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AMERICAN LAKE GARDEN TRACT (ALGT) FOCUSED FEASIBILITY STUDY

Joint Base Lewis-McChord
Pierce County, Washington

Joint Base Lewis-McChord Public Works – Environmental Division
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American Lake Garden Tract (ALGT)
Focused Feasibility Study

Prepared for

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ABBREVIATIONS AND ACRONYMS

μg/L	micrograms per liter
ALGT	American Lake Garden Tract
ARAR	Applicable or Relevant and Appropriate Requirement
bgs	below ground surface
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CSM	conceptual site model
CUL	clean up level
CY	calendar year
DCE	dichloroethane
EA	EA Engineering, Science, and Technology, Inc., PBC
Ecology	Washington State Department of Ecology
EISB	enhanced in-situ bioremediation
EPA	U.S. Environmental Protection Agency
EVO	emulsified vegetable oil
FFS	Focused Feasibility Study
FS	Feasibility Study
GAC	granular activated carbon
GPT	groundwater pump-and-treat
GRA	general response action
GSI	GSI Environmental, Inc.
IRP	Installation Restoration Program
ISCO	*In Situ* Chemical Oxidation
JBLM	Joint Base Lewis-McChord
LLRW	low-level radioactive waste
MCL	maximum contaminant level
MNA	monitored natural attenuation
MTCA	Model Toxics Control Act
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List

OSWER	Office of Solid Waste and Emergency Response
PFAS	perfluorinated alkylated substances
PNNL	Pacific Northwest National Laboratory
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RI	remedial investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SEPA	State Environmental Policy Act
STF	shear-thinning fluid
TBC	To Be Considered
TCE	trichloroethene
TtEC	Tetra Tech EC, Inc.
USC	United States Code
VC	vinyl chloride
VOC	volatile organic compound
WAC	Washington Administrative Code

1. INTRODUCTION

This document presents the Focused Feasibility Study (FFS) conducted by EA Engineering, Science, and Technology, Inc., PBC (EA) for American Lake Garden Tract (ALGT) located at Joint Base Lewis-McChord (JBLM), Washington.

1.1 PURPOSE OF REPORT

In this FFS, a limited list of remedial alternatives are developed and assessed in accordance with *Guidance for Conducting Remedial Investigation and Feasibility Studies* under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (Office of Solid Waste and Emergency Response [OSWER] Directive 9355.3-01) (U.S. Environmental Protection Agency [EPA] 1988) and *Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (OSWER Directive 9355.0-75) (EPA 2000). This FFS provides a basis for evaluating alternatives to the existing remedy in place (utilization of a groundwater pump-and-treat [GPT] system) and determines which of the alternative cleanup actions is warranted based on data from the current groundwater monitoring program and past remedial investigations.

The existing remedy in place, which included operation of the GPT system, has not effectively driven the site towards closure in an expedient manner. The GPT removed 108 pounds of trichloroethene (TCE) during 22 years of operation and was expensive to operate and maintain. Contaminant concentration data collected from a rebound test initiated in 2016 indicate that the plume is in a steady-state condition without the extraction system running (Tetra Tech EC, Inc. [TtEC] 2018).

1.2 SITE DESCRIPTION

JBLM is located approximately 9 miles south-southwest of Tacoma in the western portion of Washington State (Figure 1). The facility is comprised of the former Fort Lewis and the former McChord Air Force Base, which merged to form a Joint Base in 2010, following the 2005 recommendations of the Base Realignment and Closure Commission. The main portions of the Base encompass an area of 90,837 acres within Pierce and Thurston counties.

ALGT is located on the western boundary of JBLM. The site is approximately three-quarter miles west of the intersection of Fairway Road and Lincoln Boulevard and is primarily occupied by the Whispering Firs Golf Course (Figure 2).

In 1984, EPA Region 10 discovered volatile organic compounds (VOCs), including TCE and cis-1,2-dichloroethane (DCE), in groundwater monitoring wells installed at ALGT. EPA concluded that the groundwater contamination at ALGT most likely originated from Area D, where several waste disposal sites in various stages of operation existed from the mid-1940s to the early 1970s. The amount of TCE disposed of at Area D is unknown. ALGT was added to the National Priorities List (NPL) under CERCLA in October 1984. ALGT included Installation Restoration Program (IRP) Sites MF-LF-004, MF-ALGT-LF-005, MF-LF-006, MF-LF-007, MF-OT-026, MF-RW-035, and MF-OT-039 (Figure 2).

