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

January 11, 2018

DAIM-ODB-LO

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

Re: Revised Final Remedial Action Work Plan Contingency Remedy for Western Plume LHAAP-35A(58), Shops Area, Group 4, Longhorn Army Ammunition Plant, Karnack, Texas, Revised January 2018

Dear Mr. Mayer,

The above-referenced document is being transmitted to you for your records. This document presents revision to the Final Remedial Action Work Plan Contingency Remedy for the Western Plume to incorporate 2016 groundwater data along with changing the substrate from sodium lactate to emulsified vegetable oil.

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

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

Sincerely,

Rose M. Zeiler

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

Copies furnished:
A. Palmie, TCEQ, Austin, TX
P. Bruckwicki, Caddo Lake NWR, TX
R. Smith, USACE, Tulsa District, OK
A. Williams, USACE, Tulsa District, OK
N. Smith, USAEC, San Antonio, TX
K. Nemmers, Bhate, Lakewood, CO (for project files)

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

January 11, 2018

DAIM-ODB-LO

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

Re: Revised Final Remedial Action Work Plan Contingency Remedy for Western Plume LHAAP-35A(58), Shops Area, Group 4, Longhorn Army Ammunition Plant, Karnack, Texas, Revised January 2018

Dear Ms. Palmie,

The above-referenced document is being transmitted to you for your records. This document presents revision to the Final Remedial Action Work Plan Contingency Remedy for the Western Plume to incorporate 2016 groundwater data along with changing the substrate from sodium lactate to emulsified vegetable oil.

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

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

Sincerely,

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

Copies furnished:
R. Mayer, USEPA Region 6, Dallas, TX
P. Bruckwicki, Caddo Lake NWR, TX
R. Smith, USACE, Tulsa District, OK
A. Williams, USACE, Tulsa District, OK
N. Smith, USAEC, San Antonio, TX
K. Nemmers, Bhate, Lakewood, CO (for project files)

REVISED FINAL
REMEDIAL ACTION WORK PLAN
CONTINGENCY REMEDY FOR WESTERN PLUME
LHAAP-35A (58), SHOPS AREA, GROUP 4
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Prepared For:

U.S. Army Corps of Engineers

Tulsa District

Prepared By:

AECOM Technical Services, Inc.
Contract No. W912DY-09-D-0059
Task Order No. DS01

Revised By:
Bhate Environmental Associates, Inc.
Contract No. W9128F-13-D-0012
Task Order No. W912BV17F0150

July 2016
Revised January 2018 (as noted in headers)

Table of Contents

1 INTRODUCTION 1-1
1.1 Organization of Work Plan 1-1
1.2 LHAAP-35A (58) Background 1-2
1.2.1 Contingency Remedy 1-3
1.2.2 Nature and Extent of Contamination 1-5
1.2.3 Site Geology and Hydrogeology 1-6
1.2.4 Remedial Action Objectives 1-6

2 LAND USE CONTROL PLAN 2-1

3 ENHANCED IN-SITU BIOREMEDIATION 3-1
3.1 Laboratory-scale Bioremediation Treatability Study 3-1
3.2 EISB Performance in the Eastern Plume at LHAAP-35A (58) 3-2
3.3 EISB Design Parameters 3-2
3.3.1 Substrate Selection 3-2
3.3.2 Substrate Loading 3-3
3.3.3 Bioaugmentation Culture Loading 3-3
3.4 Direct Push Technology Injections 3-4
3.4.1 Radius of Influence and Injection Point Spacing 3-5
3.5 EISB Performance Monitoring 3-5
3.5.1 Baseline Groundwater Monitoring 3-5
3.5.2 EISB Performance Monitoring 3-5

4 FIELD PREPARATION AND METHODS 4-1
4.1 Permitting 4-1
4.2 Pre-mobilization Activities 4-1
4.3 Preliminary Activities/Mobilization 4-1
4.4 Site/Utility Clearance 4-1
4.5 Monitoring Well Installation 4-1
4.6 Site Survey 4-1
4.7 Investigation Derived Wastes 4-1
4.8 Decontamination of Equipment and Personnel 4-2
4.9 Health and Safety Procedures 4-2
4.10 Quality Assurance/Quality Control 4-2

5 REMEDY PERFORMANCE EVALUATION AND REPORTING ... 5-1
5.1 EISB Evaluation ... 5-1
6 SCHEDULE ... 6-1
7 REFERENCES ... 7-1

List of Figures

Figure 1-1: LHAAP Site Area Map
Figure 1-2: LHAAP-35A (58) Site Vicinity Map
Figure 1-3: LHAAP-35A (58) Location of Monitoring Wells
Figure 1-4: LHAAP-35A (58) Groundwater Elevation Map, Shallow Zone (October 2016)
Figure 1-5: LHAAP-35A (58) COC Concentrations in Shallow Groundwater (October 2016)
Figure 1-6: LHAAP-35A (58) Proposed Injection Locations

List of Tables

Table 1-1: Groundwater Cleanup Levels
Table 6-1: Schedule and Duration of Major Site Activities

Acronyms and Abbreviations

µg/L	Micrograms Per Liter
AECOM	AECOM Technical Services, Inc.
ARAR	Applicable or Relevant and Appropriate Requirements
bgs	Below Ground Surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cis-1,2-DCE	cis-1,2-Dichloroethene
COC	Chemical of Concern
DCA	1,1-Dichloroethane
DCE	1,1-Dichloroethene
DHB	Dehalobacter
DHC	Dehalococcoides Ethenogens
DoD	Department Of Defense
DPT	Direct Push Technology
EISB	Enhanced In-Situ Bioremediation
EVO	Emulsified Vegetable Oil
FFA	Federal Facility Agreement
ft	Feet
gpm	Gallons Per Minute
IDW	Investigation Derived Waste
LHAAP	Longhorn Army Ammunition Plant
LTM	Long-Term Monitoring
LUC	Land Use Control
MCL	Maximum Contaminant Level
MNA	Monitored Natural Attenuation
msl	Mean Sea Level
NCP	National Oil and Hazardous Substances Contingency Plan
NPL	National Priorities List
O&M	Operation and Maintenance
PCE	Tetrachloroethene
PPE	Personal Protective Equipment

PSI	Pounds per Square Inch
RA	Remedial Action
RACR	Remedial Action Completion Report
RAO	Remedial Action Objective
RA(O)	Remedial Action-Operation
RAWP	Remedial Action Work Plan
RD	Remedial Design
ROD	Record of Decision
SRS	Small Droplet Emulsified Vegetable Oil
TBD	To Be Determined
TCA	1,1,2-Trichloroethane
TCE	Trichloroethene
TCEQ	Texas Commission on Environmental Quality
TD	Total Depth
TOC	Total Organic Carbon
TS	Treatability Study
U.S.	United States
U.S. Army	U.S. Department of the Army
USEPA	U.S. Environmental Protection Agency
UU/UE	Unrestricted Use and Unlimited Exposure
VC	Vinyl Chloride
VOC	Volatile Organic Compound

1 INTRODUCTION

The former Longhorn Army Ammunition Plant (LHAAP) is an inactive, government-owned, formerly contractor operated and maintained, Department of Defense (DoD) facility located in central east Texas (**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. Department of the Army (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 U.S. Environmental Protection Agency (USEPA) National Priorities List (NPL) on August 9, 1990. Activities to remediate contamination began in 1990. After its listing on the NPL, the U.S. Army, the USEPA, and the Texas Water Commission (currently known as the Texas Commission on Environmental Quality [TCEQ]) entered into a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) §120 Federal Facility 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 has been transferred by the U.S. Army to the U.S. Fish and Wildlife Service for management as the Caddo Lake National Wildlife Refuge.

Remedial activities are required under the Record of Decision (ROD) issued for the LHAAP-35A (58) site in September 2010 (Shaw, 2010). The Remedial Action Work Plan (RAWP) for the entire site was prepared in August 2013 in accordance with the ROD and was implemented in September 2013. The monitored natural attenuation (MNA) remedy for the western plume at this site, as presented in the ROD, calls for an evaluation of the remedy after two years of MNA remedial action-operation (RA(O)) implementation. The ROD also provides for implementation of a contingency remedy to enhance MNA if MNA is found to be ineffective. RA(O) implementation for the site was completed between October 2013 and October 2015 and the 2nd year RA(O) report was finalized in May 2016. After two years of MNA, the 2nd year RA(O) report concludes that MNA is ineffective and implementation of a contingency remedy is appropriate. The contingency remedy for the western plume at the site is enhanced in-situ bioremediation (EISB). Therefore, this RAWP addendum addresses EISB implementation for the groundwater plume located on the western side of the site, based on the Remedial Design (RD) for the LHAAP-35A (58) site, which was approved by the regulatory agencies in September 2011 (Shaw, 2011).

