water and Toxic Enforcement Act of 1986. The product contains no chemicals known to the State of California to cause cancer.

16. Other Information

NFPA Ratings: Health: **1** Flammability: **1** Reactivity: **1**

Date Prepared: May 7, 2025

Revision Information: SDS Section(s) changed since last revision of document include: Updated Section 3 Composition/Information on Ingredients.

Disclaimer: Terra Systems provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving



terrasystems

the information must exercise their independent judgment in determining its appropriateness for a particular purpose. TERRA SYSTEMS MAKES NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE INFORMATION SET FORTH HEREIN OR THE PRODUCT TO WHICH THE INFORMATION REFERS. ACCORDINGLY, TERRA SYSTEMS WILL NOT BE RESPONSIBLE FOR DAMAGES RESULTING FROM USE OF OR RELIANCE UPON THIS INFORMATION.

Prepared by:

Terra Systems

Phone Number:

(302) 798-9553 (U.S.A.)



terrasystems

SODIUM BICARBONATE

Safety Data Sheet

1. Product Identification

Synonyms: Sodium Hydrogen Carbonate, Baking Soda
CAS No: 144-55-8
Chemical Formula: NaHCO_3
Recommended Use: Food ingredient, pharmaceutical, water treatment
Supplier: Terra Systems
130 Hickman Road, Suite 1
Claymont, Delaware 19703
Telephone (302) 798-9553
Fax (302) 798-9554
www.terrasystems.net

2. Hazards Identification

Emergency Overview

Caution: None
Health Rating: 0 - None
Flammability Rating: 0 - None
Reactivity Rating: 0 - None
Contact Rating: 0 - None
Protective Equipment: Goggles; Proper Gloves
Storage Color Code: Green (General Storage)
Potential Health Effects



terrasystems

Inhalation:	Not expected to be a health hazard. If heated, may produce vapors or mists that irritate the mucous membranes and cause irritation, dizziness, and nausea. Remove to fresh air. Possible irritant.
Ingestion:	Not expected to be a health hazard via ingestion. Material is practically non-toxic. Small amounts (1-2 tablespoonfuls) swallowed during normal handling operations are not likely to cause injury as long as the stomach is not overly full; swallowing larger amounts may cause injury.
Skin Contact:	Not a skin irritant.
Eye Contact:	Not an eye irritant.
Chronic Exposure:	Based on published studies on its effects in animals and humans, sodium bicarbonate is not teratogenic or genotoxic. Only known subchronic effect is that of a marked systemic alkalosis. Not classified as carcinogenic by NTP, IARC, OSHA, ACGIH or NIOSH.
Aggravation of Pre-existing Conditions:	No information found.

3. Composition/Information on Ingredients

Ingredient	Synonyms	CAS #	Percent	Hazardous
Sodium Bicarbonate	Baking soda	144-5-8	100	No

White crystalline powder; no odor.

4. First Aid Measures

Inhalation:	Not expected to require first aid measures. Remove to fresh air. Get medical attention for any breathing difficulty.
--------------------	--



terrasystems

Ingestion:	If large amounts were swallowed, do not induce vomiting. Give water to drink if person is conscious and get medical advice.
Skin Contact:	Not expected to require first aid measures. Wash exposed area with soap and water. Get medical advice if irritation develops.
Eye Contact:	Check for and remove contacts. Immediately flush eyes with plenty of water for at least 15 minutes, lifting upper and lower eyelids occasionally. Get medical attention if irritation persists.
Note to Physician:	Large doses may produce systemic alkalosis and expansion in extracellular fluid volume with edema.

5. Fire Fighting Measures

Fire:	Not combustible. Not considered to be a fire hazard. Isolate from heat and open flame.
Explosion:	Not considered to be an explosion hazard.
Fire Extinguishing Media:	Use extinguishing media suitable against surrounding fire or the cause of the fire.
Special Information:	Carbon Dioxide may be generated making necessary the use of a self-contained breathing apparatus (SCBA) and full protective equipment (Bunker Gear). Carbon dioxide is an asphyxiant at levels over 5% w/w. Sodium oxide, another thermal decomposition product existing at temperatures above 1564°F is a respiratory, eye, and skin irritant. Avoid inhalation, eye and skin contact with sodium oxide dusts



6. Accidental Release Measures

Scoop up into dry, clean containers. Wash away small uncontaminated amounts of residue with water.

7. Handling and Storage

Keep in a tightly closed container, stored in a cool, dry, ventilated area. Protect against physical damage. Containers of this material are not hazardous when empty since they do vapors or harmful substances; observe all warnings and precautions listed for the product. Do not store above 49 C (120 F). Keep container tightly closed and upright when not in use to prevent leakage.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits: None established.

Ventilation System: Not expected to require any special ventilation.

Personal Respirators (NIOSH

Approved): Dust mask required if total dust level exceeds 10 mg/m³.

Skin Protection: Wear protective gloves and clean body-covering clothing.

Eye Protection: Use chemical safety glasses when handling bulk material or when dusts can be generated. Provide readily accessible eye wash stations and safety showers.

9. Physical and Chemical Properties

Appearance: White crystalline.

Molecular Weight: 84.02

Odor: None.

Solubility: 86 g/L at 20 C.

Bulk Density: 9.94 g/cm³ or 62 pounds/ft³

pH: 8.2 (1% aqueous solution)

% Volatiles by volume

@ 21C (70F): Negligible.

Boiling Point: Not applicable.

130 Hickman Road – Suite 1 – Claymont – Delaware 19703

Phone: 302-798-9553

www.terra systems.net



terrasystems

Melting Point:	Not applicable.
Flash Point (F):	Not applicable.
Autoignition Temperature:	Not flammable, will not support combustion.
Decomposition Temperature:	50 C.
Vapor Density (Air=1):	No information found.
Vapor Pressure (mm Hg):	Not applicable.
Evaporation Rate (BuAc=1):	No information found.
Partition Coefficient (octanol/water):	No information found.

10. Stability and Reactivity

Stability:	Stable under ordinary conditions of use and storage.
Reactivity:	Not reactive under ordinary conditions. Reacts with acids to yield carbon dioxide.
Hazardous Decomposition Products:	Carbon dioxide may form when heated to decomposition at >100 C. If heated to >850 C, yields sodium oxide which should inhalation, eye and skin contact should be avoided.
Hazardous Polymerization:	Will not occur.
Incompatibilities:	Strong acids.
Conditions to Avoid:	Incompatibles. Isolate from heat and open flame.

11. Toxicological Information

Toxic Dose:	4,220 mg/kg (oral rat).
Inhalation:	High concentrations of dust may cause transient irritation to upper respiratory tract.
Ingestion:	Ingestion of small amounts is unlikely to cause any adverse effects. Ingestion of (excessive amounts) may cause vomiting, nausea, convulsions



terrasystems

Skin: Repeated or prolonged contact may cause mild irritation and/or drying (defatting) of skin.

Eyes: The material was minimally irritating to unwashed eyes and practically non-irritating to washed eyes (rabbits).

12. Ecological Information

Environmental Fate: No information found.

Environmental Toxicity: 4,100 mg/L EC50 Daphnids. 7,100 mg/L LC50 Bluegills. 7,700 mg/L: LCtO Rainbow trout.

Persistence: This product is expected to persist in the environment. It is inorganic and not subject to biodegradation.

Soil Mobility: This compound will move with groundwater until it reacts with acid.

Bioaccumulation Potential: This product is not expected to bioaccumulate

13. Disposal Considerations

Bury in a secured landfill in accordance with all local, state and federal environmental regulations. Empty containers may be incinerated or discarded as general trash.

14. Transport Information

Not regulated.

15. Regulatory Information

CLEAN AIR ACT SECTION 611: Material neither contains nor is it manufactured with ozone depleting substances (ODS). FEDERAL WATER POLLUTION CONTROL ACT (40 CFR 401.15): Material contains no intentionally added or detectable (contaminant) levels of EPA priority toxic pollutants.



FEDERAL WATER POLLUTION CONTROL ACT (40 CFR 401.15): Material contains no intentionally added or detectable (contaminant) levels of EPA priority toxic pollutants.

FOOD AND DRUG ADMINISTRATION: Generally Recognized As Safe (GRAS) direct food additive (21 CFR 184.1736).

US DEPARTMENT OF AGRICULTURE: List of Proprietary Substances – Permitted Use Codes 3A, J1, A1, G1, and L1.

CERCLA REPORTABLE QUANTITY: None

OSHA: Not hazardous under 29 CFR 1910.1200

RCRA: Not a hazardous material or a hazardous waste by listing or characteristic.

SARA TITLE III:

Section 302, Extremely Hazardous Substances: None

Section 311/312, Hazardous Categories: Non-hazardous

Section 313, Toxic Chemicals: None

Sodium Bicarbonate is reported in the EPA TSCA Inventory List.

Contains no VOCs.

NSF STANDARD 60: Corrosion and Scale Control in Potable Water. Max use 200 mg/l.

16. Other Information

NFPA Ratings:

Date Prepared:

Revision Information:

Health: **0** Flammability: **0** Reactivity: **0**

May 8, 2025

SDS Section(s) changed since last revision of document include: None.

Disclaimer: Terra Systems provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to



terrasystems

the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving the information must exercise their independent judgment in determining its appropriateness for a particular purpose. TERRA SYSTEMS MAKES NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE INFORMATION SET FORTH HEREIN OR THE PRODUCT TO WHICH THE INFORMATION REFERS. ACCORDINGLY, TERRA SYSTEMS, WILL NOT BE RESPONSIBLE FOR DAMAGES RESULTING FROM USE OF OR RELIANCE UPON THIS INFORMATION

Terra Systems
(302) 798-9553 (U.S.A.)

Prepared by:
Phone Number:



TERRA SYSTEMS DECHLORINATING BIOAUGMENTATION CULTURE (TSI-DC) SAFETY DATA SHEET

1. Product Identification

Synonyms:	<i>Dehalococcoides</i> or DHC Microbial Consortium (TSI-DC)
Recommended Use:	Bioremediation of groundwater contaminated with chlorinated solvents such as tetrachloroethene and trichloroethene. The TSI-DC culture contains >1E11 <i>Dehalococcoides mccartyi</i> /L and the tceA and vcrA functional genes for reductive dechlorination of TCE and vinyl chloride.
Supplier:	Terra Systems 130 Hickman Road, Suite 1 Claymont, Delaware 19703 Telephone (302) 798-9553 Fax (302) 798-9554 www.terrasystems.net

2. Hazards Identification

The available data indicates no known hazards associated with exposure to this product. Nevertheless, individuals who are allergic to enzymes or other related proteins should avoid exposure and handling. Health effects associated with exposure to similar organisms are listed below.

Emergency Overview

Caution:	May cause eye irritation or discomfort if ingested or inhaled or allergic reaction to sensitive individuals.
Health Rating:	1 - Slight
Flammability Rating:	0 - None
Reactivity Rating:	0 - None
Contact Rating:	1 - Slight
Protective Equipment:	Goggles; Proper Gloves
Storage Color Code:	Green (General Storage)
Potential Health Effects	



Inhalation:	Not expected to be a health hazard. Hypersensitive individuals may experience breathing difficulties after inhalation of aerosols.
Ingestion:	Not expected to be a health hazard via ingestion. Ingestion of large quantities may result in abdominal discomfort including nausea, vomiting, cramps, diarrhea, and fever.
Skin Contact:	No adverse effects expected. May cause irritation or sensitization in sensitive individuals upon prolonged contact.
Eye Contact:	May cause mild irritation, possible reddening unless immediately rinsed.
Chronic Exposure:	No information found.
Aggravation of Pre-existing Conditions:	No information found.

3. Composition/Information on Ingredients

Ingredient	Synonyms	CAS #	Percent	Hazardous
Non-hazardous ingredients	DHC	Not applicable	100%	No

4. First Aid Measures

Inhalation:	Not expected to require first aid measures. Remove to fresh air. Get medical attention for any breathing difficulty or if allergic symptoms develop.
Ingestion:	Thoroughly rinse mouth with water. Do not induce vomiting unless directed to do so by medical personnel. Get immediate medical attention. Never give anything by mouth to an unconscious or convulsing person.
Skin Contact:	Not expected to require first aid measures. Wash exposed area with soap and water. Get medical advice if irritation develops.
Eye Contact:	Immediately flush eyes with plenty of water for at least 15 minutes, lifting upper and lower eyelids occasionally. Get medical attention if irritation persists.
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.

5. Fire Fighting Measures

Fire:	Non-flammable. Flash point and flammable limits are not available.
Explosion:	Not considered to be an explosion hazard.
Fire Extinguishing Media:	Dry chemical, foam, carbon dioxide, or water.
Special Information:	In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode.

6. Accidental Release Measures

Clean-up personnel may require protective clothing and avoid skin contact. Absorb in sand, paper towels, or other inert material. Scoop up and containerize for disposal. Flush trace residues to sewer with soap and water. Containerized waste may be sent to an approved waste disposal facility. After clean-up, disinfect all cleaning materials and storage containers that come in contact with the spilled liquid.

7. Handling and Storage

Avoid breathing aerosol. Avoid contact with skin. Use personal protective equipment recommended in Section 8. Keep containers tightly closed in a cool, well-ventilated area. The DHC microbial consortium (TSI-DC) can be supplied in stainless steel kegs designed for maximum working pressure of 130 psi and equipped with pressure relief valves. The kegs are pressurized with nitrogen gas up to the pressure of 15 psi. Do not exceed pressure of 15 psi during transfer of DHC microbial consortium (TSI-DC) from kegs. Don't open keg if content of the keg is under pressure. DHC microbial consortium (TSI-DC) may be stored for up to 3 weeks at temperature 2–4°C without aeration. Avoid freezing.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:	None established.
Ventilation System:	Not expected to require any special ventilation. Provide adequate ventilation to remove odors.
Personal Respirators (NIOSH Approved):	Not expected to require personal respirator usage. If aerosols might be generated, use N95 respirator.



Skin Protection:	Wear protective rubber, nitrile, or vinyl gloves and clean body-covering clothing.
Eye Protection:	Use chemical safety goggles and/or a full face shield where splashing is possible. Provide readily accessible eye wash stations and safety showers.

9. Physical and Chemical Properties

Appearance:	Light greenish, murky liquid.
Odor:	Musty.
Solubility:	Soluble in water.
Specific Gravity (water=1):	1.0. 8.34 pounds per gallon.
pH:	6-8
% Volatiles by volume	
@ 21C (70F):	Negligible.
Boiling Point:	100C (212F)
Melting Point:	0C (32F)
Flash Point (F):	No information found.
Autoignition Temperature:	No information found.
Decomposition Temperature:	No information found.
Vapor Density (Air=1):	No information found.
Vapor Pressure (mm Hg):	24 mm @ 25C (77F).
Evaporation Rate (BuAc=1):	No information found.
Viscosity @23 C (73 F):	1 centipoises
Partition Coefficient	
(octanol/water):	No information found.

10. Stability and Reactivity

Stability:	Stable under ordinary conditions of use and storage.
Reactivity:	Not reactive under ordinary conditions.
Hazardous Decomposition Products:	None.
Hazardous Polymerization:	Will not occur.
Incompatibilities:	Strong oxidizers, acids, water reactive materials.
Conditions to Avoid:	Incompatibles. Isolate from heat and open flame.

11. Toxicological Information

TSI-DC	No information found on toxicology. It is not a carcinogen listed by IARC, NTP, NIOSH, OSHA, or
---------------	---



ACGIH. It has tested negative for pathogenic microorganisms such as *Bacillus cereus*, *Listeria monocytogens*, *Salmonella* sp., *Pseudomonas* sp., fecal coliform, total coliform, yeast, and mold.

12. Ecological Information

Environmental Fate:	No information found.
Environmental Toxicity:	No information found.
Degradability:	This product is completely biodegradable under both aerobic and anaerobic conditions.
Soil Mobility:	This compound will move with groundwater until adsorbed onto the soil.
Bioaccumulation Potential:	No information found.

13. Disposal Considerations

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

14. Transport Information

DOT Classification:	N/A
Labeling:	NA
Shipping Name:	Not regulated

15. Regulatory Information

OSHA STATUS: This product is not hazardous under the criteria of the Federal OSHA hazard Communication Standard 29 CFR 1910.1200.

TSCA STATUS: No component of this product is listed on the TSCA inventory.

CERCLA (Comprehensive Response Compensation, and Liability Act): Not reportable.

SARA TITLE III (Superfund Amendments and Reauthorization Act)

Section 312 Extremely Hazardous Substances: None

Section 311/312 Hazard Categories: Non-hazardous Under Section 311/312

Section 313 Toxic Chemicals: None



RCRA STATUS: If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste. (40 CFR 261.20–24)

CALIFORNIA PROPOSITION 65: The following statement is made in order to comply with the California safe Drinking Water and Toxic Enforcement Act of 1986. The product contains no chemicals known to the State of California to cause cancer.

16. Other Information

NFPA Ratings: Health: **1** Flammability: **0** Reactivity: **0**

Date Revised: June 5, 2017

Revision Information: SDS Section(s) changed since last revision of document include: Added *Dehalococcoides* numbers and statement that the culture contains the tceA and vcrA functional genes.

Disclaimer: Terra Systems provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving the information must exercise their independent judgment in determining its appropriateness for a particular purpose. TERRA SYSTEMS. MAKES NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE INFORMATION SET FORTH HEREIN OR THE PRODUCT TO WHICH THE INFORMATION REFERS. ACCORDINGLY, TERRA SYSTEMS WILL NOT BE RESPONSIBLE FOR DAMAGES RESULTING FROM USE OF OR RELIANCE UPON THIS INFORMATION.

Prepared by: Terra Systems.

Phone Number: (302) 798-9553 (U.S.A.)



SODIUM ASCORBATE

SAFETY DATA SHEET

1. Product Identification

Synonyms: Sodium Salt of Vitamin C

Recommended Use: Additive for treatment of water to remove dissolved oxygen.

CAS#: 134-03-2

Supplier: Terra Systems
130 Hickman Road, Suite 1
Claymont, Delaware 19703
Telephone (302) 798-9553
Fax (302) 798-9554
www.terrasystems.net

2. Hazards Identification

Emergency Overview

Caution: May cause eye or skin irritation.

Health Rating: 2 - Moderate

Flammability Rating: 1 - Slight

Reactivity Rating: 0 - None

Contact Rating: 1 - Slight

Protective Equipment: Goggles; Proper Gloves

Storage Color Code: Green (General Storage)

Potential Health Effects

Inhalation: Not expected to be a health hazard.

Ingestion: Hazard via ingestion.

Skin Contact: May cause irritation or sensitization in sensitive individuals.

Eye Contact: May cause mild irritation.

Chronic Exposure: No information found.

Aggravation of Pre-existing**Conditions:** No information found.

3. Composition/Information on Ingredients

Ingredient	Synonyms	CAS #	Percent	Hazardous
Sodium Ascorbate	Sodium Salt of Vitamin C	134-03-2	100	No

4. First Aid Measures

Inhalation:	Not expected to require first aid measures. Remove to fresh air.
Ingestion:	Get medical attention for any breathing difficulty. If large amounts were swallowed, give water to drink and get medical advice.
Skin Contact:	Not expected to require first aid measures. Wash exposed area with soap and water. Get medical advice if irritation develops.
Eye Contact:	Immediately flush eyes with plenty of water for at least 15 minutes, lifting upper and lower eyelids occasionally. Get medical attention if irritation persists.

5. Fire Fighting Measures

Fire:	Flash point and auto ignition: not available. May be combustible at high temperature. Isolate from heat and open flame.
Explosion:	Slightly explosive in presence of open flames and sparks. Nonflammable in presence of shocks.
Fire Extinguishing Media:	Dry chemical powder for small fires. Water spray, fog, or foam may be effective for large fires. Do not use water jet. .



Special Information: In the event of a fire, wear full protective clothing and NIOSH approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode. Fine dust dispersed in air at sufficient concentrations with an ignition source is a potential dust explosion hazard.

6. Accidental Release Measures

Clean-up personnel may require protective clothing. Scoop up and containerize for disposal. Flush trace residues to sewer with soap and water. Containerized waste may be sent to an approved waste disposal facility.

7. Handling and Storage

Keep in a tightly closed container, stored in a cool, dry, ventilated area away from sources of heat or ignition. Protect against physical damage. Containers of this material may pose a fire risk due to dusts. Keep container tightly closed and upright when not in use to prevent leakage. Sensitive to light. Store in light-resistant containers.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits: None established.

Ventilation System: Use ventilation to keep exposure below exposure limits.

Personal Respirators (NIOSH

Approved): Use dust respirator usage.

Skin Protection: Wear protective gloves and clean body-covering clothing.

Eye Protection: Use chemical safety goggles and/or a full face shield where splashing is possible. Provide readily accessible eye wash stations and safety showers.

9. Physical and Chemical Properties

Appearance: White to yellowish granular or crystalline solid

Molecular Weight: 198.11 g/mole

Odor: Odorless.

Solubility:	620 g/L solubility in water at 25 C.
Specific Gravity (water=1):	1.66 (water = 1).
pH:	Not available
% Volatiles by volume	
@ 21C (70F):	Negligible.
Boiling Point:	No information found.
Melting Point:	No information found.
Flash Point (F):	No information found.
Autoignition Temperature:	No information found.
Decomposition	Decomposition temperature 200 C (392 F)
Temperature:	
Vapor Density (Air=1):	No information found.
Vapor Pressure (mm Hg):	Not applicable.
Evaporation Rate (BuAc=1):	Not applicable.
Partition Coefficient	
(octanol/water):	No information found.

10. Stability and Reactivity

Stability:	Stable under ordinary conditions of use and storage.
Reactivity:	Not reactive under ordinary conditions.
Hazardous Decomposition	
Products:	Carbon dioxide and carbon monoxide may form when heated to decomposition.
Hazardous Polymerization:	Will not occur.
Incompatibilities:	Strong oxidizers, reducing agents, acids, alkalis.
Conditions to Avoid:	Incompatibles. Isolate from heat and open flame.

11. Toxicological Information

Routes of Entry	Inhalation and ingestion.
Toxicity to Animals:	Acute oral toxicity (LD50): 16300 mg/kg Rat.
Chronic Effects on Humans:	Carcinogenic effects – classified 4 (no evidence) by NTP and none by OSHA. Mutagenic effects – mutagenic to mammalian somatic cells. May cause damage to kidneys, gastrointestinal tract, and upper respiratory tract. May affect genetic material (mutagenic) based on animal test data. No human data found



Other Toxic Effects: (Registry of Toxic Effects of Chemicals). May cause cancer based on animal test data. No human data found (Registry of Toxic Effects of Chemicals). Hazardous in case of ingestion. Slightly hazardous in case of skin contact (irritant) or inhalation.

12. Ecological Information

Environmental Fate: No information found.
Environmental Toxicity: No information found.
Degradability: This product is inherently biodegradable under both aerobic and anaerobic conditions.
Soil Mobility: No information found.
Bioaccumulation Potential: Does not bioaccumulate.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be managed in an appropriate and approved waste disposal facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Not regulated.

15. Regulatory Information

OSHA STATUS: This product is not hazardous under the criteria of the Federal OSHA hazard Communication Standard 29 CFR 1910.1200. However, thermal processing and decomposition fumes from this product may be hazardous as noted in Section 10.

TSCA STATUS: No component of this product is listed on the TSCA inventory.



CERCLA (Comprehensive Response Compensation, and Liability Act): Not reportable.

SARA TITLE III (Superfund Amendments and Reauthorization Act)

Section 312 Extremely Hazardous Substances: None

Section 311/312 Hazard Categories: Non-hazardous Under Section 311/312

Section 313 Toxic Chemicals: None

RCRA STATUS: If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal whether a material containing the product or derived from the product should be classified as a hazardous waste. (40 CFR 261.20-24) CALIFORNIA PROPOSITION 65: The following statement is made in order to comply with the California safe Drinking Water and Toxic Enforcement Act of 1986. The product contains no chemicals known to the State of California to cause cancer.

16. Other Information

NFPA Ratings: Health: **2** Flammability: **1** Reactivity: **0**

Date Prepared: March 14, 2025

Revision Information: SDS Section(s) changed since last revision of document include: None.

Disclaimer: Terra Systems. provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving the information must exercise their independent judgment in determining its appropriateness for a particular purpose. TERRA SYSTEMS MAKES NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE INFORMATION SET FORTH HEREIN OR THE PRODUCT TO WHICH THE



INFORMATION REFERS. ACCORDINGLY, TERRA
SYSTEMS WILL NOT BE RESPONSIBLE FOR DAMAGES
RESULTING FROM USE OF OR RELIANCE UPON THIS
INFORMATION.

Prepared by: Terra Systems
Phone Number: (302) 798-9553 (U.S.A.)

Attachment B – Pilot Quote



Pioneering Bioremediation Solutions for over 30 years

United States Patent# RE40,448 Emulsified Vegetable Oil Substrate

Prepared By: Charlie Lawrence 130 Hickman Road, Suite 1 Claymont, Delaware 19703 Phone 302-798-9553 Cell: 609-231-1931 Email: clawrence@terrasystems.net	7/31/825 TSD Proposal #: 251120 Quote Version: 1
Jessenia Guzman Peralta Environmental Designer HDR 50 Tice Blvd, Suite 210 Woodcliff Lake, NJ 87677	Longhorn Army Project: Ammunition Plant Bld 47 Location: Karnack TX Client Reference #: Mobilization:

QTY	UNIT	DESCRIPTION	UNIT PRICE	AMOUNT
986	Gallon	Terra Systems' patented small-droplet "injection ready" 60% SRS®-SD Emulsified Vegetable Oil (EVO) Substrate that includes 60% US grown soy bean oil, 5.5% quick release substrate, proprietary nutrients and Vitamin B12.	\$15.00 /Gallon	\$14,790.00
84	Pound	Sodium Ascorbate (Vitamin C salts) to drive the water anaerobic for the bioaugmentation culture injections. Shipped in n 55 pound boxes. Special order repackaged lesser quantities (bags or buckets).	\$18.00 /Pound	\$1,512.00
10	Bag	Sodium Bicarbonate buffer in fifty pound bags.	\$50.00 /Bag	\$500.00
84	Liter	Terra Systems TSI-DC Dehalococcoides mccartyi Bioaugmentation Culture® containing >1E11 Dehalococcoides/L.	\$135.00 /Liter	\$11,340.00
5	Keg	TSI-DHC Shipping	\$275.00	\$1,375.00
1	Truck	Product Delivery	\$7,000.00	\$7,000.00
0	Truck	Dry Good	\$0.00 /	\$0.00

Product Sub Total	\$28,142.00
Estimated Freight	\$8,375.00
Tax	\$2,282.31
Total	\$38,799.31

Terms and Conditions

Payment Terms: Net 30 days. Price is valid for 30 days, unless otherwise noted.

ACH payments/wires(preferred)
 Bank of America, 222 Broadway, New York, NY 10038 Acct #381069359275
 ABA #021200339 ACH wires, ABA #026009593 Domestic wires
 SWIFT:BOFAUS3N (US WIRES) SWIFT:BOFAUS6S(Foreign Wires)
 remit advice to: mfarrell@terrasystems.net

Check payments remit to:
 Terra Systems of DE, LLC
 11 Princess Rd, Suite B
 Lawrenceville, NJ 08648

THANK YOU FOR YOUR BUSINESS

<http://www.terrasystems.net/>

August 1, 2025

**Longhorn Army Ammunition Plant Site 47
TSD Proposal No. 251120**

Attachment C – Full Scale Quotes



Pioneering Bioremediation Solutions for over 30 years

United States Patent# RE40,448 Emulsified Vegetable Oil Substrate

Prepared By: Charlie Lawrence 130 Hickman Road, Suite 1 Claymont, Delaware 19703 Phone 302-798-9553 Cell: 609-231-1931 Email: clawrence@terrasystems.net	7/31/825 TSD Proposal #: 251120 Quote Version: 1
Jessenia Guzman Peralta Environmental Designer HDR 50 Tice Blvd, Suite 210 Woodcliff Lake, NJ 87677	Longhorn Army Project: Ammunition Plant Bld 47 Location: Karnack TX Client Reference #: Mobilization:

QTY	UNIT	DESCRIPTION	UNIT PRICE	AMOUNT
67,863	Gallon	Terra Systems' patented small-droplet "injection ready" 60% SRS®-SD Emulsified Vegetable Oil (EVO) Substrate that includes 60% US grown soy bean oil, 5.5% quick release substrate, proprietary nutrients and Vitamin B12.	\$12.00 /Gallon	\$814,356.00
5,675	Pound	Sodium Ascorbate (Vitamin C salts) to drive the water anaerobic for the bioaugmentation culture injections. Shipped in n 55 pound boxes. Special order repackaged lesser quantities (bags or buckets).	\$10.00 /Pound	\$56,750.00
682	Bag	Sodium Bicarbonate buffer in fifty pound bags.	\$50.00 /Bag	\$34,100.00
11,062	Liter	Terra Systems TSI-DC Dehalococcoides mccartyi Bioaugmentation Culture® containing >1E11 Dehalococcoides/L.	\$105.00 /Liter	\$1,161,510.00
583	Keg	TSI-DHC Shipping	\$275.00	\$160,325.00
14	Truck	Product Delivery	\$3,700.00	\$51,800.00
1	Truck	Dry Good	\$3,700.00 /	\$3,700.00

Product Sub Total	\$2,066,716.00
Estimated Freight	\$215,825.00
Tax	\$142,658.81
Total	\$2,425,199.81

Terms and Conditions

Payment Terms: Net 30 days. Price is valid for 30 days, unless otherwise noted.

ACH payments/wires(preferred)
 Bank of America, 222 Broadway, New York, NY 10038 Acct #381069359275
 ABA #021200339 ACH wires, ABA #026009593 Domestic wires
 SWIFT:BOFAUS3N (US WIRES) SWIFT:BOFAUS6S(Foreign Wires)
 remit advice to: mfarrell@terrasystems.net

Check payments remit to:
 Terra Systems of DE, LLC
 11 Princess Rd, Suite B
 Lawrenceville, NJ 08648

THANK YOU FOR YOUR BUSINESS

<http://www.terrasystems.net/>



Pioneering Bioremediation Solutions for over 30 years

United States Patent# RE40,448 Emulsified Vegetable Oil Substrate

Prepared By: Charlie Lawrence 130 Hickman Road, Suite 1 Claymont, Delaware 19703 Phone 302-798-9553 Cell: 609-231-1931 Email: clawrence@terrasystems.net	7/31/825 TSD Proposal #: 251120 Quote Version: 1
--	--

Jessenia Guzman Peralta Environmental Designer HDR 50 Tice Blvd, Suite 210 Woodcliff Lake, NJ 87677	Longhorn Army Project: Ammunition Plant Bld 47 Location: Karnack TX Client Reference #: Mobilization:
---	---

QTY	UNIT	DESCRIPTION	UNIT PRICE	AMOUNT
345,877	Pounds	Terra Systems' patented small-droplet "injection ready" 60% SRS®-SE Nonemulsified Vegetable Oil (EVO) and emulsifier package. Soybean oil shipped direct to Site	\$2.15 /pound	\$743,635.55
5,675	Pound	Sodium Ascorbate (Vitamin C salts) to drive the water anaerobic for the bioaugmentation culture injections. Shipped in n 55 pound boxes. Special order repackaged lesser quantities (bags or buckets).	\$10.00 /Pound	\$56,750.00
682	Bag	Sodium Bicarbonate buffer in fifty pound bags.	\$50.00 /Bag	\$34,100.00
11,062	Liter	Terra Systems TSI-DC Dehalococcoides mccartyi Bioaugmentation Culture® containing >1E11 Dehalococcoides/L.	\$105.00 /Liter	\$1,161,510.00
583	Keg	TSI-DHC Shipping	\$275.00	\$160,325.00
2	Truck	Product Delivery	\$3,700.00	\$7,400.00
1	Truck	Dry Good	\$3,700.00 /	\$3,700.00

Product Sub Total	\$1,995,995.55
Estimated Freight	\$171,425.00
Tax	\$135,463.78
Total	\$2,302,884.33

Terms and Conditions

Payment Terms: Net 30 days. Price is valid for 30 days, unless otherwise noted.