On 23 August 1989, the Air Force, EPA Region 10, and Washington State Department of Ecology (Ecology) signed a Federal Facility Agreement to manage the NPL sites at JBLM. A remedial investigation (RI)/feasibility study (FS) was performed at Area D/ALGT from 1989 through 1991 (Ebasco Environmental 1991a, 1991b).

The RI/FS concluded that VOCs in groundwater samples associated with IRP sites MF-ALGT-LF-005 and MF-OT-039 exceeded health-based levels and/or EPA maximum contaminant levels (MCLs) and required remediation. Groundwater remediation goals were established for four contaminants of concern: TCE (5 micrograms per liter [µg/L]); cis-1,2-DCE (70 µg/L); 1,1-DCE (0.07 µg/L); and vinyl chloride (VC) (0.04 µg/L) (Table 1). In 1991, the Air Force, EPA, and Ecology signed a Record of Decision (ROD) specifying containment of the plume by a GPT system as the selected remedy for groundwater contamination (EPA et al. 1991).

Operation of the ALGT GPT occurred from 1994 to 2016. The decision to cease operation of the GPT was approved following the submittal of a technical memorandum in 2015, which recommended conducting a Site Management Improvement Study in order to evaluate monitored natural attenuation (MNA) as a viable treatment technology to replace the GPT system (TtEC 2015a).

1.3 GEOLOGY

The geology of JBLM has been described by Griffin et al. (1962), Walters and Kimmel (1968), Brown and Caldwell (1985), and Borden and Troost (2001). Additional hydrogeologic studies, such as JRB Associates (1983), Shannon and Wilson (1986), Science Applications International Corporation (1986), Envirosphere (1988), and Ebasco Environmental (1991a, 1991b) were conducted as part of the JBLM-Lewis IRP investigations.

1.3.1 Regional Geology

JBLM is in the south-central portion of the Puget Trough, which is a large north-south-trending structural depression bounded by the Cascade Mountains on the east and the Olympic Mountains on the west. The trough is filled with a thick sequence of Tertiary fluvial and shallow marine sediments. During the Quaternary Period, a thick sequence of unconsolidated, fluvial, and glacial sediments was deposited on top of the older basin fill material. In the vicinity of JBLM McChord Field, the sequence is up to 2,000 feet thick. The Quaternary sequence beneath JBLM McChord Field is composed of interbedded glacial and nonglacial sediments deposited during a series of glacial advances and retreats into the southern Puget Lowland.

The Quaternary sequence underlying the Base is summarized in Table 2 (Ebasco Environmental 1991a; Borden and Troost 2001). There are numerous glacial and interglacial geologic units in the region of ALGT, including 1) the Vashon Drift, 2) Olympia Beds, 3) Pre-Olympia Drift, 4) Second Non-Glacial Deposits, 5) Third Glacial Drift, 6) Third Non-Glacial Deposits, and 7) Puyallup Interglacial Deposits (Table 2). These units vary both horizontally and vertically, making hydrological interpretation very difficult. One or more of the glacial sequence deposits of advance outwash, till, and recessional outwash have been recognized beneath JBLM.

The Vashon Drift (Qv) is a key unit at ALGT and is composed locally of the Steilacoom Gravel (Qvs), the Vashon Recessional Outwash (Qvr), the Vashon Till (Qvt), and the Vashon Advance Outwash (Qva). The Qvs is a laterally continuous, essentially unsaturated surficial deposit consisting of open-work coarse gravel with abundant cobbles. The Qvs has been observed at JBLM McChord Field with thicknesses between 0 and 20 feet. Below the Qvs is the Qvr, which consists of glacial outwash gravels (sandy gravel with lenses of gravelly sand and silt) and outwash sands. Below the Qvr is the Qvt, which consists of shallow discontinuous layers and lenses of lodgment till (compact gravel in a clay, silt, and sand matrix) and ablation till (loose, heterogeneous mixture of gravel, sand, silt, and clay). The Qva is the next unit encountered and is underneath the Qvt, where present, or the Qvr. The Qva is predominantly sandy gravel with lenses of gravelly sand and is dense where overlain by Qvt.

Between each major glacial interval, fluvial and lacustrine deposits accumulated, forming four recognizable nonglacial units. From youngest to oldest, these units are represented by 1) the Olympia Beds, 2) unnamed second nonglacial deposits that may correlate to the Whidbey Formation, 3) unnamed third nonglacial deposits, and 4) the Puyallup Formation.