1.1 Organization of Work Plan

This work plan is comprised of the following sections:

- Section 1: “Introduction” presents the site background, proposed remedy including the chemicals of concern (COCs) and their respective cleanup levels, the nature and extent of contamination, and Remedial Action Objectives (RAOs).
- Section 2: “Land Use Control Plan” references the Final RAWP for LHAAP-35A (58) (AECOM, August 2013), wherein the Land Use Control Plan is presented.

- Section 3: "Enhanced In-Situ Bioremediation" describes the injection of amendments to enhance microbial degradation of contaminants and groundwater monitoring associated with EISB in the western plume.
- Section 4: "Field Preparation and Methods" describes the activities that will be performed prior to the start of field work and the methods that will be followed to complete field work.
- Section 5: "Remedy Performance Evaluation and Reporting" describes the EISB performance evaluation reporting and five-year reviews to be performed for the contingency remedy.
- Section 6: "Schedule" presents the proposed implementation schedule for the EISB contingency remedy.
- Section 7: "References" provides a list of references cited in this document.

Activities specified in this work plan will be conducted in accordance with the Installation-Wide Work Plan (July 2014) in place when field work is executed.

1.2 LHAAP-35A (58) Background

The LHAAP-35A (58) site, also known as the Shops Area, is located in the north-central portion of LHAAP and currently covers an area of approximately 11 acres (**Figure 1-2**) (USACE, 2010). The surface features include asphalt-paved roads, a parking area, and areas that are wooded and overgrown with grasses and other vegetation. The topography is relatively flat with the surface drainage flowing into the tributaries of Goose Prairie Creek, which eventually discharges into Caddo Lake.

The Shops Area, which is now designated as LHAAP-35A (58), was established in 1942 as part of the installation's initial construction (Shaw, 2011). The facility was used to provide plant-operated laundry, automotive, woodworking, metalworking, painting, refrigeration, and electrical services. The site was active throughout the LHAAP's mission and was deactivated along with the rest of the installation in 1996-1997. The LHAAP-35A (58) site boundary has changed over the years. Earlier investigations for LHAAP-35A (58) were performed in areas to the south that are no longer included within the site boundary. LHAAP-35A (58) includes the following sites:

- LHAAP-02, vacuum truck overnight parking;
- LHAAP-03, Paint Shop Building 722 (waste collection);
- LHAAP-60, Former Storage Building 714;
- LHAAP-68, mobile storage tank parking area; and
- LHAAP-69, service station with underground storage tanks.

The following sites were within the historical LHAAP-35A (58) site boundary, but are not within the current site boundary:

- LHAAP-04, former Pilot Wastewater Treatment Plant
- LHAAP-56, vehicle wash rack and oil/water separator Building 744-A

- LHAAP-59, Storage Building 725
- LHAAP-60, Building 411
- LHAAP-61, Water Treatment Plant
- LHAAP-66

The following sites are within the land use control (LUC) boundary for LHAAP-35A (58):

- LHAAP-02, vacuum truck overnight parking;
- LHAAP-03, Paint Shop Building 722 (waste collection);
- LHAAP-56, vehicle wash rack & oil/water separator Building 744-A
- LHAAP-59, Storage Building 725
- LHAAP-60, Former Storage Building 714;
- LHAAP-65, Former Building 209 (flammable materials storehouse);
- LHAAP-68, mobile storage tank parking area; and
- LHAAP-69, service station with underground storage tanks.

LHAAP-60, Building 411, which is located within the historical site boundary of LHAAP-35A (58), will be included within the LUC boundary for LHAAP-04.

Between 1992 and 2015, multiple investigations were conducted in a phased approach to determine the nature and extent of contamination at LHAAP-35A (58). In 2009, a Feasibility Study was completed, which includes a natural attenuation evaluation (Shaw, 2009). These investigations concluded that the Shallow Zone groundwater was impacted with volatile organic compounds (VOCs), however, the soil and former sump/waste rack sump areas posed no unacceptable threat to human health or the environment (Shaw, 2011).

The previous remedy implemented at LHAAP-35A (58) was developed and selected in accordance with the CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986, and, to the extent practicable, the National Oil and Hazardous Substances Contingency Plan (NCP) (40 Code of Federal Regulations 300). The selected remedy, finalized in the ROD was developed based on the industrial land use scenario, which is consistent with the anticipated future use as a national wildlife refuge (Shaw, 2010). A deed notice was recorded at the Harrison County Courthouse stating that the site is suitable for non-residential use. A groundwater use restriction was also recorded in the Harrison County Courthouse to ensure that there is no withdrawal or use of groundwater beneath the site for anything other than environmental monitoring and testing until the cleanup levels are met. A restriction against residential use of groundwater will remain in effect until the levels of the COCs in groundwater allow unrestricted use and unlimited exposure (UU/UE). The restriction and notification encompasses the sites within the LUC boundary of LHAAP-35A (58) listed above.

1.2.1 Contingency Remedy

The description of the proposed remedy for the LHAAP-35A (58) site was presented for two separate geographic areas: 1) eastern plume; and 2) western plume. **Figure 1-3** shows monitoring wells installed at the LHAAP-35A (58) site. **Figure 1-4** presents the most recent (October 2016) potentiometric surface information for the site and **Figure 1-5** presents analytical results from monitoring wells during the October 2016 sampling event. EISB was performed in the eastern plume in September 2013 and the eastern plume appears to be shrinking. The proposed EISB remedy described herein applies to the western plume only.

As discussed in the ROD and in the 2nd Annual Remedial Action Operation Report (May 2016), the western groundwater plume at LHAAP-35A (58) is impacted with the following COCs: tetrachloroethene (PCE), trichloroethene (TCE), 1,1-dichloroethene (1,1-DCE), cis-1,2-dichloroethene (cis-1,2-DCE), and vinyl chloride (VC) (**Figure 1-5**).

The Safe Drinking Water Act maximum contaminant levels (MCLs) will be used as cleanup levels for VOCs in groundwater, as presented in **Table 1-1**.

Table 1-1: Groundwater Cleanup Levels

Chemical of Concern (COC)	Concentration	Basis
Groundwater (µg/L)		
Tetrachloroethene	5	MCL
Trichloroethene	5	MCL
1,1-Dichloroethene	7	MCL
Cis-1,2-dichloroethene	70	MCL
Vinyl chloride	2	MCL
1,1,2-trichloroethane[(a)]	5	MCL
1,2-dichloroethane[(a)]	5	MCL

Notes and Abbreviations:
µg/L – micrograms per liter
MCL – maximum contaminant level
[(a)] Not currently classified as a constituent of concern, but will be included in the list of chemicals for Long-Term Monitoring

Although arsenic has not been designated as a COC, groundwater will be monitored for arsenic as described in the 2nd Year RA(O) report (AECOM, May 2016). Monitoring for arsenic will allow evaluation of any arsenic concentration trends after implementation of EISB in the western plume. The MCL for arsenic is 10 µg/L.

In the western plume area, the highest concentrations of COCs have been observed in the Shallow Zone groundwater near monitoring well 35AWW20, which is located in a former vehicle wash rack and oil/water separator Building 744-A area (**Figure 1-5**). This area is also within the primary target area of the western plume, which is located in the western portion of the western plume, near wells 35AWW20, LHSMW07, and 35AWW06. In addition, 1,1-DCE has been detected above its MCL in monitoring wells 35AWW11 and 35AWW19, located on eastern and southern boundaries of the western plume, respectively. The western plume contingency remedy will include EISB in the area with the highest levels of contamination.

The remedy for the western plume at LHAAP-35A (58) is intended to protect human health and the environment by preventing human exposure to the contaminated groundwater and preventing contaminated groundwater from migrating into nearby surface water. The final western plume remedy will consist of LUC (already implemented), EISB, MNA (ensuing EISB), and Long Term Monitoring (LTM)/Five-year Reviews.