ACH payments/wires(preferred)
 Bank of America, 222 Broadway, New York, NY 10038 Acct #381069359275
 ABA #021200339 ACH wires, ABA #026009593 Domestic wires
 SWIFT:BOFAUS3N (US WIRES) SWIFT:BOFAUS6S(Foreign Wires)
 remit advice to: mfarrell@terrasystems.net

Check payments remit to:
 Terra Systems of DE, LLC
 11 Princess Rd, Suite B
 Lawrenceville, NJ 08648

THANK YOU FOR YOUR BUSINESS

<http://www.terrasystems.net/>



Pioneering Bioremediation Solutions for over 30 years

United States Patent# RE40,448 Emulsified Vegetable Oil Substrate

Prepared By: Charlie Lawrence 130 Hickman Road, Suite 1 Claymont, Delaware 19703 Phone 302-798-9553 Cell: 609-231-1931 Email: clawrence@terrasystems.net	7/31/825 TSD Proposal #: 251120 Quote Version: 1
Jessenia Guzman Peralta Environmental Designer HDR 50 Tice Blvd, Suite 210 Woodcliff Lake, NJ 87677	Longhorn Army Project: Ammunition Plant Bld 47 Location: Karnack TX Client Reference #: Mobilization:

QTY	UNIT	DESCRIPTION	UNIT PRICE	AMOUNT
67,863	Gallon	Terra Systems' patented small-droplet "injection ready" 60% SRS®-SD Emulsified Vegetable Oil (EVO) Substrate that includes 60% US grown soy bean oil, 5.5% quick release substrate, proprietary nutrients and Vitamin B12.	\$12.00 /Gallon	\$814,356.00
5,675	Pound	Sodium Ascorbate (Vitamin C salts) to drive the water anaerobic for the bioaugmentation culture injections. Shipped in n 55 pound boxes. Special order repackaged lesser quantities (bags or buckets).	\$10.00 /Pound	\$56,750.00
682	Bag	Sodium Bicarbonate buffer in fifty pound bags.	\$50.00 /Bag	\$34,100.00
11,062	Liter	Terra Systems TSI-DC Dehalococcoides mccartyi Bioaugmentation Culture® containing >1E11 Dehalococcoides/L.	\$105.00 /Liter	\$1,161,510.00
583	Keg	TSI-DHC Shipping	\$275.00	\$160,325.00
14	Truck	Product Delivery	\$2,500.00	\$35,000.00
1	Truck	Dry Good	\$7,000.00 /	\$7,000.00

Product Sub Total	\$2,066,716.00
Estimated Freight	\$202,325.00
Tax	\$141,815.06
Total	\$2,410,856.06

Terms and Conditions

Payment Terms: Net 30 days. Price is valid for 30 days, unless otherwise noted.

ACH payments/wires(preferred)
 Bank of America, 222 Broadway, New York, NY 10038 Acct #381069359275
 ABA #021200339 ACH wires, ABA #026009593 Domestic wires
 SWIFT:BOFAUS3N (US WIRES) SWIFT:BOFAUS6S(Foreign Wires)
 remit advice to: mfarrell@terrasystems.net

Check payments remit to:
 Terra Systems of DE, LLC
 11 Princess Rd, Suite B
 Lawrenceville, NJ 08648

THANK YOU FOR YOUR BUSINESS

<http://www.terrasystems.net/>



Leading Science · Lasting Solutions

130 Stone Road West
Guelph, ON N1G 3Z2

Quotation to:	Ship to:	Quotation: Si-08773A-073025
Jessenia Guzman Peralta HDR 50 Tice Blvd, Suite 210 Woodcliff Lake, NJ 07677 201-335-9330 Jessenia.GuzmanPeralta@hdrinc.com	1203 E Grand Avenue, #B Marshall, TX 75670	Date: 30 Jul 2025 Site name: Longhorn Army Ammunition Plant Valid until: 31 Dec 2025 Prepared by: Jeff Roberts

Product	Unit	Quantity	Description	Unit Price	AMOUNT
KB-1® (10X Concentrated) Pilot Area 1 9 Points	Liter	36 (10X Concentrated to 3.6 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^a	\$4,140
KB-1® (10X Concentrated) Pilot Area 2 9 Points	Liter	36 (10X Concentrated to 3.6 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^a	\$4,140
KB-1® (10X Concentrated) Pilot Area 3 5 Points	Liter	20 (10X Concentrated to 2.0 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^a	\$2,300
KB-1® (10X Concentrated) Pilot Area 4 24 Points	Liter	24 (10X Concentrated to 2.4 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^a	\$2,760
KB-1® Primer	Pounds	42 (7 lbs treats 1,000 G of water)	KB-1® Primer is used to rapidly prepare anaerobic injection water for bioremediation applications including dispersion of electron donors and protection of anaerobic bioaugmentation cultures during injection into aquifers.	\$30 ^a	\$1,260



Product	Unit	Quantity	Description	Unit Price	AMOUNT
Complementary KB-1 Trac®	Each	2	Molecular genetic analyses using an 8-target digital array test (KB-1® Trac) to quantify multiple Dhc functional genes and other important KB-1® microbes in site groundwater.	\$435	Provided Free of Charge
Shipping & Handling (Culture)	Event	4	Outbound and Return Shipping Charges	\$675 β	\$2,700
Shipping & Handling (Primer)	Event	1	Outbound Shipping Charges	\$350 β	\$350
Total (USD)					\$17,650*

*plus applicable taxes
αUnit price costs based on volume discounts for entire project
βPrices subject to change based on rates at time of shipment

OPTIONAL ADDITIONAL PRODUCTS AND SERVICES

Product	Description
VFAs	Used to monitor the quantity and form of fermentation by products of electron donors – Used to monitor electron donor status and manage (re)application requirements. \$120/sample
Dissolved hydrocarbon gases	Quantifies ethene, the non-toxic dechlorination product of chlorinated ethenes, also quantifies ethane and methane. \$85/sample

NOTES:

1. The proposed bioaugmentation is anticipated to result in reductive dechlorination of chlorinated ethenes in approximately three months (“the response time”) as evidenced by significant trends in production of ethene and/or increasing *Dehalococcoides* concentrations. Should the commencement of complete dechlorination, or increases in *Dehalococcoides* populations, not be achieved within the specified response time, and if all conditions outlined in Attachment A are fulfilled, the guarantee (attached) will be applicable.
2. **Payment terms are Net 30 days.**
3. All price quotes are valid until the expiration date shown in this quotation.
4. Shipping charges are estimates; actual charges are calculated at the time of invoice.
5. Note that SiREM requires a minimum of 2 weeks’ notice to ensure supply of quoted volume of culture.
6. The guarantee and use limitations for the microbial culture are provided in Exhibit A.
7. By your signature below SiREM is authorized to proceed with this the products and services as provided in this Quotation and the signatory and its Company accepts and is bound by SiREM’s Use Limitations (Exhibit A) and the Terms and Conditions for SiREM Products and Services (Exhibit B)

NOTE: RETURN ENTIRE SIGNED DOCUMENT

Exhibit A: Guarantee and Use Limitations

Exhibit B: Terms and Conditions for SiREM Products and Services

If you have any questions concerning this quotation, contact Jeff Roberts (+1 519-515-0840)

Quotation Acceptance:

Name (Signature)		Title:	
Name (Print)		Date:	
E-Mail			
Phone			
Purchase Order Number			
Invoice Remittance Address (if different than above)			
Invoice Remittance E-Mail AP Contact Name & E-Mail			

EXHIBIT A : GUARANTEE AND USE LIMITATIONS

SiREM, a division of Geosyntec Consultants International, Inc, is an authorized distributor of KB-1[®], Low pH KB-1[®] Plus, and KB-1[®] Plus (Custom Formulations) bioaugmentation cultures, proprietary products. This Limited Guarantee and Use Limitations for applications of SiREM's bioaugmentation cultures are subject to the following conditions.

CONDITIONS REQUIRED TO VALIDATE GUARANTEE:

	KB-1 [®]	Low pH KB-1 [®] Plus	KB-1 [®] Plus (custom formulations)
Bioaugmentation culture is injected only by SiREM staff or their approved designate;	x	x	x
initial target VOC concentrations at the site are sufficient to sustain the growth of <i>key degrading</i> organisms (i.e., in excess of 100 micrograms per liter [µg/L]);	x	x	x
inhibitory compounds/conditions	chloroform concentrations in excess of 50 µg/L, 1,1,1-TCA in excess of 200 µg/L) are absent		As specified in order
geochemical conditions	redox levels [ORP] below -75 millivolts [mV], dissolved oxygen levels less than 0.2 milligrams per Liter [mg/L], depletion of sulfate and nitrate, average groundwater temperature above 10°C		
	pH between 6 and 8.5	pH above 5.6	pH between 6 and 8.5
suitable electron donor or acceptor is provided at appropriate concentration consistently	x	x	x
the site is not physically, chemically or geochemically disrupted after bioaugmentation.	x	x	x
Minimum application dosage to achieve indicated response time is 1 liter bioaugmentation culture per 35,000 liters of groundwater	x	x	x

After bioaugmentation, specific organisms attributable to the bioaugmentation culture will colonize the site as determined by increasing concentrations and/or dispersing populations (based on Quantitative Gene-Trac tests relevant to the culture being applied) and/or the appearance of, or increases in, the concentration of degradation end-products (e.g., ethene in the case of chlorinated ethene degradation) (hereafter referred to as "impact[s]"). The impact(s) are to occur within the response time provided in the SiREM's quotation at either the injection point(s), or downgradient, provided the above site conditions are maintained throughout the bioaugmentation and acclimation (response time) period.

LIMITED PERFORMANCE GUARANTEE: In the event there is an absence of impact(s) at the injection points, or downgradient, within the designated response time following bioaugmentation, SiREM will provide an additional quantity of bioaugmentation culture free of charge (including delivery and associated expenses) equal to the initial volume used at the location(s) for which bioaugmentation is deemed unsuccessful. Should additional bioaugmentation to be proven ineffective, SiREM will refund, in full, the cost of the culture (KB-1[®] only) for the specific locations where bioaugmentation is deemed to be unsuccessful.

ADDITIONAL CONDITIONS: This limited guarantee is conditional upon receipt of payment in full for bioaugmentation culture purchases prior to its use. SiREM reserves the right, at its sole discretion, to confirm the concentration of degradation end-products, s organisms and other relevant geochemical parameters by collection and submission of groundwater or soil samples to a mutually agreeable independent laboratory. **No other warranty, expressed or implied, including, but not limited to, any and all warranties of merchantability and/or fitness for a particular purpose is made or intended.**

RESTRICTIONS AND LIMITATIONS

Bioaugmentation culture may only be used as set forth in this Exhibit A, and any project specific parameters that may be attached.

Bioaugmentation culture may only be used at the project site identified in SiREM's proposal.

The Terms and Conditions for SiREM Products and Services, Attachment B, shall apply to the use of SiREM products or services. All other terms or conditions introduced are expressly rejected.

EXHIBIT B: Terms and Conditions for SiREM Products and Services

The following terms and conditions are an integral part of the contractual relationship between the Client ("Client") identified in the Confirming Order or Quotation ("Order") and SiREM, a division of Geosyntec Consultants International, Inc., ("SiREM"), and they apply to the purchase, sale, and shipment of products, equipment, materials or supplies (collectively "Products"), and any related testing, research or evaluative services (collectively "Services") rendered by SiREM. Client and SiREM shall be referred to individually as "Party" and collectively as "Parties":

1. **Acceptance of Terms.** These terms and conditions are incorporated into the Order which shall describe the Products being sold and any related Services to be rendered. The Order and these terms and conditions are deemed accepted and become effective upon Client's acknowledgment of the Order or SiREM's initial performance in accordance with the Order. All prior or contemporaneous terms, representations or agreement, and any proposal or offer of additional or different terms and conditions is expressly rejected. This Order shall constitute the full agreement between the Client and SiREM and all prior or contemporaneous communications, representations or agreements are superseded unless expressly incorporated into this Order by written amendment signed by both Parties.

2. **Delivery.** SiREM shall provide Products or Services as specified in Order. Products shall be packaged and supported in a manner to ensure safety and protection against damage during shipment. Ownership of the Products shall transfer from SiREM to Client upon shipment.

3. **Payment.** All fees and charges, including shipping for Products shall be reflected in the Order. Payment for Products and Services shall be as indicated in the Order. SiREM shall invoice Client and payment is due within 30 days of invoice date. Client shall pay an additional charge of one percent (1%) of the amount of the invoice per month or the maximum percentage allowed by law, whichever is the lesser, for any payment received by SiREM beyond the payment terms set forth herein.

4. **Intellectual Property Rights/Obligations.** Intellectual Property shall mean ideas, results, technical information, patents, patent applications, know-how, copyrights, inventions, developments, trade-secrets, models, drawings, specifications, prototypes, deliverables and discoveries, whether registered or not, relating to the Products and the Services. All rights, including but not limited to ownership rights, to the Intellectual Property in the Products and Services are owned by SiREM and others, but not Client. SiREM is an authorized seller of the Products which are provided to Client in accordance with the limitations imposed upon SiREM. Upon payment in full of the amount reflected in the Order SiREM transfers to the Client a non-exclusive, non-commercial, non-transferable right to use the Products and the associated Intellectual Property for the limited application of the Products as set forth in the Order, and only at the project site described in the Order, and at no other site and for no other project or purpose. The Client does not have, nor will it acquire, any ownership interest or rights in the Product and/or the associated Intellectual Property and Client shall not sell, resell or transfer any of the Products to any third-party under any circumstances. In addition, Client agrees that it will not "reverse engineer" or undertake any activity which would enable Client, or any other person or entity, to duplicate, imitate, reproduce, copy, grow or culture the Products.

5. **Confidential Information.** In connection with the Order, Products and/or Services, Client will have access to confidential, proprietary and other non-public or sensitive information, including but not limited to Intellectual Property, belonging or licensed to SiREM (collectively "Confidential Information"). Except as, and to the extent necessary, to comply with the Order, Client shall not directly or indirectly disclose any Confidential Information. Furthermore, Client agrees (i) the Confidential Information shall be used solely for the purpose intended in this Order; (ii) it will not use any Confidential Information disclosed hereunder to compete with or negatively impact Discloser, either directly or indirectly; (iii) it will not distribute, disclose or disseminate any Confidential Information to anyone except its employees and agents with a need to know and who, in each case, have been informed of the confidential nature of the Confidential Information and have agreed to be bound by the terms of this Order; and (iv) it will keep all Confidential Information separate from all of its other documentation and records. In the event that the Client is requested or required to disclose any part of the Confidential Information, the Client will provide immediate written notice to SiREM for prior approval of release.

6. **Force Majeure.** Neither Party shall be liable for delays or defaults due to an act of god, and act of government, public enemy, strike, natural disaster or other unforeseeable causes beyond the reasonable control of the Parties.

7. **Termination or Suspension.** Client may by written notice terminate or suspend this Order, in whole or in part, for any reason at any time. Upon receipt of a notice of termination SiREM shall immediately stop all performance under this Order. Client shall reimburse SiREM for any costs incurred in connection with the Order up until receipt of the notice of termination.

8. **Assignment.** Neither Party shall assign its obligations under this Order without the prior written approval of the other Party. There shall be no third-party beneficiary to this Order.

9. **Standard of Care.** The Services rendered by SiREM will render its Services in a manner consistent with the level of care and skill ordinarily exercised by other firms rendering the same services under similar circumstances at the same time the Services are performed.

10. **LIMITED WARRANTY.** SiREM WARRANTS THAT THE PRODUCTS SUPPLIED PURSUANT TO THIS ORDER WILL NOT INFRINGE THE INTELLECTUAL PROPERTY RIGHTS OF ANYONE NOT A PARTY TO THIS ORDER. SiREM WARRANTS THAT IT IS DULY LICENSED, QUALIFIED AND CAPABLE OF FULFILLING ITS OBLIGATIONS UNDER THE ORDER. ALL OTHER WARRANTIES AND GUARANTEES OF ANY KIND, WHETHER EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR PURPOSE ARE DISCLAIMED.

11. **Collecting Procedures.** If the Order includes Services for testing, Client will collect and obtain samples to be shipped to and tested by SiREM at Client's sole expense. At Client's request, SiREM will provide sample containers at no cost. If recollection or resampling becomes necessary, for any reason other than SiREM's gross negligence or willful misconduct, Client shall be responsible for re-collecting and re-shipping the samples. The results of the testing will be delivered to Client in SiREM's standard report format.

12. **Liability.** To the maximum extent permitted by Law, Client agrees to limit SiREM's liability for the Client's damages to the greater of SiREM's fee or \$50,000. In no event will SiREM be liable to Client for any incidental or consequential damages arising in connection with this Order, the use of the Product or the Services rendered by SiREM.

13. **Disputes.** The Parties agree to promptly resolve their differences through good faith negotiations as a condition precedent to filing a formal claim. In the event disputes remain following such negotiations, any remaining dispute shall be submitted to senior representatives of the Parties who shall have the authority to enter into an agreement to resolve the dispute ("Representative"). The Representatives shall not have been directly involved in the performance of the Subcontracted Services. If the Representatives are unable to resolve the dispute within three weeks or within such longer time period as the Representatives may agree, the dispute shall be mediated by an independent third-party agreed to by both parties. Any disputes or portions thereof remaining following mediation shall be determined by remedies at law or equity, as they may be available, subject to the limitations in this Agreement. Any applicable statute of limitations on any claim in any way related to Agreement shall commence to run and alleged cause of action shall be deemed to have accrued no later than the date of either SiREM's final invoice or termination of this Agreement by either Party. Both Parties agree that the applicable statute of limitations for any claims in any way related to this Agreement shall be shortened to a period not longer than two years, unless a shorter statute of limitations would otherwise apply.

Quotation to:	Ship to:	Quotation: Si-08773B-073025
Jessenia Guzman Peralta HDR 50 Tice Blvd, Suite 210 Woodcliff Lake, NJ 07677 201-335-9330 Jessenia.GuzmanPeralta@hdrinc.com	1203 E Grand Avenue, #B Marshall, TX 75670	Date: 30 Jul 2025 Site name: Longhorn Army Ammunition Plant Valid until: 31 Dec 2025 Prepared by: Jeff Roberts

Product	Unit	Quantity	Description	Unit Price	AMOUNT
KB-1® (10X Concentrated) Grid Area 1S 1,298 Points	Liter	1,298 (10X Concentrated to 129.8 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^α	\$149,270
KB-1® (10X Concentrated) Grid Area 2S 722 Points	Liter	722 (10X Concentrated to 72.2 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^α	\$83,030
KB-1® (10X Concentrated) Grid Area 3S 608 Points	Liter	608 (10X Concentrated to 60.8 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^α	\$69,920
KB-1® Primer	Pounds	2,313 (7 lbs treats 1,000 G of water)	KB-1® Primer is used to rapidly prepare anaerobic injection water for bioremediation applications including dispersion of electron donors and protection of anaerobic bioaugmentation cultures during injection into aquifers.	\$30 ^α	\$69,390
Complementary KB-1 Trac®	Each	2	Molecular genetic analyses using an 8-target digital array test (KB-1® Trac) to quantify multiple Dhc functional genes and other important KB-1® microbes in site groundwater.	\$435	Provided Free of Charge

Jessenia Guzman Peralta
30 Jul 2025
Si-08773B-073025



Product	Unit	Quantity	Description	Unit Price	AMOUNT
Shipping & Handling (Culture)	Event	8	Outbound and Return Shipping Charges	\$920 ^β	\$7,360
Shipping & Handling (Primer)	Event	1	Outbound Shipping Charges	\$5,875 ^β	\$5,875
Total (USD)					\$384,845*

*plus applicable taxes

^αUnit price costs based on volume discounts for entire project

^βPrices subject to change based on rates at time of shipment

OPTIONAL ADDITIONAL PRODUCTS AND SERVICES

Product	Description
VFAs	Used to monitor the quantity and form of fermentation by products of electron donors – Used to monitor electron donor status and manage (re)application requirements. \$120/sample
Dissolved hydrocarbon gases	Quantifies ethene, the non-toxic dechlorination product of chlorinated ethenes, also quantifies ethane and methane. \$85/sample

NOTES:

1. The proposed bioaugmentation is anticipated to result in reductive dechlorination of chlorinated ethenes in approximately three months (“the response time”) as evidenced by significant trends in production of ethene and/or increasing *Dehalococcoides* concentrations. Should the commencement of complete dechlorination, or increases in *Dehalococcoides* populations, not be achieved within the specified response time, and if all conditions outlined in Attachment A are fulfilled, the guarantee (attached) will be applicable.
2. **Payment terms are Net 30 days.**
3. All price quotes are valid until the expiration date shown in this quotation.
4. Shipping charges are estimates; actual charges are calculated at the time of invoice.
5. Note that SiREM requires a minimum of 2 weeks’ notice to ensure supply of quoted volume of culture.
6. The guarantee and use limitations for the microbial culture are provided in Exhibit A.
7. By your signature below SiREM is authorized to proceed with this the products and services as provided in this Quotation and the signatory and its Company accepts and is bound by SiREM’s Use Limitations (Exhibit A) and the Terms and Conditions for SiREM Products and Services (Exhibit B)

NOTE: RETURN ENTIRE SIGNED DOCUMENT

Exhibit A: Guarantee and Use Limitations

Exhibit B: Terms and Conditions for SiREM Products and Services

If you have any questions concerning this quotation, contact Jeff Roberts (+1 519-515-0840)

Quotation Acceptance:

Name (Signature)		Title:	
Name (Print)		Date:	
E-Mail			
Phone			
Purchase Order Number			
Invoice Remittance Address (if different than above)			
Invoice Remittance E-Mail AP Contact Name & E-Mail			

EXHIBIT A : GUARANTEE AND USE LIMITATIONS

SiREM, a division of Geosyntec Consultants International, Inc, is an authorized distributor of KB-1[®], Low pH KB-1[®] Plus, and KB-1[®] Plus (Custom Formulations) bioaugmentation cultures, proprietary products. This Limited Guarantee and Use Limitations for applications of SiREM's bioaugmentation cultures are subject to the following conditions.

CONDITIONS REQUIRED TO VALIDATE GUARANTEE:

	KB-1 [®]	Low pH KB-1 [®] Plus	KB-1 [®] Plus (custom formulations)
Bioaugmentation culture is injected only by SiREM staff or their approved designate;	x	x	x
initial target VOC concentrations at the site are sufficient to sustain the growth of <i>key degrading</i> organisms (i.e., in excess of 100 micrograms per liter [µg/L]);	x	x	x
inhibitory compounds/conditions	chloroform concentrations in excess of 50 µg/L, 1,1,1-TCA in excess of 200 µg/L) are absent		As specified in order
geochemical conditions	redox levels [ORP] below -75 millivolts [mV], dissolved oxygen levels less than 0.2 milligrams per Liter [mg/L], depletion of sulfate and nitrate, average groundwater temperature above 10°C		
	pH between 6 and 8.5	pH above 5.6	pH between 6 and 8.5
suitable electron donor or acceptor is provided at appropriate concentration consistently	x	x	x
the site is not physically, chemically or geochemically disrupted after bioaugmentation.	x	x	x
Minimum application dosage to achieve indicated response time is 1 liter bioaugmentation culture per 35,000 liters of groundwater	x	x	x

After bioaugmentation, specific organisms attributable to the bioaugmentation culture will colonize the site as determined by increasing concentrations and/or dispersing populations (based on Quantitative Gene-Trac tests relevant to the culture being applied) and/or the appearance of, or increases in, the concentration of degradation end-products (e.g., ethene in the case of chlorinated ethene degradation) (hereafter referred to as "impact[s]"). The impact(s) are to occur within the response time provided in the SiREM's quotation at either the injection point(s), or downgradient, provided the above site conditions are maintained throughout the bioaugmentation and acclimation (response time) period.

LIMITED PERFORMANCE GUARANTEE: In the event there is an absence of impact(s) at the injection points, or downgradient, within the designated response time following bioaugmentation, SiREM will provide an additional quantity of bioaugmentation culture free of charge (including delivery and associated expenses) equal to the initial volume used at the location(s) for which bioaugmentation is deemed unsuccessful. Should additional bioaugmentation to be proven ineffective, SiREM will refund, in full, the cost of the culture (KB-1[®] only) for the specific locations where bioaugmentation is deemed to be unsuccessful.

ADDITIONAL CONDITIONS: This limited guarantee is conditional upon receipt of payment in full for bioaugmentation culture purchases prior to its use. SiREM reserves the right, at its sole discretion, to confirm the concentration of degradation end-products, s organisms and other relevant geochemical parameters by collection and submission of groundwater or soil samples to a mutually agreeable independent laboratory. **No other warranty, expressed or implied, including, but not limited to, any and all warranties of merchantability and/or fitness for a particular purpose is made or intended.**

RESTRICTIONS AND LIMITATIONS

Bioaugmentation culture may only be used as set forth in this Exhibit A, and any project specific parameters that may be attached.

Bioaugmentation culture may only be used at the project site identified in SiREM's proposal.

The Terms and Conditions for SiREM Products and Services, Attachment B, shall apply to the use of SiREM products or services. All other terms or conditions introduced are expressly rejected.

EXHIBIT B: Terms and Conditions for SiREM Products and Services

The following terms and conditions are an integral part of the contractual relationship between the Client ("Client") identified in the Confirming Order or Quotation ("Order") and SiREM, a division of Geosyntec Consultants International, Inc., ("SiREM"), and they apply to the purchase, sale, and shipment of products, equipment, materials or supplies (collectively "Products"), and any related testing, research or evaluative services (collectively "Services") rendered by SiREM. Client and SiREM shall be referred to individually as "Party" and collectively as "Parties":

1. **Acceptance of Terms.** These terms and conditions are incorporated into the Order which shall describe the Products being sold and any related Services to be rendered. The Order and these terms and conditions are deemed accepted and become effective upon Client's acknowledgment of the Order or SiREM's initial performance in accordance with the Order. All prior or contemporaneous terms, representations or agreement, and any proposal or offer of additional or different terms and conditions is expressly rejected. This Order shall constitute the full agreement between the Client and SiREM and all prior or contemporaneous communications, representations or agreements are superseded unless expressly incorporated into this Order by written amendment signed by both Parties.

2. **Delivery.** SiREM shall provide Products or Services as specified in Order. Products shall be packaged and supported in a manner to ensure safety and protection against damage during shipment. Ownership of the Products shall transfer from SiREM to Client upon shipment.

3. **Payment.** All fees and charges, including shipping for Products shall be reflected in the Order. Payment for Products and Services shall be as indicated in the Order. SiREM shall invoice Client and payment is due within 30 days of invoice date. Client shall pay an additional charge of one percent (1%) of the amount of the invoice per month or the maximum percentage allowed by law, whichever is the lesser, for any payment received by SiREM beyond the payment terms set forth herein.

4. **Intellectual Property Rights/Obligations.** Intellectual Property shall mean ideas, results, technical information, patents, patent applications, know-how, copyrights, inventions, developments, trade-secrets, models, drawings, specifications, prototypes, deliverables and discoveries, whether registered or not, relating to the Products and the Services. All rights, including but not limited to ownership rights, to the Intellectual Property in the Products and Services are owned by SiREM and others, but not Client. SiREM is an authorized seller of the Products which are provided to Client in accordance with the limitations imposed upon SiREM. Upon payment in full of the amount reflected in the Order SiREM transfers to the Client a non-exclusive, non-commercial, non-transferable right to use the Products and the associated Intellectual Property for the limited application of the Products as set forth in the Order, and only at the project site described in the Order, and at no other site and for no other project or purpose. The Client does not have, nor will it acquire, any ownership interest or rights in the Product and/or the associated Intellectual Property and Client shall not sell, resell or transfer any of the Products to any third-party under any circumstances. In addition, Client agrees that it will not "reverse engineer" or undertake any activity which would enable Client, or any other person or entity, to duplicate, imitate, reproduce, copy, grow or culture the Products.

5. **Confidential Information.** In connection with the Order, Products and/or Services, Client will have access to confidential, proprietary and other non-public or sensitive information, including but not limited to Intellectual Property, belonging or licensed to SiREM (collectively "Confidential Information"). Except as, and to the extent necessary, to comply with the Order, Client shall not directly or indirectly disclose any Confidential Information. Furthermore, Client agrees (i) the Confidential Information shall be used solely for the purpose intended in this Order; (ii) it will not use any Confidential Information disclosed hereunder to compete with or negatively impact Discloser, either directly or indirectly; (iii) it will not distribute, disclose or disseminate any Confidential Information to anyone except its employees and agents with a need to know and who, in each case, have been informed of the confidential nature of the Confidential Information and have agreed to be bound by the terms of this Order; and (iv) it will keep all Confidential Information separate from all of its other documentation and records. In the event that the Client is requested or required to disclose any part of the Confidential Information, the Client will provide immediate written notice to SiREM for prior approval of release.

6. **Force Majeure.** Neither Party shall be liable for delays or defaults due to an act of god, and act of government, public enemy, strike, natural disaster or other unforeseeable causes beyond the reasonable control of the Parties.

7. **Termination or Suspension.** Client may by written notice terminate or suspend this Order, in whole or in part, for any reason at any time. Upon receipt of a notice of termination SiREM shall immediately stop all performance under this Order. Client shall reimburse SiREM for any costs incurred in connection with the Order up until receipt of the notice of termination.

8. **Assignment.** Neither Party shall assign its obligations under this Order without the prior written approval of the other Party. There shall be no third-party beneficiary to this Order.

9. **Standard of Care.** The Services rendered by SiREM will render its Services in a manner consistent with the level of care and skill ordinarily exercised by other firms rendering the same services under similar circumstances at the same time the Services are performed.

10. **LIMITED WARRANTY.** SiREM WARRANTS THAT THE PRODUCTS SUPPLIED PURSUANT TO THIS ORDER WILL NOT INFRINGE THE INTELLECTUAL PROPERTY RIGHTS OF ANYONE NOT A PARTY TO THIS ORDER. SiREM WARRANTS THAT IT IS DULY LICENSED, QUALIFIED AND CAPABLE OF FULFILLING ITS OBLIGATIONS UNDER THE ORDER. ALL OTHER WARRANTIES AND GUARANTEES OF ANY KIND, WHETHER EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR PURPOSE ARE DISCLAIMED.

11. **Collecting Procedures.** If the Order includes Services for testing, Client will collect and obtain samples to be shipped to and tested by SiREM at Client's sole expense. At Client's request, SiREM will provide sample containers at no cost. If recollection or resampling becomes necessary, for any reason other than SiREM's gross negligence or willful misconduct, Client shall be responsible for re-collecting and re-shipping the samples. The results of the testing will be delivered to Client in SiREM's standard report format.

12. **Liability.** To the maximum extent permitted by Law, Client agrees to limit SiREM's liability for the Client's damages to the greater of SiREM's fee or \$50,000. In no event will SiREM be liable to Client for any incidental or consequential damages arising in connection with this Order, the use of the Product or the Services rendered by SiREM.

13. **Disputes.** The Parties agree to promptly resolve their differences through good faith negotiations as a condition precedent to filing a formal claim. In the event disputes remain following such negotiations, any remaining dispute shall be submitted to senior representatives of the Parties who shall have the authority to enter into an agreement to resolve the dispute ("Representative"). The Representatives shall not have been directly involved in the performance of the Subcontracted Services. If the Representatives are unable to resolve the dispute within three weeks or within such longer time period as the Representatives may agree, the dispute shall be mediated by an independent third-party agreed to by both parties. Any disputes or portions thereof remaining following mediation shall be determined by remedies at law or equity, as they may be available, subject to the limitations in this Agreement. Any applicable statute of limitations on any claim in any way related to Agreement shall commence to run and alleged cause of action shall be deemed to have accrued no later than the date of either SiREM's final invoice or termination of this Agreement by either Party. Both Parties agree that the applicable statute of limitations for any claims in any way related to this Agreement shall be shortened to a period not longer than two years, unless a shorter statute of limitations would otherwise apply.