Recent geologic processes in the Puget Sound region and central Pierce County include postglacial erosion and deposition. Thin deposits of recent Quaternary sediments and soils cover the project area discontinuously and consist predominantly of peat and stream alluvium. Topsoil has developed locally on top of the exposed Quaternary units. Fill composed mainly of silty gravel and concrete rubble is found within the boundaries of the Base.

1.3.2 Site Geology

Within ALGT, the Qvr sediments are underlain primarily by Olympia beds and/or lacustrine beds of variable thickness. About a quarter mile downgradient of the ALGT Area D source area, sand-dominated outwash sediments of the Pre-Olympia drift form a local paleo-topographic high. Downgradient of the Pre-Olympia high, Qvr is underlain by a lacustrine sediment-filled paleochannel that forms a thick hydraulic barrier above the underlying Qva.

1.4 HYDROGEOLOGY

1.4.1 Surface Water

Local surface water bodies most likely to be impacted by contaminated groundwater under ALGT include Lamont Lake, the Duck Pond (also referred to as the Golf Course Pond), Baxter Lake, Whitman Lake, Carter Lake, Emerson Lake, Lake Mondress, and an unnamed pond at ALGT. These surface water sites are principally groundwater fed.

1.4.2 Regional Hydrogeology

Two near-surface aquifers occur beneath ALGT that are commonly used for water supply systems in the area: the unconfined Vashon Aquifer and the Sea Level Aquifer (Table 2). The unconfined Vashon Aquifer (Unit A) contains two distinct glacial intervals (Vashon Drift and pre-Olympia Drift) and one non-glacial interval (Olympia Beds), as presented on Table 3. In some places beneath the Base, a discontinuous aquitard unit known as the Vashon Till (Qvt, Unit A2) may separate the Vashon Drift sequence into two aquifers: the unconfined Upper Vashon Aquifer (Unit A1) located in the Vashon Recessional Outwash (Qvr) and the confined Lower Vashon Aquifer (Unit A3) located in the Vashon Advance Outwash(Qva). Below the Vashon Aquifer lies a confining unit of non-glacial origin, which, depending on location, has been described as the Olympia Beds (Qpon) and the Lawton Clay (Qvlc). This confining layer (Unit B) is widespread but has been breached in certain locations by erosional channels. Below confining Unit B is the Sea Level Aquifer (Unit C), found in the Third Glacial Drift ($Qpog_2$, Borden and Troost 2001). This unit was previously described as the Salmon Springs Drift and Salmon Springs Aquifer in the ALGT RI (Ebasco Environmental 1991a). Base-wide, the aquitards have been shown to be laterally discontinuous and therefore have only local effects on the vertical movement of groundwater.

The predominant flow direction in the Qvr unconfined aquifer is to the west/northwest. The overall groundwater gradient in the unconfined aquifer across the Clover Creek/Chambers Creek basin is about 25 feet per mile (Brown and Caldwell 1985). The upper aquifer receives precipitation recharge on Base, and creeks such as Clover Creek tend to lose water to the aquifer throughout the year (Ebasco Environmental 1991a). There are no known springs on Base, but the ephemeral lakes within the Area D/ALGT site are mainly fed by the unconfined aquifer. There is generally a downward gradient within the upper aquifers (Qvr and Qva) and between the upper aquifers and the Sea Level Aquifer. The predominant flow direction in the Qva confined aquifer is to the northwest. The Sea Level Aquifer comprises the entire Third Glacial Drift and is equivalent to Hydrostratigraphic Layer C identified by Brown and Caldwell (1985). The bottom of the Sea Level Aquifer is bounded by the Puyallup Aquitard (Unit D). The Salmon Springs Till is the only aquitard unit within the Sea Level Aquifer, but it is laterally discontinuous and is known to be missing in some areas beneath the Base.

Where the till is present, the Sea Level Aquifer may locally act as two distinct aquifers. Below Area D on the Base, a difference in head of 15 feet has been observed above and below the Salmon Springs Till (Ebasco Environmental 1991a). The predominant groundwater flow direction within the Sea Level Aquifer is to the north or northwest, generally subparallel to the flow direction within the Vashon unconfined aquifer, although locally the flow may be somewhat at variance with this general direction.

1.4.3 Site Hydrogeology

ALGT is located on an extensive upland glacial drift plain which occupies much of central Pierce County. The site consists of highly permeable sand and gravel glacial outwash materials separated by till layers and interspersed non-glacial units. A cross section of the site is provided in Figure 3.