The specific remedy components are discussed below:

- LUC in the impacted area will ensure protection of human health by restricting the use of groundwater to environmental monitoring and testing until cleanup levels are met. The LUC restricting residential use of groundwater will remain in effect until the levels of the COCs in groundwater allow for UU/UE.
- EISB will be implemented in the western plume area. At LHAAP-35A (58), the highest concentrations of contaminants have been observed in the Shallow Zone groundwater in the vicinity of wells 35AWW20, LHSMW07, and 35AWW06. This area is designated as the western plume primary target area (**Figure 1-5**). EISB will be also implemented near monitoring wells 35AWW11, 35AWW14, and near one proposed new monitoring well (35AWW23) location.

  EISB is the process of removing contaminant mass as a result of microbes utilizing contaminants in the groundwater during respiratory or metabolic activities. The treatment involves injecting amendments which may include microbial cultures, electron donor sources, and nutrients, into the subsurface.
- MNA constitutes a passive remedy that relies on natural biological, chemical, and physical processes that act to reduce the mass and concentrations of groundwater contaminants under favorable conditions. MNA will be implemented to verify that the western VOC plume is stable or shrinking and will not migrate to nearby surface water at levels that pose an unacceptable risk to human health or the environment. Natural attenuation is expected to reduce contaminant concentrations to their respective clean-up levels, and return groundwater to its beneficial use, wherever practicable, after the successful implementation of the EISB. MNA will be evaluated annually, with groundwater monitoring performed on a quarterly basis.
- LTM/Five-year Reviews: If MNA is effective, MNA monitoring will be performed at a semi-annual frequency for three years, then annually until the next five-year review. However, LTM will continue at least once every five years until cleanup levels are achieved. A cleanup time has not been estimated for the western plume and will be evaluated following implementation of EISB.

1.2.2 Nature and Extent of Contamination

Figure 1-6 presents the current estimated extent of the VOC plumes in groundwater. The source of the western plume area is centered near well 35AWW20. Based on the October 2016 isoconcentration map, the western plume has an area of approximately 325,000 square feet, and a vertical extent of approximately five feet. Using an estimated effective porosity of 0.3, the calculated volume of contaminated groundwater in the western plume is 3.65 million gallons.

Site-specific porosity values for this site are not available. The highest effective porosity value typical for unconsolidated material is 0.3 (Driscoll, 1986). This typical value is likely higher than the actual effective porosity values for the subsurface lithologies present at the site. In the absence of site-specific data, a conservative value of 0.3 is utilized to avoid underestimation of impacted water volume.

A value of five feet is used for the average saturated thickness at the site for estimation of impacted groundwater volume. The actual thicknesses, based on the lithologic information, could be higher or lower than the average estimated thickness of five feet. However, for the purposes of estimating impacted groundwater volume, a value of five feet was used.

1.2.3 Site Geology and Hydrogeology

The surface geology at LHAAP-35A (58) consists predominantly of clay and silty clays, with thin lenses of sand. The sand lenses are approximately 3 to 5 feet thick and the depth of occurrence varies across the site.

The site hydrogeology, as presented in the Draft Final RACR (AECOM 2015), includes three water-bearing zones identified as the Shallow Zone, Intermediate Zone, and Deep Zone. The Shallow Zone extends to approximately 40 feet (ft) below ground surface (bgs). The lithology of the Shallow Zone is characterized by discontinuous, fine-grained layers of interbedded silt, sand, and clay. Groundwater elevations in the Shallow Zone in October 2016 ranged from 186.47 ft above mean sea level (msl) to 204.27 ft above msl. Groundwater surface elevation contours for the Shallow Zone, based on October 2016 groundwater level measurements, are shown in **Figure 1-4**.

Boring logs from 35AWW02, which was drilled to a total depth (TD) of 140 ft bgs in the Deep Zone; and 35AWW05, which was drilled to a TD of 75.75 ft bgs in the Intermediate Zone demonstrate that the geology of the Intermediate and Deep Zones consists mostly of clay, with occasional silt and sand layers. The predominance of clay below the Shallow Zone creates a basal aquitard that impedes downward migration of groundwater from the Shallow Zone. Groundwater surface measurements for all three units are available for October 2013. The groundwater elevations for the Shallow Zone ranged from approximately 194 ft to 202 ft above msl. The elevation of the Intermediate Zone potentiometric surface was approximately 178 ft above msl, and the elevation of Deep Zone potentiometric surface was 175.75 ft above msl. The differences in groundwater elevations between the Intermediate and Deep Zones reflect an upward groundwater gradient between these two units.

Hydraulic conductivities in the Shallow Zone wells range from 3.5×10^{-5} to 1.4×10^{-3} centimeters per second (Jacobs, 2002). Using an estimated hydraulic gradient of 0.022 feet per foot from **Figure 1-4** and the range of hydraulic conductivities (Jacobs, 2002), the calculated groundwater flow velocity in the Shallow Zone ranges from 2.66 to 114 ft per year.

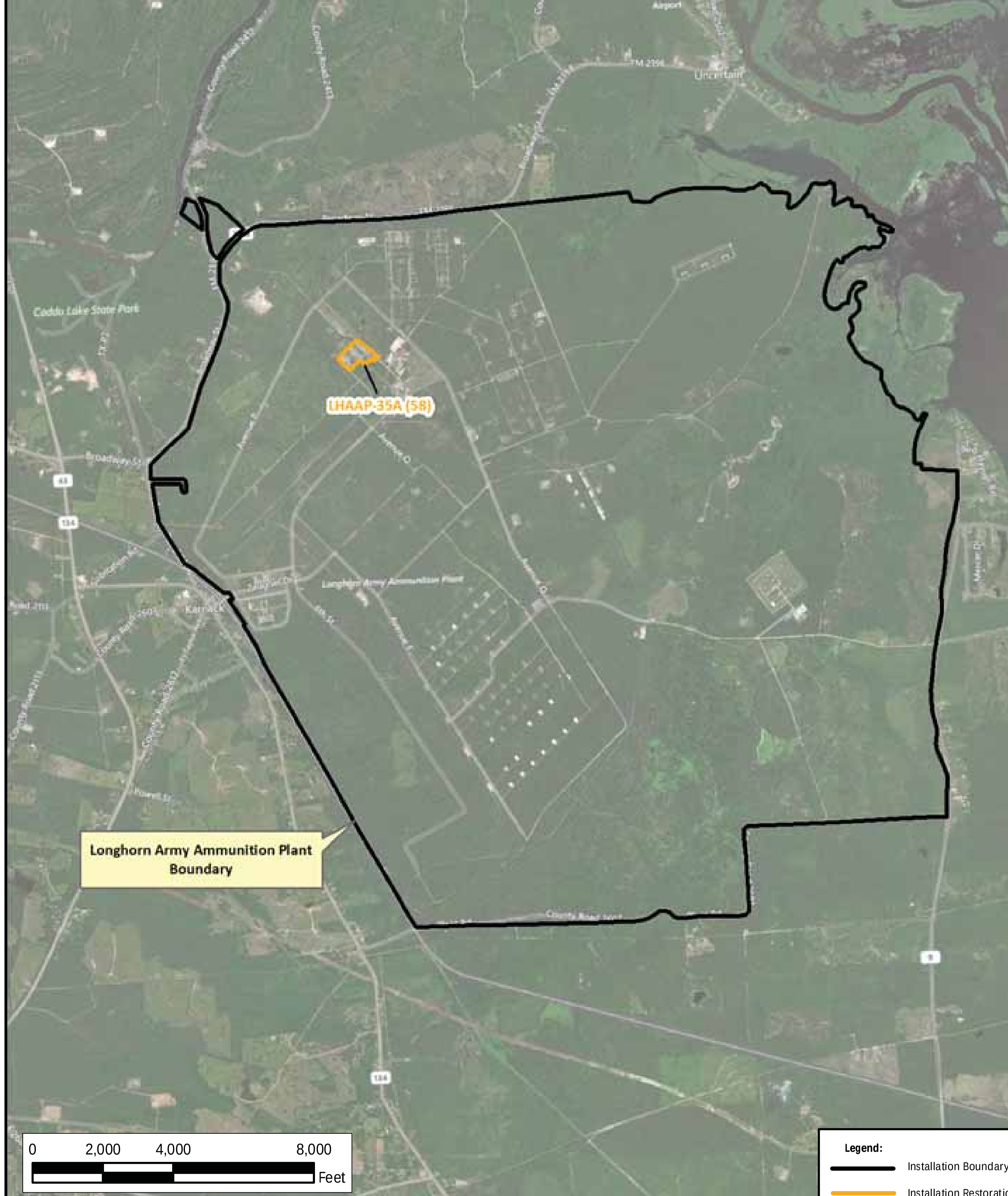
1.2.4 Remedial Action Objectives

The final remedy for groundwater at LHAAP-35A (58) will protect human health and meet Applicable or Relevant and Appropriate Requirements (ARARs). The site was determined to pose no significant ecological risks (Shaw, 2011). The RAOs for LHAAP-35A (58) are consistent with the reasonably anticipated future use of the site as a national wildlife refuge and include:

- Protection of human health by preventing human exposure to the contaminated groundwater.
- Protection of human health and the environment by preventing contaminated groundwater from migrating to nearby surface water.
- Return of groundwater to its potential beneficial use as drinking water, wherever practicable.