Quotation to:	Ship to:	Quotation: Si-08773C-073025
Jessenia Guzman Peralta HDR 50 Tice Blvd, Suite 210 Woodcliff Lake, NJ 07677 201-335-9330 Jessenia.GuzmanPeralta@hdrinc.com	1203 E Grand Avenue, #B Marshall, TX 75670	Date: 30 Jul 2025 Site name: Longhorn Army Ammunition Plant Valid until: 31 Dec 2025 Prepared by: Jeff Roberts

Product	Unit	Quantity	Description	Unit Price	AMOUNT
KB-1® (10X Concentrated) Grid Area 1S1 260 Points	Liter	780 (10X Concentrated to 78.0 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^a	\$89,700
KB-1® (10X Concentrated) Grid Area 2S1 56 Points	Liter	168 (10X Concentrated to 16.8 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^a	\$19,320
KB-1® (10X Concentrated) Grid Area 3S1 128 Points	Liter	384 (10X Concentrated to 38.4 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^a	\$44,160
KB-1® (10X Concentrated) Grid Area 456S1 1224 Points	Liter	3,672 (10X Concentrated to 367.2 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^a	\$422,280
KB-1® (10X Concentrated) Bio1-South 81 Points	Liter	324 (10X Concentrated to 32.4 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^a	\$37,260

Product	Unit	Quantity	Description	Unit Price	AMOUNT
KB-1® (10X Concentrated) Bio1-South 81 Points	Liter	324 (10X Concentrated to 32.4 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^a	\$37,260
KB-1® (10X Concentrated) Bio1-South 81 Points	Liter	324 (10X Concentrated to 32.4 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^a	\$37,260
KB-1® (10X Concentrated) Bio2 36 Points	Liter	144 (10X Concentrated to 14.4 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^a	\$16,560
KB-1® (10X Concentrated) Bio1-North 21 Points	Liter	84 (10X Concentrated to 8.4 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^a	\$9,660
KB-1® (10X Concentrated) Bio3 29 Points	Liter	116 (10X Concentrated to 11.6 L)	KB-1® is a natural microbial consortium containing Dehalococcoides bacteria that dechlorinate chlorinated ethenes to ethene.	\$115 ^a	\$13,340
KB-1® Primer	Pounds (7 lbs treats 1,000 G of water)	1,615	KB-1® Primer is used to rapidly prepare anaerobic injection water for bioremediation applications including dispersion of electron donors and protection of anaerobic bioaugmentation cultures during injection into aquifers.	\$30 ^a	\$48,450

Jessenia Guzman Peralta
30 Jul 2025
Si-08773C-073025



Product	Unit	Quantity	Description	Unit Price	AMOUNT
Complementary KB-1 Trac®	Each	2	Molecular genetic analyses using an 8-target digital array test (KB-1® Trac) to quantify multiple Dhc functional genes and other important KB-1® microbes in site groundwater.	\$435	Provided Free of Charge
Shipping & Handling (Culture)	Event	13	Outbound and Return Shipping Charges	\$1,150 β	\$14,950
Shipping & Handling (Primer)	Event	1	Outbound Shipping Charges	\$4,125 β	\$4,125
Total (USD)					\$719,805*

*plus applicable taxes

^αUnit price costs based on volume discounts for entire project

^βPrices subject to change based on rates at time of shipment

Jessenia Guzman Peralta
30 Jul 2025
Si-08773C-073025



OPTIONAL ADDITIONAL PRODUCTS AND SERVICES

Product	Description
VFAs	Used to monitor the quantity and form of fermentation by products of electron donors – Used to monitor electron donor status and manage (re)application requirements. \$120/sample
Dissolved hydrocarbon gases	Quantifies ethene, the non-toxic dechlorination product of chlorinated ethenes, also quantifies ethane and methane. \$85/sample

NOTES:

1. The proposed bioaugmentation is anticipated to result in reductive dechlorination of chlorinated ethenes in approximately three months ("the response time") as evidenced by significant trends in production of ethene and/or increasing *Dehalococcoides* concentrations. Should the commencement of complete dechlorination, or increases in *Dehalococcoides* populations, not be achieved within the specified response time, and if all conditions outlined in Attachment A are fulfilled, the guarantee (attached) will be applicable.
2. **Payment terms are Net 30 days.**
3. All price quotes are valid until the expiration date shown in this quotation.
4. Shipping charges are estimates; actual charges are calculated at the time of invoice.
5. Note that SiREM requires a minimum of 2 weeks' notice to ensure supply of quoted volume of culture.
6. The guarantee and use limitations for the microbial culture are provided in Exhibit A.
7. By your signature below SiREM is authorized to proceed with this the products and services as provided in this Quotation and the signatory and its Company accepts and is bound by SiREM's Use Limitations (Exhibit A) and the Terms and Conditions for SiREM Products and Services (Exhibit B)

NOTE: RETURN ENTIRE SIGNED DOCUMENT

Exhibit A: Guarantee and Use Limitations

Exhibit B: Terms and Conditions for SiREM Products and Services

If you have any questions concerning this quotation, contact Jeff Roberts (+1 519-515-0840)

Quotation Acceptance:

Name (Signature)		Title:	
Name (Print)		Date:	
E-Mail			
Phone			
Purchase Order Number			
Invoice Remittance Address (if different than above)			
Invoice Remittance E-Mail AP Contact Name & E-Mail			

EXHIBIT A : GUARANTEE AND USE LIMITATIONS

SiREM, a division of Geosyntec Consultants International, Inc, is an authorized distributor of KB-1[®], Low pH KB-1[®] Plus, and KB-1[®] Plus (Custom Formulations) bioaugmentation cultures, proprietary products. This Limited Guarantee and Use Limitations for applications of SiREM's bioaugmentation cultures are subject to the following conditions.

CONDITIONS REQUIRED TO VALIDATE GUARANTEE:

	KB-1 [®]	Low pH KB-1 [®] Plus	KB-1 [®] Plus (custom formulations)
Bioaugmentation culture is injected only by SiREM staff or their approved designate;	x	x	x
initial target VOC concentrations at the site are sufficient to sustain the growth of <i>key degrading</i> organisms (i.e., in excess of 100 micrograms per liter [µg/L]);	x	x	x
inhibitory compounds/conditions	chloroform concentrations in excess of 50 µg/L, 1,1,1-TCA in excess of 200 µg/L) are absent		As specified in order
geochemical conditions	redox levels [ORP] below -75 millivolts [mV], dissolved oxygen levels less than 0.2 milligrams per Liter [mg/L], depletion of sulfate and nitrate, average groundwater temperature above 10°C		
	pH between 6 and 8.5	pH above 5.6	pH between 6 and 8.5
suitable electron donor or acceptor is provided at appropriate concentration consistently	x	x	x
the site is not physically, chemically or geochemically disrupted after bioaugmentation.	x	x	x
Minimum application dosage to achieve indicated response time is 1 liter bioaugmentation culture per 35,000 liters of groundwater	x	x	x

After bioaugmentation, specific organisms attributable to the bioaugmentation culture will colonize the site as determined by increasing concentrations and/or dispersing populations (based on Quantitative Gene-Trac tests relevant to the culture being applied) and/or the appearance of, or increases in, the concentration of degradation end-products (e.g., ethene in the case of chlorinated ethene degradation) (hereafter referred to as "impact[s]"). The impact(s) are to occur within the response time provided in the SiREM's quotation at either the injection point(s), or downgradient, provided the above site conditions are maintained throughout the bioaugmentation and acclimation (response time) period.

LIMITED PERFORMANCE GUARANTEE: In the event there is an absence of impact(s) at the injection points, or downgradient, within the designated response time following bioaugmentation, SiREM will provide an additional quantity of bioaugmentation culture free of charge (including delivery and associated expenses) equal to the initial volume used at the location(s) for which bioaugmentation is deemed unsuccessful. Should additional bioaugmentation to be proven ineffective, SiREM will refund, in full, the cost of the culture (KB-1[®] only) for the specific locations where bioaugmentation is deemed to be unsuccessful.

ADDITIONAL CONDITIONS: This limited guarantee is conditional upon receipt of payment in full for bioaugmentation culture purchases prior to its use. SiREM reserves the right, at its sole discretion, to confirm the concentration of degradation end-products, s organisms and other relevant geochemical parameters by collection and submission of groundwater or soil samples to a mutually agreeable independent laboratory. **No other warranty, expressed or implied, including, but not limited to, any and all warranties of merchantability and/or fitness for a particular purpose is made or intended.**

RESTRICTIONS AND LIMITATIONS

Bioaugmentation culture may only be used as set forth in this Exhibit A, and any project specific parameters that may be attached.

Bioaugmentation culture may only be used at the project site identified in SiREM's proposal.

The Terms and Conditions for SiREM Products and Services, Attachment B, shall apply to the use of SiREM products or services. All other terms or conditions introduced are expressly rejected.

EXHIBIT B: Terms and Conditions for SiREM Products and Services

The following terms and conditions are an integral part of the contractual relationship between the Client ("Client") identified in the Confirming Order or Quotation ("Order") and SiREM, a division of Geosyntec Consultants International, Inc., ("SiREM"), and they apply to the purchase, sale, and shipment of products, equipment, materials or supplies (collectively "Products"), and any related testing, research or evaluative services (collectively "Services") rendered by SiREM. Client and SiREM shall be referred to individually as "Party" and collectively as "Parties":

1. **Acceptance of Terms.** These terms and conditions are incorporated into the Order which shall describe the Products being sold and any related Services to be rendered. The Order and these terms and conditions are deemed accepted and become effective upon Client's acknowledgment of the Order or SiREM's initial performance in accordance with the Order. All prior or contemporaneous terms, representations or agreement, and any proposal or offer of additional or different terms and conditions is expressly rejected. This Order shall constitute the full agreement between the Client and SiREM and all prior or contemporaneous communications, representations or agreements are superseded unless expressly incorporated into this Order by written amendment signed by both Parties.

2. **Delivery.** SiREM shall provide Products or Services as specified in Order. Products shall be packaged and supported in a manner to ensure safety and protection against damage during shipment. Ownership of the Products shall transfer from SiREM to Client upon shipment.

3. **Payment.** All fees and charges, including shipping for Products shall be reflected in the Order. Payment for Products and Services shall be as indicated in the Order. SiREM shall invoice Client and payment is due within 30 days of invoice date. Client shall pay an additional charge of one percent (1%) of the amount of the invoice per month or the maximum percentage allowed by law, whichever is the lesser, for any payment received by SiREM beyond the payment terms set forth herein.

4. **Intellectual Property Rights/Obligations.** Intellectual Property shall mean ideas, results, technical information, patents, patent applications, know-how, copyrights, inventions, developments, trade-secrets, models, drawings, specifications, prototypes, deliverables and discoveries, whether registered or not, relating to the Products and the Services. All rights, including but not limited to ownership rights, to the Intellectual Property in the Products and Services are owned by SiREM and others, but not Client. SiREM is an authorized seller of the Products which are provided to Client in accordance with the limitations imposed upon SiREM. Upon payment in full of the amount reflected in the Order SiREM transfers to the Client a non-exclusive, non-commercial, non-transferable right to use the Products and the associated Intellectual Property for the limited application of the Products as set forth in the Order, and only at the project site described in the Order, and at no other site and for no other project or purpose. The Client does not have, nor will it acquire, any ownership interest or rights in the Product and/or the associated Intellectual Property and Client shall not sell, resell or transfer any of the Products to any third-party under any circumstances. In addition, Client agrees that it will not "reverse engineer" or undertake any activity which would enable Client, or any other person or entity, to duplicate, imitate, reproduce, copy, grow or culture the Products.

5. **Confidential Information.** In connection with the Order, Products and/or Services, Client will have access to confidential, proprietary and other non-public or sensitive information, including but not limited to Intellectual Property, belonging or licensed to SiREM (collectively "Confidential Information"). Except as, and to the extent necessary, to comply with the Order, Client shall not directly or indirectly disclose any Confidential Information. Furthermore, Client agrees (i) the Confidential Information shall be used solely for the purpose intended in this Order; (ii) it will not use any Confidential Information disclosed hereunder to compete with or negatively impact Discloser, either directly or indirectly; (iii) it will not distribute, disclose or disseminate any Confidential Information to anyone except its employees and agents with a need to know and who, in each case, have been informed of the confidential nature of the Confidential Information and have agreed to be bound by the terms of this Order; and (iv) it will keep all Confidential Information separate from all of its other documentation and records. In the event that the Client is requested or required to disclose any part of the Confidential Information, the Client will provide immediate written notice to SiREM for prior approval of release.

6. **Force Majeure.** Neither Party shall be liable for delays or defaults due to an act of god, and act of government, public enemy, strike, natural disaster or other unforeseeable causes beyond the reasonable control of the Parties.

7. **Termination or Suspension.** Client may by written notice terminate or suspend this Order, in whole or in part, for any reason at any time. Upon receipt of a notice of termination SiREM shall immediately stop all performance under this Order. Client shall reimburse SiREM for any costs incurred in connection with the Order up until receipt of the notice of termination.

8. **Assignment.** Neither Party shall assign its obligations under this Order without the prior written approval of the other Party. There shall be no third-party beneficiary to this Order.

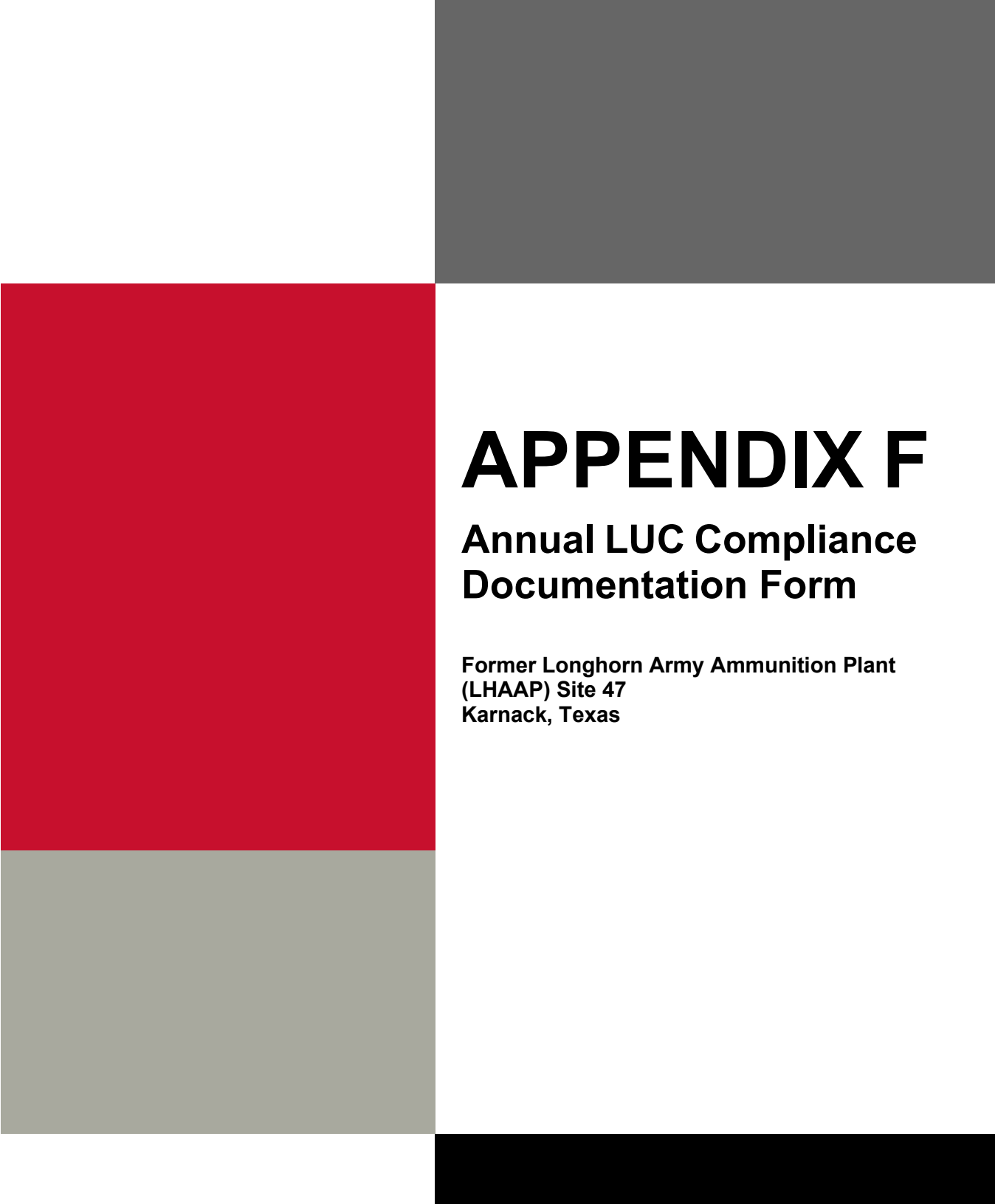
9. **Standard of Care.** The Services rendered by SiREM will render its Services in a manner consistent with the level of care and skill ordinarily exercised by other firms rendering the same services under similar circumstances at the same time the Services are performed.

10. **LIMITED WARRANTY.** SiREM WARRANTS THAT THE PRODUCTS SUPPLIED PURSUANT TO THIS ORDER WILL NOT INFRINGE THE INTELLECTUAL PROPERTY RIGHTS OF ANYONE NOT A PARTY TO THIS ORDER. SiREM WARRANTS THAT IT IS DULY LICENSED, QUALIFIED AND CAPABLE OF FULFILLING ITS OBLIGATIONS UNDER THE ORDER. ALL OTHER WARRANTIES AND GUARANTEES OF ANY KIND, WHETHER EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR PURPOSE ARE DISCLAIMED.

11. **Collecting Procedures.** If the Order includes Services for testing, Client will collect and obtain samples to be shipped to and tested by SiREM at Client's sole expense. At Client's request, SiREM will provide sample containers at no cost. If recollection or resampling becomes necessary, for any reason other than SiREM's gross negligence or willful misconduct, Client shall be responsible for re-collecting and re-shipping the samples. The results of the testing will be delivered to Client in SiREM's standard report format.

12. **Liability.** To the maximum extent permitted by Law, Client agrees to limit SiREM's liability for the Client's damages to the greater of SiREM's fee or \$50,000. In no event will SiREM be liable to Client for any incidental or consequential damages arising in connection with this Order, the use of the Product or the Services rendered by SiREM.

13. **Disputes.** The Parties agree to promptly resolve their differences through good faith negotiations as a condition precedent to filing a formal claim. In the event disputes remain following such negotiations, any remaining dispute shall be submitted to senior representatives of the Parties who shall have the authority to enter into an agreement to resolve the dispute ("Representative"). The Representatives shall not have been directly involved in the performance of the Subcontracted Services. If the Representatives are unable to resolve the dispute within three weeks or within such longer time period as the Representatives may agree, the dispute shall be mediated by an independent third-party agreed to by both parties. Any disputes or portions thereof remaining following mediation shall be determined by remedies at law or equity, as they may be available, subject to the limitations in this Agreement. Any applicable statute of limitations on any claim in any way related to Agreement shall commence to run and alleged cause of action shall be deemed to have accrued no later than the date of either SiREM's final invoice or termination of this Agreement by either Party. Both Parties agree that the applicable statute of limitations for any claims in any way related to this Agreement shall be shortened to a period not longer than two years, unless a shorter statute of limitations would otherwise apply.



APPENDIX F

Annual LUC Compliance Documentation Form

**Former Longhorn Army Ammunition Plant
(LHAAP) Site 47
Karnack, Texas**

Annual Land Use Control Compliance Inspection Form

In accordance with the Remedial Design dated _____ for LHAAP-47 an inspection of the site was conducted by _____ [indicate transferee] on _____.

The land use control mechanisms are:

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

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

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

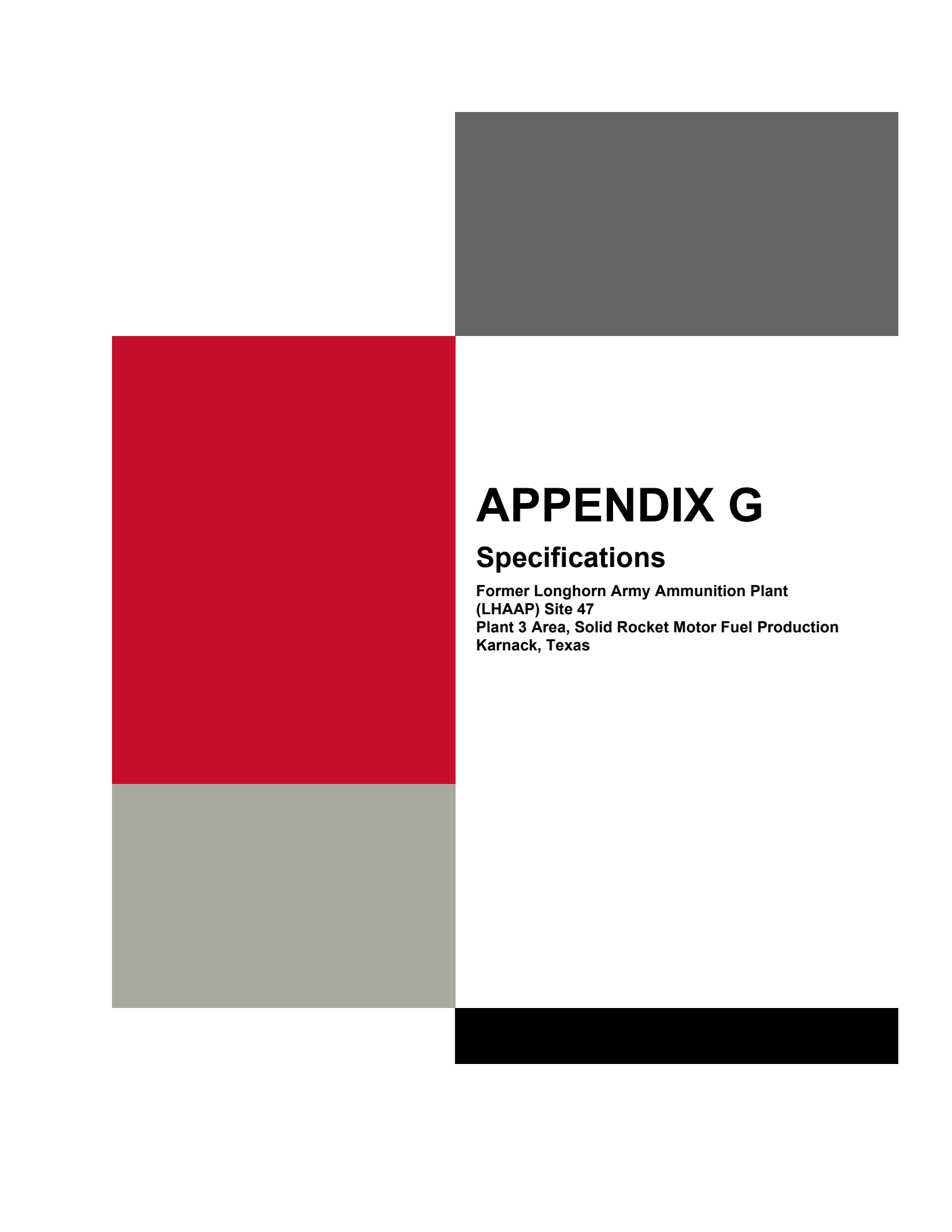
I, the undersigned, do document that the inspection was conducted as indicated above, and that the above information is true and correct to the best of my knowledge, information, and belief.

Date: _____

Name/Title: _____

Signature: _____

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



APPENDIX G

Specifications

**Former Longhorn Army Ammunition Plant
(LHAAP) Site 47**

**Plant 3 Area, Solid Rocket Motor Fuel Production
Karnack, Texas**

Table of Contents

Division 1

Section No.

01 35 45

Title

Chemical Data Quality Control

Division 2

Section No.

02 53 17

Title

In-Situ Bioremediation Injection Procedures and Monitoring

Division 3

Section No.

31 23 00

Title

Backfill, Compaction, and Grading

31 23 10

Excavation and Handling of Contaminated Materials

31 23 20

Transportation and Disposal of Contaminated Material

31 25 00

Erosion Control and Stormwater Management

31 38 50

Site Restoration

SECTION 01 35 45
CHEMICAL DATA QUALITY CONTROL

PART 1 - GENERAL

1.1 SUMMARY

- A. This section covers requirements for the Contractor's Chemical Data Quality Control (CDQC) for Remedial Action (RA) work at the site. This section is to be used to prepare a Uniform Federal Policy Quality Assurance Project Plan (UFP-QAPP) for the project utilizing a Basewide UFP-QAPP available as part of the Installation-Wide Work Plan (IWWP) for the Longhorn Army Ammunition Site (Bhate, 2018). The project UFP-QAPP shall be prepared for securing laboratory(ies), monitoring of subcontract laboratory performance, data validation, data reporting, and preparing a chemical data final report. The project UFP-QAPP shall contain the necessary technical detail and directions for all sampling and field measurements and specifies all quality assurance (QA) and quality control (QC) procedures required for planning, implementation, and assessment of the RA.
- B. Field measurements and samples shall be collected by the Contractor and will include but not limited to:
 - 1. Samples related to excavation
 - a. Waste characterization sampling (soil and water)
 - b. Post-excavation confirmation sampling (soil)
 - c. Field photoionization detector (PID) readings
 - d. Backfill materials sampling
 - e. Topsoil sampling
 - f. Sampling beneath stockpile areas to check for stockpiles cross-contaminating underlying material (soil)
 - 2. Performance monitoring sampling (soil and groundwater) during in-situ thermal desorption (ISTD) implementation
 - 3. Baseline and Performance monitoring sampling during In-situ Bioremediation (ISB) pilot testing and full-scale ISB implementation (groundwater and surface water)

1.2 REFERENCES

- A. References
 - 1. The publications listed below form a part of this Specification to the extent referenced. The publications are referred to in the text by basic designation only. Where reference is made to one of the standards below, the revision in effect at the time of contract award shall apply.
 - a. American Society for Testing and Materials (ASTM)
 - 1) ASTM D5268-23 Standard Specification for Topsoil Used for Landscaping and Construction Purposes.
 - b. United States Army Corps of Engineers (USACE), Tulsa District
 - 1) Final Installation Wide Work Plan for Longhorn Army Ammunition Plant (LHAAP IWWP), Karnack, Texas, revised by Bhate Environmental Associates, Inc. (May 2018; IWWP).
 - 2) Final Basewide Uniform Federal Policy Quality Assurance Project Plan – Longhorn Army Ammunition Plan (May 2018; Basewide UFP-QAPP)
 - c. Environmental Protection Agency (EPA)

- 1) EPA 450/4-89/015 Data Quality Objectives for Ambient Air Monitoring Around Superfund Sites (Stages I and II).
 - 2) EPA 450/4-89/005 Non-Methane Organic Compound Monitoring Program, Final Report, Volume II: Urban Air Toxics Monitoring Program.
 - 3) EPA 402/B-04/001A Multi-Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual, Volume I.
 - 4) EPA/240/B-06/001 Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4. February 2006.
 - 5) EPA/240/R-02/009 Guidance for Quality Assurance Project Plans, EPA QA/G-5. December 2002.
 - 6) EPA/240/B-01/003 EPA Requirements for Quality Assurance Project Plans, EPA QA/R-5. March 2001. Reissued May 2006.
 - 7) EPA 540/P-87/001B Compendium of Superfund Field Operation Methods, Volume 2.
 - 8) EPA 540/R-014/013 Sampler's Guide: Contract Laboratory Program Guidance for Field Samplers. October 2014.
 - 9) EPA 542-R-20-006 National Functional Guidelines for Inorganic Superfund Data Review. November 2020.
 - 10) EPA 540-R-20-005 National Functional Guidelines for Superfund Organic Methods Data Review. November 2020.
 - 11) EPA 540-R-20-005 Sampler's Guide: Contract Laboratory Program Guidance for Field Samplers. November 2020.
 - 12) EPA 600/R-96/055 Guidance for the Data Quality Objective Process, August 2000
 - 13) EPA 600/R-04/003 National Environmental Laboratory Accreditation Conference (NELAC) Standard, Chapter 5 – Quality Systems, June 2003 (or the 2009 NELAC Institute standards if already implemented by the applicable state accrediting body).
 - 14) EPA 600/4-79/020 Methods for Chemical Analysis of Water and Wastes. March 1983.
 - 15) Directive 9240.0-05A EPA Specifications and Guidance for Contaminant-Free Sample Containers, EPA/540/R-93/051.
 - 16) Directive 9200.1-103 Inclusion of Scribe into the Role of Tracking Superfund Sampling Data.
 - 17) EPA Contract Laboratory Program, Statement of Work for Superfund Analytical Methods, Multi-Media, Multi-Concentration (SFAM01.1). November 2020.
- d. Intergovernmental Data Quality Task Force (IDQTF)
- 1) EPA 505/B-04/900A Intergovernmental Data Quality Task Force (IDQTF), Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP) Part 1 - Evaluating, Assessing, and Documenting Environmental Data Collection and Use Programs. March 2005.
 - 2) EPA 505/B-04/900B Intergovernmental Data Quality Task Force (IDQTF), Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP) Part 2B – Quality Assurance/Quality Control Compendium: Minimum QA/QC Activities. March 2005.
 - 3) EPA 505/B-04/900C Intergovernmental Data Quality Task Force (IDQTF), Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP) Part 2A – UFP-QAPP Workbook (March 2005). Optimized UFP-QAPP Worksheets. March 2012.
- e. Code of Federal Regulations (CFR)

- 1) 40 CFR 261 Identification and Listing of Hazardous Waste.

B. Definitions

1. The definition of acronyms used by the Contractor that pertain to CDQC shall be clearly defined for all contract-related products and communications.

1.3 SUBMITTALS

- A. Approval from the Contracting Officer's Representative, in consultation with the regulators is required for submittals with an "RA" designation; submittals having an "FIO" designation are for information only. The Contractor shall submit the following to the Contracting Officer's Representative:
1. Contractor Uniform Federal Policy Quality Assurance Project Plan (UFP-QAPP); Pre-Construction Submittals; RA
 - a. The Contractor UFP-QAPP (modified from the Basewide UFP-QAPP, provided in Appendix C of the IWWP) shall be submitted to the Contracting Officer's Representative for approval at least 30 calendar days prior to the Pre-Work Conference in accordance with Paragraph 3.3.
 2. Trip Report; Test Reports; FIO
 - a. The Contractor shall submit Trip Reports in accordance with Paragraph 1.5.H.1.a.
 3. Topsoil and Backfill Material Testing Results; Test Reports; RA
 - a. The Contractor shall submit topsoil and backfill sample results to the Contracting Officer's Representative for approval prior to use of such sources in accordance with Paragraph 3.5.A.2.
 4. Analytical Data; Test Reports; FIO
 - a. An electronic copy of all the analytical data collected at the site shall be submitted to the Contracting Officer's Representative in accordance with Paragraph 3.8.B.
 5. Field Screening Data; Test Reports; FIO
 - a. Electronic copy of all field screening data collected at the site to verify the effectiveness of the decontamination method.
 6. Non-Conformance Reports; Test Reports; FIO
 - a. Reports shall be submitted within 48-hours of the occurrence of any significant problem with sampling, analytical procedures, instrument calibration and maintenance, and project quality control. Significant problems shall include, without limitation, the items specified herein as requiring corrective actions by the Contractor.
 7. Chemical Data Final Report (CDFR); Test Reports; RA
 - a. The CDFR as described in Paragraph 3.10 shall be submitted to the Contracting Officer's Representative within 30 calendar days of completing work (submitted separately for each RA component: soil excavation, ISTD, and ISB) at the site and before final payment. Each report shall be labeled with the contract number, project name, and location.

1.4 ADMINISTRATIVE REQUIREMENTS

A. Coordination Meeting

1. The Contractor shall meet with the Contracting Officer's Representative at the construction site prior to construction and discuss the CDQC Plan and the UFP-QAPP.
2. The coordination meeting shall be simultaneous to any required CQC coordination meeting unless otherwise indicated or directed.

3. A list of definable features of work that involve chemical measurements shall be agreed upon. At a minimum, each matrix (soil, groundwater, surface water, etc.) shall be a definable feature of work.
4. Management of the chemical data quality system including project DQOs, project submittals, chemical data documentation, chemical data assessment, required sampling and analysis protocols, and minimum data reporting requirements shall be agreed upon.
5. The meeting will serve to establish an interrelationship between the Contractor's chemical data quality management and USACE chemical quality assurance requirements.
6. Minutes of the meeting shall be documented by the Contractor and shall be signed by both the Contractor and the Contracting Officer's Representative. The minutes shall include any or all unresolved chemical issues along with the conditions for resolution and shall become a part of the contract file.
7. There may be occasions when subsequent conferences will be called by either party to reconfirm mutual understandings and/or address deficiencies in the CQC system or procedures that may require corrective action by the Contractor.

1.5 QUALITY ASSURANCE

- A. The Contractor shall be responsible for the following QA/QC elements necessary to monitor and ensure the quality of chemical data produced.
- B. Analytical Testing Laboratories
 1. The Contractor shall use the pre-contracted and pre-approved laboratory indicated in the Basewide UFP-QAPP.
 2. The use of subcontract laboratories shall be approved by the Contracting Officer's Representative. The Contractor shall provide justification for use of a subcontract laboratory to the Contracting Officer's Representative indicating the required analyses, turnaround times, special requests, etc. The subcontract laboratory shall meet the certification requirements listed in Paragraph 1.5.E.
- C. Subcontracted Laboratory Analytical Requirements
 1. The Contractor shall provide chemical analyses for all parameters by methods specified in the Contract Documents to achieve the project DQOs.
- D. Subcontract Laboratory Certification
 1. Environmental laboratory services are to be provided only by laboratories compliant with the most recently published version of the DOD Quality Systems Manual (QSM), including the National Environmental Laboratory Accreditation Conference (NELAC) Standard Chapter 5 and Appendix requirements (EPA/600/R-04/003), holding a current National Environmental Laboratory Accreditation Program (NELAP) accreditation for all appropriate fields-of-testing, and certified by the State of Texas. Before testing services can be performed by the laboratory, the Contractor shall verify the candidate laboratory's acceptability by reviewing their certifications. NELAP accreditation information is to be provided annually. The laboratory shall notify the Contracting Officer's Representative immediately of any change in the status of laboratory operations that may affect ongoing compliance with these requirements. The Contracting Officer's Representative may, at any time, conduct audits (including requests for pertinent data or information) that support an environmental laboratory's self-declaration of compliance with this policy. If the Contracting Officer's Representative finds the laboratory is in non-compliance, the Contractor shall utilize alternate, compliant laboratory services until such time as compliance is again demonstrated. Before

performing environmental testing, the laboratory shall have access to the approved UFP-QAPP.

E. Subcontracted Laboratory Performance

1. The Contractor shall provide oversight to ensure continued acceptable analytical performance and shall establish a procedure to address data deficiencies noted by review and/or quality control sample results. The Contractor shall provide and implement a mechanism for providing analytical laboratories with the UFP-QAPP, for monitoring the laboratory's performance and for performing corrective action procedures. The Contractor shall acquire analytical services with NELAP-accredited and State of Texas -certified laboratories.

F. Contractor QC Sample Collection and Analysis

1. QC samples shall be collected and analyzed by the Contractor in accordance with the Contract Laboratory Program Guidance for Field Samplers (EPA 540/R-014/013), the Basewide UFP-QAPP, and other guidance documents and the Contractor's approved UFP-QAPP. QC samples shall be collected as described in the Contractor's approved UFP-QAPP. The following summarizes the minimum QC sampling requirements:
 - a. Field duplicates shall be collected at the rates specified in the Basewide UFP-QAPP.
 - b. The Contractor shall include one trip blank with each cooler that contains aqueous samples collected for VOC analysis to verify the presence or absence of cross contamination in VOC samples during handling and shipment from the field to the laboratory (as specified in the Basewide UFP-QAPP).
 - c. Equipment/rinsate blanks shall be collected at a frequency of one per decontamination event, not to exceed one per day, for each equipment type and for each sample matrix to assess the effectiveness of equipment decontamination (as specified in the Basewide UFP-QAPP).
 - d. The Contractor shall include one cooler temperature indicator or "temperature blank" in each cooler containing samples (solid and aqueous) for analysis to verify that samples have been maintained at 0-6° C (as specified in the Basewide UFP-QAPP).
 - e. The Contractor will collect one matrix spike/matrix spike duplicate (MS/MSD) at the rate specified in the Basewide UFP-QAPP to demonstrate the accuracy of laboratory analysis. MS/MSDs are not required for VOC and SVOC analysis in EPA Region 6.