The uppermost hydrogeologic unit generally found across the site is the Vashon Drift/Vashon Aquifer, which consists of the Steilacoom Gravel, and recessional outwash, till, and advance outwash units as well as lacustrine silt and undifferentiated outwash and till units. The Steilacoom Gravel and the outwash units contain the unconfined aquifer unit that extends from the water table at about 20 feet below ground surface (bgs) to a depth of between 80 feet and 160 feet bgs. The underlying Olympia Beds are a non-glacial unit that generally represents a regional aquitard, but locally has been found to be discontinuous and relatively permeable. The Sea Level Aquifer underlies the Kitsap and consists of recessional and advance outwash units separated by a low permeability layer referred to as the Salmon Springs Till.

Unconfined groundwater flow beneath the site is generally to the west or northwest. Estimates of groundwater velocity have ranged from 0.5 feet/day in the 1991 RI (Ebasco Environmental 1991a) to as low as 0.02 feet/day in the 2018 Site Management Improvement Study (TtEC 2018). During the RI, the retardation factor for TCE in site aquifer materials was estimated at 2 (Ebasco Environmental 1991). The groundwater gradient in the Vashon Unconfined Aquifer, as calculated from the September 2019 groundwater elevations (Figure 4), is 4.4 feet per mile from the source area to mid plume, and then steepens to 16.6 feet per mile from the mid plume to the toe of the plume. Groundwater gradients calculated for those same segments from March 2019 data are shallower, with a gradient of 1.7 feet per mile from the source area to mid plume and 6.8 feet per mile from mid plume to the toe of the plume. Seasonal fluctuations in water table elevations near ALGT typically average around 6 to 7 feet. The lowest levels are generally observed in late summer or early fall, and the highest levels generally occur in early spring.

1.5 PREVIOUS INVESTIGATIONS AND REMEDIAL ACTIONS

The following documents summarize the prior RI/FS and remedial actions associated with ALGT and Area D:

***Final Remedial Investigation Report: McChord Air Force Base Area D/American Lake Garden Tract* (Ebasco Environmental 1991a, in association with Shannon & Wilson, Inc.)**

The Area D/ALGT RI was conducted from 1989 through 1991 and included investigation of soil, groundwater, surface water, and sediments at IRP Sites MF-LF-004, MF-ALGT-LF-005, MF-LF-006, MF-LF-007, MF-OT-026, MF-RW-035, and MF-OT-039 (Figure 2). Fifty-one existing groundwater monitoring wells and 73 new groundwater monitoring wells were sampled and analyzed for VOCs, semivolatile organic compounds, pesticides, polychlorinated biphenyls, and inorganics.

The primary contaminants found in the groundwater were TCE and cis-1,2-DCE. The contaminant plume was determined to be approximately 3,500 feet long, 500 feet wide, and 40 feet thick, extending from the vicinity of site MF-ALGT-LF-005 to the west toward ALGT. Groundwater contamination was not above regulatory levels at the other six IRP sites. Contamination was not reported above regulatory limits in the soil, sediment, or surface water at any of the sites at Area D/ALGT.

Final Feasibility Study Report: McChord Air Force Base Area D/American Lake Garden Tract (Ebasco Environmental 1991b)

The FS evaluated four alternatives for groundwater remediation: No Action (Alternative 1), One Groundwater Extraction System/One Carbon Adsorption Facility (Alternative 2), Three Groundwater Extraction Systems/Two Carbon Adsorption Facilities (Alternative 3), and Three Groundwater Extraction Systems/Two Carbon Adsorption Facilities plus Bioremediation (Alternative 4).

Record of Decision, McChord Air Force Base, Washington/American Lake Garden Tract (EPA et. al 1991)

Based on the RI/FS and the Baseline Risk Assessment, the ROD determined that no remedial action was necessary for soil, surface water, or sediment. The ROD indicated that site MF-ALGT-LF-005 was the main source area of the TCE plume. The ROD presented Alternative 3 as the selected remedy; however, the installed GPT system was a hybrid of Alternatives 2 and 3 (two extraction systems/one granular activated carbon [GAC] adsorption treatment system, and recharge of the treated water).

Final Design: Area D/American Lake Garden Tract, Groundwater Treatment, McChord Air Force Base, Washington (U.S. Army Corps of Engineers 1992)

The final design for the ALGT GPT system included three groundwater extraction wells (DX-1, DX-2, and DX-3 [Figure 4]), a groundwater treatment plant (Building 887) with two 20,000-pound vessels of GAC connected in series, and two recharge trenches. Extraction wells DX-1, DX-2, and DX-3 were designed with flow rates of 25, 40, and 75 gallons per minute, respectively. Extraction well DX-1 has remained off since December 1999 after the Air Force and Ecology agreed that discontinuing pumping from this well would have no adverse impact on hydraulic control of the TCE plume.