OKLAHOMA
Oklahoma City
Memphis
ARKANSAS
Longhorn Army Ammunition Plant
Karnak, Texas
Dallas
TEXAS
LOUISIANA
Austin
Houston
San Antonio
Monterrey
Saltillo
NUEVO LEON
Earthstar Geographics SIO © 2017 HERE © 2017 Microsoft Corporation

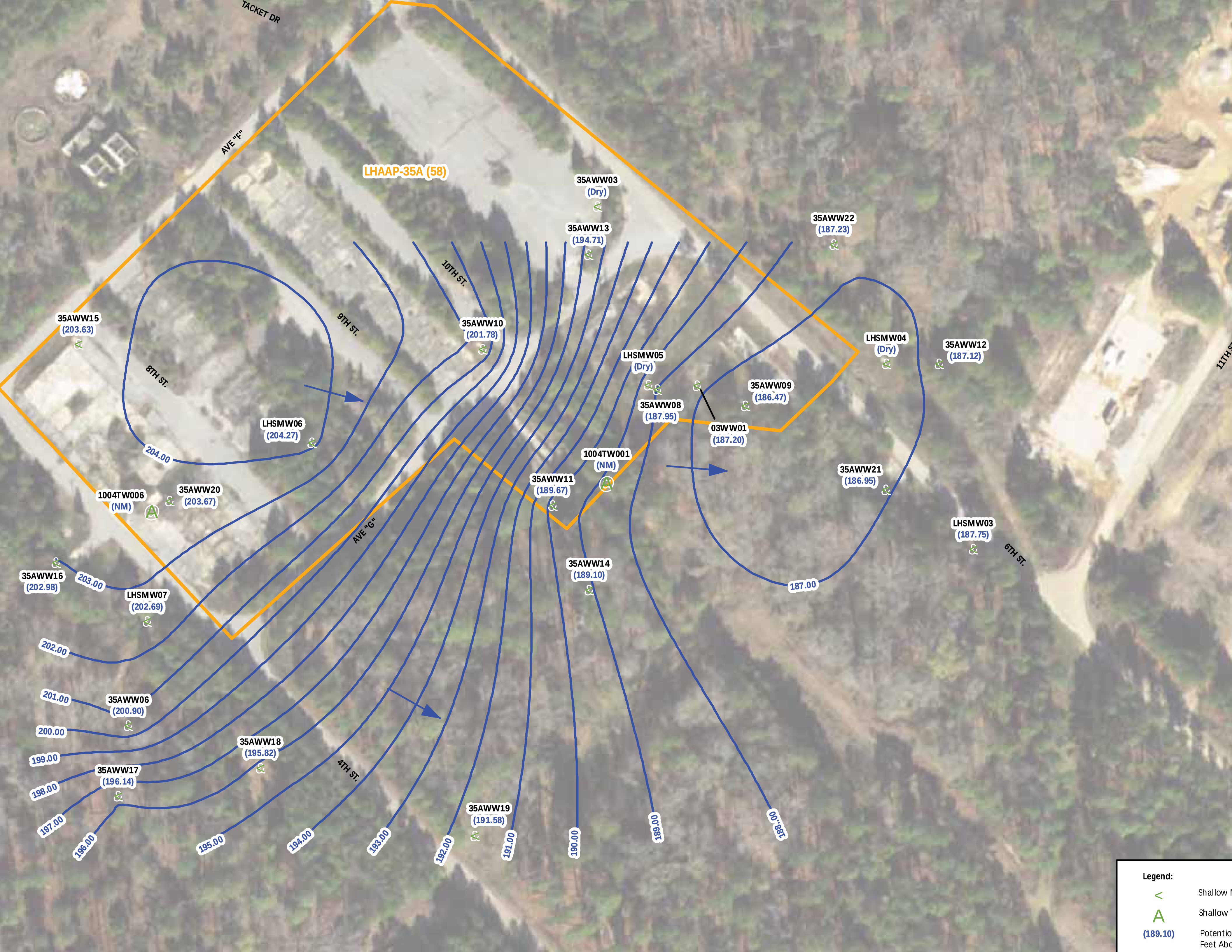
Smithland
Trees
Goat Island
Clinton Lake
Oil City
Caddo Lake
Uncertain
Mooringsport
Longhorn Army Ammunition Plant
South Shore
Leigh
Latex



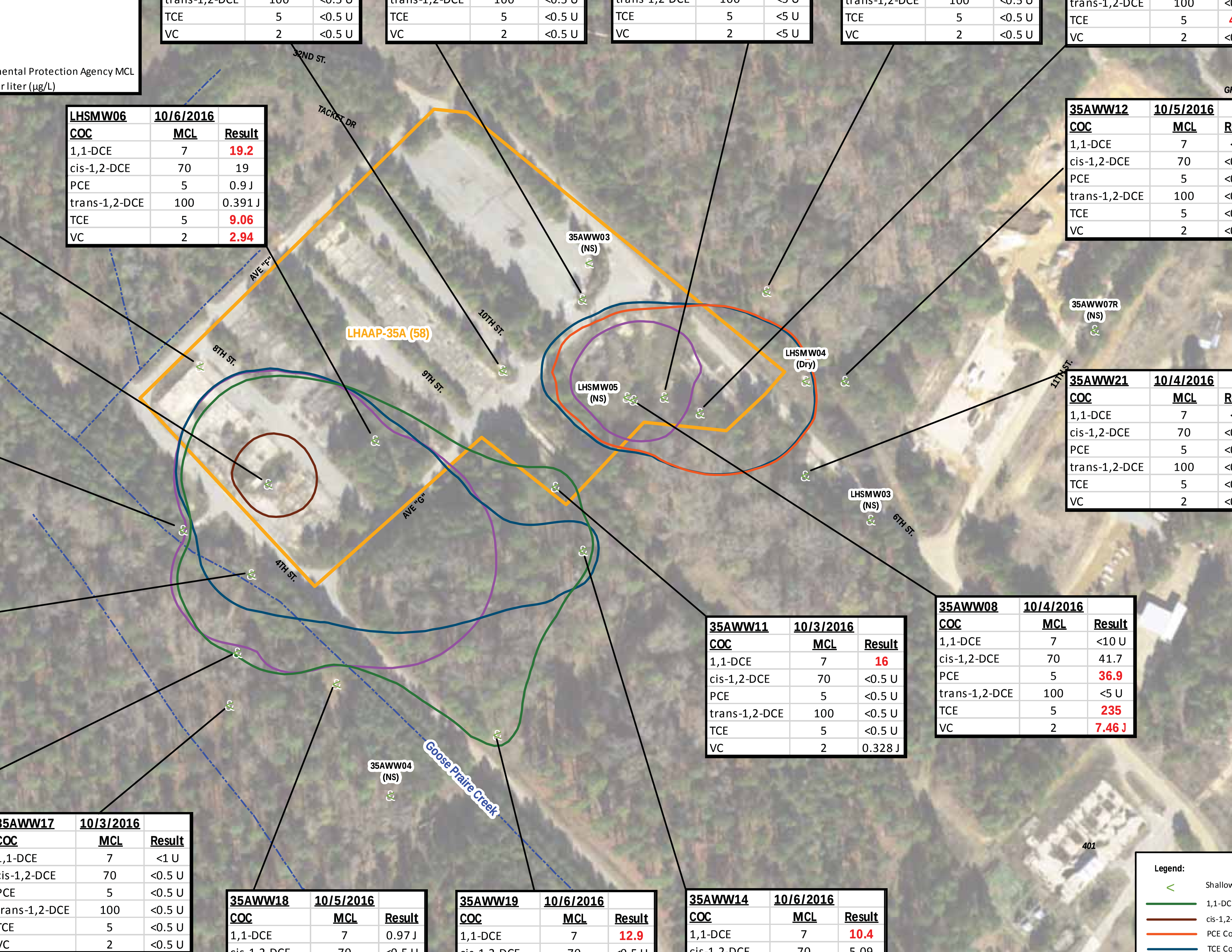
Caddo Lake State Park
LHAAP-35A (58)
Longhorn Army Ammunition Plant
Karnack
Uncertain
Longhorn Army Ammunition Plant Boundary
0
2,000
4,000
8,000
Feet
Legend:
Installation Boundary
Installation Restoratio