G. Documentation of Sample Collection and Analysis

1. Subcontract Laboratory
 - a. The Contractor shall meet the timing, pathways, documentation, etc. requirements specified in the Basewide UFP-QAPP.

H. Review of Primary Laboratory Data

- a. The Contractor shall be responsible for the independent review of the entire data set.

I. Data Validation

1. The Contractor shall validate analytical data for samples analyzed by the Contractor's subcontract laboratory. The Contractor shall provide validation SOPs for methods listed in the UFP-QAPP. Radionuclide data shall be evaluated in accordance with MARLAP Chapter 8, Section 5 (EPA/402/B-04/001A). Items listed below shall be assessed as part of the data validation. The data validation criteria shall be consistent with project DQOs and discussed in the approved UFP-QAPP. The Contractor shall prepare a data validation report, which shall include a

summary of the independent data reviewer's findings. The summary shall consist of a table listing each QC result outside of established criteria, the established criteria, and the validation actions. Comments shall be included on how these data affect the validity of analytical results of the samples including data qualifiers used. The data validation report shall include, but not be limited to, the following parameters:

- a. Data completeness
 - b. Method blank and field blank results
 - c. Holding time including sample integrity
 - d. Surrogate recovery results
 - e. Instrument calibration
 - f. Matrix spike results
 - g. Continuing calibration verification
 - h. Laboratory and field duplicate results
 - i. Laboratory control samples
 - j. Verification of sample results
2. The Contractor shall have the laboratory data validated by an organization independent of the organization generating the data. The data validation reports shall be submitted as an appendix to the Chemical Data Final Report discussed in Paragraph 3.10.
 3. Data validation shall be conducted as specified in the Basewide UFP-QAPP.

PART 2 - PRODUCTS (NOT APPLICABLE TO THIS SPECIFICATION SECTION)

PART 3 - EXECUTION

3.1 GENERAL REQUIREMENTS

- A. The Contractor shall be responsible for chemical sample acquisition, sample analysis, instrumental measurements of chemical parameters and for CDQC. An effective CDQC system that meets the requirements for the chemical measurement DQO applicable to the project shall be established. The chemical data QC system shall consist of a chemical Quality Management staff responsible for the UFP-QAPP, analytical procedures, minimum data reporting requirements and the organization necessary to produce the required chemical data. The system shall cover chemical measurements pertaining to and required for Contractor- and subcontractor-produced chemical data. The Contractor shall control field screening, sampling, and testing in conjunction with remedial activities to meet all DQOs, minimize the amount of excavated material requiring temporary storage, prevent dilution of contaminated soils with clean soils, and ensure completion of work within the required time.

3.2 CONTRACTOR QUALITY CONTROL PLAN

- A. General
 1. The CQC Plan shall incorporate the qualifications, authority and responsibilities of all chemical quality management and support personnel.
- B. Chemistry Elements of the CQC Plan
 1. To cover contract related chemical measurements by the Contractor and all subcontractors, the CQC Plan shall include the following at a minimum:
 - a. Qualifications
 - 1) Names, education, experience qualifications, authorities, and decision-making responsibilities of all chemical quality management and support personnel (as exemplified in the Basewide UFP-QAPP). The CQC Plan

shall contain a copy of a letter from the project QC manager designating and authorizing a Chemical Quality Control Officer and chemical quality control organization staff.

b. Authority and Responsibility

- 1) A diagram, flow chart, or figure clearly depicting the chemical data quality management and support staff and the authority and responsibility of each of the staff for chemical sampling and analysis, procedures for corrective actions, deliverables and submittals, deviations and changes, chemical quality documentation, data validation, minimum data reporting requirements, and DQO for chemical parameter measurement by the Contractor and subcontractors (as exemplified in the Basewide UFP-QAPP). The contents of this section of the CQC Plan shall be included in the applicable "Project Organization" elements of the QAPP.

3.3 UNIFORM FEDERAL POLICY QUALITY ASSURANCE PROJECT PLAN (UFP-QAPP)

A. General

1. The UFP-QAPP shall describe all chemical parameter measurements for all phases of the remedial action. The Contractor must provide sufficient detail for the project team to obtain data that meet the DQOs of the project. The Contractor's QAPP shall be in accordance with the UFP-QAPP Manuals referenced in Paragraph 1.2.

B. Level of Detail

1. The UFP-QAPP shall contain necessary technical details and directions (as exemplified in the Basewide UFP-QAPP), such that field and laboratory personnel understand all sampling and field measurement requirements. It shall document all aspects of the project, planning, implementation, assessment, corrective actions, and reconciliation of completed tasks with documented planned objectives. It shall contain sufficient direction and detail that on-site personnel can perform all on-site activities required to attain project DQOs, including collection of samples for off-site chemical analysis, shipment of samples for off-site analyses, performance of on-site instrument measurements, and documentation and reporting requirements. The level of detail in the UFP-QAPP shall be such that any technically competent personnel unfamiliar with the Site can follow the plan and perform all required work. It shall contain sufficient direction and detail that analytical laboratory personnel understand the analytical methods required and project-required reporting limits, project DQIs measurement performance criteria, and project data validation and reporting requirements.

C. Appendices

1. The Appendices section of the UFP-QAPP shall contain all Contractor standard forms, project figures and tables, and SOPs, and all references pertaining to the project requirements included in the UFP-QAPP relating to project DQOs, standard and non-standard measurement methods, equivalency data, U.S. Government and regional agency guidance and regulatory documents, existing Site-related documents, and other contract-related chemical analysis documents (as exemplified in the Basewide UFP-QAPP). Reference to all applicable SOPs from EPA/540/P-87/001B, Compendium of Superfund Field Operations Methods, or Contractor SOPs, where applicable, shall be included.

D. Content

1. The UFP-QAPP shall meet the requirements of the UFP-QAPP Manual and shall cover, at a minimum, the following topics:
 - a. Distribution List

- b. Title and Approval Page
 - c. Project Description
 - d. Introduction, including Summary of Scope and Objectives, Site History and Contaminants
 - e. Existing Site Data Summary – Evaluation of Secondary Data and Use Limitations
 - f. Project Description/Problem Definition/Site-Specific Analysis Problems
 - g. Project Objectives/Systematic Planning Documentation/Data Quality Objectives
 - h. Sampling Design and Rationale
 - i. Scope and Objectives
 - j. Project Schedule and Timelines
 - k. Project Organization and Responsibility
 - l. Personnel Responsibilities, Qualifications and Special Training Requirements
 - m. Field Activities and Standard Operation Procedures (SOPs)
 - n. Field and Laboratory QC Samples
 - o. Sampling Procedures and Container/Preservation Requirements
 - p. Sample Custody, Chain-of-Custody/Sample Documentation
 - q. Sample Handling/Identification
 - r. Field Logbooks and Contents; Documentation Procedures
 - s. Sample Packaging and Shipping
 - t. Equipment Decontamination
 - u. Contractor Quality Control
 - v. Daily Quality Control Reports
 - w. Field Quality Control and Corrective Actions
 - x. Sampling Apparatus and Field Instrumentation
 - y. Data Quality Objectives and Measurement Performance Criteria
 - z. Sample Custody and Holding Times
 - aa. Analytical Procedures
 - bb. Reference Limits and Evaluation of Quantitation Limit Goals
 - cc. Laboratory Calibration Procedures and Frequency
 - dd. Internal QC Checks
 - ee. Calculation of Data Quality Indicators
 - ff. Laboratory Corrective Actions
 - gg. Data Reduction, Review, Validation and Reporting
 - hh. Laboratory Reporting Requirements
 - ii. Preventive Maintenance (Field and Laboratory)
 - jj. Performance and System Audits
 - kk. QC Reports to Management
 - ll. Appendices
- E. The UFP-QAPP shall include a table of contents; crosswalk showing that all UFP-QAPP elements have been addressed; definitions, acronyms, and references pertaining to the project; and other related chemical analysis documents such as the data validation SOPs.
- F. The “Sampler’s Guide: Contract Laboratory Program Guidance for Field Samplers” (EPA 540/R-014/013), October 2014 procedures shall be followed for sample packing and shipment.
- G. All Department of Transportation (DOT) regulations under 40 CFR 261 shall be followed regarding shipment of the samples.

3.4 CHEMISTRY REQUIREMENTS

- A. Chemical data shall be acquired, documented, verified, and reported in a manner that assures that the precision, accuracy, and completeness requirements are achieved, as specified in the Contractor's approved UFP-QAPP. The Contractor must demonstrate the analytical chemistry methods' ability to meet the project data quality objectives (DQOs). Where national standard methods are not available for the medium, methods published by reputable technical organizations (e.g., ASTM) shall be utilized. Sampling, analysis, and measurement requirements listed in the following subsections shall be included in the UFP-QAPP.
- B. Data Quality Objectives
1. Project Objective - the overall project objective is to remove the contaminated material (source materials including associated wastes and contaminated soil) from the site, backfill the excavation with certified clean fill material, and remediate residual DNAPL and impacted groundwater, in accordance with the Contract Documents.
 2. Sampling Objectives
 - a. Samples shall be acquired, and chemical parameter measurements shall be performed in such a manner that the resulting data meets and supports data use requirements. Both definitive and field screening data are anticipated for this project, as defined by the EPA Guidance for Systematic Planning (EPA 240/B-06/001) and as indicated in the Basewide UFP-QAPP.
 - b. Field screening quality data shall be generated for health and safety purposes, as well as to identify media or samples that may be subject to further analysis. The Contractor shall also include a field screening method, if any proposed for the site.
 - c. Definitive level quality data shall be used to delineate soil and groundwater contamination, characterize cleared vegetation, characterize excavated material, demonstrate backfill materials and topsoil quality, and verify that the remediation cleanup levels have been met, and determine if contamination occurred below decontamination areas as a result of remedial activities. Definitive quality data shall be acquired, documented, verified, and reported to ensure that the specified data quality indicators (DQIs) (precision, accuracy, representativeness, comparability, completeness, and sensitivity) measurement performance criteria are achieved. Sampling objectives are discussed in detail to ensure that the data obtained will be of sufficient quality and quantity to meet the DQOs.
 - 1) Waste characterization samples from excavated soil shall be analyzed in accordance with disposal facility sampling requirements. Waste disposal characterization water samples from dewatering and decontamination operations shall be analyzed in accordance with disposal facility sampling requirements. The analytical results obtained by the Contractor shall be sufficient to address any and all requirements of the selected disposal facility. The sampling requirements to be contained in the Contractor's UFP-QAPP shall include specific disposal facility requirements for sampling, analysis, and reporting.
 - 2) Samples of topsoil and backfill materials from each off-site source shall be collected and analyzed for the parameters listed in Paragraph 3.5.A.2. Sample data shall be sufficient to demonstrate that topsoil and backfill materials do not contain contaminant levels that are hazardous to human health or the environment. The Contractor shall compare chemical sample

- data to the TCEQ Risk Reduction Standard No. 2 Soil MSCs for industrial use. Radiological sample data shall be compared to the criteria specified in Paragraph 3.5.A.2.c. Sample results exceeding the TCEQ Risk Reduction Standard No. 2 Soil MSCs for industrial use and radiological criteria specified herein, where those numbers are not below method detection levels, shall be unacceptable as topsoil or backfill. The gamma spectroscopy sample summary shall include all detectable radionuclides. No backfill or topsoil shall be brought to the site without written approval from the Contracting Officer's Representative.
- 3) Post-excavation soil samples shall be analyzed for contaminants of concern to confirm the final limits of excavation. The analytical results obtained by the Contractor shall be sufficient to confirm the final limits of excavation. The sampling requirements to be contained in the Contractor's UFP-QAPP shall include specific chemical concentrations as stated in the remedial action levels defined in Table 01 35 45-1A.
 - 4) Samples from beneath contaminated soil stockpile areas and decontamination pads shall be collected after removal of the stockpiles/decontamination pads to verify that no cross-contamination has occurred in the area due to leakage. The samples shall be analyzed and compared to the remedial cleanup levels. Areas where sample results exceed the criteria in Table 01 35 45-1 shall be scraped to remove the contamination in accordance with SECTION 31 23 10 – EXCAVATION AND HANDLING OF CONTAMINATED MATERIALS and be re-sampled.
 - 5) Baseline and performance monitoring groundwater and surface water samples collected during the In-situ Bioremediation (ISB) implementation and In-situ Thermal Desorption treatment (ISTD) shall be analyzed in accordance with the Contract Documents.
3. Chemical DQO
 - a. Chemical data shall be acquired, documented, verified, and reported in a manner that ensures that the precision, accuracy, and completeness requirements provided in Table 4 of the Basewide UFP-QAPP are achieved. The UFP-QAPP shall comply with the DQO process requirements as specified in EPA 600/R-96/055.

3.5 SAMPLING, ANALYSIS, AND MEASUREMENT REQUIREMENTS

- A. Sampling, analysis, and measurement requirements listed in the following subsections shall be included in the UFP-QAPP.
 1. Waste Characterization Sampling Requirements
 - a. Samples from excavated contaminated soil shall be collected and analyzed in accordance with the Contractor's approved disposal facility requirements.
 - b. Samples shall be analyzed for waste characteristics to determine handling, transportation, and disposal requirements. The number and volume of samples will be determined by the disposal facility.
 - c. Standard analytical requirements for waste characterization samples are listed below:
 - 1) Paint Filter Liquid Test
 - 2) Corrosivity
 - 3) Ignitability
 - 4) Reactivity – Hydrogen Cyanide
 - 5) Reactivity – Hydrogen Sulfide

- 6) Toxicity Characteristic Leaching Procedure (TCLP) – Metals
- 7) TCLP – Volatile Organic Compounds (VOCs)
- 8) TCLP – Semi-volatile Organic Compounds (SVOCs)
- 9) TCLP – Pesticides
- 10) TCLP – Herbicides
- 11) Polychlorinated Biphenyls (PCBs)
- 12) Moisture Content
- d. Analytical methods for the above parameters are included in Table 8 of the Basewide UFP-QAPP.
- e. The Contractor shall ensure that all the disposal facility requirements are met prior to shipment of the waste. EPA approval is required to utilize a disposal facility for hazardous waste generated from the Site.
2. Backfill and Topsoil Sampling Requirements
 - a. Clean backfill and topsoil material samples shall be collected as stated in SECTION 31 23 00 – BACKFILL, COMPACTION AND GRADING to ensure that they are free of chemical contamination.
 - b. Analytical parameters to verify that backfill and topsoil are free of chemical contamination include:
 - 1) EPA TAL metals, mercury, and cyanide
 - 2) EPA Target Compound List (TCL) compounds + Acrolein, Acrylonitrile, Benzidine, 1,2-Diphenylhydrazine, N-Nitrosodimethylamine and Tertiary Butyl Alcohol
 - 3) Extractable Petroleum Hydrocarbon (EPH)
 - 4) Radium-226 (Gamma Spectroscopy)
 - 5) Gamma Radiation Exposure Rate (Field Screening)
 - 6) Soil pH (using method SW-846 9045D)
 - c. Analytical methods for the above parameters are included in Table 8 of the Basewide UFP-QAPP.
 - 1) The criteria for backfill to be free of radiological contamination are listed below:
 - a) Radium-226 < 3 picoCuries per gram (pCi/g) (assuming background level of 1 pCi/g)
 - b) Gamma Radiation Exposure Rate < 30 micro-Roentgen per hour (μR/hr)
 - d. Analytical parameters for topsoil shall include, at a minimum, total organic carbon, pH, and nutrients (nitrogen, phosphate, and potassium). Sample data shall be sufficient to demonstrate that topsoil materials meet ASTM D5268-23 requirements in accordance with SECTION 31 38 50 – SITE RESTORATION.
3. Post-excavation samples shall be collected as per SECTION 31 23 10 – EXCAVATION AND HANDLING OF CONTAMINATED MATERIALS and as shown in the Design Drawings. The samples shall be sent to the off-site laboratory for analyses to confirm or revise excavation requirements in accordance with the criteria listed in Table 01 35 45-1.
4. Decontamination Area and/or Stockpiles Area Sampling Requirements
 - a. The Contractor shall collect samples from the decontamination areas to verify that no cross-contamination has occurred in these areas due to leakage. The samples shall be collected as per SECTION 31 23 10 – EXCAVATION AND HANDLING OF CONTAMINATED MATERIALS. The samples shall be sent to the off-site laboratory for analysis to verify the results are below the criteria listed in Table 01 35 45-1.

5. Baseline and performance monitoring soil, groundwater, and surface water Sampling Requirements
 - a. Baseline and performance monitoring for groundwater and surface water shall be conducted in accordance with the Contract Documents.

3.6 CONTROL OF CHEMICAL DATA QUALITY

A. General

1. Contractor CDQC shall ensure that a quality control program is in place that assures sampling and analytical activities and the resulting chemical parameter measurement data comply with the DQO and the requirements of the QAPP. The Contractor shall utilize the three phased control system that includes a preparatory, initial and follow up phase for each definable feature of work. The Contractor's three phase chemical data control process shall ensure that data reporting requirements are achieved and shall be implemented in accordance with the Contract Documents.

B. Three Phase Process

1. The preparatory phase shall include a review of the Specifications, UFP-QAPP, and all relevant SOPs for the chemical parameter measurement and/or chemical sample acquisition and shipment. It shall include a physical examination of all required forms, materials, and equipment to ensure conformance with the UFP-QAPP and that all materials are on Site. It shall include a demonstration of sampling procedures by the Contractor's field sampling personnel.
2. The initial phase shall be performed at the initiation of each definable feature of work by the CQC Representative to confirm compliance with the UFP-QAPP, including instrument calibration, operation and performance checks, sample acquisition, labeling, and shipment in accordance with required SOPs, sampling equipment decontamination, and completion of all required documentation.
3. The follow up phase shall require daily inspections to ensure compliance with the UFP-QAPP.

3.7 SUBCONTRACT ANALYTICAL TESTING LABORATORIES

A. General

1. The Contractor shall propose the analytical laboratories to be used for the sample analyses in case the pre-contracted and pre-approved laboratory cannot accept the samples. Laboratory certification requirements shall be in accordance with Paragraph 1.5.E. The Contractor may utilize its own laboratory or utilize subcontract laboratories to achieve the required sample analyses.

B. Laboratory Analytical Requirements

1. The Contractor shall provide the chemical analyses specified in these Specifications through the subcontracted laboratory. The Contractor shall provide chemical analyses for all parameters by methods specified in the project Specifications to achieve the project DQOs.

C. Laboratory Performance

1. The Contractor shall monitor and ensure continued acceptable analytical performance and shall establish a procedure to address data deficiencies noted by review and/or quality assurance sample results. The Contractor shall provide and implement a mechanism for providing analytical laboratories with the QAPP, for monitoring the laboratories' performance and for performing corrective action procedures. The Contractor shall acquire analytical services with NELAP-accredited and State of Texas-certified laboratories.

3.8 ANALYTICAL DATA

A. Electronic Copy

1. The chemistry data packages shall be reproduced and provided to the Contracting Officer's Representative no later than 4 weeks after receipt of the analytical data package from the laboratory. The chemistry data package shall contain information to demonstrate that the project's DQO have been fulfilled.

B. Electronic Data Deliverables (EDD)

1. The Contractor shall prepare and submit to USACE a final EDD for all samples collected by the Contractor in accordance with the procedures and requirements set forth in the Comprehensive Specification Manual (current edition).
2. The EDD shall include sample information including sample locations (horizontal coordinates and surface elevation) and sample results. The EDD shall also include an updated geo- referenced electronic base map in AutoCAD drawing exchange (DXF) format showing Site features, monitoring well locations, and updated Site grades following the soil remediation program.
3. The Contractor shall provide the Contracting Officer's Representative with a copy of the transmittal letter for all EDD submissions, identifying what data were provided in the EDD. The Contractor shall also provide the Contracting Officer's Representative with a copy of the notice from EPA that the EDD submittal was successfully uploaded.

3.9 QUALIFICATIONS

A. Chemical Quality Control Officer

1. As a minimum, the Contractor's Chemical Quality Control Officer shall have a bachelor's degree (B.A. or B.S.) in Chemistry and three years of experience with Hazardous Toxic and Radioactive Waste (HTRW) Quality Control including hazardous waste manifesting. The Chemical Quality Control Officer shall ensure that all chemistry-related requirements including responsibilities for DQO definitions, sampling and analysis, project requirements for data documentation and validation, and final project reports are attained. The Chemical Quality Control officer need not be present on Site during routine sampling but shall be available for consultation with the Contracting Officer's Representative and Contractor personnel.

B. Environmental Sampler

1. As a minimum, the Contractor's Environmental Sampler shall have a B.A. or B.S. degree in Chemistry or closely related scientific/technical field, 1 year of experience in and knowledge of EPA methods for collecting environmental and hazardous waste samples and 1 year of experience in calibration and operation of field screening equipment. The Environmental Sampler shall collect all on-site samples as well as perform all field-screening tests. The Environmental Sampler shall review the sampling results and provide recommendations for the Contractor's sampling program. The Environmental Sampler shall be on-site during excavation and stockpiling operations involving soil to be checked for contamination.

C. Project Chemist

1. At a minimum, the Contractor's Project Chemist shall have: a B.A. or B.S. degree in chemistry; 3 years of experience related to investigations, studies, design, and remedial actions at Hazardous, Toxic, and Radioactive Waste (HTRW) sites; 2 field seasons of experience in calibrating and operating various field monitoring devices; and 2 years of sample analysis experience in HTRW program and activities. The Project Chemist shall ensure that all chemistry-related goals of the program are attained.

3.10 CHEMICAL DATA FINAL REPORT (CDFR)

- A. The CDFR shall be produced after project completion; it shall include a summary of quality control practices employed and all chemical parameter measurement activities. This includes, but is not limited to, all data analyzed by the Contractor's subcontract laboratories, if any, and shall include all definitive data. At a minimum, the CDFR shall contain the following:
1. Summary of project scope and description
 2. Summary of any deviations from the design chemical parameter measurement Specifications
 3. Summary of chemical parameter measurements performed as contingent measurements
 4. Summary discussion of resulting data including achieving data reporting requirements
 5. Summary of DQO parameters including achieving sampling project specific DQO
 6. Presentation and evaluation of the data to include an overall assessment on the quality of the data for each method and matrix
 7. Internal QC data generated during the project, including tabular summaries correlating sample identifiers with all blank, matrix spikes, surrogates, duplicates, laboratory control samples, and batch identifiers
 8. A list of the affected sample results for each analyte (indexed by method and matrix) including the appropriate data qualifier flag (J, U, UJ, and R), where sample results are potentially impacted by quality control outliers
 9. Summary of field and laboratory oversight activities, providing a discussion of the reliability of the data, QC problems encountered, and a summary of the evaluation of data quality for each analysis and matrix as indicated by the laboratory QC data and any other relevant findings
 10. Conclusions and recommendations
 11. Appendices containing chemistry data packages for all subcontract laboratory data (hardcopy and electronic copy on disk) and data validation reports.

3.11 NOTIFICATION OF NON-COMPLIANCE

- A. The Contracting Officer's Representative will notify the Contractor of any detected noncompliance with the foregoing requirements. The Contractor shall take immediate corrective action after receipt of such notice.

END OF SECTION

TABLE 01 35 45-1A
Record of Decision Remediation Cleanup Levels for Target COCs in Soil

Contaminant of Concerns (COCs) Targeted for Remediation	Cleanup Level ^a (mg/kg)
Perchlorate	7.2
TCE	0.5

Notes:

^a Unless otherwise noted, cleanup level applies to soil from surface to groundwater interface.

mg/kg - milligram per kilogram

TCE - trichloroethylene

Source: Revised Final Record of Decision for LHAAP-47, Plant 3 Area, Solid Rocket Motor Fuel Production (HDR, 2022)

TABLE 01 35 45-1B
Record of Decision Remediation Cleanup Levels Target COCs in Groundwater

COCs Targeted for Remediation	MCL (µg/L)	TRRP Tier 1 Residential Groundwater PCLs (µg/L)	Background (µg/L)	Cleanup Level (µg/L)
Perchlorate	--	17	--	17
1,1-Dichloroethene	7	--	--	7
1,2-Dichloroethane	5	--	--	5
Acetone	--	22,000	--	22,000
Chloroform	80	--	--	80
cis-1,2-Dichloroethene (cis-1,2-DCE)	70	--	--	70
Tetrachloroethene (PCE)	5	--	--	5
trans-1,2-Dichloroethene (trans-1,2-DCE) (daughter product)	100	--	--	100
Trichloroethene (TCE)	5	--	--	5
Vinyl Chloride (VC)	2	--	--	2
2,4,6-Trinitrotoluene	--	12	--	12
2,4-Dinitrotoluene	--	1.3	--	1.3
2,6-Dinitrotoluene	--	1.3	--	1.3
bis(2-Ethylhexyl)phthalate	6	--	--	6
Pentachlorophenol	1	--	--	1
Aluminum	--	24,000	2,680	24,000
Antimony	6	--	12.2	12.2
Arsenic	10	--	34.2	34.2
Cadmium	5	--	5.1	5.1
Chromium	100	--	15.8	100
Cobalt	--	240	187	240
Manganese	--	1,100	7,820	7,820
Nickel	--	490	229	490
Silver	--	120	1.92	120
Strontium	--	15,000	7,330	15,000
Thallium	2	--	--	2
Tin	--	15,000	--	15,000
Vanadium	--	44	3.99	44

Notes:

1. Source: The source of this table is the Final Feasibility Study, LHAAP-47, Plant 3, Group 4 (Shaw, 2011) Background concentration from Final Evaluation of Perimeter Well Data for Use as Groundwater Background (Shaw, 2007c)

µg/L - micrograms per liter

COCs - Contaminants of Concern

MCL - Safe Drinking Water Act maximum contaminant level

TRRP - Texas Risk Reduction Program

PCL - Protective Concentration Level

TRRP - Tier 1 Residential Groundwater PCL

SECTION 02 53 17
IN-SITU BIOREMEDIATION
INJECTION PROCEDURES AND MONITORING

PART 1 - GENERAL

1.1 SUMMARY

- A. This section describes the requirements for completing an in-situ bioremediation (ISB) injection program to treat contaminated groundwater at the site. The section includes substrates and amendments to be injected, sequencing for injections, secondary containment and spill prevention, and monitoring.
- B. ISB injection program is assumed to be implemented in two phases, with Phase II ISB implementation dependent on the monitoring and performance results generated during Phase I.
 - 1. Phase I – ISB Pilot Tests consisting of four ISB pilot tests (three grids and one biobarrier) in strategically selected locations to determine key ISB design parameters, along with the installation of additional monitoring wells for baseline and long-term monitoring.
 - 2. Phase II – Full-Scale ISB, consisting of implementation of ISB grid injections in nine target areas where perchlorate concentrations exceed 20,000 micrograms per liter ($\mu\text{g/L}$) and/or total volatile organic compound (VOC) concentrations exceed 1,000 $\mu\text{g/L}$, construction of three ISB biobarriers at the northern, southern, and eastern edges of the VOC and perchlorate plumes, and performance monitoring and reapplication of bio-amendments.

1.2 REFERENCES

- A. References
 - 1. The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.
 - a. American Society Mechanical Engineers International (ASME)
 - 1) ASME B40.100 (2022) Pressure Gauges and Gauge Attachments
 - 2) ASME PTC 19.5 (2025) Flow Measurement
 - b. Code of Federal Regulations (CFR)
 - 1) 29 CFR 1910 Occupational Safety and Health Standards
 - 2) 40 CFR 144-148 Underground Injection Control Program
 - c. United States Army Corps of Engineers (USACE), Tulsa District
 - 1) Final Installation Wide Work Plan for Longhorn Army Ammunition Plant (LHAAP IWWP), Karnack, Texas, revised by Bhate Environmental Associates, Inc. (May 2018; IWWP).
 - d. Texas Administrative Code (TAC)
 - 1) 16 TAC 76.100 - Technical Requirements--Locations and Standards of Completion for Wells
 - 2) 30 TAC 331, Subchapters A, C, and H – Underground Injection Control

1.3 SUBMITTALS

- A. Approval from the Contracting Officer's Representative, in consultation with the regulators is required for submittals with an "RA" designation; submittals having an

“FIO” designation are for information only. The Contractor shall submit the following to the Contracting Officer’s Representative:

1. Injections Work Plan; Pre-Construction Submittals; RA
2. Injection System Layout; Shop Drawings; RA
3. Sequencing and Scheduling for injections; Product Data; RA
4. Equipment and Materials; Product Data; RA
5. Instrumentation and Controls; Product Data; RA
6. Secondary Containment Systems; Product Data; RA
7. Daily Injection Logs; Test Reports
8. Groundwater Sample Results; Test Reports
9. ISB Completion Report (One ISB completion report should be submitted for each injection event); RA
10. Closeout Submittals; RA

1.4 ADMINISTRATIVE REQUIREMENTS

A. Not used.

1.5 QUALITY ASSURANCE

A. Contractor Qualifications

1. The Contractor shall be required to have experience on at least three ISB projects of comparable size and scope within the past three (3) years.
2. Such experience shall be current and explicitly display knowledge and hands-on expertise in current technologies and current regulations specifically applicable to this work.
3. Key personnel shall have experience of ISB projects of comparable size and scope. Experience shall be current and explicitly display knowledge and hands-on expertise in current technologies and current regulations specifically applicable to this work.
4. All Contractor personnel must be 40-hr Occupational Safety and Health Administration (OSHA) trained as required in 29 CFR 1910.120 for hazardous waste operations.

1.6 SUBSURFACE CHARACTERISTICS

A. Geology

1. Site stratigraphy consists of layered units of the Wilcox Group extending from the surface to approximately 95 feet below ground surface (bgs), comprising shallow clay-rich soils, intermediate silty sands with interbedded clays, and deeper sandy clay and sand units.
 - a. Shallow Wilcox Group (surface to 35 feet bgs) consists predominantly of clay to silty clay with laterally variable mixtures of fine sand, silt, and sandy/silty clay. A thin silty sand layer (3 feet thick) occurs at the base of this interval and is discontinuous across the site.
 - b. Intermediate Wilcox Group (35–65 feet bgs) consists primarily of silty sands interbedded with thin silty clay layers of variable thickness. The boundary between shallow clay and intermediate silty sand is undulant and discontinuous, contributing to hydraulic complexity.
 - c. The Deep Wilcox Group soils (70 to 95 feet bgs) consist of a continuous sandy clay unit that overlies the deepest saturated interval consisting of sand. The Deep Zone terminates near the top of the Midway Group.

B. Hydrogeology

1. Contamination from historical activities at LHAAP-47 have impacted two groundwater zones: the Shallow Zone and Shallow/Intermediate Zone.
 - a. Groundwater in the Shallow Zone has been observed at depths ranging from 26 to 29 feet bgs, with higher elevations associated with locations where the silty sand unit occurs closer to the surface.
 - b. Groundwater in the Shallow/Intermediate Zone flows to the northeast/north and extends to approximately 65 feet bgs. The Shallow/Intermediate Zone exhibits greater saturation and more consistent groundwater presence, particularly in areas where the sand units are thicker, most notably in the central and southeastern portions of the site.
 - c. Groundwater generally flows to the northeast across LHAAP-47 towards Caddo Lake.