LHAAP-02
LHAAP-03
LHAAP-04
LHAAP-35A (58)
LHAAP-47
LHAAP-59
LHAAP-60A
LHAAP-60B
LHAAP-60C
LHAAP-60D
LHAAP-61
LHAAP-65
LHAAP-66
LHAAP-68
LHAAP-69
Historical LHAAP-35A (58)
Site Boundary
Goose Praire Creek
AVE "P"
AVE "G"
AVE "F"
AVE "I"
TACKET DR
4TH ST.
6TH ST.
8TH ST.
9TH ST.
10TH ST.
11TH ST.
60TH ST.
Legend:

TACKET DR
AVE "F"
AVE "G"
10TH ST.
9TH ST.
8TH ST.
6TH ST.
4TH ST.
Goose Praire Creek
LHAAP-61
LHAAP-02
LHAAP-35A (58)
LHAAP-03
LHAAP-60D
LHAAP-68
LHAAP-69
LHAAP-59
LHAAP-65
402-L
413-B-1
413-B-2
413-A
272
704D
707-F
707-G
707-J
717
713
722-E
726
722-F
716
715
714
113
744
724-D-2
744-A
707-K
707-L
723
722-P
734
718-A
724-B
724-A
725
206
209
35AWW03
35AWW13
35AWW22
35AWW15
35AWW10
35AWW01
35AWW02
LHSMW05
35AWW08
03WW01
35AWW09
LHSMW04
35AWW12
LHSMW06
35AWW20
1004TW006
35AWW11
1004TW001
35AWW21
LHSMW03
35AWW16
35AWW05
LHSMW07
35AWW14
35AWW06
35ASW03
35AWW18
35AWW17
35AWW19
35AWW04
Legend:
Shallow Monitoring Well Location
Shallow Monitoring Well Location
Shallow Temporary Monitoring W
Intermediate Monitoring Well Loc
Deep Monitoring Well Location
Surface Water Sample Location



TACKET DR
AVE "F"
AVE "G"
4TH ST.
6TH ST.
8TH ST.
9TH ST.
10TH ST.
LHAAP-35A (58)
35AWW03 (Dry)
35AWW13 (194.71)
35AWW22 (187.23)
35AWW15 (203.63)
35AWW10 (201.78)
LHSMW05 (Dry)
LHSMW04 (Dry)
35AWW12 (187.12)
35AWW09 (186.47)
35AWW08 (187.95)
03WW01 (187.20)
LHSMW06 (204.27)
1004TW001 (NM)
35AWW11 (189.67)
35AWW21 (186.95)
1004TW006 (NM)
35AWW20 (203.67)
LHSMW03 (187.75)
35AWW14 (189.10)
35AWW16 (202.98)
LHSMW07 (202.69)
35AWW06 (200.90)
35AWW18 (195.82)
35AWW17 (196.14)
35AWW19 (191.58)
204.00
203.00
202.00
201.00
200.00
199.00
198.00
197.00
196.00
195.00
194.00
193.00
192.00
191.00
190.00
189.00
188.00
187.00
Legend:
(189.10)



trans-1,2-DCE	100	<0.5 U
TCE	5	<0.5 U
VC	2	<0.5 U

trans-1,2-DCE	100	<0.5 U
TCE	5	<0.5 U
VC	2	<0.5 U

trans-1,2-DCE	100	<5 U
TCE	5	<5 U
VC	2	<5 U

trans-1,2-DCE	100	<0.5 U
TCE	5	<0.5 U
VC	2	<0.5 U

trans-1,2-DCE	100	
TCE	5	4
VC	2	<

35AWW12	10/5/2016	
COC	MCL	R
1,1-DCE	7	<
cis-1,2-DCE	70	<
PCE	5	<
trans-1,2-DCE	100	<
TCE	5	<
VC	2	<

LHSMW06	10/6/2016	
COC	MCL	Result
1,1-DCE	7	19.2
cis-1,2-DCE	70	19
PCE	5	0.9 J
trans-1,2-DCE	100	0.391 J
TCE	5	9.06
VC	2	2.94

35AWW21	10/4/2016	
COC	MCL	R
1,1-DCE	7	<
cis-1,2-DCE	70	<
PCE	5	<
trans-1,2-DCE	100	<
TCE	5	<
VC	2	<

35AWW08	10/4/2016	
COC	MCL	Result
1,1-DCE	7	<10 U
cis-1,2-DCE	70	41.7
PCE	5	36.9
trans-1,2-DCE	100	<5 U
TCE	5	235
VC	2	7.46 J

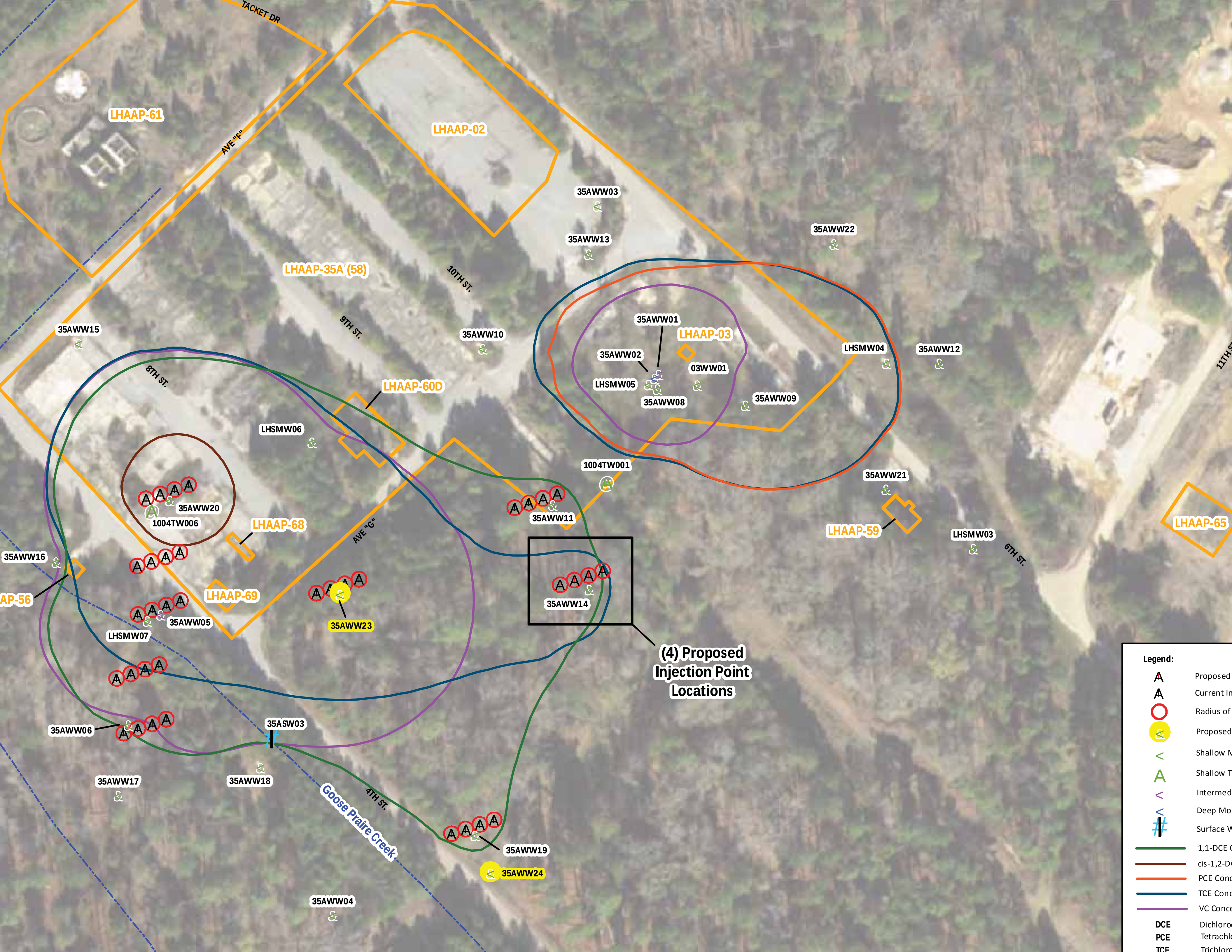
35AWW11	10/3/2016	
COC	MCL	Result
1,1-DCE	7	16
cis-1,2-DCE	70	<0.5 U
PCE	5	<0.5 U
trans-1,2-DCE	100	<0.5 U
TCE	5	<0.5 U
VC	2	0.328 J