1.7 TREATMENT AREA

- A. As per the Contract Documents, injections will be conducted during Phase I of the remedial action in the four pilot test areas.
 1. ISB Pilot Test Area 1 is located downgradient of Building 46A, this area contains the highest trichloroethene (TCE) concentration, with a maximum of 5,990 micrograms per liter ($\mu\text{g/L}$), and represents contamination in both the Shallow and Shallow/Intermediate groundwater zones. The pilot test will evaluate differences in substrate distribution between these two geological units and assess how varying biogeochemical conditions influence contaminant degradation. The pilot will also help confirm the radius of influence in both zones.
 2. ISB Pilot Test Area 2 is located within the northern VOC plume and contains elevated TCE and perchlorate concentrations, with a maximum of 2,970 $\mu\text{g/L}$ and 91 $\mu\text{g/L}$, respectively, representing contamination in the Shallow/Intermediate groundwater zone. The pilot test will assess how contaminant degradation is influenced by biogeochemical conditions in the presence of perchlorate within the VOC plume.
 3. ISB Pilot Test Area 3 is located along the eastern boundary within LHAAP-47 boundary and contains lower-level TCE contamination, with a maximum of 5,190 $\mu\text{g/L}$, representing the leading edge of the southern VOC Shallow/Intermediate Zone plume. The pilot will evaluate substrate distribution and injection performance using permanent injection wells to support biobarrier design.
 4. ISB Pilot Test Area 4 is located within the southern VOC plume near Goose Prairie Creek and contains elevated TCE concentrations, with a maximum of 1,890 $\mu\text{g/L}$, representing contamination in the Shallow groundwater zone. This pilot test will assess how contaminant degradation is influenced by biogeochemical conditions in the portion of the plume located outside the LHAAP-47 boundary.
- B. During remedial action Phase II, injections will be conducted to treat groundwater in an area of approximately 36.5 acres (15,87,500 square feet {sf}) with a saturated thickness between 10 to 20 vertical feet to a maximum depth of 57 feet bgs as per the Contract Documents. Groundwater is primarily contaminated with TCE and perchlorate, with maximum concentrations of 10,000 $\mu\text{g/L}$, and 23,600 $\mu\text{g/L}$, respectively.
 1. Injections in ISB grids will be implemented to address elevated perchlorate (greater than approximately 20,000 $\mu\text{g/L}$) and/or TCE (range from 1,000 to 10,000 $\mu\text{g/L}$) concentrations to treat both the Shallow and Shallow/Intermediate Zone groundwater.
 - a. Shallow Zone contains three grid areas:

- 1) ISB Grid Area 1S: Targets Shallow Zone VOC contamination within the LHAAP-47 boundary downgradient of Building 46A and covers approximately 167,000 sf.
- 2) ISB Grid Area 2S: Targets Shallow Zone VOC contamination within the LHAAP-47 boundary in the northern plume and covers approximately 123,000 sf.
- 3) ISB Grid Area 3S: Targets Shallow Zone VOC contamination outside the LHAAP-47 boundary and covers approximately 103,000 sf, extending across Goose Prairie Creek.
- b. Shallow/Intermediate Zone contains 3 grid areas:
 - 1) ISB Grid Area 1SI: Targets VOC contamination within the LHAAP-47 boundary downgradient of Building 46A, where the highest TCE concentrations occur, and covers approximately 181,000 sf.
 - 2) ISB Grid Area 2SI: Targets perchlorate contamination within the LHAAP-47 boundary in the southern perchlorate plume and cover approximately 36,000 sf.
 - 3) ISB Grid Area 3SI: Targets perchlorate and VOC contamination within the northern plume and covers approximately 94,000 sf.
 - 4) ISB Grid Areas 4SI, 5SI, and 6SI: Target VOC contamination within and outside the LHAAP-47 boundary in the southern plume and collectively cover approximately 762,000 sf, with Areas 5SI and 6SI extending across Goose Prairie Creek.
2. Injections in ISB biobarriers will be implemented to provide Shallow/Intermediate Zone groundwater treatment and containment. The ISB biobarriers will extend a total of approximately 3,000 linear feet, with a total of approximately 109 injection points. Each biobarrier is described below in detail.
 - a. ISB Biobarrier 1: A continuous biobarrier approximately 1,200 feet long within the LHAAP-47 boundary will target VOC and perchlorate contamination in the Shallow/Intermediate Zone along the eastern Site boundary, transecting the southern VOC plume.
 - b. ISB Biobarrier 2: A continuous biobarrier approximately 1,000 feet long outside the LHAAP-47 boundary will target VOC contamination in the Shallow/Intermediate Zone and will transect the leading edge of the southern plume across Goose Prairie Creek.
 - c. ISB Biobarrier 3: A biobarrier approximately 800 feet long within the LHAAP-47 boundary will target perchlorate contamination in the Shallow/Intermediate Zone along the eastern and northern edge of the southern perchlorate plume to limit further migration.

1.8 SEQUENCING AND SCHEDULING

- A. Initiation of ISB activities in Pilot Test Area 1 shall not occur until subsurface temperatures have decreased to levels suitable for effective bioremediation. Following Electrical Resistance Heating (ERH) system shutdown, the Contractor shall perform temperature monitoring at monitoring well PMW-01 to evaluate subsurface thermal dissipation.
- B. ISB Pilot Test activities in Area 1 shall commence only after temperatures at PMW-01 have decreased to $\leq 30\text{--}35$ Celsius ($^{\circ}\text{C}$) ($86\text{--}95$ Fahrenheit $\{^{\circ}\text{F}\}$). This temperature range represents conditions under which the selected bioremediation injectants and microbial cultures can safely and effectively function.
- C. Delaying initiation of ISB activities until subsurface temperatures fall below this threshold is required to ensure that residual heat from ERH operations does not

adversely impact the performance of the bioremediation amendments or inhibit microbial activity.

PART 2 - PRODUCTS

2.1 EQUIPMENT, MATERIALS AND STORAGE

- A. Equipment and storage facilities shall be provided for storage and handling of substrates and amendments necessary for ISB. All equipment and materials must be compatible with the substrates and amendments used and stored at the site. The Contractor shall follow the substrate and amendment manufacturer instructions and precautions for storage and handling of all substrates and amendments.
 - 1. Capacity
 - a. All tanks used to store substrates and amendments must be adequately sized and constructed of a material compatible with the contents being stored.
 - b. Instrumentation and Sampling Instrumentation and equipment, including sensors, local indicators, connecting devices, recorders, analyzers, and components necessary to monitor and control the safe and efficient operation of the mixing and injection systems shall be provided.
 - c. Pressure Gauges shall conform to ASME B40.100 and be of pressure detecting class, single Bourdon tube style, and suitable for detecting air pressure.
 - d. Flow meters shall conform to ASME PTC 19.5, with type and flow range suitable for the use encountered.
 - 2. Substrate/Amendment and Mixing Storage Tanks
 - a. Substrate/Amendment storage tanks shall be approved by the Contracting Officer's Representative prior to mobilization.
 - 3. Secondary Containment
 - a. Secondary containment shall be constructed of materials compatible with the chemicals being stored and must have sufficient strength and thickness to prevent failure as a result of physical contact with chemicals stored, climatic conditions, or the stress of daily operations.

2.2 SUBSTRATES AND AMENDMENTS

- A. All substrates used shall be environmentally safe and manufactured for the purpose of injecting into the subsurface for treatment of contaminated groundwater. Substrates shall be compatible with site hydrogeologic conditions and capable of supporting effective reductive dechlorination.
- B. The Contractor may select any substrate or substrate blend that meets the minimum performance and composition requirements identified in this specification. Proprietary products listed herein (e.g., SRS®-SD, SRS®-SE) are preferred substrates due to demonstrated performance; however, the Contractor may propose equivalent non-proprietary or proprietary products meeting or exceeding these requirements. All proposed equivalents shall be submitted for approval by the Contracting Officer's Representative.
- C. General Requirements for Carbon Sources
 - 1. The carbon sources shall have the following characteristics:
 - a. Support anaerobic biodegradation of chlorinated VOCs through reductive dechlorination.
 - b. Provide a combination of short-term and long-term carbon release appropriate for sustained treatment over multiple years.

- c. Form a stable emulsion or suspension suitable for injection through Direct Push Technology (DPT) points or injection wells without causing formation clogging or excessive injection pressures.
- d. Adhere to soil surfaces and supply electron donor for the duration required by the design (typically multiple years).
- e. Be non-toxic, food-grade, and fully biodegradable.
- f. Be compatible with groundwater velocities, site hydrogeology, and treatment objectives.
- g. Include any emulsifiers, surfactants, or additives necessary to achieve stable distribution, subject to the Contracting Officer's Representative approval.
- 2. Emulsified Vegetable Oil (EVO) – General Equivalent Requirements
 - a. Contractor-selected EVO formulations shall:
 - 1) Be composed of food-grade, biodegradable oils suitable for reductive dechlorination.
 - 2) Maintain effectiveness for 3–5 years post-injection.
 - 3) Be shipped as water-mixable oil (no water included).
 - 4) Be mixed on site with the Contracting Officer's Representative approved oils, emulsifiers, and additives.
- 3. Preferred Proprietary Carbon Sources (or Approved Equivalent)
 - a. Slow-Release Substrate – Small Droplet (SRS® SD or Equivalent)
 - 1) An approved equivalent shall meet the following criteria:
 - 2) Nontoxic, food grade emulsified vegetable oil (EVO) with nonionic emulsifier.
 - 3) Contains $\geq 60\%$ soybean oil as the slow-release carbon source.
 - 4) Includes a quick release carbon source (e.g., sodium lactate or equivalent) to rapidly establish anaerobic conditions.
 - 5) Contains nutrients and Vitamin B12 to enhance microbial activity.
 - 6) Provides at least 5–7 years of dissolved organic carbon release in sandy aquifers.
- 4. Slow-Release Substrate – Self-Emulsifier Type (SRS®-SE or Equivalent)
 - a. An approved equivalent shall meet the following criteria:
 - 1) Can be field-mixed as an oil-in-water emulsion.
 - 2) Results in a mixture of approximately 10% premix, 30% water, 60% soybean oil.
 - 3) Produces small droplet sizes (approx. 1–5 μm) using high-shear mixing.
- 5. Extended-Release Substrate (EDS-ER™ or Equivalent)
 - a. An extended-release donor formulation shall:
 - 1) Be water-miscible and injection-ready.
 - 2) Contain $\geq 92\%$ natural seed oils.
 - 3) Provide long-term organic carbon release suitable for multi-year treatment.

D. Nutrient Addition

- 1. Nutrients shall:
 - a. Provide essential macronutrients (nitrogen, phosphorus) and trace elements required for microbial growth.
 - b. Be soluble and compatible with the selected carbon source.
 - c. Be added in concentrations proportional to total mix water volume.
 - d. Be shipped in sealed containers (e.g., buckets or bags) and stored per manufacturer guidelines.
 - e. Require the Contracting Officer's Representative approval for nutrient type, concentration, and additives prior to injection.
 - f. Preferred Proprietary Nutrient Blend if the carbon source does not contain any nutrients:

- 1) TersOx™ Nutrients-QR (Tersus Environmental) or an approved equivalent fast-acting soluble nutrient blend.

E. Buffering Agent

1. A pH buffering agent shall be included in the substrate formulation to maintain conditions suitable for effective anaerobic biodegradation. A typical buffering agent for this purpose is sodium bicarbonate.
2. The Contractor shall submit the proposed buffering agent type and the percentage to be used in the substrate mix for review and approval by the Contracting Officer's Representative prior to initiating injections.
3. Sodium bicarbonate, when used, shall be supplied in bagged form and added to mix water based on a mass-per-volume ratio appropriate for achieving the required pH buffering capacity.

F. Bioaugmentation Culture

1. The Contractor shall provide a dechlorinating bioaugmentation culture capable of supporting reductive dechlorination. Acceptable options include:
 - a. TSI-DC (Terra Systems of Delaware), containing multiple strains of *Dehalococcoides mccartyi* (DHC), or
 - b. KB-1® (SiREM), containing a natural consortium of dechlorinating microorganisms,
 - c. or an approved equivalent meeting or exceeding these performance characteristics.
2. Requirements for TSI-DC (If Selected)
 - a. The bioaugmentation culture shall consist of a DHC-based consortium (TSI-DC) suitable for use in the ISB injection program.
 - b. TSI-DC shall be supplied in 19-liter stainless steel kegs designed for a maximum working pressure of 130 pound per square inch (psi), equipped with pressure-relief valves. Kegs are shipped pressurized with nitrogen gas up to 15 psi.
 - c. During transfer, the Contractor shall not exceed 15 psi. Kegs shall not be opened if internal pressure remains above ambient.
 - d. TSI-DC may be stored for up to 3 weeks at 2–4°C, provided it remains sealed and not aerated.
3. Requirements for KB-1® (If Selected)
 - a. KB-1® shall consist of a natural consortium of dechlorinating bacteria suitable for chlorinated VOC degradation.
 - b. Only KB-1® supplied by SiREM shall be used as the bioaugmentation culture for the ISB injection program.
 - c. KB-1® is shipped in stainless steel pressure vessels, maintained under anaerobic conditions to prevent oxygen exposure to the oxygen-sensitive microbial community.
 - d. Vessels are shipped with approximately 1 psi internal pressure. Valves shall remain closed until properly connected to injection lines.
 - e. Pressure vessels shall not be exposed to temperatures below 0°C or above 30°C, as temperature extremes may harm the microbial culture or vessel integrity. All valves must remain closed when not actively in use to maintain anaerobic conditions.
 - f. The Contractor shall avoid exposing the culture to air at all times, as oxygen exposure will kill the dechlorinating microorganisms.

G. Anaerobic Water

1. The Contractor shall prepare anaerobic water using one of the following:
 - a. Sodium ascorbate (TSD), or
 - b. KB-1® Primer (SiREM),
 - c. or an approved equivalent with comparable performance.
2. Requirements for Sodium Ascorbate (If Selected)
 - a. Sodium ascorbate shall be used to remove dissolved oxygen and establish anaerobic conditions prior to the injection of TSI-DC.
 - b. Sodium ascorbate shall be supplied in 55-pound boxes and stored in a cool, dry, well-ventilated area away from heat sources.
3. Requirements for KB-1® Primer (If Selected)
 - a. KB-1® Primer shall be used to prepare anaerobic water for dispersing electron donors and protecting bioaugmentation cultures during injection.
 - b. KB-1® Primer will be prepared in the field in 1,000-gallon batches using a single 3.2-kg pouch of product.
 - c. Anaerobic injection water prepared using KB-1® Primer shall meet the following criteria:
 - 1) Oxidation-Reduction Potential (ORP): < -75 millivolts (mV)
 - 2) pH: between 6.5 and 8.3

PART 3 - EXECUTION

3.1 INJECTIONS WORK PLAN

- A. The Contractor shall submit the Injections Work Plan describing all work that will be performed. The plan shall include the following minimum information:
 1. Diagram of the work site with layout showing location(s) of substrate and amendment storage areas, injection locations, equipment staging, decontamination facilities, site access points.
 2. List of all equipment that will be used, including size, material type, and planned use. Equipment includes but is not limited to storage tanks, mixing tanks, secondary containment, generators, pumps, valves, gauges, etc.
 3. List of key personnel along with resumes demonstrating knowledge and experience in the injection of ISB.
 4. Level of personal protective equipment (PPE).
 5. Total volume of each substrate and amendment delivered to the site and description of means and methods used to prepare solution for injection.
 6. Safety Data Sheets (SDS) for all substrates and amendments to be used on site.
 7. Procedures, means, and methods for monitoring injections.
 8. Identification of permit equivalences/approvals.
 9. Procedures for handling and storing all substrates and amendments.
 10. Procedures for handling, storage, and disposal of waste materials generated during injections.
 11. Schedule for work.
 12. Emergency actions that will be taken by the Contractor in the event of a spill.

3.2 PERMIT EQUIVALENCES/APPROVALS

- A. The Contractor will be responsible for obtaining all permit equivalences/approvals related to injections before beginning any injections including Underground Injection Control (UIC) Authorization/Permit Equivalent for ISB amendment injections conducted through direct-push injection points or permanent injection wells used for amendment delivery. Copies of permit equivalences shall be submitted to the Contracting Officer's Representative at least two weeks before performing injections.

- B. The Contractor shall notify Texas Commission on Environmental Quality and United States Environmental Protection Agency (in accordance with 40 CFR 144-148) two weeks in advance of commencement of fieldwork for injection activities.

3.3 UTILITY CLEARANCE

- A. The Contractor shall conduct utility location and clearance for intrusive activities in accordance with Section 3.1 of the IWWP prior to drilling as follows:
- B. The Contractor shall prepare a map indicating the area(s) where intrusive activity is planned to occur.
- C. The Contractor shall perform the necessary document reviews.
- D. The Contractor shall contact the Texas Excavation Safety System, Inc. utility notification service by calling 811 or 800-892-0123. This notification must 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.
- E. The Contractor shall 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.
- F. The Contractor shall mark all overhead utilities with their kilovolts rating on the map.
- G. The Contractor shall notify the appropriate agencies, the Contracting Officer's Representative, and subcontractor responsible for operating the existing Groundwater Treatment Plant.
- H. The Contractor shall confirm utility clearance is complete and documented.
- I. The Contractor shall hold a safety meeting, and a job safety analysis shall be completed by all personnel who are involved in the intrusive activities prior to initiating work.

3.4 LAYOUT

- A. The Contractor shall maintain all equipment and materials in the designated areas shown on the Contract Documents. If additional area is needed, the Contractor shall discuss obtaining additional area with the Contracting Officer's Representative before beginning injections. The Contractor shall phase the injection sequence to maintain access and designate access points during injections with cones or other measures to keep unauthorized persons from being in proximity to wells being actively injected.
- B. Security
 - 1. The substrate and amendment storage areas shall be surrounded by temporary chain link fence at all times. During non-working hours, the gate shall be locked to prevent any unauthorized access.

3.5 GENERAL INJECTION STRATEGIES

- A. The substrate will be injected using DPT at all pilot scale and full-scale ISB areas. Permanent injections wells (IWs) will be used to inject substrate at ISB Pilot Test Area 3 and the full-scale Shallow/Intermediate ISB Biobarrier 1 within the LHAAP-47 boundary, as specified in the Contract Documents. The Contractor shall install the injection wells as per Section 3.6.
- B. For areas requiring injection wells, the Contractor shall complete IWs to the required depth intervals specified in the remedial action work plan (RAWP) prior to mobilization

for injection of amendments. The following subsections outline the minimum requirements for ISB implementation.

3.6 INSTALLATION OF INJECTION WELLS

- A. The Contractor shall install injection wells prior to mobilization for injections in accordance with the procedures described in Section 3.2 Task 2 - Monitoring Well/Compliance Well Installation, and SOP A7-Monitoring Well Installation, of Appendix A of the Final Installation Wide Work Plan for Longhorn Army Ammunition Plant, Karnack, Texas, with the following exceptions: the well screen slot size, sand, and completion with a threaded connection to connect the injection hoses for injections. Injection wells shall meet the requirements of 16 TAC 76.100 and 30 TAC 331, Subchapters A, C, and H.
- B. The details of the injection wells are provided in the Contract Documents and shall be included in the approved RAWP for the site.
- C. The Contractor shall log the lithology at new well locations as per the procedure outlined in SOP A2 – Lithologic Description of Subsurface Samples and Completion of Drill Logs 2-1 in Appendix A of the IWWP.
- D. Each newly installed well shall be developed no sooner than 24 hours following well completion. Well development shall be conducted in accordance with Section 3.2.2 Well Development of the IWWP. Procedures for well development are detailed in SOP A8 - Monitoring Well Development in Appendix A of IWWP.
- E. The Contractor shall thoroughly develop all injection wells prior to beginning injections to obtain maximum injection rates and minimize the injection time.
- F. The Contractor shall provide additional care when installing a cement/bentonite well seal directly above the target injection interval to reduce surface breakout when the substrates/amendments are injected under pressure.
- G. Injection wells shall be able to withstand injection pressures at a minimum of 10 pounds per square gauge.
- H. Injection wells shall be installed with at least 6 to 24 inches of PVC casing projecting above grade with a glue-on threaded PVC coupling, so that the injection hose can then be connected directly to the injection well.

3.7 INSTALLATION OF MONITORING WELLS

- A. The Contractor shall install any new monitoring wells required for performance monitoring as per the Contract Documents and procedures described in Task 2, Monitoring Well/Compliance Well Installation, and SOP A7-Monitoring Well Installation, of Appendix A of the Final Installation Wide Work Plan for Longhorn Army Ammunition Plant, Karnack, Texas, as well as 16 TAC 76.100.
- B. All monitoring wells required for performance monitoring shall be developed prior to groundwater sampling.
- C. Monitoring wells shall be installed as stickups with the top of protective outer casing two to three feet above grade.

3.8 SUBSTRATE AND AMENDMENT STORAGE AND HANDLING

- A. All substrates and amendments shall be stored and handled in accordance with their SDS, the manufacturer's recommendations and all governing regulations.

- B. Containers shall be kept tightly closed in a cool, well-ventilated area and kept from freezing conditions.
- C. Special Storage and Handling of SRS®-SD and SRS®-Premix
 - 1. The Contractor shall store SRS®-SD and SRS®-Premix in a cool, dry, well-ventilated area and shall not store the material in direct sunlight or at temperatures exceeding 32 °C. If any container begins to bulge, the Contractor shall slowly loosen the cap to release carbon dioxide generated by biological activity and shall immediately contact the TSD.
- D. Special Storage and Handling of Bioaugmentation Culture
 - 1. If Contractor decide to use TSI-DC with DHC, the following requirements shall apply:
 - a. The Contractor shall avoid breathing aerosols and shall avoid contact with skin during handling of the DHC microbial consortium (TSI-DC).
 - b. Appropriate PPE shall be used at all times.
 - c. The Contractor shall keep all containers tightly closed and stored in a cool, well-ventilated area.
 - d. The DHC microbial consortium (TSI-DC) shall be supplied in stainless steel kegs designed for a maximum working pressure of 130 psi and equipped with pressure-relief valves. Kegs are pressurized with nitrogen gas up to 15 psi.
 - e. The Contractor shall not exceed a transfer pressure of 15 psi during handling or transfer of the DHC microbial consortium (TSI-DC). Kegs shall not be opened if the contents remain under pressure.
 - f. The DHC microbial consortium (TSI-DC) may be stored for up to 3 weeks at a temperature of 2–4 °C, provided it remains sealed and protected from aeration. Freezing of the material shall be avoided.
 - 2. If Contractor decide to use KB-1®, the following requirements shall apply:
 - a. KB-1® is shipped in stainless steel pressure vessels and connected to injection lines and inert gas is used to pressurize the vessel to displace the contents. KB-1® shall be handled with care to avoid any spillage.
 - b. Vessels will be shipped with 1 pound per square inch (psi) pressure; valves shall not be opened until connections to appropriate lines for subsurface injection are in place.
 - c. The Contractor shall avoid exposing stainless steel pressure vessels to undue temperature extremes. Temperatures less than 0°C or greater than 30°C may result in harm to the microbial cultures and damage to the vessels.
 - d. All valves shall be in a closed position when the vessel is not pressurized or not in use to prevent the escape of gases and to maintain anaerobic conditions in the vessel.
 - e. The Contractor shall avoid exposing the culture to air, as the presence of oxygen will kill dechlorinating microorganisms.
- E. Special Storage and Handling of Sodium Ascorbate
 - a. The Contractor shall avoid breathing aerosols and shall avoid contact with skin during handling of Sodium Ascorbate.
 - b. The Contractor shall keep containers tightly closed and stored upright in a cool, dry, well-ventilated area.
 - c. Containers shall not be stored in direct light, as the material is light-sensitive and must be kept in light-resistant containers.

- d. Containers of Sodium Ascorbate may pose a fire risk due to dust generation; therefore, proper housekeeping and dust-control practices shall be maintained at all times.

3.9 HAZARDOUS MATERIALS

- A. If any process residuals are found to contain hazardous materials, they shall be transported and disposed of in accordance with all applicable Federal, State, and local regulations.

3.10 SPILL PREVENTION, CONTAINMENT, AND EMERGENCY RESPONSE

- A. Spill Response
 - 1. The Contractor shall have a plan included in the approved Injections Work Plan to quickly respond to spills or surfacing that may occur during ISB operations.
 - 2. The Contractor's spill response measures shall be in accordance with each substrate's SDS, the manufacturer's recommendations and all governing regulations.
 - 3. The Contractor's spill response measures shall include at a minimum the following:
 - a. Procedures for immediately shutting down injections to affected wells and providing containment for any substrate or amendment releases; and
 - b. Measures to cleanup affected areas. All substrate or amendment cleanups shall be conducted in accordance with the manufacturer's recommendations.

3.11 PRE-INJECTION ACTIVITIES

- A. The Contractor shall install new injection and monitoring wells as per the Contract Documents.
- B. The Contractor shall collect baseline (pre-remedy) readings and groundwater samples from existing and new monitoring wells as per the Contract Documents.
- C. The Contractor shall also collect baseline field readings and surface water samples from the Goose Prairie Creek at locations near the biobarrier as per the Contract Documents.
- D. The Contractor shall survey the newly installed monitoring and injection wells as per Section 3.3 Task 3 – Surveying of the IWWP. Detailed procedures for conducting survey of the monitoring and injection wells are provided in SOP A15-Surveying in Appendix A of the IWWP.
- E. The Contractor shall dispose of wastes generated during the well installation and injection activities.
- F. The Contractor shall review well completion logs for existing wells, which are included in the Contract Documents.
- G. The Contractor shall review data from new wells and adjust any amendment quantities if needed if contamination is higher than expected.

3.12 INJECTION ACTIVITIES

- A. Injection activities shall be conducted in accordance with Section 3.10 Task 10 – In-situ Bioremediation of the IWWP.
- B. Injections shall be conducted during weekdays (and not on weekends) in order to facilitate visits by the U.S. Army and regulatory personnel for observation.
- C. The Contractor shall mobilize materials, equipment, mixing tanks, and labor for injections.

- D. The Contractor shall lay out injection arrays and clear DPT injection points as per the sequence provided in the Contract Documents.
- E. The Contractor shall core concrete/asphalt at injection points, if needed, and adjust any points if obstructions are found.
- F. The Contractor shall begin preparing substrate solution mix a day before its planned injection. Preparation of substrate solution mix shall be a continual activity. KB-1® Primer shall not be mixed until just before its injection; all anaerobic water mixed on a given day shall be injected that same day.
- G. The Contractor shall start injecting ISB amendments following the sequencing as outlined in the Contract Documents (Design Analysis Report text section 4.2.3 and 4.2.4) and herein using the DPT locations and injection wells.
- H. The Contractor shall continuously monitor for surfacing near the injection locations during injections.
- I. Once injections are complete, the Contractor shall decontaminate and demobilize equipment, materials, and mixing tanks.
- J. The Contractor shall restore the site to pre-injection conditions and demobilize personnel.

3.13 SITE PREPARATION

- A. Prior to the ISB injections, the Contractor shall clear the site for aboveground hazards.
- B. The Contractor shall use a global positioning system (GPS) device to locate each injection point and lay out the injection grids.
- C. After all underground utilities have been marked out, the Contractor shall verify that there are no injection points that will impact any utility. If there are points that are affected, the Contractor shall alter the plan and relocate those points to avoid the utility, while still meeting the injection objectives and submitting the revised plan to the Contracting Officer's Representative.
- D. The final DPT injection locations shall be recorded with a GPS.

3.14 SUBSTRATE PREPARATION

- A. The Contractor shall place water tanks (rigid or flexible pillow tanks) near the treatment area and fill each with treated effluent water from the existing groundwater treatment plant (GWTP) located near the LHAAP-18/24.
- B. The Contractor shall prepare substrate and all other required amendments in a properly sized mixing tank as per the manufacturer's instruction provided in the approved Injections Work Plan.
 - 1. The mixing tanks shall be located near the treatment areas.
 - 2. The water required for mixing shall be obtained from the GWTP or from an off-base fire hydrant and transported to the water tanks or directly to the mixing tanks in a water truck.
- C. SRS®-SE proposed for full-scale ISB grid areas and biobarriers injection shall be provided by TSD as SRS®-Premix that contains no water as shipped; therefore, it shall be mixed with water in the field.
 - 1. SRS®-SE would be prepared on site by adding a ratio of 6 parts locally sourced soybean oil to 1 part of the SRS®-Premix and 3 parts of water.

2. The Contractor shall mix the SRS®-Premix with soybean oil and water in the field with the high shear mixer to make a consistent mixture of small oil droplets for easy distribution with less permeability loss and to prevent pressure build up. The field mix will likely have a droplet size between 1 to 5 micro meter (µm).
3. TSD shall provide following:
 - a. one high shear mixer
 - b. one person for two days to assist in the initial setup
 - c. Tanker quantities of locally sourced soybean oil for direct delivery to the site
4. The Contractor shall provide following:
 - a. Sufficient quantity and quality of dilution water
 - b. All utilities required (e.g., electrical drop and wiring hookup for 230/460 volt, three-phase, 30 ampere service), lighting, convenience electrical, secure dry storage and work area, and material handling equipment
 - c. Tankage for emulsion storage (nominally 7,000 gallon capacity for neat oil and sufficient capacity for mixed material)
 - d. All transfer pumps, tankage, and piping

3.15 INJECTIONS

A. DPT Injections

1. The Contractor shall use a DPT rig to push down to the required depth and inject amendment through probe rods.
2. A DPT rig shall be used to inject the amendment mixture at 2-to 3-feet intervals to cover the entire target interval using a top down or bottom-up approach depending on the lithology and field conditions.
3. An injection tool string shall be advanced to the top of the injection interval and the amendment will be pumped through the probe rods.
4. The injection cycle shall be repeated to provide coverage across the entire target depth interval.
5. The Contractor shall use a simple injection system manifold (as shown in the Design Drawings), with each injection line consisting of a dedicated pressure gage, air blow-off valve, flow totalizer, and flow control valve to facilitate injections at several locations at one time.
6. A minimum of two DPT locations shall be injected at one time.
7. No soil cuttings shall be generated using DPT.
8. Once injection is complete at a DPT injection point, the Contractor shall abandon the point as per the procedures outlined in SOP A16 – Soil Boring/Monitoring Well Abandonment in Appendix A of the IWWP.
9. The Contractor shall record DPT injection point locations with GPS.
10. Injections shall be performed at pressures (less than 100 psi) and shall in no case exceed 200 psi unless prior approval is received from the Contracting Officer's Representative.

B. Injection via Wells

1. Injection via wells shall be conducted using newly installed injection wells per the Contract Documents.
2. The injection well screen, installed over the target interval shall be able to facilitate injections in the target interval; however, the injection well screen interval may be modified during well installation based on field observations including depth to groundwater.

3. The Contractor shall install a permanent injection system manifold with each injection line consisting of a dedicated pressure gage, air blow-off valve, flow totalizer and flow control valve to facilitate injections at several injection wells at one time.
4. A minimum of four injection well locations shall be injected at one time.
5. Injections shall be performed at low pressures (less than 10 psi) and shall in no case exceed 30 psi unless prior approval is received from the Contracting Officer's Representative.

3.16 MONITORING DURING INJECTIONS

- A. During active injections, the injection system must be continuously monitored by designated personnel.
- B. The Contractor shall monitor pressure, volume, and flow rates into each injection point (DPT or well) by observing the gauges and totalizers on the injection system. 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.
- C. The Contractor shall record the injection interval during injections and injection information on the injection log provided in Attachment A.
- D. During active injections at the Shallow/Intermediate ISB Biobarrier Wall 1, ISB Grid Areas 4SI, ISB Grid Areas 5SI and ISB Grid Areas 6SI, the Contractor shall have a dedicated person monitor the area between the biobarrier, grid, and Goose Prairie Creek.
- E. During pilot testing, the Contractor shall use bromide as an indicator of distribution of the substrate. The bromide concentrations will be monitored, and an increase in bromide concentrations above the baseline results will indicate amendment distribution. Samples shall be collected and analyzed for bromide to determine if there is an increase in bromide over baseline to evaluate distribution of amendment.

3.17 FIELD READINGS

- A. The Contractor shall collect the field readings using a handheld field instrument and record readings on field forms provided in Attachment A during the injections to ensure consistency.
- B. The Contractor shall use a water quality meter probe placed in the creek for a direct reading from the Goose Prairie Creek. If the carbon source reaches the creek, 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 dissolved oxygen (DO) is observed to below baseline readings or a visual change is observed in the water (murkiness) along the creek bank, the Contractor shall suspend injection activities in the vicinity of Goose Prairie Creek.
- C. The Contractor shall conduct additional monitoring and visual observations to determine if the decrease in DO is from injection materials or changes in the environmental conditions. If injections are suspended, corrective actions (placement of aerators and/or hay bales) shall be implemented if needed. Once DO has stabilized and no visual confirmation of injection materials into the Goose Prairie Creek is confirmed, the Contractor can resume injection activities.
- D. During and after injections in the vicinity of Goose Prairie Creek, the Contractor shall monitor surface water of the Goose Prairie Creek for DO at a minimum of four

locations. The following monitoring frequency will be conducted along the Goose Prairie Creek:

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

3.18 INJECTATE SURFACING

- A. In the event that daylighting (injectate surfacing) occurs, the Contractor shall immediately lower injection rates in the area of surfacing, notify the Contracting Officer's Representative, and fulfill the spill response requirements in the approved Injections Work Plan.
- B. If daylighting continues, the Contractor and Contracting Officer's Representative will evaluate site conditions causing the daylighting and will consider how to modify injections in order to complete the injection event.
- C. Steps that may be considered include but are not limited to:
 1. Further lowering the injection flow rate.
 2. Reducing the amount of substrate and amendment injected per event.
 3. Over-injecting in high-producing adjacent injection locations.
 4. Abandoning the problem DPT injection locations, offsetting, and installing new DPT injection locations near the originally planned locations.
 5. Decommissioning problem injection wells and installing replacement injection wells.
- D. If daylighting in the Goose Prairie Creek is detected, injection rates will be reduced, or injections will be ceased.
 1. If a spill is observed along the Goose Prairie Creek, the Contractor shall isolate and control further migration of the amendments using sandbags and hay bales. The Contractor shall collect and dispose of the affected materials.
 2. The Contractor shall have a solar powered aerator available for use, if needed, to aerate and reoxygenate impacted surface water.

3.19 INJECTION SCHEDULE

- A. A minimum of two injection events will be conducted. The first two injection events will be provided by the Contractor with an option for two additional injection events.
- B. The first two injection events will be conducted a minimum of 3 years apart. Following each injection event performance groundwater samples will be collected to evaluate ISB performance. If additional events are needed these will be completed a minimum of 3 years apart or as otherwise determined by the Contracting Officer's Representative.
- C. The schedule for injection events shall be developed by the Contractor and included in the Injections Work Plan.
- D. An Injection Sequence shall be developed by the Contractor and included in the Injections Work Plan.