35AWW17	10/3/2016	
COC	MCL	Result
1,1-DCE	7	<1 U
cis-1,2-DCE	70	<0.5 U
PCE	5	<0.5 U
trans-1,2-DCE	100	<0.5 U
TCE	5	<0.5 U
VC	2	<0.5 U

35AWW18	10/5/2016	
COC	MCL	Result
1,1-DCE	7	0.97 J

35AWW19	10/6/2016	
COC	MCL	Result
1,1-DCE	7	12.9

35AWW14	10/6/2016	
COC	MCL	Result
1,1-DCE	7	10.4
cis-1,2-DCE	70	5.09



LHAAP-61
LHAAP-02
LHAAP-35A (58)
LHAAP-03
LHAAP-60D
LHAAP-68
LHAAP-69
LHAAP-59
LHAAP-65
AP-56
TACKET DR
AVE "F"
AVE "G"
10TH ST.
9TH ST.
8TH ST.
6TH ST.
4TH ST.
11TH S
Goose Praire Creek
35AWW03
35AWW13
35AWW22
35AWW01
35AWW02
03WW01
LHSMW05
35AWW08
35AWW09
LHSMW04
35AWW12
35AWW15
35AWW10
LHSMW06
1004TW001
35AWW21
LHSMW03
35AWW20
1004TW006
35AWW11
35AWW16
35AWW14
35AWW05
35AWW23
LHSMW07
35AWW06
35ASW03
35AWW17
35AWW18
35AWW19
35AWW24
35AWW04
(4) Proposed Injection Point Locations
Legend:
Proposed
Current In
Radius of
Proposed
Shallow M
Shallow T
Intermed
Deep Mo
Surface W
1,1-DCE C
cis-1,2-D
PCE Conc
TCE Conc
VC Conce
DCE Dichloro
PCE Tetrachlo
TCE Trichlor

2 LAND USE CONTROL PLAN

The U.S. Army or its representatives are responsible for LUC implementation and certification, reporting, and enforcement. The U.S. Army will address any LUC problems within its control that are likely to impact remedy integrity as soon as practicable. The details of LUC components are provided in the RAWP (August 2013). The continued successful implementation of LUC is presented in the annual RA(O) reports.

3 ENHANCED IN-SITU BIOREMEDIATION

This section discusses the objectives and details of the EISB component of this RAWP addendum.

EISB will be performed in the western plume target area. The purpose of EISB is to accelerate the rate of biological degradation of chlorinated ethenes and ethanes in the Shallow Zone groundwater and to create subsurface conditions that are favorable for MNA. EISB will be implemented in the western plume target area encompassing the Shallow Zone wells 35AWW20, 35AWW06, and LHSMW07. This area is characterized by relatively high concentrations of TCE, 1,1-DCE, cis-1,2-DCE, and VC. 1,1-DCE was also reported above the MCL in monitoring wells located in the eastern (35AWW11) and southern (35AWW19) portions of the western plume. Therefore, EISB will also be implemented near these wells and one proposed monitoring well location (35AWW23) in the area (see **Figure 1-6**).

In September 2013, EISB was implemented by injecting Wilclear Plus in the eastern plume in the vicinity of monitoring wells 03WW01 and 35AWW08, followed by bioaugmentation using KB-1® Plus in November 2013. Groundwater samples collected in October 2013 show increases in ferrous iron, alkalinity, and *dehalococcoides/dehalobacter* species; and decreases in PCE and TCE concentrations. These changes indicate reductive dechlorination of chlorinated VOCs was occurring in the EISB treatment area. Similarly, it is anticipated that EISB implementation will reduce contaminant mass in the western plume and create more favorable conditions for natural attenuation.

In general, EISB treatment will include injection of a carbon substrate and a microbial consortium, if needed, which will include *dehalococcoides ethenogenes* (DHC) and *dehalobacter* (DHB). It is well documented in the literature that DHC and DHB have demonstrated ability to reduce chlorinated ethenes and ethanes, respectively. The role of the carbon substrate is to provide a food source for indigenous and bio-augmented microorganisms. As the carbon substrate is metabolized by the microorganisms, hydrogen gas is produced, which provides available protons required for reductive dechlorination. Competing processes include those that involve other electron acceptors, such as oxygen and sulfate. Reductive dechlorination may be delayed until competing electron acceptors have sufficiently decreased to below competing levels.

During biological reductive dechlorination, the chlorinated ethenes (such as PCE) serve as an electron acceptor and chlorine atoms are sequentially replaced with protons to yield TCE, cis-1,2-DCE, VC, and ethene as daughter products. A common observation is that PCE and TCE are reductively dechlorinated under relatively mild reducing conditions (e.g., sulfate-reducing conditions), whereas reductive dechlorination of cis-1,2-DCE and VC generally require increasingly stronger reducing conditions (e.g. methanogenic conditions).

3.1 Laboratory-scale Bioremediation Treatability Study

A laboratory-scale bioremediation Treatability Study (TS) was conducted between February 25, 2013, and June 2013. One lactate based carbon source (e.g. sodium lactate) and one vegetable oil-based carbon source (e.g. emulsified vegetable oil [EVO]) were evaluated in the TS. The lactate-based carbon source was Wilclear Plus, manufactured by JRW Bioremediation, LLC, in

Lenexa, Kansas. The vegetable oil carbon source was SRS® - SD Small Droplet Emulsified Vegetable Oil (SRS), manufactured by Terra Systems, Inc., in Claymont, Delaware.

Results of the TS indicate that both treatment microcosms (Wilclear Plus Amended and SRS Amended) achieved complete dechlorination (reduction of PCE/TCE to ethene). The chlorinated VOCs in the control microcosms remained stable as expected. Similarly, reductions in sulfate concentrations were observed in both treatment microcosms. The Wilclear amendment, which is lactate-based, is a relatively fast substrate compared to the EVO-type substrates, as evidenced by the TS data. Complete details of the TS are provided in the 2013 RAWP for LHAAP-35A (58).

3.2 EISB Performance in the Eastern Plume at LHAAP-35A (58)

In September 2013, EISB implementation was conducted by injecting Wilclear Plus in the eastern plume in the vicinity of monitoring wells 03WW01 and 35AWW08, followed by bioaugmentation using KB-1® Plus in November 2013. Groundwater monitoring was performed in August 2013 prior to EISB implementation (baseline event), October 2013 (performed after the carbon substrate injections), and in January 2014, May 2014, October 2014, January 2015, April 2015, July 2015, and October 2015, after bioaugmentation culture injections. Following EISB implementation, major reductions were observed in PCE in both wells. TCE, a degradation product of PCE, initially decreased between August 2013 and October 2013, but subsequently increased (due to reduction of PCE into TCE), demonstrating that the early stages of dechlorination were occurring. After the initial increase, TCE concentrations subsequently decreased, due to degradation of TCE to daughter products, and plateaued near the August 2013 concentrations. The concentrations of cis-1,2-DCE, a degradation product of TCE, increased in both wells during the October 2015 monitoring period, suggesting that dechlorination of TCE was occurring. To date, VC has not been detected in either well, potentially indicating the occurrence of a cis-1,2-DCE stall, a phenomenon known to occur in the absence of sufficient active culture of *dehalococcoides* bacteria. After two years of monitoring, no rebound has been observed, which indicates reductive dechlorination of chlorinated VOCs is effective in the EISB treatment area within the eastern groundwater plume.