3.20 CONTINGENCY INJECTION EVENTS

- A. Additional injection events may be necessary following evaluation of the results of groundwater samples collected after the second injection event. If additional injection events are required, the Contractor shall submit a new Work Plan with the below information for review and acceptance by the Contracting Officer's Representative. This Work Plan will only be prepared and submitted after receiving approval from the Contracting Officer's Representative to perform additional injections beyond the two base injection events.
 - a. Injection wells proposed for injections.
 - b. Type and volumes of substrates/amendments per additional injection event.
 - c. Collection of groundwater samples to evaluate performance of each injection event with time frames of when samples will be collected.
 - d. Injection sequence.
- B. The Contractor shall allow for a minimum review period by the Contracting Officer's Representative of 30 days.

3.21 BASELINE SAMPLING

- A. The Contractor shall collect baseline groundwater samples prior to conducting Phase I pilot testing and Phase II full-scale ISB implementation from existing and new monitoring well locations identified in the Contract Documents.
- B. The Contractor shall collect baseline groundwater samples prior to the implementation of injections to characterize the site contaminant concentrations and geochemical conditions in the Shallow Zone and Shallow/Intermediate Zone.
- C. The Contractor shall collect baseline field readings and groundwater samples from existing and new monitoring wells as per the Contract Documents. Procedures for purging and sampling the wells are detailed in SOP A10-Low Stress Groundwater Sampling in Appendix A of the IWWP. Groundwater samples shall be analyzed as per the Contract Documents and Section 01 35 45 – CHEMICAL DATA QUALITY CONTROL.
- D. The Contractor shall also collect baseline field readings and surface water samples from the Goose Prairie Creek at locations near the biobarrier and grid as per the Contract Documents. Detailed procedures for collecting surface water are provided in SOP A11-Surface Water Sampling in Appendix A of the IWWP. Surface water samples shall be analyzed as per the Contract Documents and Section 01 35 45 – CHEMICAL DATA QUALITY CONTROL.

3.22 PERFORMANCE MONITORING SAMPLING

- A. The Contractor shall collect performance monitoring groundwater samples during Phase I pilot testing and Phase II full-scale ISB implementation from existing and new monitoring well locations (refer to Attachment A) identified in the Contract Documents.
- B. The Contractor shall collect groundwater data as per the Contract Document at these frequencies to evaluate effectiveness of injections.
 - 1. First Two Months of Each Injection Event
 - a. Collect field reading for DO, ORP, and pH each month at locations specified in the Contract Documents.
 - b. Collect groundwater samples each month at locations specified in the Contract Document for analytical parameters, including Bromide and Total Organic Carbon (TOC). Procedures for purging and sampling the wells are

detailed in SOP A10-Low Stress Groundwater Sampling in Appendix A of the IWWP. Groundwater samples shall be analyzed as per the Contract Documents and Section 01 35 45 – CHEMICAL DATA QUALITY CONTROL.

2. Year 0-1 of Each Injection Event
 - a. Collect field readings for DO, ORP, and pH for four quarters at locations specified in the Contact Documents.
 - b. Collect groundwater samples quarterly at locations specified in the Contract Document for analytical parameters including perchlorate, VOCs, alkalinity, anions, ethene, ethane, methane, DHC, Bromide, and TOC. Procedures for purging and sampling the wells are detailed in SOP A10-Low Stress Groundwater Sampling in Appendix A of the IWWP. Groundwater samples shall be analyzed as per the Contract Documents and Section 01 35 45 – CHEMICAL DATA QUALITY CONTROL.
3. Year 1-2 of Each Injection Event
 - a. Collect field readings for DO, ORP, and pH quarterly at locations specified in the Contact Documents.
 - b. Collect groundwater samples quarterly at locations specified in the Contract Document for analytical parameters including perchlorate, VOCs, alkalinity, anions, ethane, methane, Bromide and TOC. Procedures for purging and sampling the wells are detailed in SOP A10-Low Stress Groundwater Sampling in Appendix A of the IWWP. Groundwater samples shall be analyzed as per the Contract Documents and Section 01 35 45 – CHEMICAL DATA QUALITY CONTROL.

3.23 DAILY INJECTION LOGS

- A. Data indicating the injection rates, pressures, and total gallons injected at each location and each vertical interval shall be recorded daily in the logs provided in Attachment A during injections.
- B. The field logbook should also describe calibration procedures conducted by the Contractor on monitoring equipment.
- C. Logs shall be maintained throughout the duration of injections and shall be made available for inspection upon request by the Contracting Officer's Representative.

3.24 DEMOBILIZATION

- A. The Contractor shall complete demobilization in accordance with the approved work plan.
- B. The Contractor shall begin demobilization after all equipment has been decontaminated as per the approved work plan.
- C. Demobilization includes disconnection of utilities, decontamination, disassembly, and removal of ISB injection equipment, and materials handling equipment.
- D. Demobilization is complete when all ISB equipment and related equipment have left the site and work areas have been restored.

3.25 RESIDUALS WASTE MANAGEMENT

- A. All residual waste substrate or amendment materials shall be collected and disposed of off-site as per the requirements of the manufacturer's recommendations, the substrate/amendment SDS, and in accordance with all local, state, and federal regulations.

- B. The following wastes generated during the well installation and injection activities shall be disposed of soil cuttings, wastewater, soil piles, PPE, sampling equipment, well materials, and miscellaneous trash. This waste shall be managed as per Section 3.7 Task 7 – Investigation-Derived Waste Management of the IWWP. Detailed procedures for managing the Investigation-Derived Waste are provided in SOP 22 – Investigation Derived Materials in Appendix A of the IWWP.

3.26 INJECTION COMPLETION REPORT

- A. The Contractor shall prepare and submit an Injection Completion Report that will summarize all activities performed during each injection event. The report shall include the following minimum information:
1. Volume of substrates, amendments, and water injected during each injection event, along with total volumes injected into each location.
 2. Estimated average injection rates for each location.
 3. Pressure and flow rate measurements collected during injections.
 4. Summary of all work performed including but not limited to:
 - a. Deliveries of substrates and amendments to the site.
 - b. Storage and handling of substrates and amendments.
 - c. Preparation of injection solutions.
 - d. Description of methods and equipment used to inject solution into subsurface.
 - e. Problems occurring during injections and resolutions taken.

END OF SECTION

LHAAP-47 - ISB Injections Log Sheet

EISB Area: _____

Drilling Company: _____

Injectors Oversight: _____

EISB Area Log Sheet No.: _____

Oversight Company: _____

Injection Operator: _____

Date: _____

[illegible]

Note:

1. Previous Vol. represents the previous cumulative volume injected at this location and depth interval.
2. Cumulative Vol. represents the new cumulative volume injected at this location and depth interval.

LHAAP-47 - Surface Water Monitoring Log

Log No.: _____

Weather Conditions: _____

Company: _____

Date: _____

Meter(s) Used: _____

Crew: _____

Equipment Calibration

Cal. Standard	Lot#	Expiration	Standard Value	Units	Pre-Cal. Reading	Post-Cal. Reading	Acceptable Range	Comments
pH								
pH								
pH								
Conductivity								
DO								

Surface Water Quality Readings

Surface Water Monitoring Location ID	Temp. (C°)	Cond. (mS/cm)	ORP (mV)	D.O. (mg/L)	pH	TDS	Sal. (ppt)	Turb. (NTU)	Observations/Comments

Notes:

New Performance Monitoring Well Locations

Location ID	Northing	Easting	Depth
PMW-01	69593335.14	3307926.63	50
PMW-02	6960003.52	3309627.19	60
PMW-03	6960061.41	3309627.18	60
PMW-04	6959980.46	3309674.27	60
PMW-05	6959828.06	3309839.50	60
PMW-06	6959263.66	3310968.12	50
PMW-07	6959188.34	3310997.92	50
PMW-08	6959270.47	3310985.32	50
PMW-09	6959195.16	3311015.12	50
PMW-10	6959124.47	3311561.79	50
PMW-11	6959073.20	3311603.56	50
PMW-12	6959162.88	3311614.22	50
PMW-13	6959178.14	3311642.05	50
PMW-14	6959132.59	3311678.13	50
PMW-15	6959872.25	3308980.49	50
PMW-16	6959095.82	3310894.38	50
PMW-17	6959350.97	3311141.96	50
PMW-18	6959186.49	3311361.10	50
PMW-19	6959469.90	3311742.51	50
PMW-20	6960145.52	3312169.78	50
PMW-21	6959800.47	3312430.81	50
PMW-22	6958200.86	3309369.75	50
PMW-23	6958054.64	3309860.52	50
PMW-24	6958162.16	3309479.29	50
PMW-25	6958097.30	3309810.81	50
PMW-26	6961282.61	3310033.53	50
PMW-27	6959218.03	3310963.01	50
PMW-28	6959069.60	3311020.62	50
PMW-29	6959439.34	3310898.43	50
PMW-30	6960710.38	3310218.73	50
PMW-31	6960165.71	3310691.63	50
PMW-32	6959807.06	3310833.57	50
PMW-33	6959448.41	3310975.50	50
PMW-34	6959089.76	3311117.44	50
PMW-35	6958761.93	3310967.21	50
PMW-36	6959986.82	3312252.22	50
PMW-37	6960302.99	3312099.55	50
PMW-38	6959936.94	3312376.48	50
PMW-39	6959753.91	3312514.94	50
PMW-40	6960165.39	3308057.17	50
PMW-41	6960399.69	3308381.37	50
PMW-42	6960633.99	3308705.57	50
PMW-43	6960868.28	3309029.77	50
PMW-44	6960936.50	3310820.86	50
PMW-45	6961264.99	3311036.86	50
PMW-46	6961878.13	3310846.78	50
PMW-47	6961701.07	3311755.47	50
PMW-48	6957792.14	3309528.00	50

SECTION 31 23 00
BACKFILL, COMPACTION, AND GRADING

PART 1 - GENERAL

1.1 SUMMARY

- A. The purpose of this section is to provide the Contractor with the minimum requirements and constraints for backfill and compaction of earthen material in the excavated areas and grading as defined in this section.
- B. The Contractor shall furnish all labor, materials, equipment, and incidentals necessary to perform all backfilling, compaction, and grading cover presented on the Design Drawings and specified herein.
- C. All earthen materials used for backfilling and final grading shall be suitable for use as backfill, as specified in this section.

1.2 REFERENCES

- A. References
 - 1. The publications listed below form a part of this Specification to the extent referenced. The publications are referred to in the text by basic designation only. Where reference is made to one of these standards, the revision in effect at the time of contract award shall apply.
 - a. American Society for Testing and Materials (ASTM)
 - 1) ASTM D2487-17 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
 - 2) ASTM D2974-25 Standard Test Methods for Determining the Water (Moisture) Content, Ash Content, and Organic Material of Peat and Other Organic Soils
 - 3) ASTM D3740 Standard Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction.
 - 4) ASTM D6913 / D6913M-17 Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis
 - 5) ASTM D4318-17e1 - Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
 - 6) ASTM D4972-24e1 Standard Test Method for pH of Soils
 - 7) ASTM D5268-23 Standard Specification for Topsoil Used for Landscaping and Construction Purposes
 - 8) ASTM D7013/D7013M-24 Standard Guide for Calibration Facility Setup for Nuclear Surface Gauges
 - b. Texas Administrative Code
 - 1) 30 TAC 111.111(a)(8)(A) - Requirements for Specified Sources
 - 2) 30 TAC 350 - Texas Risk Reduction Program
- B. Definitions
 - 1. Satisfactory materials
 - a. Satisfactory materials for common fill shall comprise any uncontaminated off-site materials classified by ASTM D 2487-17 as GW, SW, GC, GM, SC, or SM that meets the requirements specified herein.
 - b. Satisfactory materials shall be free of:

- 1) Trees, stumps, branches, roots, noxious weeds, or other wood or lumber.
- 2) Rocks larger than 2 inches.
- 3) Wire, steel, cast iron, cans, drums, or other foreign material.
- c. Common fill and topsoil obtained from an off-site borrow source shall be tested and approved prior to initiating the removal action.
- d. The testing requirements for common fill and topsoil shall be in accordance with the standards outlined in Paragraph 3.4, SOIL TESTING.
- e. All imported backfill material, including common fill, and topsoil shall meet the criteria outlined in Paragraph 1.5.A, CERTIFICATION OF MATERIALS, and shall meet the requirements of PART 2 – PRODUCTS of this Specification.
2. Unsatisfactory Materials
 - a. Unsatisfactory materials shall comprise any materials not meeting the standards of Paragraph 1.2.B.1 SATISFACTORY MATERIALS. This shall include any contaminated materials/soils, trash/refuse, materials containing excessive organic matter, or materials classified by ASTM D 2487-17 as PT, OH and OL.

1.3 SUBMITTALS

- A. Approval from the Contracting Officer's Representative, in consultation with the regulators is required for submittals with an "RA" designation; submittals having an "FIO" designation are for information only. The Contractor shall submit the following to the Contracting Officer's Representative:
 1. Samples of Proposed Fill and Topsoil; Samples; RA
 - a. The Contractor shall submit samples of each earthen material weighing approximately 50 pounds. The Contractor shall not use these materials as part of the contract work until receiving written authorization from the Contracting Officer's Representative.
 2. Laboratory and Field Test Results; Test Reports; RA
 - a. The Contractor shall submit the results of all laboratory and field testing, as specified in Paragraph 3.4, SOIL TESTING, within 24 hours of receipt. These shall include the results of all chemical testing, sieve analyses performed, and all other testing performed of backfill materials.
 3. Backfill Materials Sources and Certification; Certificates; RA
 - a. The Contractor shall submit the proposed source for all backfill materials including common fill and topsoil. The Contractor shall include certificates of compliance attesting those materials meet the specified requirements for particle size, pH, organic matter content, textural class, soluble salts, chemical, and mechanical analyses as per SECTION 01 35 45 - CHEMICAL DATA QUALITY CONTROL.
 4. Laboratory Certification Credentials; Certificates; RA
 - a. The Contractor shall submit licenses or certifications of qualifications of the commercial testing laboratory and/or associated personnel for the Contractor's testing facilities, for the performance of field and laboratory testing in compliance with ASTM D3740.

1.4 ADMINISTRATIVE REQUIREMENTS

- A. Not used.

1.5 QUALITY ASSURANCE

- A. Certification of Materials

1. All materials used as fill, including off-site common fill and standard topsoil shall be tested to ensure they are free from chemical and radiological contamination, as specified in SECTION 01 35 45 - CHEMICAL DATA QUALITY CONTROL.
2. Results shall be certified in writing. The Contracting Officer's Representative will accompany the Contractor to visit all backfill sources during sample collection and inspect all backfill materials. A minimum of one chemical test shall be performed per 1,000 cubic yards (CY) of material and no less than one test per borrowed area. Additional tests shall be performed at a frequency of one sample per 1,000 CY of material or as requested by the Contracting Officer's Representative.
3. Analytical parameters to verify that fill materials are free of chemical contamination are included in SECTION 01 35 45 - CHEMICAL DATA QUALITY CONTROL.

1.6 DELIVERY, STORAGE AND HANDLING

- A. If filled materials are delivered to the site prior to placement approval, materials shall be stockpiled on-site within the Support Zone as directed by the Contracting Officer's Representative. Provisions shall be implemented to minimize surface water impact on the stockpile. Removal and placement of fill material shall be done in a manner to minimize intrusion of soils adjacent to and beneath the stockpile.

PART 2 - PRODUCTS

2.1 COMMON FILL

- A. Off-site common fill shall meet the requirements of Paragraph 1.2.B.1 – SATISFACTORY MATERIALS, and shall meet the following requirements:
 1. Well graded.
 2. Free of rocks larger than 2 inches, loam, organic matter, very soft clays, swelling clays, or fine uniform sands that may be difficult to compact.
 3. Fill material shall meet the TCEQ Risk Reduction Standard No. 2 Soil MSCs for industrial use.
 4. A liquid limit of not more than 35 and plasticity index of not more than 12 in accordance with ASTM D4318-17e1.
 5. ASTM D2487 Group Symbol: Any except those described as poorly graded and except PT, OH and OL.

2.2 TOPSOIL

- A. Topsoil shall meet the requirements of Paragraph 1.2.B.1 – SATISFACTORY MATERIALS, and shall meet the following requirements:
 1. Friable loam, neither of heavy clay nor of very light sandy nature.
 2. Reasonably free of roots, fragments larger than 3 inches in size, rocks or lumps larger than 1 inch in diameter, debris, weeds, plants or their roots, vegetation, seeds of noxious weeds, stolons, seeds; salts; soil sterilant; chemical contaminants; invasive species; or other materials detrimental to plant growth.
 3. Acidity Range (pH): 5.5 to 7.5, determined in accordance with ASTM D4972-24e1.
 4. Containing minimum 3 percent and maximum 10 percent organic matter. determined in accordance with ASTM D2974-25.
 5. Containing salt less than 2.5 ms/cm (millisiemens/cm) total salts.
 6. Capable of supporting growth of grass.
 7. Shall meet the requirements of ASTM D5268-23.

PART 3 - EXECUTION

3.1 GENERAL

- A. All backfill material brought on-site shall be clean, in accordance with Paragraph 1.5.A – CERTIFICATION OF MATERIALS. The written certification attesting to this shall be submitted to the Contracting Officer's Representative.
- B. The Contractor shall coordinate the delivery of backfill materials with the performance of backfilling work to minimize the quantities of materials requiring on-site stockpiling.
- C. In cases where stockpiling of backfill material on-site is unavoidable, the Contractor shall place all such materials upon a 10-mil thick sheet of plastic, which will be stretched across the ground surface in a location approved by the Contracting Officer's Representative.
- D. Fill materials shall be stored in a manner that prevents the common fill from becoming saturated, airborne, or mixed with contaminated soil in accordance with the Contractor's approved work plan.
- E. The Contractor shall be responsible for scheduling the delivery of all backfill materials with the overall project schedule such that no delays in construction occur.
- F. The Contractor shall remove any water accumulating in open excavations and transfer it to the off-site disposal facility.

3.2 BACKFILL PLACEMENT AND COMPACTION

- A. Common fill material shall be backfilled to the specified lines, grades, sections, and elevations shown on the Design Drawings to restore all excavations performed by the Contractor, making allowance for settlement of the material.
- B. The backfill shall be certified to meet the requirements of Paragraph 1.2.B.1 – SATISFACTORY MATERIALS.
- C. Backfill shall not be placed on snow, ice, standing water, or frozen ground surfaces.
- D. Backfill shall not be placed over contaminated material. Backfill shall not be placed when the material is too wet either from rain or from excess application of water. At such times, work shall be suspended until the previously placed and new materials have thawed and/or dried to permit proper compaction.
- E. Each lift of common fill shall be placed in horizontal layers not exceeding 12 inches (+ or – 0.5 inches) in loose thickness.
- F. Upon completion of the backfill operations, the surface of the fill shall be sloped to facilitate surface drainage. This grade shall be maintained throughout backfilling operations, except where controlled by other specified grade and elevations. The final finished grade shall be as specified in Paragraph 3.6 – GRADING and as shown in the Design Drawings.
- G. Settlement or washing that occurs in graded, topsoiled, or backfilled areas prior to acceptance of the work shall be repaired and grades reestablished to the required elevations and slopes. The Contractor shall notify the Contracting Officer's Representative of unexpected subsurface conditions and discontinue work in the affected area until notified to resume work.
- H. Dust control and mitigation and air monitoring shall be performed in accordance with the Contractor's approved Site Safety and Health Plan, as specified under the Final

Health and Safety Plan for Longhorn Army Ammunition Plant Karnack, Texas.
Requirements for air monitoring are provided in the IWWP Appendix A SOP A21.2.1 – Air Monitoring. Visible emissions shall not exceed the limit specified in 30 TAC 111.111(a)(8)(A).

3.3 COMPACTION

- A. The Contractor shall compact each lift of backfill as specified herein. Compaction shall be performed using conventional earthwork equipment (e.g., tracked equipment or mechanical compactors). Material shall be moistened or aerated as necessary to provide the moisture content that will readily facilitate obtaining the specified compaction with the equipment used.
- B. First lift of soil placed shall be a minimum of 12 inches in loose lift thickness. Loose lift thickness of each subsequent lift greater than 12 inches is unacceptable. Each lift shall be compacted using conventional earthwork equipment or traffic compaction methods, with a minimum of six one-way passes over all areas. .
- C. If the Contracting Officer's Representative determines that added moisture is required, water shall be applied by sprinkler tanks or other sprinkler systems, which shall ensure uniform distribution of the water over the area to be treated and give complete and accurate control of the amount of water to be used. If too much water is added, the area shall be permitted to dry before compaction is continued.
- D. The Contractor shall supply all hose, piping, valves, sprinklers, pumps, sprinkler tanks, hauling equipment, and all other materials and equipment necessary to place the water in the fill in the manner specified. Water shall be provided and obtained at the Contractor's expense.
- E. No density-based compaction testing is required.
- F. Approved compacted subgrades that are disturbed by the Contractor's operations or adverse weather shall be scarified and recompactd as per traffic compaction requirements, prior to further construction.

3.4 SOIL TESTING

- A. Initial conformance testing shall be performed to show that the backfill and topsoil materials meet the Specification requirements and to identify the compaction properties of the soils.
- B. Testing shall be performed by an approved commercial testing laboratory or may be performed by the Contractor, subject to approval by the Contracting Officer's Representative.
- C. The Contractor shall submit to the Contracting Officer's Representative for approval licenses or certifications of qualification for the performance of field and laboratory testing. At a minimum, the tests listed below shall be conducted for each material and submitted as initial conformance test results.
- D. In addition, periodic conformance testing shall be conducted by the Contractor's Quality Control Laboratory on common fill soils prior to their use on the project.
- E. The Contracting Officer's Representative reserves the right to reject material based on the results of these conformance tests and/or independent quality assurance testing conducted by the Contracting Officer's Representative. Rejected materials shall be removed from the site at no additional cost.
 - 1. Chemical Testing

- a. Prior to the use of any backfill on-site, the Contractor shall be responsible for performing chemical testing by an off-site laboratory of the proposed borrow material, in accordance with SECTION 01 35 45 – CHEMICAL DATA QUALITY CONTROL.
- 2. Sieve Analysis
 - a. Sieve analysis shall be performed in accordance with ASTM D6913/D6913M-17 (2021). A retest for classification shall be performed at a minimum of every 1,000 cubic yards.
- 3. Imported Material Acceptance
 - a. If tests indicate that the material does not meet Specification requirements, material placement shall be terminated until corrective actions are taken. Material that does not conform to the Specification requirements and is placed in the work shall be removed and replaced at the Contractor's sole expense. The presence of any compound above the requirements of Section 1.5.A herein shall be reason to reject the source, regardless of other test results.

3.5 SPREADING TOPSOIL

- A. Areas where fill material has been placed and will be seeded shall be covered with a minimum topsoil thickness of 6 inches, as shown in the Design Drawings.
- B. The surface shall be free of materials that would hinder planting or maintenance operations. The subgrade shall be pulverized to a depth of 2 inches by disking or plowing for the bonding of topsoil with the subsoil.
- C. Topsoil shall then be uniformly spread, graded, and compacted to the thickness, elevations, and slopes shown, and left free of surface irregularities.
- D. Topsoil shall be compacted by one pass of a cultipacker, roller, or equivalent.
- E. Topsoil shall not be placed when the subgrade is frozen, excessively wet, extremely dry, or in a condition otherwise detrimental to seeding or proper grading.

3.6 GRADING

- A. The Contractor shall uniformly smooth, and grade all filled areas to provide a finished surface that is reasonably smooth, compacted to the specified project requirements, free from irregular surface changes, and sloped to drain properly. Grading shall not create swales or areas where ponding of water will occur. The finished surface shall be as indicated on the Design Drawings, as confirmed by surveying operations. The area shall be graded to form a mound approximately one foot above the surrounding finished grade unless otherwise indicated on the Design Drawings.
- B. During the process of grading, the area to be graded shall be maintained in such a condition that it shall be well drained at all times. When directed, temporary drains and drainage ditches shall be installed to intercept or divert surface water that may affect the execution or condition of the work.
- C. If at the time of grading it is not possible to place any material in its final location, it shall be stockpiled in approved areas for later use. No extra payment will be made for the stockpiling or double handling of excavated material.
- D. The right is reserved to make minor adjustments or revisions in lines or grades if found necessary as the work progresses, in order to obtain satisfactory construction.

- E. After grading is completed and accepted by the Contracting Officer's Representative, no further filling or grading shall be permitted except with the approval of and inspection by the Contracting Officer's Representative.

3.7 QUALITY CONTROL PROGRAM

- A. An independent soil testing laboratory shall be retained by the Contractor and approved by the Contracting Officer's Representative to provide fill materials conformance and compaction testing as indicated herein.

3.8 SOIL EROSION AND SEDIMENT CONTROLS

- A. Newly-graded areas shall be protected from erosion by installing soil erosion and sediment controls, in accordance with SECTION 31 25 00 – EROSION CONTROL AND STORMWATER MANAGEMENT and the Contractor's approved Soil Erosion and Sediment Control (SESC) Plan.

3.9 SOIL TREATMENT

- A. No treatment of the backfill material with insecticides or herbicides is necessary as part of this Remedial action.

END OF SECTION

SECTION 31 23 10
EXCAVATION AND HANDLING OF CONTAMINATED MATERIALS

PART 1 - GENERAL

1.1 SUMMARY

- A. The purpose of this section is to provide the Contractor with the minimum requirements and constraints for excavation and handling of approximately 9,900 cubic yards of contaminated soil and collection and analysis of post-excavation confirmation samples, as indicated on the Design Drawings, specified herein, and in accordance with the approved Remedial Action Work Plan.
- B. The work shall include, without limitation, removal of existing impermeable liner and soil cover previously installed within the excavation area, excavation, and disposal of contaminated soil identified herein and in the Design Drawings; and collection and off-site analysis of post-excavation confirmation soil samples.
- C. Excavation shall extend to the widths and depths shown in the Design Drawings or as specified herein and shall include side slopes (maximum slope of 1V:2H).
- D. The excavation work consists of the following:
 - 1. Removal of approximately 3,400 cubic yards of contaminated soil from Excavation Area 1, which was identified with perchlorate exceedances in soil between the depths of 0 and 12 feet below ground surface (bgs), including soil from this area and its side slopes.
 - 2. Removal of approximately 1,700 cubic yards of contaminated soil from Excavation Area 2, which was identified with perchlorate exceedances in soil between the depths of 0 and 12 feet bgs, including soil from this area and its side slopes.
 - 3. Removal of approximately 500 cubic yards of contaminated soil from Excavation Area 3, which was identified with perchlorate exceedances in soil between the depths of 0 and 7 feet bgs, including soil from this area and its side slopes.
 - 4. Removal of approximately 140 cubic yards of contaminated soil from Excavation Area 4, which was identified with perchlorate exceedances in soil between the depths of 0 and 4 feet bgs, including soil from this area and its side slopes.
 - 5. Removal of approximately 4,100 cubic yards of contaminated soil from Excavation Area 5, which was identified with perchlorate exceedances in soil between the depths of 0 and 14 feet bgs, including soil from this area and its side slopes.
- E. Approximate areas of contaminated soil and extent of previously installed impermeable liner / soil cover are shown in the Design Drawings. The Contractor shall submit a Remedial Action Work Plan, specified herein.
- F. The Contractor shall notify the Contracting Officer's Representative within 24 hours and before advancing excavations if contaminated material is discovered that has not been previously identified or if other discrepancies between data provided and actual field conditions are discovered. Aside from clean material excavated in the course of the remedial action, additional backfill material is not available on-site.
- G. All required sampling and chemical analysis shall be conducted in accordance with the requirements of SECTION 01 35 45 - CHEMICAL DATA QUALITY CONTROL.

- H. No site personnel shall be allowed to enter the excavated area unless the excavation is performed in accordance with Occupational Safety and Health Administration (OSHA) regulations as specified in 29 CFR 1926, Subpart P.
- I. The Contractor shall obtain the services of a Texas-licensed Surveyor to document the limits of excavation for the purposes of measurement and payment, and for preparation of As-Built drawings.

1.2 REFERENCES

A. References

- 1. The publications listed below form a part of this Specification to the extent referenced. The publications are referred to in the text by basic designation only. Where reference is made to one of these standards, the revision in effect at the time of contract award shall apply.
 - a. Code of Federal Regulations (CFR)
 - 1) 29 CFR 1926, Subpart P Safety and Health Regulations for Construction - Subpart P: Excavations
 - 2) 29 CFR 1926, Subpart M Safety and Health Regulations for Construction - Subpart M: Fall Protection
 - 3) 29 CFR 1926, Subpart O Safety and Health Regulations for Construction - Subpart O: Motor Vehicles, Mechanized Equipment, and Marine Operations
 - 4) 40 CFR 268 Land Disposal Restrictions
 - 5) 40 CFR 261 Identification and Listing of Hazardous Waste
 - 6) 40 CFR 264 Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities Treatment, Storage, and Disposal Facilities
 - 7) 40 CFR 302 Designation, Reportable Quantities, and Notification
 - b. United States Army Corps of Engineers (USACE), Tulsa District
 - 1) Final Health and Safety Plan for Longhorn Army Ammunition Plant (LHAAP HASP), Karnack, Texas (2018).
 - 2) Final Installation Wide Work Plan for Longhorn Army Ammunition Plant (LHAAP IWWP), Karnack, Texas, revised by Bhate Environmental Associates, Inc. (May 2018; IWWP).
 - 3) EM 385-1-1 Safety and Occupational Health (SOH) Requirements (March 2024)
 - c. Texas Administrative Code
 - 1) 30 TAC 335 – Industrial Solid Waste and Municipal Hazardous Waste
 - 2) 30 TAC 111 – Control of Air Pollution from Visible Emissions and Particulate Matter
 - 3) 30 TAC 101.4 – Nuisance
 - d. United States Code, 2010 Edition, Title 10
 - 1) 10 U.S.C. 101(e)(5)
 - 2) 10 U.S.C. 2710(e)(2)
 - 3) 10 U.S.C. 2710(e)(3)

B. Definitions

- 1. Debris
 - a. Debris including previously installed impermeable liner and demolition debris in the form of concrete, scrap metals, remnants from previous investigation activities, etc.
- 2. Hazardous Waste

- a. A waste that meets criteria established in Resource Conservation and Recovery Act (RCRA) or specified by the EPA in 40 CFR 261 or which has been designated as hazardous by an RCRA authorized state program.
- 3. Non-hazardous Waste
 - a. Any waste that does not meet the criteria of hazardous waste.
- 4. Post-Excavation Confirmation Sample
 - a. Soil sample collected subsequent to primary and secondary excavations to confirm that the soil cleanup levels have been met.

1.3 SUBMITTALS

- A. Approval from the Contracting Officer's Representative, in consultation with the regulators, is required for submittals with an "RA" designation; submittals with an "FIO" designation are for information only. The Contractor shall submit the following to the Contracting Officer's Representative:
 - 1. Excavation and Handling Plan; Pre-Construction Submittals; RA
 - a. The Contractor shall include an Excavation and Handling Plan as part of their work plan and submit it at least 30 calendar days prior to the Pre-Construction Conference. The Contractor should note that adverse conditions (heavy rain) may be encountered during excavation operations and provisions should be made for such an event. No work at the site, with the exception of site inspections and pre-construction surveys, shall be performed until the plan is approved. The Contractor shall allow 30 calendar days in the schedule for review by the Contracting Officer's Representative. No adjustment for time or money will be made if resubmittals of the plan are required due to deficiencies in the plan.
 - b. At a minimum, the Excavation and Handling Plan shall include all elements listed below.
 - 1) Schedule of Activities – Provide a schedule for all activities. This schedule should include a phasing plan and sequence of events for all construction activities required to complete the work.
 - 2) Personnel requirements.
 - 3) Removal and excavation approach and sequence.
 - 4) Equipment and methods of excavation and backfill.
 - 5) Storage methods and locations for contaminated fluids and solids.
 - 6) Methods for prevention of cross-contamination at the stockpile area to be built within the containment area.
 - 7) Waste Characterization Sampling – The Contractor shall provide a plan for sampling required for waste characterization of the soil and impacted water to be disposed of off-site.
 - 8) Handling of contaminated soil.
 - 9) Coordinating waste segregation and stockpiling logistics . The Contractor shall provide a plan showing the location of proposed stockpile areas within the containment area and how stockpiles will be protected to prevent the runoff of contaminated soil. The Contractor shall provide the locations for disposing of the excavated soil designated as hazardous and non-hazardous waste and shall provide a truck route plan.
 - 10) Shoring, bracing, and/or sloping as per the applicable OSHA requirements.
 - 11) Coordinating with the Site Safety and Health Plan for spill and discharge control and procedures.
 - 12) Post-excavation confirmation sampling and analysis procedures.