3.3 EISB Design Parameters

This section presents the general EISB design parameters for the western plume. The EISB design is based on an evaluation of current site conditions, an understanding of the COCs, and their physical and geochemical properties in groundwater.

3.3.1 Substrate Selection

As indicated by the TS data, the EVO-type substrate can achieve complete dechlorination of the COCs in site groundwater and is proposed for the contingency remedy.

There are various formulations of EVO-type substrates commercially available for groundwater remediation. The specific formulation of EVO-type substrate for this project is the SRS® - SD Small Droplet Emulsified Vegetable Oil (SRS) or equivalent.

3.3.2 Substrate Loading

The EVO-type substrate will be delivered to the site in bulk as a concentrated medium. An approximate working solution strength of 10 to 20 % EVO-type substrate volume per volume of water will be generated in the field using a centrifugal pump, recirculation, and in-line mixer for micro emulsion. Water will be used with the EVO-type substrate to create the appropriate solution strength. The water will be sourced from the pump house serving the Groundwater Treatment Plant.

The mass of EVO-type substrate required for the target treatment area was calculated based on site characteristics (e.g., target area, depth of the Shallow Zone etc.) and stoichiometric demand exerted by the native (e.g., dissolved oxygen, sulfate etc.) and anthropogenic electron acceptors (COCs). These calculations were performed using the spreadsheet-based Substrate Estimating Tool for Enhanced Anaerobic Bioremediation of Chlorinated Solvents (Version 1.2, November 2010) developed by the Environmental Security Technology Certification Program (Parsons, 2010). The estimated quantities of EVO-type substrate are subject to modification, based on the field conditions encountered during the injection program.

The total estimated mass of concentrated EVO-type substrate (at 60% EVO) proposed for injection is approximately 14,625 pounds. The concentrated solution of EVO-type substrate will be diluted by mixing 1 part of EVO-type substrate with 5 to 10 parts of water (~10 to 20 % solution). The diluted EVO-type substrate will be injected into 36 injection points within the target treatment area.

The injection volume will be optimized to enhance and/or maintain biogeochemical conditions conducive to enhanced reductive dechlorination. The diluted EVO-type substrate will be applied to the subsurface at a target volume of 24 gallons per vertical foot.

3.3.3 Bioaugmentation Culture Loading

The TS indicated that augmenting the treatment microcosms with appropriate microbial culture enhanced the rate of biodegradation of the target VOCs in the microcosms. In the TS, KB-1 plus, a proprietary microbial culture comprised of a mix of DHC (bacteria well known for degradation of PCE/TCE, cis-1,2-DCE, and VC) and DHB (bacteria well known for degradation of 1,1,2-trichloroethane [TCA] and 1,1-dichloroethane [DCA]) was added into the treatment microcosms. Bioaugmentation using KB-1 plus microbial culture was also added to the EISB area in the eastern plume and is intended to be performed during implementation of the EISB.

Typically, DHC concentrations above 1×10^7 cells per liter are required for sufficiently high rates of EISB and ethene production (Lu et. al., 2006). Based on experience with field bioaugmentation of EISB in the eastern plume, and using technical recommendation provided by the microbial culture manufacturer (Sirem), a quantity of approximately two to three liters of KB-1 plus culture per injection point is proposed to be injected after the EISB implementation. The KB-1 plus culture comes in the form of a liquid solution pressurized under a compressed gas (argon or nitrogen). Bioaugmentation will be performed approximately two to four weeks after the EISB implementation until appropriate redox conditions are established.

3.4 Direct Push Technology Injections

EISB will be implemented in the area of elevated COC concentrations in the western plume (**Figure 1-6**). Based on the October 2016 isoconcentration map, the target treatment area is estimated to be approximately 325,000 square feet and will require approximately 36 injection points at a spacing of approximately 15 to 20 ft (anticipated radius of influence of 7.5 to 10 ft). Four injection points will be placed in a row approximately 15 to 20 ft upgradient of each of the following monitoring wells: 35AWW20, 35AWW14, LHSMW-07, 35AWW11, 35AWW19, one proposed new monitoring well (35AWW23), and downgradient from well 35AWW06. Since concentrations of COCs are relatively high at monitoring wells 35AWW20 and LHSMW07, two rows of four injection points each will be placed between monitoring wells 35AWW20 and LHSMW07, and monitoring wells LHSMW07 and 35AWW06. The target depth for each injection point will be within the Shallow Zone (approximately 20 to 30 feet bgs).

The EVO-type substrate will be injected into the subsurface through direct push technology (DPT) injection points either utilizing a single point injection system or using a mobile manifold injection system. The mobile manifold injection system will be capable of injecting the solution into multiple locations simultaneously. The injection system will consist of a bulk storage tank, mixing equipment, an injection pump, and volume metering and control equipment. EVO-type substrate, diluted as discussed above, will be pressure-fed into each injection point utilizing a transfer pump and a portable polyethylene mixing tank. Injection flow rates are expected to range from 2 to 10 gallons per minute (gpm) at injection pressures from 20 to 100 pounds per square inch (PSI). Injections will be conducted at the lowest pressure practical which yields an acceptable flow rate.

The substrate solution will be injected using a "bottom-up" approach at each proposed injection point at 2- to 5-foot intervals to cover the entire Shallow Zone groundwater treatment interval. Under this approach, the drill rods will be advanced to the bottom portion of the injection interval. The DPT drill rods will be pulled up exposing a stainless steel screen, between 2 and 5 ft in length, which will act as the temporary well screen. Injectate will be pumped down through the DPT drilling rods (acting as a temporary well casing) to the injection interval and injectate will be forced through the stainless steel screen into the surrounding formation. The tools are then withdrawn to the next injection depth and the material is again pumped through the rods. This cycle is repeated to provide coverage across the entire vertical treatment interval.

If the substrate solution delivery is not successful at a selected depth interval, the remaining volume may be injected into an adjacent depth interval within the same injection point or into the same depth interval at an adjacent injection point.

Real-time field conditions and the location of any subsurface structures will be used to adjust injection locations, depths and/or volumes to optimize substrate delivery into the subsurface as the remedial action (RA) progresses. Subsurface utilities and other structures may not only impede injection placement, but may also act as a preferential flow path for groundwater and injectate migration.

As discussed in Section 3.3.3, bioaugmentation will be performed approximately two to four weeks after the EISB implementation until appropriate redox conditions are established.

Bioaugmentation will involve injecting the microbial culture (KB-1 plus) via the direct push points located generally at the same locations where the EISB injections were performed. The injection tubing is advanced into the drive point at the desired injection depth and purged with argon or nitrogen gas to displace oxygen from the column. The culture is then injected into the drive point with the compressed gas.

The microbial culture will be injected under pressure in the same target depth intervals as the carbon substrate solution. Small quantities of the carbon substrate solution may be injected into the same points during bioaugmentation, so that a sufficient 'food source' is provided to the microbial culture as soon as it enters the subsurface environment.

3.4.1 Radius of Influence and Injection Point Spacing

The EISB injections will utilize 36 injection points with spacings of approximately 15 to 20 feet, to achieve an expected radius of influence of 7.5 to 10 ft. Data generated from the ESIB implemented at the eastern plume indicate that this radius of influence is conservative for the LHAAP-35A (58) site.

3.5 EISB Performance Monitoring

Performance monitoring will be used to evaluate the effectiveness of the EISB treatment and to determine if additional substrate injections are necessary. A single injection event is currently proposed. Following the first injection event, groundwater will be monitored quarterly for two years. The groundwater monitoring data will be used to evaluate the effectiveness of EISB in meeting the RAOs and to determine if a second round of injections is necessary. Experience from the eastern plume indicates that one event is sufficient to achieve significant reduction in chlorinated VOCs. After the end of performance monitoring for EISB, the monitoring schedule for the western plume target area will be aligned with the schedule for the rest of the western plume.