- 13) The Contractor shall coordinate haul routes.
- 14) Surveying of excavated areas and determination of excavation quantities.
2. Post-Excavation Confirmation Sampling Results; Test Reports; FIO
 - a. The Contractor shall provide the post-excavation confirmation sampling results in a format consistent with the requirements. The analysis and reporting shall meet the requirements of SECTION 01 35 45 - CHEMICAL DATA QUALITY CONTROL.
3. Surveys; Shop Drawings; RA
4. Closure Report; Product Data; RA
5. Excavation field logs; Closeout Submittals; RA
6. Field screen readings; Closeout Submittals; RA
7. Quantity of materials removed from each area of contamination; Closeout Submittals; RA
8. Quantity of water removed during stormwater dewatering; Closeout Submittals; RA
9. Sampling locations; Closeout Submittals; RA
10. Scaled drawings; Closeout Submittals; RA
 - a. Scaled drawings (a scale of no more than 50 feet/inch) showing limits of excavation, limits of contamination, known underground utilities within 50 feet of excavation, sample locations, sample identification numbers. On-site stockpiles and loading areas shall also be shown.
11. Progress photographs; Closeout Submittals; FIO
 - a. Digital, color photographs with correct exposure and focus, high resolution and sharpness, maximum depth of field, and minimum distortion, shall be used to document work progress. Photos of the site showing a minimum of four views of each contaminated area targeted for excavation, four views of the entrance/exit access road, and any other notable site conditions shall be taken before work begins. After work has started, activities at each work location shall be photographed daily. Photographs shall include:
 - 1) Soil removal.
 - a) Any stormwater dewatering operations.
 - b) Post-excavation confirmation sampling.
 - c) Fill placement and grading.
 - 2) Site restoration.
 - 3) Miscellaneous activities:
 - a) Unanticipated events such as spills and the discovery of additional source materials.
 - b) Contaminated material/water storage, handling, characterization sampling, treatment, and discharge/disposal.
 - c) Post construction photographs shall be taken after completion of the work.
 - b. Electronic copies of the progress photographs shall be uploaded to a cloud-based file sharing service, compatible with USACE systems, at minimum once a week for review by stakeholders off-site.
12. Other Submittal Requirements; Closeout Submittal; RA
 - a. Submit cross-sections of the excavation area before and after excavation and after backfilling, test results, and the Closure Report within 14 calendar days of work completion at the site.

1.4 ADMINISTRATIVE REQUIREMENTS

A. Not used.

1.5 REGULATORY REQUIREMENTS

A. Permit Equivalences and Licenses

1. These requirements governing transportation, administrative requirements and methods of treatment and disposal of hazardous wastes, and all other applicable Federal, State, or local laws, codes, and ordinances, which govern or regulate hazardous wastes, shall apply to the work of this section. The Contractor shall be responsible for obtaining permit equivalency necessary for excavation, stormwater dewatering, stockpiling and any other features of work associated with the excavation of contaminated soil. The Contractor may commence remedial action field activities after project approvals are obtained and permit equivalency documentation has been prepared and submitted, as applicable. Approval or issuance of permit equivalents is not required prior to initiation of remedial action under CERCLA.
2. Excavations for sites under this remedial action are expected to be less than 1 acre in size and are thus not subject to the storm water pollution prevention requirements of Chapter 26 of the Texas Water Code and TCEQ General Permit TXR15000.

B. Air Emissions

1. The Contractor shall monitor and control air emissions in accordance with the Final Health and Safety Plan for Longhorn Army Ammunition Plant Karnack, Texas.

1.6 QUALITY ASSURANCE

A. Shoring Plan

1. The Contractor shall submit drawings describing the methods for any shoring of excavations. Drawings shall include material sizes and types, arrangement of members, and the sequence and method of installation and removal. Calculations shall include data and references used.

1.7 DESIGN AND PERFORMANCE RESPONSIBILITY

- A. The Contractor is responsible for the design and execution of the means and methods to achieve the target excavation depths and minimize disturbance.
- B. The Contractor is responsible for monitoring water quality and controlling the impact to the surface water bodies (Goose Prairie Creek) affected by the work specified herein.
- C. Any design review and field monitoring activities performed by the Contracting Officer's Representative shall not relieve the Contractor of responsibility for the work.

1.8 SITE SOIL CLEANUP LEVEL

- A. The remediation soil cleanup level for this project is:
 1. Perchlorate – 7.2 mg/kg

1.9 POST-EXCAVATION CONFIRMATION SAMPLING CRITERIA

- A. All excavations require verification in accordance with the requirements herein and the IWWP Section 3.8.3.
- B. The Contractor shall collect a post-excavation confirmation sampling for each excavation area will consist of one 5-point composite bottom sample per 1,000 square feet of the excavation bottom and one 5-point composite sidewall sample per 1,000 sq feet of vertical sidewall. The five points for each composite sidewall sample will be selected to represent the full height of the sidewall.. In addition to the post-excavation confirmation sampling, QA/QC sampling shall also be performed in accordance with SECTION 01 35 45 – CHEMICAL DATA QUALITY CONTROL.

- C. Bottom Samples shall be collected from 0 to 3 inches at the bottom of the excavation.
- D. Excavation Based on the primary excavation limits shown in Design Drawings, approximately 12 confirmation samples will be collected from the excavated bottom, and approximately 26 confirmation samples will be collected from the sidewalls of the excavation areas.
- Excavation Area 1: Approximately 4 composite bottom samples and 8 composite sidewall samples.
 - Excavation Area 2: Approximately 2 composite bottom samples and 6 composite sidewall samples.
 - Excavation Area 3: Approximately 1 composite bottom samples and 4 composite sidewall samples.
 - Excavation Area 4: Approximately 1 composite bottom samples and 4 composite sidewall samples.
 - Excavation Area 5: Approximately 4 composite bottom samples and 4 composite sidewall samples.
- E. The Contractor shall bias the post-excavation confirmation sample locations within each 1,000-square-foot area to the locations with highest concentrations, based on field screening and data from previous investigation sample locations, type and characteristics of contaminant, and visual and other indicators of potential contamination.
- F. If contaminants are detected above their soil cleanup levels during the confirmation sampling, the area shall be excavated at least two to five feet laterally and one additional foot vertically. Excavations shall continue until confirmation samples demonstrate the contaminants remaining in the soil are below their cleanup level or until groundwater is encountered.

1.10 WASTE TYPES

- A. The following types of wastes are expected from the excavation operation:

TABLE 31 23 10 - 1

Waste Type	Waste Definition
Hazardous – RCRA	• Soils and impacted water that meet the criteria established in Resource Conservation and Recovery Act (RCRA) or specified by the EPA in 40 CFR 261 or which has been designated as hazardous by an RCRA authorized state program.
Non-Hazardous – Subtitle D	• Soils and impacted water with contaminant concentrations do not meet the above definition for Hazardous Waste. • Debris including existing impermeable liner. • Tree stumps from grubbing operations.
Recyclable – Non-hazardous	• Vegetation from clearing operations

PART 2 - PRODUCTS (NOT APPLICABLE TO THIS SPECIFICATION SECTION)

PART 3 - EXECUTION

3.1 SURVEYS

- A. Surveys shall be performed in accordance with the IWWP Appendix A SOP A15 - Surveying.
- B. Surveys shall be performed immediately prior to commencing excavations and immediately after the Contracting Officer's Representative confirms that all target contaminated material has been removed to determine the total volume of contaminated material removed from each excavation area.
- C. Surveys shall also be performed after backfilling and grading showing final grade. Locations of post-excavation confirmation samples shall also be surveyed and shown in the drawings.

3.2 EXISTING STRUCTURES AND UTILITIES

- A. The Contractor will be responsible for contacting the appropriate utility service providers and independently performing a geophysical investigation at the site prior to commencement of subsurface activities.
- B. The Contractor shall discuss the approach to managing utilities with the Contracting Officer's Representative and any utility owners prior to commencement of subsurface activities.
- C. The Contractor shall field-verify and mark the locations of all utilities within the work area prior to mobilizing heavy construction equipment, supplies, and facilities and to protect all existing utilities and structures for the duration of construction in accordance with this Section and Design Drawings.
- D. The Contractor shall contact the Texas Excavation Safety System, Inc. utility notification service by calling 811 or 800-892-0123. This notification must 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.
- E. Damage to existing structures and utilities outside the scope of work shall be repaired at no additional cost to the Government.
- F. Unexpected active utilities encountered during excavation shall not be disturbed without written approval from the Contracting Officer's Representative.

3.3 CLEARING

- A. Clearing shall be performed as required. Cleared vegetation shall be chipped to a maximum size of 2 inches by 2 inches and can be recycled or reused on-site.
- B. Grubbing shall consist of the removal and disposal of stumps, roots, buried logs, and all tap roots, lateral roots, or other projections over 1.5 inches in diameter within the area of excavation.
- C. All grubbed material is assumed to be contaminated as non-hazardous and shall be disposed of off-site.

3.4 SITE PREPARTION

- A. Site preparation shall be completed prior to excavation, as shown in the Design Drawings.
- B. The Contractor will be permitted to remove existing walls, slabs, or other structural elements as required to perform excavation. The Contractor shall coordinate all removal activities with the Contracting Officer's Representative and shall comply with applicable safety and environmental requirements.

3.5 EXCAVATION SEQUENCING

- A. Excavation shall be conducted as shown in the Design Drawings and as follows:
 - 1. Perform a Global Positioning System (GPS) survey to approximate locate and mark the vertices of the excavation areas as shown on the Design Drawings, including the extent of the existing liner..
 - 2. Prior to excavation, remove existing impermeable liner and soil cover adjacent to Building 25C.
 - 3. Perform excavations starting in shallow areas (Excavation Area 4 and 5) first and then perform excavations in deeper areas (Excavation Area 1, 2, 3) and lastly Excavation Area 6. .
 - 4. The Contractor shall perform post-excavation confirmation sampling for each area based on the Post-Excavation confirmation Sampling Criteria listed in Paragraph 1.9, concurrently with the excavation activity.
 - a. In case post-excavation confirmation sample analytical results show contaminant concentrations greater than the soil cleanup levels, then the Contractor shall pause the excavation and contact Contracting Officer's Representative for further direction.
 - b. The Contractor shall perform secondary excavation of contaminated material based on the results of post-excavation confirmation sample analysis and/or field observations with approval from the Contracting Officer's Representative.
 - c. The Contractor shall perform post-excavation confirmation sampling to confirm that the site soil cleanup level has been achieved.
 - 5. During the excavation, the Contractor shall perform a civil survey to confirm the horizontal and vertical extent of excavation meets the Design Drawings.
 - 6. The Contractor shall conduct waste disposal sampling and soil load out activities concurrently with the excavation activity.

3.6 EXCAVATION

- A. General
 - 1. An electronic copy of the Design Drawings will be provided to the Contractor to establish sampling locations and the corners of all primary excavation areas, as shown on the Design Drawings. The Contractor shall use North American Datum 1983 (NAD83) Texas State Plane North Central FIPS 4202 coordinates to lay out sample locations and the limits of excavation, using the services of a Texas State Licensed Surveyor.
 - 2. The Contractor shall perform all excavations to the lines, grades, and elevations shown on the Design Drawings. Vertical excavation shall stop if groundwater is encountered. The survey work to measure quantities shall be performed by the Contractor prior to backfilling the excavation and shall be accurate to the nearest 0.1 feet.
 - 3. Excavation shall be performed in a manner that will limit spills and the potential for contaminated material to be mixed with uncontaminated material. An excavation

log describing visible signs of contamination encountered shall be maintained for each area of excavation.

4. The Contractor shall remove and dispose of any material that becomes contaminated as a result of the Contractor's operation at no additional cost to the Government.
5. The Contractor shall stage operations to minimize the time the contaminated soil is exposed to the weather.
6. The Contractor shall be responsible for benching or sloping the excavation, as necessary, or for providing other temporary supports to prevent soil slippage along the side slopes and any other slope stability issues in accordance with the Contractor's approved Excavation and Handling Plan. All Contractor-designed sloping shall comply with the requirements of OSHA 1926, Subpart P. The soil type shall be considered Type C unless additional soil analysis is completed.
7. All slopes shall be inspected daily by a qualified staff member for cracks in the soil at the head or along the face of the slopes and other changed conditions such as bulges or sloughs on the slopes. Inspection results shall be documented in a Daily Inspection Log and any unusual or changed conditions shall be brought to the attention of the Contracting Officer's Representative.
8. The Design Drawings depict a maximum side slope of 1V:2H for excavation areas exceeding 4 feet in depth for design and estimating purposes. The Contractor shall evaluate site-specific conditions, including excavation duration, soil stability, and presence of groundwater, and shall be responsible for selecting and implementing appropriate side slopes or other support measures (e.g., benching or shoring) in accordance with applicable safety requirements. Where conditions warrant, including long-duration excavations or the presence of groundwater, the Contractor shall flatten slopes or implement additional stabilization measures as necessary to maintain excavation stability and safety. The Contractor shall maintain an excavation of sufficient size to allow workers ample room to complete the work.
9. Stockpiles shall be covered prior to any storm events to prevent re-saturation of dried material. Contaminated stockpiles shall meet the regulations defined in 40 CFR 264.250.
10. Blasting shall not be permitted.
11. Loading and transporting contaminated material shall be in accordance with SECTION 31 23 20 – TRANSPORTATION AND DISPOSAL OF CONTAMINATED MATERIAL. Following the receipt of waste characterization sample results collected in accordance with SECTION 31 23 20 – TRANSPORTATION AND DISPOSAL OF CONTAMINATED MATERIAL, the Contractor may perform direct loading of all excavation materials for off-site transport and disposal, unless moisture conditions require stockpiling and drying.
12. The stockpile areas shall be built in accordance with the Design Drawings. The Contractor shall stage contaminated soil on-site in stockpile areas in either lined roll-off containers or stockpiled. The roll-off containers and/or the stockpiled soil shall be covered in the event of rainfall.
13. Non-hazardous decontamination water shall be stored in 55-gallon drums or larger until disposal at the off-site disposal facility. The miscellaneous waste shall be placed in plastic bags until disposal.
14. Dust control and mitigation and air monitoring shall be performed in accordance with 30 TAC 111, 30 TAC 101.4, and the Contractor's approved Site Safety and Health Plan, as specified under Final Health and Safety Plan for Longhorn Army Ammunition Plant Karnack, Texas. Requirements for air monitoring are provided in the IWWP Appendix A SOP A21.2.1 – Air Monitoring.

15. Areas being excavated shall be maintained in a clean condition, free from leaves, brush, sticks, trash, and other debris. Organic materials including stumps, roots, and debris encountered during excavation shall be considered grubbed material and shall be disposed as a contaminated material in accordance with SECTION 31 23 20 – TRANSPORTATION AND DISPOSAL OF CONTAMINATED MATERIAL.
16. Surface water shall be directed away from open excavation and construction areas to prevent soil erosion, surface water runoff from coming in contact with contaminated material, and the accumulation of surface water in excavation areas. Diversion ditches, dikes, and grading shall be provided as necessary and soil erosion controls shall be implemented in accordance with SECTION 31 25 00 – EROSION CONTROL AND STORMWATER MANAGEMENT and the Design Drawings. The Contractor shall stop work and reduce the exposed surface when heavy rain is predicted. After the rainfall event, any stormwater accumulated in the excavation will be pumped to a frac tank, allowed to settle, and then conveyed to the off-site disposal facility.
17. During the completion of both the excavation and backfilling stages of construction, all trapped sediment in the containment area shall be collected and removed as contaminated material.
18. All vehicles and equipment used for excavation shall be decontaminated prior to demobilization in accordance with the Contractor's approved Site Safety and Health Plan, prior to entering clean areas.
19. If wildlife is identified within work areas, the Contractor shall immediately notify the Contracting Officer's Representative of their presence. The Contractor shall cease site operations if directed by the Contracting Officer's Representative.

B. Primary Excavation

1. In total, five primary excavation areas have been designed to remove contamination as shown on the Design Drawings.
2. The Contractor shall conduct excavations based on the approved Excavation and Handling Plan to the limits and depths shown on the Design Drawings. Excavation areas shall be excavated to not more than 0.2 feet beyond the final elevation or depths and extent indicated in the Design Drawings, unless directed otherwise by the Contracting Officer's Representative.

3.7 POST-EXCAVATION CONFIRMATION SAMPLING AND SECONDARY EXCAVATION

- A. The Contractor shall collect post-excavation confirmation bottom and sidewall samples and send them to an off-site laboratory for perchlorate analysis with a turn-around-time (TAT) of 48 hours. All post-excavation sample results shall be compared to the site soil cleanup level.
- B. Secondary Excavation beyond the primary excavation limits shown on the Design Drawings shall be performed based solely on analytical results of post-excavation samples and/or visual observations of soil contamination. Secondary Excavation shall be performed only with the approval of the Contracting Officer's Representative.
- C. If analytical results of a bottom post-excavation sample exceed the soil cleanup levels, the Contractor shall perform secondary excavation of the corresponding 1,000-square-foot bottom sampling grid in 1-foot vertical increments, and then collect a new bottom sample. This process shall be repeated until the soil cleanup levels are met, or groundwater is encountered or as otherwise directed by the Contracting Officer's

Representative. Additional sidewall post-excavation samples shall be collected for every 2 to 5 vertical feet of new sidewall exposed during secondary excavation.

- D. If analytical results of a sidewall sample exceed the soil cleanup levels, the Contractor shall perform secondary excavation of the corresponding 1,000-square-foot sidewall sampling grid in 2- to 5-foot horizontal increments, and then collect new post excavation sidewall samples. This process shall be repeated until the soil cleanup level is met, or as otherwise directed by the Contracting Officer's Representative. If the excavation expands horizontally, the Contractor shall monitor the overall excavation area to determine whether additional bottom samples are required to ensure that the post-excavation confirmation sampling criteria listed herein are met.
- E. All required sampling and chemical analysis shall be conducted in accordance with IWWP Appendix A SOP A13 – Sample Control and Documentation and the Contractor's approved UFP-QAPP and the requirements of SECTION 01 35 45 – CHEMICAL DATA QUALITY CONTROL.

3.8 WASTE HANDLING

- A. The Contractor shall segregate the excavated material into distinct stockpiles corresponding to their respective categories in accordance with IWWP Appendix A SOP A22 – Investigation Derived Materials. All excavated contaminated material shall be transported off-site and routed to the appropriate disposal facilities for treatment and/or disposal in accordance with SECTION 31 23 20 – TRANSPORTATION AND DISPOSAL OF CONTAMINATED MATERIAL.

3.9 UNDERGROUND STORAGE TANKS (USTS)

- A. No known USTs are present within the site. If an UST is encountered during the course of excavations, excavations in the vicinity of the UST shall be ceased and the Contracting Officer's Representative shall be immediately notified.

3.10 CONTAMINATED MATERIAL STORAGE

- A. Material shall be placed in temporary stockpiles within the containment area immediately after excavation.
- B. Stockpiles
 - 1. Stockpiles shall be constructed near the excavation area as shown on the Design Drawings.
 - 2. Each stockpile shall be covered with two layers of 6-millimeter polyethylene sheets beneath sand and geo-textile cover free of holes or other damage to prevent precipitation from entering the stockpile. The cover material shall be extended over the berms and weighted with sandbags to prevent it from being removed or damaged by wind.

3.11 SAMPLING BENEATH THE SOIL STOCKPILE AREAS

- A. Samples from beneath the soil stockpile/loadout areas (including the shallow soil stockpiles if analytical results preclude their use as backfill) shall be collected after removal of the soil stockpiles to verify that no cross-contamination has occurred in the area. Five-point composite samples shall be collected at a frequency of one composite sample per 1,000 square feet of disturbed area (stockpile area), from a depth interval of 0 to 0.5 feet. Samples shall be collected from biased areas based on visual indications of potential leaks. Samples shall be analyzed for contaminants of concern only in accordance with the requirements of SECTION 01 35 45 – CHEMICAL DATA QUALITY CONTROL.

- B. Areas showing contaminant sample results above the soil cleanup level shall be scraped to remove the contamination and re-sampled.

3.12 SPILLS

- A. In the event of a spill or release of a hazardous substance (as designated in 40 CFR 302), pollutant, contaminant, or oil, the Contractor shall notify the Contracting Officer's Representative immediately.
- B. If the spill exceeds the reporting threshold, the Contractor shall follow the pre-established procedures as described in the 2018 IWWP, Health and Safety Plan for immediate reporting and containment. The Contractor shall take immediate containment actions to minimize the effect of any spill or leak.
- C. Cleanup shall be in accordance with applicable federal, state, and local regulations. As directed by the Contracting Officer's Representative, additional sampling and testing shall be performed to verify spills have been cleaned up. Spill cleanup and testing shall be done at no additional cost to the Government.

3.13 BACKFILLING

- A. Confirmation Test Results
 - 1. Excavations shall be backfilled immediately after all contaminated materials have been removed and confirmation test results have been approved by the Contracting Officer's Representative. Backfilling shall be conducted as shown in the Design Drawings and in accordance with SECTION 31 23 00 – BACKFILL, COMPACTION, AND GRADING.
- B. Compaction
 - 1. Compaction shall be in accordance with SECTION 31 23 00 – BACKFILL, COMPACTION, AND GRADING.

3.14 DISPOSAL REQUIREMENTS

- A. Off-site disposal of contaminated material shall be in accordance with SECTION 31 23 20 – TRANSPORTATION AND DISPOSAL OF CONTAMINATED MATERIAL.

END OF SECTION

SECTION 31 23 20

TRANSPORTATION AND DISPOSAL OF CONTAMINATED MATERIAL

PART 1 - GENERAL

1.1 SUMMARY

- A. The purpose of this section is to provide the Contractor with the minimum requirements for the transportation and disposal of contaminated materials.
- B. The Contractor shall be responsible for obtaining all permits required for off-site transportation of waste in accordance with applicable Federal, State, and local regulations.
- C. At a minimum, the Contractor shall be required to furnish all labor, material, equipment, and incidentals necessary for on-site preparation and off-site transportation, treatment, and disposal of materials from the remediation and associated activities. Waste generated shall be treated and disposed at approved Resource Conservation and Recovery Act (RCRA) Treatment, Storage, and Disposal Facilities (TSDFs), RCRA Subtitle C landfill(s), Subtitle D landfill(s), or a Construction and Demolition (C&D) landfill, depending on waste characteristics.
- D. The Contractor shall prepare and maintain waste shipment records and manifests required by RCRA (as applicable), U.S. Federal Department of Transportation (DOT), and Texas State transportation department.
- E. The Contractor shall be required to perform all sampling required for waste characterization and landfill acceptance of excavated soils, debris (including existing impermeable liner and soil cover previously installed), and impacted water. The Contractor shall also be required to provide all waste profile information to the landfill, per their requirements.
- F. The Contractor shall ensure that all operations for loading and hauling of wastes comply with Federal and State DOT regulations, and all other applicable Federal, State, and local requirements.

1.2 REFERENCES

- A. References
 - 1. The publications listed below form a part of this Specification to the extent referenced. The publications are referred to in the text by the basic designation only. Where reference is made to one of the standards below, the revision in effect at the time of contract award shall apply.
 - a. American Society for Testing and Materials (ASTM)
 - 1) ASTM D751-19 Standard Test Methods for Coated Fabrics
 - b. Code of Federal Regulations (CFR)
 - 1) 29 CFR 1910 Occupational Safety and Health Standards
 - 2) 40 CFR 261 Identification and Listing of Hazardous Waste
 - 3) 40 CFR 264 Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities
 - 4) 40 CFR 265 Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities
 - 5) 40 CFR 268 Land Disposal Restrictions

- 6) 40 CFR 270 EPA Administered Permit Programs: The Hazardous Waste Permit Program
- 7) 40 CFR 300 National Oil and Hazardous Substances Pollution Contingency Plan
- 8) 40 CFR 302 Designation, Reportable Quantities, and Notification
- 9) 49 CFR 107 Hazardous Materials Program Procedures
- 10) 49 CFR 172 Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, Training Requirements, and Security Plans
- 11) 49 CFR 173 Shippers – General Requirements for Shipments and Packaging
- c. United States Code (U.S.C.)
 - 1) 10 U.S.C. 101(e)(5) Definitions
 - 2) 10 U.S.C. 2701(e)(2) Environmental Restoration Program
 - 3) 10 U.S.C. 2701(e)(3) Environmental Restoration Program
 - 4) 33 U.S.C. 2701 et seq. Oil Pollution Act (OPA)
 - 5) 42 U.S.C. 6901 et seq. Resource Conservation and Recovery Act
 - 6) 42 U.S.C. 9601 et seq. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
- d. United States Army Corps of Engineers (USACE), Tulsa District
 - 1) Final Health and Safety Plan for Longhorn Army Ammunition Plant (LHAAP HASP), Karnack, Texas (2018).
 - 2) Final Installation Wide Work Plan for Longhorn Army Ammunition Plant (LHAAP IWWP), Karnack, Texas, revised by Bhate Environmental Associates, Inc. (May 2018; IWWP).

B. Definitions

- 1. Debris
 - a. Debris including previously installed impermeable liner and demolition debris in the form of concrete, scrap metals, remnants from previous investigation activities, etc.
- 2. Hazardous Waste
 - a. A waste that meets criteria established in RCRA or specified by the EPA in 40 CFR 261, or that has been designated as hazardous by a RCRA-authorized state program.
- 3. Non-Hazardous Waste
 - a. Any waste that does not meet the criteria of hazardous waste. It is anticipated that contaminated soil will be classified as non-hazardous.

1.3 SUBMITTALS

- A. Approval from the Contracting Officer's Representative, in consultation with the regulators, is required for submittals with an "RA" designation; submittals with an "FIO" designation are for information only. The Contractor shall submit the following to the Contracting Officer's Representative:
 - 1. Waste Management and Transportation Plan; Pre-Construction Submittals; RA
 - a. The Contractor shall prepare the Waste Management and Transportation Plan as part of their work plan and submit it to the Contracting Officer's Representative for approval at least 30 days prior to the Pre-Work Conference. Deficiencies in the Waste Management and Transportation Plan will be discussed at the Pre-Work Conference. The Contractor shall make all necessary amendments required by the Contracting Officer's Representative and resubmit

it for approval. This procedure shall continue until the Contracting Officer's Representative gives final written approval. The Contractor shall make the necessary effort so that only one resubmittal is required. The plan shall include, at a minimum, the following:

- 1) Procedures for contaminated material management on-site and the management practices to be utilized.
 - 2) Waste minimization methods.
 - 3) Soil stockpile area where contaminated material is to be handled.
 - 4) Proposed landfill facilities for waste disposal, including alternate facilities in the event that the primary facility cannot accept the waste.
 - 5) Names, certificates, permits, licenses, EPA identification (ID) numbers, locations, and telephone numbers for the proposed disposal facility/facilities and waste haulers.
 - 6) RCRA waste classification and volume estimates for the waste types, if existing sample results are sufficient for landfill acceptance. Otherwise, the Contractor shall conduct waste characterization sampling to meet landfill acceptance requirements.
 - 7) Letters of commitment from the proposed waste haulers and disposal facilities, certifying acceptance of the LHAAP-47 waste.
 - 8) Methods and equipment to be used to ensure accurate weight measurements of waste material.
 - 9) Waste manifesting procedures.
 - 10) Locations and procedures for the on-site waste handling areas.
 - 11) Types of transport vehicles to be used for each type of material.
 - 12) Packaging and transporting requirements for each type of waste, including any special requirements of the disposal facility.
 - 13) Proposed truck routes from the worksite to the disposal facility/facilities. The route(s) to and from the disposal facility shall be in accordance with the disposal facility/facilities requirements and all Federal, State, and local regulations, laws, ordinances, and weight restrictions. The established truck routes from the site to the closest major freeway, minimizing transport on residential streets as much as feasible. Use of these routes shall be strictly enforced.
 - 14) Methods to contain and clean up spills.
 - 15) Procedures for incident response, including details of manpower and equipment available and the coordination necessary to mobilize forces in an emergency.
 - 16) The Emergency Response Name and Telephone number that will be available on a 24/7 basis during the shipment period, and this information will be included in the Shipments Manifests as per the USDOT Regulations.
2. Notices of Non-Compliance and Notices of Violation; Product Data; RA
- a. Notices of non-compliance or notices of violation issued by a Federal, State, or local regulatory agency issued to the Contractor in relation to any work performed under this contract. The Contractor shall immediately provide copies of such notices to the Contracting Officer's Representative. The Contractor shall also furnish all relevant documents regarding the incident and any information requested by the Contracting Officer's Representative and shall coordinate its response to the notice with the Contracting Officer's Representative prior to submission to the notifying authority. The Contractor shall also furnish a copy to the Contracting Officer's Representative of all

- documents submitted to the regulatory authority, including the final reply to the notice, and all other materials, until the matter is resolved.
3. Contaminated Material Stockpile Reports; Product Data; RA
 - a. When contaminated materials are in interim storage, submit on a weekly basis, an inventory of the types, quantity, and locations of all contaminated materials in interim storage, and a record of the date, quantity, source, and disposition of all contaminated materials placed into or taken out of interim storage. Report all test results from sampling of stored material.
 4. Annual and Biennial Reports; Test Reports; RA
 - a. Information necessary to file State annual or USACE biennial reports for waste transported, treated, stored, or disposed of under this contract shall be submitted to the Contracting Officer's Representative at the specified time and shall not be forwarded directly to the regulatory agency. The submittal shall contain all the information necessary for filing of the formal reports in the form and format required by the governing Federal, State, and local regulatory agency. A cover letter shall accompany the data including the contract number, Contractor's name and project locations.
 5. Spill Response; Test Reports; RA
 - a. In the event of a spill or release of a pollutant, contaminant, hazardous substance (as designated in 40 CFR 302), or oil (as governed by 33 U.S.C. 2701 et seq.), the Contractor shall notify the Contracting Officer's Representative immediately and contact the National Response Center as per the Final Health and Safety Plan for Longhorn Army Ammunition Plant Karnack, Texas. If the spill exceeds a reporting threshold, the Contractor shall follow the pre-established procedures for immediate reporting to the Contracting Officer's Representative.
 6. Manifest Exception Reports; Test Reports; RA
 - a. In the event that a manifest copy documenting receipt of waste at the disposal facility is not received within 35 days of shipment initiation, the Contractor shall prepare and submit an exception report to the Contracting Officer's Representative within 37 days of shipment initiation.
 7. Certification; Certificates; RA
 - a. Copies of the current certificates of registration required by 49 CFR 107, Subpart G issued to the Contractor and/or Subcontractors or written statements certifying exemption from these requirements.
 8. Transportation and Disposal Coordinator; Certificates; RA
 - a. Transportation and Disposal Coordinator qualifications including proof of at least one year of specialized experience in management and transportation of hazardous wastes; proof of current Department of Transportation Hazardous Materials Training Certification.
 9. Training; Certificates; RA
 - a. Documentation that employees preparing or transporting hazardous materials have been trained, tested, and certified per 49 CFR 172, Subpart H, including general security awareness requirements and, where applicable, site-specific security plan requirements.
 10. EPA Off-Site Policy; Certificates; RA
 - a. A letter certifying that EPA considers the facilities to be used for all off-site disposal to be acceptable in accordance with the Off-Site Policy in 40 CFR 300.440. This certification shall be provided for wastes from sites governed by 42 U.S.C. 6901 et seq. or 42 U.S.C. 9601 et seq. A sample Off-Site Policy certification memo is provided in Attachment A.

11. Transport Certification; Certificates; FIO
 - a. The Contractor shall submit certification that all operators and vehicles used to transport contaminated material meet all existing Federal, State, and local regulations for vehicle operations.
12. Certificates of Disposal; Certificates; RA
 - a. The Contractor shall provide certificates documenting the ultimate disposal of CERCLA remediation wastes within 180 days of initial shipment. Receipt of these certificates will be required for final payment.
13. Shipping Documents; Certificates; RA
 - a. The Contractor shall submit all transportation-related shipping documents to the Contracting Officer's Representative for review including draft waste manifests, draft bills of lading, lists of corresponding proposed labels, packages, marks, and placards to be used for shipment, waste profiles, supporting waste analysis documents, for review a minimum of 14 calendar days prior to the anticipated shipping date. Packaging assurances shall be furnished prior to transporting the material, "generator copies" of hazardous waste manifests, bill of landings, and supporting waste analysis documents shall be furnished when shipments are originated. "Receipt copies" of waste manifests at the designated disposal facility shall be furnished no later than 35 days after acceptance of the shipment.

1.4 ADMINISTRATIVE REQUIREMENTS

A. Qualifications

1. Transportation and Disposal Coordinator
 - a. The Contractor shall designate, by position and title, one person to act as the Transportation and Disposal Coordinator (TDC) for this contract. The TDC shall serve as the single point of contact for all environmental regulatory matters and shall have overall responsibility for total environmental compliance at the site including, but not limited to, accurate identification and classification of hazardous waste and hazardous materials; determination of proper shipping names; identification of marking, labeling, packaging and placarding requirements; completion of waste profiles, hazardous waste manifests, bill of landings, exception and discrepancy reports; and all other environmental documentation. The TDC shall have, at a minimum, one year of specialized experience in the management and transportation of hazardous waste and have been DOT-certified under 49 CFR 172, Subpart H.
2. Training
 - a. The Contractor's hazardous materials employees shall be trained, tested, and certified to carry out their assigned duties safely and effectively in accordance with the Final Health and Safety Plan for Longhorn Army Ammunition Plant Karnack, Texas. The Contractor's employees transporting hazardous materials or preparing hazardous materials for transportation, including samples, shall be trained, tested, and certified in accordance with 49 CFR 172, Subpart H, including security awareness and any applicable security plans. Contractor employees making determinations that shipments do not constitute DOT regulated hazardous materials shall also be trained, tested, and certified in accordance with 49 CFR 172, Subpart H.

1.5 LAWS AND REGULATORY REQUIREMENTS

- A. Work shall meet or exceed the minimum applicable requirements established by Federal, State, and local laws and regulations. These requirements are amended

frequently, and the Contractor shall be responsible for complying with amendments as they become effective. In the event that compliance exceeds the scope of work or conflicts with specific requirements of the contract, the Contractor shall notify the Contracting Officer's Representative immediately. At a minimum the requirements stipulated in the regulations referenced in Paragraph 1.2 – REFERENCES shall be met.