3.5.1 Baseline Groundwater Monitoring

A baseline groundwater monitoring event will be conducted prior to EISB implementation to establish baseline COC concentrations and geochemical conditions. The baseline groundwater sampling results will be compared with monitoring results following substrate emplacement to assess the performance of EISB. Groundwater samples during baseline event will be analyzed for VOCs and for the following biogeochemical parameters: alkalinity, common anions (chloride, sulfate, nitrate, nitrite), sulfide, total organic carbon (TOC), dissolved iron and manganese, total phosphorus, carbon dioxide, dissolved gases (methane, ethane, and ethene), total iron, DHC, DHB, and tracer (if used).

3.5.2 EISB Performance Monitoring

Groundwater monitoring will be performed for eight quarterly events following implementation of EISB to demonstrate effectiveness of the EISB remedy. A total of six monitoring wells (35AWW20, LHSMW07, 35AWW06, 35AWW11, 35AWW19, and proposed well, 35AWW23) will be included in the EISB monitoring program for collection and analysis of groundwater samples for VOCs and biogeochemical parameters. These wells were selected for their placement relative to the VOC plumes to monitor the effectiveness of EISB at LHAAP-35A (58). Other monitoring wells included in the semi-annual sampling program for this site will continue to be sampled.

4 FIELD PREPARATION AND METHODS

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

4.1 Permitting

AECOM will prepare and obtain any necessary permits prior to initiation of EISB. This may include applicable requirements to satisfy Underground Injection Control guidelines.

4.2 Pre-mobilization Activities

A pre-construction meeting will be held prior to initiation of field activities.

4.3 Preliminary Activities/Mobilization

A field schedule will be finalized with the selected drilling and/or injection subcontractor prior to mobilizing to the LHAAP-35A (58) site. An on-site project kickoff meeting will be held with the subcontractor to review the scope of work, including the drilling locations, utility clearances, and health and safety issues/requirements.

4.4 Site/Utility Clearance

Existing utility maps will be utilized to locate subsurface utilities. All proposed locations of monitoring well borings and DPT injection points will be marked, Underground Service Alert (One Call) will be notified at least two working days prior to intrusive work, and the utility clearance standard operating procedure will be followed.

4.5 Monitoring Well Installation

Two new monitoring wells are proposed in the Shallow Zone. One well will be located in the center of the western plume and will be used to monitor EISB performance as discussed in **Section 1.2.1**. The second well will be installed to the south and downgradient from monitoring well 35AWW19 for 1,1-DCE plume extent delineation. The monitoring wells will be installed using hollow-stem auger or mud rotary drilling techniques. Well installation and development will follow the procedures specified in the Installation-Wide Work Plan (July 2014).

4.6 Site Survey

After completion of the sampling activities, the new monitoring wells will be surveyed by a licensed land surveyor. The survey activities (for location and elevation) will be performed in accordance with the Installation-Wide Work Plan (July 2014).

4.7 Investigation Derived Wastes

Investigation-derived waste (IDW) generated during the investigation and monitoring activities will include disposable sampling equipment, purge water, equipment decontamination fluids, drill cuttings, and used personal protective equipment (PPE). IDW (except PPE and disposable sampling equipment) will be containerized and stored on-site pending analytical results and waste profiling. The IDW management, storage, and disposal will be performed in accordance with the Installation-Wide Work Plan (July 2014).

4.8 Decontamination of Equipment and Personnel

Decontamination of equipment and personnel will be performed in accordance with the Installation-Wide Work Plan (July 2014).

4.9 Health and Safety Procedures

The health and safety procedures described in the LHAAP Installation-Wide Work Plan (July 2014) will be complied with during field activities. The field work is anticipated to be performed in Level D modified PPE that will include a hard hat, safety glasses, steel-toed boots, and nitrile gloves. Additional PPE may include bug spray, Tyvek® suits, poison oak block, and reflective safety vests, depending on the location and type of field activities.

The medical center associated with this project is the Workcare (Occupational Clinic) located at Marshall, Texas. An emergency contact list and emergency route map are included in the Installation-Wide Work Plan.

4.10 Quality Assurance/Quality Control

All work will be performed in accordance with the Installation-Wide Work Plan (July 2014). The Installation-Wide Work Plan provides information on Quality Assurance/Quality Control procedures for this project, identifies personnel, procedures, controls, instructions, tests, verifications, documents, and forms to be used and the types of records to be maintained. The Installation-Wide Work Plan also addresses quality control requirements specific to each major feature of work.

5 REMEDY PERFORMANCE EVALUATION AND REPORTING

Reporting will consist of formal annual reports, supplemented by distribution of validated data to the Army as they become available, to shorten the lag time between sampling and providing analytical results to the regulators.

EISB evaluation reports will be completed at the end of the first year of quarterly monitoring and at the end of the second year of quarterly monitoring. Following completion of the contingency remedy, a Remedial Action Completion Report (RACR) Addendum will be prepared. The RACR Addendum will include an Operation and Maintenance (O&M) Plan detailing O&M of the well system and other features of the remedy. The information required for LTM and Five Year Review Reports for the LHAAP-35A (58) site is provided in 2013 RAWP.

5.1 EISB Evaluation

Technical evaluations of EISB effectiveness will be performed at the end of the first year and the end of the second year. The objective of the evaluations is to determine whether the injections in the western plume target area have been effective, or whether a second round of injections is needed to achieve RAOs. If there is a second round of injections, the design for the supplemental injections will be determined by the results of the groundwater sampling during performance monitoring. The report will include:

- Figures of the site, and groundwater elevation contours;
- Groundwater analytical results;
- Plume extent and COC concentrations over time;
- An evaluation of the effectiveness of EISB in creating conditions favorable for MNA, based on the first and second lines of evidence (see 2013 RAWP for description of these lines of evidence),
- A recommendation on whether a second round of injections is appropriate. If a second injection round is recommended, the injection design will optimized using the EISB performance monitoring results.

6 SCHEDULE

Table 6-1 shows the estimated duration for each major site activity and timeline. This schedule is reasonable and achievable. Adverse weather and unknown site conditions could affect this schedule.

Table 6-1: Schedule and Duration of Major Site Activities

Activit	Duration	Elapsed Time
Groundwater monitoring: EISB	1 week	2 months
Mobilization / site setup	1 day	-
Groundwater sampling	4 days	-
Demobilization	1 day	-
Well Installation	1 month	1 month
In situ bioremediation injections	2 week	3 months
Mobilization / site setup	2 day	-
Direct push injections	5 days	-
Demobilization	1 day	-
Groundwater monitoring: EISB: 8	24 Months	27 Month
Mobilization / site setup	1 day	-
Groundwater sampling	4 days	-
Demobilization	1 day	-
Estimated duration	6 days per event	-
In situ bioremediation evaluation	12 months	24 months
Achieve cleanup levels	TBD	TBD
Western Plume	TBD	TBD

TBD – to be determined

7 REFERENCES

AECOM Technical Services, Inc. (AECOM), 2013, *Final Remedial Action Work Plan LHAAP-35A (58), Shops Area, Group 4 Longhorn Army Ammunition Plant, Karnack, Texas*, August

AECOM, 2014, *Final Installation-Wide Work Plan, Longhorn Army Ammunition Plant, Karnack, Texas*, July.

AECOM, 2016, *2nd Annual Remedial Action Operation Report (January 2015-October 2015) Plan LHAAP-35A (58), Shops Area, Longhorn Army Ammunition Plant, Karnack, Texas*, May

Driscoll, F.G., 1986, *Groundwater and Wells*, 2nd Edition, 1986.

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

Lu, X., Wilson, J.T., Kampbell, D.H., 2006, *Relationship between Dehalococcoides DNA in groundwater and rates of reductive dechlorination at field scale*. Water Research 40:3131-3140.

Parsons, 2010, *Loading Rates and Impacts of Substrate Delivery for Enhanced Anaerobic Bioremediation, Final Report*, ESTCP Project No. ER-0627, February.

Shaw Environmental, Inc. (Shaw), 2009, *Final Feasibility Study, LHAAP-35A (58), Shops Area, Group 4, Karnack, Texas,* December.

Shaw, 2011, *Final Remedial Design, LHAAP-35A (58), Shops Area, Group 4, Longhorn Army Ammunition Plant, Karnack, Texas,* September.

USACE, 2010, *Record of Decision, LHAAP-35A (58), Shops Area, Group 4, Longhorn Army Ammunition Plant, Karnack, Texas*, September