- B. The Contractor shall comply with the Land Disposal Restrictions (LDR) 40 CFR 268 when treating and disposing of hazardous wastes.
- C. The Contractor shall comply with 40 CFR 268.49, Alternative LDR Treatment Standards for Contaminated Soil, when treating and disposing of contaminated soil.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. The Contractor shall provide all the materials required for the packaging, labeling, marking, placarding and transportation of hazardous materials, hazardous waste, and non-hazardous wastes in conformance with DOT standards. Details in this Specification shall not be construed as establishing the limits of the Contractor's responsibility.
- B. Spill Response Materials
 - 1. The Contractor shall provide spill response materials including, but not limited to, containers, absorbent, shovels, and personal protective equipment. Spill response materials shall be available at all times during which waste is being handled or transported. Spill response materials shall be compatible with the type of material being handled.

2.2 CONTAINERS

- A. Shipping Containers
 - 1. Impermeable containers shall be suitable to receive and retain contaminated materials until they are disposed of at an approved facility. The containers shall meet the standards of a "Strong, Tight Container" and conform to DOT Standard 49 CFR 173.24. Containers in a shipment must be loaded and braced securely to prevent shifting and damage during transport. Cover systems shall meet the criteria for a closed transport vehicle as specified in 49 CFR 173.403.

2.3 EQUIPMENT AND TOOLS

- A. The Contractor shall provide miscellaneous equipment and tools necessary to handle waste in a safe and environmentally sound manner. The Contractor shall provide equipment that is appropriate to accomplish this type of work and shall maintain and use of it in strict compliance with Occupational Safety and Health Administration (OSHA) requirements (29 CFR 1910). The Contractor shall take all necessary precautions for safe operation of the equipment and the protection of the public from injury and damage from such equipment.

2.4 FACILITIES

- A. The Contractor shall provide, install, and maintain any temporary loading facilities as required for the material handling operations. [Temporary loading facilities will be included in the Draft Final RD submittal].

2.5 LABELING

- A. The Contractor shall provide primary and subsidiary labels for materials/wastes consistent with the Federal, State, and local requirements. Labels shall be durable and weather resistant and capable of withstanding, without deterioration or substantial color change, a 180-day exposure to conditions reasonably expected to be encountered during container storage and transportation.

2.6 PLACARDS

- A. For each off-site shipment of materials/wastes, the Contractor shall provide primary and subsidiary placards as required by Federal, State, and local regulations. Placards shall be provided for each side and each end of bulk packaging, freight containers, and transport vehicles requiring such placarding. Placards may be plastic, metal, or other material capable of withstanding, without deterioration, a 30-day exposure to open weather conditions.

2.7 TARPAULINS

- A. Waterproof tarpaulins (tarps) shall be nylon vinyl-coated on both sides with a tearing strength of 70 pounds conforming to ASTM D751-19, or equal. All edges shall be hemmed, with reinforced grommets on maximum 4 feet on centers.

PART 3 - EXECUTION

3.1 GENERAL

- A. The Contractor shall manage all contaminated material in accordance with IWWP Appendix A SOP A22 – Investigation Derived Materials, except where modified herein.
- B. The Contractor shall ensure that all transport vehicles containing waste are covered with tarps before leaving the site. In addition to tarping all loads, the tailgate and bumper shall be swept to remove any spillage from the loading operation. All transport vehicles shall be decontaminated when leaving the loading area.
- C. The Contractor shall coordinate the schedule for vehicle arrival and material deliveries at the construction site to meet the approved project schedule. The schedule shall be compatible with the availability of equipment and personnel for material handling operations. No claims shall be made by the Contractor for additional compensation due to a delay in the schedule related to vehicle arrival or material availability.
- D. The Contractor shall organize and maintain the material shipment records required by the Federal and the State of Texas regulations.
- E. The Contractor is responsible for obtaining and filling out waste profile sheets required by the disposal facility. The quantity of sheets per contained waste shall be in accordance with Federal, State, or local regulations. The Contractor shall submit each profile sheet to the Contracting Officer's Representative.
- F. The Contractor shall notify the Contracting Officer's Representative immediately upon learning that a job-related accident has occurred. Notification of the accident shall include location of the accident, resultant damage or injury, person(s) involved, probable cause, amount of waste spilled, and any other pertinent information concerning the accident.

- G. Accident cleanup operations shall be performed as directed by the Contracting Officer's Representative at the expense of the Contractor. Cleanup shall be performed immediately.
- H. The Contractor shall provide transportation of the waste directly to the disposal facility/facilities.
- I. The Contractor shall provide all sampling and analytical services necessary for disposal in accordance with disposal facility requirements, and all applicable Federal, State, and local regulations, and as specified in SECTION 01 35 45 – CHEMICAL DATA QUALITY CONTROL.

3.2 CHARACTERIZATION AND SEGREGATION OF WASTE MATERIALS

- A. The Contractor shall excavate contaminated material, stockpile material, and collect waste disposal samples per disposal facility requirements and in accordance with IWWP Appendix A SOP A13 – Sample Control and Documentation and SECTION 01 35 45 – CHEMICAL DATA QUALITY CONTROL.
- B. The Contractor shall utilize the existing data found in the Contract Documents to the maximum extent possible for landfill acceptance. The Contractor shall perform additional waste characterization sampling and testing required by the landfill for acceptance.
- C. The Contractor shall be responsible for segregating all waste generated as a result of construction and remedial activities. Excavated soil shall be segregated as described in SECTION 31 23 10 – EXCAVATION AND HANDLING OF CONTAMINATED MATERIALS.
- D. Temporary stockpiles of non-hazardous impacted soil and hazardous materials shall be covered with plastic sheeting or equivalent material to protect waste from adverse weather conditions and to prevent dust emissions. Erosion and sedimentation controls shall be installed around all stockpiles.

3.3 NON-HAZARDOUS WASTE MANAGEMENT

- A. Non-hazardous waste from the site shall be disposed of off-site in an approved landfill in accordance with the approved Waste Management and Transportation Plan
- B. Contaminated soil with concentrations below 75% of TCLP values shall be considered non-hazardous and disposed of at an approved Subtitle D landfill. The following non-hazardous wastes are expected from the site: Excavated soil with contaminant of concern concentrations more than the soil cleanup levels but less than the TCLP values.
- C. Non-hazardous wastes above Remediation Cleanup Levels shall not be used as backfill, topsoil or sub-grade material.

3.4 HAZARDOUS WASTE MANAGEMENT

- A. The Contractor shall be responsible for ensuring compliance with all Federal, State, and local hazardous waste laws and regulations and shall verify those requirements when preparing reports, waste shipment records, hazardous waste manifests, or other documents.
- B. Hazardous Waste Characterization
 - 1. The Contractor shall be required to perform any and all sampling required for landfill acceptance of excavated soil and debris. The Contractor shall also be required to provide all waste profile information to the landfill, per their

requirements. Sampling and field screening methods shall be in accordance with disposal facility requirements and applicable Federal, State, and local regulations. The Contractor shall complete the waste profile information and submit it to the Contracting Officer's Representative for approval prior to sending it to the disposal facility.

2. The Contractor, in consultation with the Contracting Officer's Representative, shall identify all hazardous waste codes applicable to each hazardous waste stream based on requirements set forth in this section, 40 CFR 261, and applicable state and local laws or regulations. The Contractor shall also identify all applicable treatment standards in 40 CFR 268 and state LDRs and shall determine whether or not the waste meets or exceeds the standards. Waste profiles, analyses, classification, and treatment standards information shall be submitted to the Contracting Officer's Representative for review and approval.
3. Solid waste material other than soil, including vegetation from clearing and other debris encountered in excavations areas, shall be stockpiled, covered, and disposed of with non-hazardous soil.
4. The USACE is the owner and generator of the hazardous wastes for the LHAAP-47. Based on the available historical information and investigation results, an estimated 10 percent of the total excavated impacted material quantity (680 in-place cubic yards) of hazardous wastes are expected from the remedial activities from LHAAP-47:

C. Stockpiles

1. The Contractor shall attempt to load hazardous soil as specified in SECTION 31 23 10 – EXCAVATION AND HANDLING OF CONTAMINATED MATERIALS.
2. The excavated material shall not be mixed, and waste shall be segregated from soil into a separate stockpile to minimize the amount of RCRA waste requiring treatment. Solid waste material shall be stockpiled and covered or loaded into roll-off containers using a loading system approved by the Contracting Officer's Representative.
3. Stockpiles shall be constructed within the containment area in the areas to be remediated to isolate stored contaminated material from the environment. If multiple stockpiles are required, each unit shall be clearly labeled with an identification number.
4. The combined volume of all stockpiles shall be a size that is manageable and not create excess odors.
5. Stockpiles shall not be more than 10 feet in height. The maximum size of each stockpile shall be 500 cubic yards. Stockpiles of excessive size with height more than 10 feet and 500 cubic yards shall be subject to approval of the Contracting Officer's Representative.
6. The stockpiles shall be constructed in accordance with SECTION 31 23 10 – EXCAVATION AND HANDLING OF CONTAMINATED MATERIALS and shall meet the regulation defined in 40 CFR 264.250.
7. Creation and maintenance of stockpiles shall not interfere with the excavation, dewatering, and other on-site activities.

D. Contact Water Storage

1. Contact water may be generated during wet weather and shall be collected from excavations and stockpiles with saturated soil. The contact water shall be

temporarily stored in frac tanks, sampled, and disposed of at off-site disposal facility.

E. Sampling of Stored Material

1. Samples of contaminated material shall be collected at a frequency consistent with the requirements of the off-site disposal facility. The Contractor shall analyze the stored material for disposal purposes. Analytical levels for material to be shipped to the off-site disposal facility shall conform to Federal, State, and local criteria as well as to the requirements of the off-site disposal facility. Documentation of all analyses performed shall be furnished to the Contracting Officer's Representative.

F. Waste Management and Transportation Plan

1. The Contractor shall prepare a plan detailing the manner in which hazardous wastes will be managed and describing the types and volumes of hazardous wastes anticipated to be managed as well as the management practices to be utilized. The plan shall identify the method to be used to ensure accurate piece counts and/or weights of shipments; shall identify waste minimization methods; shall propose facilities to be utilized for treatment, storage, and/or disposal; shall identify areas on-site where hazardous wastes are to be handled; shall identify whether transfer facilities are to be utilized; and if so, how the wastes will be tracked to ultimate disposal.

G. Disposal Facility and Transporter

1. The Contractor shall provide the Contracting Officer's Representative with EPA ID numbers, names, locations, and telephone numbers of disposal facilities and transporters. This information shall be contained in the Waste Management and Transportation Plan and shall be approved by the Contracting Officer's Representative prior to waste disposal.

H. Status of the Facility

1. Facilities receiving hazardous waste must be permitted in accordance with 40 CFR 270 or operating under interim status in accordance with 40 CFR 265 requirements or must be permitted by a state authorized by the Environmental Protection Agency to administer the RCRA permit program. Additionally, prior to using a TSDF, the Contractor shall contact the EPA Regional Office specified in 40 CFR 300.440 to determine the facility's status and document all information necessary to satisfy the requirements of the EPA Off-Site policy and furnish this information to the Contracting Officer's Representative.

I. Shipping Documents and Packaging Certification

1. The Contractor shall be responsible for obtaining all permits and shipping documents to ship contaminated soil off-site.
2. Prior to shipment of any hazardous material off-site, the Contractor's TDC shall provide written certification to the Contracting Officer's Representative that hazardous materials have been properly packaged, labeled, and marked in accordance with Department of Transportation and USACE requirements. The Contractor's TDC shall also provide written certification regarding waste minimization efforts documenting the efforts that have been taken to reduce the volume and toxicity of waste to the degree economically practicable and that the method of treatment, storage, or disposal selected minimizes threats to human health and the environment.

J. Vehicle Inspection

1. Vehicles may be inspected by the Contracting Officer's Representative at the site prior to loading to ensure that the vehicles have no fluids leaks, no unusually noisy mufflers or tailpipes, tires that are in good condition, and operational brakes, horn, steering, operating controls, and safety devices. Vehicles shall be free of excess dirt, debris, oil, grease, and excessive rust. Vehicle beds used for hauling shall be free from drain holes, cracks, or other conditions that might permit waste material or contaminated water to leak from the vehicle beds. If the vehicle used for hauling has tailgates for dumping, the Contractor shall demonstrate to the Contracting Officer's Representative that the tailgates can be sealed watertight during operation. Any vehicle bed not providing an adequate leakproof seal shall be repaired or replaced as required. Tarpaulin covers shall be placed over all vehicle beds during waste transport to the disposal facility. Covers shall be placed over trucks, trailers or other conveyances used for bulk shipment to avoid spillage of the waste material and entrance of rain or snow during transport. The covers shall completely enclose the bulk shipment with no open areas along the sides or openings on the top. Cover systems shall meet the criteria for a closed transport vehicle as specified in 49 CFR 173.403. Failure of the shipping container, liner, seals, hatches, doors, or tarpaulin system to meet the above requirements which causes material to be rejected by disposal facility shall be addressed at the Contractor's expense.
2. The Contractor shall coordinate recording quantities of waste leaving the site with the Contracting Officer's Representative.
3. Vehicles/containers, either empty or loaded, shall not remain at the site, unless specific arrangements are made otherwise. Immediately after loading, they shall be sealed, weighed, and transported directly to the disposal facility.
4. The Contractor shall provide clean containers/hauling vehicles for loading during normal work hours.
5. Each vehicle/container shall be monitored for external contamination by the Contractor prior to leaving the worksite. The Contractor shall perform and document decontamination procedures prior to leaving the worksite and again before leaving the disposal site.

K. Transportation

1. The Contractor shall meet all existing Federal, State, and local regulations for vehicle operations in transporting the waste on public roads and highways. All construction vehicles shall be decontaminated prior to leaving the site using the temporary decontamination facility. All haul and access roads shall be maintained in a clean condition so that no dirt or contamination is tracked onto clean areas or public roads and highways.
2. Manifests requiring shipper's certification number shall be signed by the Contracting Officer's Representative. Copies of all manifests and waste profiles shall be submitted to the Contracting Officer's Representative within five days following shipment, and within five days after notification of receipt at the permitted disposal facility. Any manifest discrepancies shall be reported immediately to the Contracting Officer's Representative and resolved by the Contractor. A detailed report documenting the final disposal of all materials removed from the site shall be submitted to the Contracting Officer's Representative.
3. The Contractor shall prepare land disposal restriction notifications as required by 40 CFR 268 or any applicable state or local law or regulation for each shipment of

hazardous waste. Notifications shall be submitted with the manifest to the Contracting Officer's Representative for review and approval.

4. The Contractor shall prepare a manifest for each shipment of hazardous waste which fulfills the shipping paper requirements. The bill of landing shall satisfy the requirements of 49 CFR 172, Subpart C, and any applicable state or local law or regulation, and shall be submitted to the Contracting Officer's Representative for review and approval. Bill of lading requiring shipper's certifications shall be signed by the Contractor.
5. The Contractor shall be responsible for any and all actions necessary to remedy situations involving material spilled or leaked in transit on- or off- site, or mud and dust tracked off-site. This cleanup shall be accomplished at the Contractor's expense.
6. Transportation routes to and from project areas shall be in accordance with the approved Waste Management and Transportation Plan. No deviation from transportation routes shall be allowed without prior written approval from the Contracting Officer's Representative.
7. The Contractor shall be responsible for all repair costs for damage to structures, roads, bridges, and any other features affected by the Contractor's off-site transportation and disposal operations.

L. Treatment and Disposal of Hazardous Wastes

1. The Contractor shall ship hazardous waste only to facilities that are properly permitted to accept the hazardous waste or operating under interim status. The Contractor shall propose the TSDFs via submission of the Waste Management and Transportation Plan, subject to the approval of the Contracting Officer's Representative.
2. RCRA Subtitle C permitted facilities shall meet the requirements of 40 CFR 264 or facilities operating under interim status which meet the requirements of 40 CFR 265. All TSDFs must be accepted by the EPA. Off-site treatment, storage, and/or disposal facilities with significant RCRA violations or compliance problems (such as facilities known to be releasing hazardous constituents into groundwater, surface water, soil, or air) shall not be used.
3. Wastewater generated from equipment decontamination, well development, sampling, and purging activities will be transported to the off-site disposal facility for disposal.
4. The Contractor shall not deliver waste to any facility other than those listed on the shipping manifest.
5. In the event that an identified and approved facility ceases to accept the stated materials or ceases operations, it is the Contractor's responsibility to locate an alternate facility and make the necessary arrangements to utilize the alternate facility. The alternate facility must be approved in writing by EPA in the same manner and with the same requirements as the original facility.
6. The Contractor shall ensure waste is treated to meet land disposal requirement standards in 40 CFR 268 prior to land disposal. Selected treatment facilities for treatment of contaminated soil shall be responsible for the ultimate disposal of the treated wastes or soil. Under no condition shall the treated waste or soil be returned to the site to be used as filling material.

M. Hazardous Materials Management

1. The Contractor, in consultation with the Contracting Officer's Representative, shall evaluate, prior to shipment of any material off-site, whether the material is regulated as a hazardous waste in addition to being regulated as a hazardous

material; this shall be done for the purpose of determining proper shipping descriptions, marking requirements, etc., as described below.

2. Identification of Proper Shipping Names
 - a. The Contractor shall use 49 CFR 172, Section 101 to identify proper shipping names for each hazardous material (including hazardous wastes) to be shipped off-site. Proper shipping names shall be submitted to the Contracting Officer's Representative in the form of draft shipping documents for review and approval.
3. Packaging, Labeling, and Marking
 - a. The Contractor shall package, label, and mark hazardous materials/wastes using the specified materials and in accordance with the referenced authorizations. The Contractor shall mark each container of hazardous waste of 110 gallons or less with the following:

"HAZARDOUS WASTE - Federal Law Prohibits Improper Disposal. If found, contact the nearest police or public safety authority or the U.S. Environmental Protection Agency.

Generator's name: The United States Army Corps of Engineers

Manifest Document Number: _____."

3.5 SHIPPING DOCUMENTS

- A. The Contractor shall ensure that each shipment of waste sent off-site is accompanied by properly completed shipping documents as specified in Paragraph 1.3.A.13. This includes shipments of samples that may potentially meet the definition of a Department of Transportation regulated hazardous material. Documents shall be submitted to the Contracting Officer's Representative for review and approval.
- B. The Contractor will be responsible for reporting waste shipments to the Texas Commission on Environmental Quality (TCEQ) One-Time Waste Shipment Program.

3.6 U.S. ARMY ID NUMBERS

- A. U.S. Army will provide waste generator identification number for use on the manifest.

3.7 RECORDKEEPING

- A. The Contractor shall organize and maintain the material shipment records/manifests required by 42 U.S.C. 6901 et seq., the State of Texas, and the state in which the disposal facility is located.

3.8 SPILL RESPONSE

- A. The Contractor shall respond to any spills of hazardous material or hazardous waste which are in the custody or care of the Contractor, pursuant to this contract. Any direction from the Contracting Officer's Representative concerning a spill or release shall not be considered a change under the contract. The Contractor shall comply with all applicable requirements of Federal, State, or local laws or regulations regarding any spill incident.

3.9 EMERGENCY CONTACTS

- A. The Contractor shall be responsible for complying with the emergency contact provisions in 49 CFR 172.604. Whenever the Contractor ships hazardous materials, the Contractor shall provide a 24-hour, 7-day a week monitoring telephone service emergency response contact. The person must be knowledgeable about the hazardous materials being shipped and who has comprehensive emergency response and incident

mitigation information for that material or has immediate access to a person who possesses such knowledge and information.

- B. The phone must be monitored on a 24-hour basis at all times when the hazardous materials are in transportation, including during storage incidental to transportation.
- C. The Contractor shall ensure that information regarding this emergency contact and phone number are placed on all hazardous material shipping documents. The Contractor shall designate an emergency coordinator and post the following information at areas in which hazardous wastes are managed:
 - 1. Emergency coordinator's name
 - 2. Emergency coordinator's phone number
 - 3. Local fire department phone number
 - 4. Fire extinguishers and spill control materials location

END OF SECTION

ATTACHMENT A
SAMPLE OFF-SITE POLICY CERTIFICATION MEMO

Project/Contract #: _____

Waste Stream: _____

Primary TSDF, EPA ID # and Location: _____

Alter. TSDF, EPA ID # and Location: _____

EPA Region Contact

I (617) 918-1769

II (732) 906-6874

III (215) 814-3240

IV (404) 562-8993

V (312) 353-8207

VI (214) 665-2282

VII (913) 551-7149

VIII (303) 312-6503

IX (415) 972-3994

X (206) 553-3859

Contracting Officer's Representative contacted: _____

Contracting Officer's Representative phone number: _____

Date contacted: _____

Comment: _____

The above Contracting Officer's Representative was contacted on _____. As of that date, the above site was considered acceptable in accordance with the Off-Site Policy in 40 CFR 300.440.

Signature: _____ Date: _____

Phone number: _____

SECTION 31 25 00
EROSION CONTROL AND STORMWATER MANAGEMENT

PART 1 - GENERAL

1.1 SUMMARY

- A. The Contractor shall furnish all labor, materials, equipment, and incidentals necessary to perform erosion control for the duration of the project. Work shall be performed as shown on the Design Drawings, specified herein and identified in the Contract Documents.

1.2 REFERENCES

- A. References
1. The publications listed below form a part of this Specification to the extent referenced. The publications are referred to in the text by basic designation only. Where reference is made to one of these standards, the revision in effect at the time of contract award shall apply.
 - a. Texas Commission on Environmental Quality (TCEQ)
 - 1) Texas Water Code Chapter 26
 - 2) General Permit TXR15000
 - 3) TCEQ RG-348, Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices
 - b. American Society for Testing and Materials (ASTM)
 - 1) ASTM D4491/D4491M-22 Test Methods for Water Permeability of Geotextiles by Permittivity
 - 2) ASTM D4632/D4632M-15a Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
 - 3) ASTM D4751-21a Standard Test Method for Determining Apparent Opening Size of a Geotextile
 - 4) ASTM D4833/D4833M-07 Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products
 - 5) ASTM D5199-12 Standard Test Method for Measuring the Nominal Thickness of Geosynthetics
 - 6) ASTM D5261-10 Standard Test Method for Measuring Mass per Unit Area of Geotextiles

1.3 SUBMITTALS

- A. Approval from the Contracting Officer's Representative, in consultation with the regulators, is required for submittals with an "RA" designation; submittals with an "FIO" designation are for information only. The Contractor shall submit the following to the Contracting Officer's Representative:
1. Soil Erosion and Sedimentation Control (SESC) Plan to be submitted as part of the work plan.
 2. Samples; RA
 - a. Samples of all materials shall be submitted for inspection and approval upon request from the Contracting Officer's Representative.
 3. Non-Woven Geotextile Filter Fabric Certificates of Compliance; Certificates; RA
 - a. The Contractor shall submit certificates of compliance, furnished by the geotextile fabric manufacturer or supplier, stating the physical properties of the

geotextile fabric to be used on-site meet the Specification requirements as described herein.

1.4 ADMINISTRATIVE REQUIREMENTS

- A. Not used.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Temporary Seeding and Mulching
1. Temporary seeding, mulching, fertilizing, and/or erosion control matting shall be used as needed to reduce erosion.
- B. Baled Hay or Straw checks
1. Baled hay or straw erosion checks are temporary measures to control erosion and prevent siltation. Bales shall be either hay or straw containing five cubic feet or more of material. The bales shall be free from noxious weeds.
- C. Temporary Diversion Dikes
1. Temporary Diversion Dikes, or straw bale dikes, are temporary measures placed downhill from a disturbed area to redirect/trap flows of debris (i.e., sediment). The dikes consist of bound bales bedded and staked in place. Diversion dikes shall be used as specified in the Design Drawings.
- D. Temporary Silt Fences
1. The siltation fence fabric shall be a geotextile material suitable for siltation control use with a minimum tensile strength of 100 pounds, meeting ASTM D4632/D4632M-15a. The equivalent opening size shall be between no. 50 and no. 70 sieve size. A 12-gauge metal fence with 4-inch by 4-inch openings shall be provided as support for the fence fabric.
- E. Polyethylene sheeting
1. The polyethylene sheeting shall be as specified in the Design Drawings.
- F. Non-woven geotextile fabric
1. The geotextile fabric shall be a non-woven fabric consisting only of continuous chain polymer filaments or yarns of polyester, formed into a stable network by needle punching. The fabric shall be mildew and rot resistant. The fabric shall contain the properties listed in Table 31 25 00-1.

Table 31 25 00-1 Non-Woven Geotextile Fabric Properties

Fabric Property	Test Method	Minimal Physical Properties
Fabric Weight	ASTM D5261-10	8.0 oz/yd ³
Fabric Thickness	ASTM D5199-12	105 mils
Grab Strength	ASTM D4632/D4632M-15a	230 lbs
Puncture Resistance	ASTM D4833/D4833M-07	100 lbs
Water Flow Rate	ASTM D4491/D4491M-22	90 gpm/feet ²
Permeability, K	ASTM D4491/D4491M-22	0.34 cm/sec
Apparent Opening Size	ASTM D4751-21a	Sieve Size 70

PART 3 - EXECUTION

3.1 SEDIMENT AND EROSION CONTROL

- A. Excavations for the site are expected to be less than 1 acre in size and thus are not subject to the storm water pollution prevention requirements of Chapter 26 of the Texas Water Code and TCEQ General Permit TXR15000.
- B. Sediment and erosion control practices shall be consistent with procedures outlined in TCEQ RG-348, Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices, July 2005.
https://www.tceq.texas.gov/assets/public/comm_exec/pubs/rg/rg348/rg-348.pdf
- C. If the Contractor desires to stockpile construction materials, such as stone, earth, etc., the location of these materials and the protection measures required shall be in accordance with the best management practices outlined in TCEQ RG-348, Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices, July 2005.
- D. The Contractor shall not be permitted to divert stormwater onto adjacent properties. Stormwater shall be diverted around open excavation areas using diversion fencing.
- E. All stormwater that comes in contact with contaminated soils shall be collected, stored, and dispose off-site. All other site run-off water shall be diverted to the on-site streams via the control measures (e.g., baled hay or straw check/silt fence filtration) as approved by the Contracting Officer's Representative.

3.2 CONSTRUCTION REQUIREMENTS

- A. The Contracting Officer's Representative has the authority to limit the surface area of erodible earth material exposed by excavation and fill operations, and to direct the Contractor to provide immediate, permanent, and/or temporary pollution control measures to prevent contamination of areas adjacent to the containment area. Such work may involve the use of temporary mulches, mats, seeding, or other control devices or methods as necessary to control erosion.
- B. The Contractor shall be required to incorporate all permanent erosion control features into the project at the earliest practicable time as outlined in its accepted schedule. Temporary pollution control measures shall be used to correct conditions that develop during construction, prior to installation of permanent pollution control features, or temporarily to control erosion that develops during normal construction practices.
- C. The Contracting Officer's Representative has the authority to limit the area of excavation and fill operations in progress commensurate with the Contractor's capability and progress in keeping the finished grading, mulching, seeding and other such temporary or permanent pollution control measures current, in accordance with the accepted schedule. Should seasonal limitations make such coordination unrealistic, temporary erosion control measures shall be taken immediately to the extent feasible and justified.
- D. In the event of conflict between these requirements and pollution control laws, rules, or regulations, or other Federal, State, or local agencies, the more restrictive laws, rules, or regulations shall apply.

3.3 CONSTRUCTION OF CONTROL MEASURES

- A. Baled Hay or Straw Erosion Checks

1. Baled hay or straw checks shall be used where the existing ground slopes toward or away from an embankment, along the toe of slopes, in ditches, or other areas where the Contractor deems necessary to prevent siltation, erosion or water runoff problems.
 2. Hay or straw erosion checks shall be embedded in the ground minimum 8 inches to prevent water from flowing under them. The bales shall also be anchored securely to the ground, as shown in the Design Drawings. Bales and anchoring shall be removed after they have served their purpose, as determined by the Contracting Officer's Representative. The Contractor shall keep the checks in good condition by replacing broken or damaged bales immediately after damage occurs. Normal debris cleanout shall be considered routine maintenance.
- B. Temporary Diversion Dikes and Silt Fences
1. Temporary silt fences shall be placed on the natural ground, at the bottom of fill slopes, in ditches, or in other areas where siltation is a problem. Silt fences are constructed of material designed for that application or another approved material on the up-grade side of the fence and anchored into the soil.
 2. Temporary diversion dikes shall be constructed as per the details provided in the Design Drawings. Diversion dikes shall be placed upstream of excavations to divert water away from excavations and into the existing stormwater drainage pathway.
 3. The Contractor shall be required to maintain diversion dikes and silt fencing in a satisfactory condition for the duration of the project or until removal is approved by the Contracting Officer's Representative. The silt accumulation at the fences shall be removed and properly disposed of as directed by the Contracting Officer's Representative. The diversion dikes and silt fencing become the property of the Contractor whenever the fence is removed.
 4. The fence shall be fastened to the fence posts with metal clips 12 inches on center or an approved equal compatible with the fence material. The filter material shall be fastened to the fence at the top, center, and bottom with metal fasteners (nails or staples) and a high-strength reinforcement material (nylon webbing, grommets, washers, etc.) placed between the fastener and the geotextile fabric.
- C. Construction Entrance
1. The access road from the site shall be maintained in a condition that will prevent tracking or flowing of sediment outside the LHAAP-47 containment area. This may require stabilizing the construction entrance and periodic top dressing with additional stone as required in order to maintain previously established stabilized construction access conditions. All construction vehicles shall be decontaminated, and wheels washed out prior to leaving the containment area at the temporary decontamination facility. No soil or sediment shall be spilled, dropped, washed, or tracked outside the containment area.
 2. The Contractor shall routinely, as required, sweep surrounding roads to control dust and runoff from the site.
- D. Maintenance
1. The temporary erosion control features installed by the Contractor shall be acceptably maintained by the Contractor until no longer needed or until permanent erosion control methods are installed. The erosion and stormwater control features shall be inspected daily. Required repairs shall be performed in a timely manner. Any related materials removed shall become the property of the Contractor.

END OF SECTION

SECTION 31 38 50

SITE RESTORATION

PART 1 - GENERAL

1.1 SUMMARY

- A. The Contractor shall furnish all labor, equipment, material, and incidentals necessary to restore the site as specified herein and/or as directed by the Contracting Officer's Representative.

1.2 REFERENCES

- A. United States Army Corps of Engineers (USACE)
 - 1. Final Health and Safety Plan for Longhorn Army Ammunition Plant (LHAAP HASP), Karnack, Texas (2018).
 - 2. Final Installation Wide Work Plan for Longhorn Army Ammunition Plant (LHAAP IWWP), Karnack, Texas, revised by Bhate Environmental Associates, Inc. (May 2018; IWWP).
 - 3. EM 385-1-1 Safety and Occupational Health (SOH) Requirements (March 2024)

1.3 SUBMITTALS

- A. Not used

1.4 ADMINISTRATIVE REQUIREMENTS

- A. Not used.

PART 2 - PRODUCTS (NOT APPLICABLE TO THIS SPECIFICATION SECTION)

PART 3 - EXECUTION

3.1 GENERAL

- A. The Contractor shall remove all equipment and materials used during project operation including, but not limited to, trailers, silt fence, stormwater diversion structures, electrical wiring, staging area, and decontamination pads, prior to demobilization from the site.
- B. The restoration of the site is to be completed within one month of the completion of each of these remedial activities listed below in accordance with the Contractor's approved remedial action schedule.
 - 1. Phase I Remedial Action
 - a. Excavation of perchlorate-impacted unsaturated soil exceeding soil cleanup level. Implementation of In-Situ Thermal Desorption (ISTD) treatment to remove residual DNAPL.
 - b. In-situ Bioremediation (ISB) pilot tests in strategically selected locations to determine the design parameters for the full-scale ISB remedy.
 - 2. Phase II Remedial Action
 - Implementation of ISB in nine target areas where perchlorate concentrations are greater than 20,000 micrograms per liter (µg/L) and/or total Volatile Organic Compound (VOC) concentrations are greater than 1,000 µg/L as shown in

Design Drawing.

- C. Implementation of ISB biobarriers near the leading edges of the northern and southern perchlorate and VOC plumes, and at the northern and eastern edge of the perchlorate plume to mitigate the risk of contaminant migration off-site, further off-site, or further into the site. Prior to demobilization, all equipment shall be decontaminated in accordance with the Final Health and Safety Plan for Longhorn Army Ammunition Plant Karnack, Texas and IWWP Appendix A SOP A1 – Decontamination Procedures.
- D. All materials removed during site restoration activities shall be disposed of at an approved off-site disposal facility by the Contractor.
- E. The Contractor shall remove the gravel access road constructed to facilitate excavation activities and restore the surface in accordance with Design Drawings.
- F. The Contractor shall inspect the restored vegetated areas. The disturbed areas shall be covered with 6 inches of topsoil and replanted with a native grass and wildflower seed mixture, selected in coordination with the U.S. Fish and Wildlife Service (USFWS), to prevent soil erosion and serve as sediment control, as shown in the Design Drawings.
- G. At the completion of the work, the Contractor shall restore all areas affected by the construction activities to conditions equivalent to or better than the original conditions and as indicated in the Design Drawings.
- H. The site will be restored when all punch list items have been completed to the satisfaction of the Contracting Officer's Representative.

END OF SECTION