Final Remedial Action Work Plan, Area D/American Lake Garden Tract Groundwater Treatment, McChord Air Force Base, Washington (U.S. Army Corps of Engineers 1994)

The Remedial Action Work Plan describes compliance monitoring to be conducted in association with the GPT system. Objectives of the groundwater monitoring relate to evaluation of system effectiveness, including the containment of the TCE plume; progress in groundwater quality and contaminant mass removal from the aquifer; and GPT system performance.

Groundwater samples have been collected from the extraction wells, the GPT system effluent, the GPT system monitoring point, and from site groundwater monitoring wells. When well DX-1 was put on standby in December 1999, compliance monitoring was modified by using groundwater monitoring well DT-1 as a replacement monitoring point for extraction well DX-1.

Preliminary Screening of Biodegradation Processes at McChord AFB, Area D/American Lake Garden Tract (URS Greiner, Inc. and Foster Wheeler Environmental Corporation 1998)

Groundwater samples were collected from 13 site groundwater monitoring wells and analyzed for natural attenuation parameters following guidance issued by the Air Force Center for Environmental Excellence. Data were tabulated and evaluated using the Air Force Center for Environmental Excellence scoring matrix. Results were interpreted as inadequate or provided limited evidence for natural biodegradation of chlorinated organics.

Five-Year Review Report for the Area D/American Lake Garden Tract, National Priorities List Site, McChord Air Force Base, Washington (U.S. Air Force 2000)

In 2000, the Air Force completed the first Five-Year Review for the ALGT. This Five-Year Review found that the GPT system had operated as designed and accomplished plume containment, but without measurable reduction in contaminant concentrations within the plume boundary. The historical known extent of the plume lies entirely within Base property; therefore, remediation goals for groundwater continue to be attained for potential downgradient, off-Base receptors in the ALGT. Although contaminant concentrations in the current plume boundary are not diminishing, institutional controls are in-place to eliminate potential risk pathways on-Base.

Attachment A to Injection Well Closure Notification Form, IRP Site RW-35, McChord Air Force Base, Washington (TtEC 2005)

In 2003, the Air Force completed excavation of a “dry well” near the Whispering Firs Golf Course maintenance shop that was the basis for listing of IRP Site MF-RW-035 (Figure 2). During excavation, an intact (solid walls and bottom) 4-foot square by 14-foot deep concrete vault was found, rather than a dry well. Potential solid low-level radioactive waste (LLRW) was identified in the bottom third of the vault, while the remainder of the vault was solid concrete. All potential LLRW debris, personal protective equipment, and concrete with radioactive readings above background were segregated and placed in one lined 55-gallon steel drum. The drum was transported to the Pacific Eco Solutions, Inc. waste processing facility in Richland, Washington, super-compacted, and transported to the US Ecology disposal facility, within the Department of Energy’s Hanford Nuclear Reservation.

There have been no reported detections of contaminants (LLRW or otherwise) above regulatory limits in soil and groundwater samples from the source area of IRP Site MW-RW-035.

Five-Year Review for Area D/American Lake Garden Tract, Joint Base Lewis McChord, McChord Field (JBLM Public Works and TtEC 2010)

In 2010, the Air Force completed another Five-Year Review for the ALGT. This Five-Year Review found that the GPT system had operated as designed and continued to accomplish static plume containment, but without measurable reduction in contaminant concentrations within the current plume boundary. The historical known extent of the plume lies entirely within Base property; therefore, remediation goals for groundwater have been attained off-Base in the ALGT.

Although contaminant concentrations in the current plume boundary are not diminishing, institutional controls are in-place to eliminate potential risk pathways on-Base.

While the Five-Year Review found that the remedy implemented at Area D/ALGT was protecting off-Base receptors and that exposure pathways had been effectively controlled until remediation goals are achieved on-Base, the review also found that the absence of reduction of contaminant concentrations within the plume suggested that the pump-and-treat system may not achieve the remediation goals in the plume within a reasonable timeframe (estimated at 50 years in the ROD).

Recommendations in the review report included continuing to evaluate alternatives to reduce source area contamination and enhance dissolved plume remediation, including verifying that the source area conceptual site model is correct.

Bioenhancement Pilot Study Summary Report, Remedial Action – Operation of Area D/ American Lake Garden Tract Groundwater Treatment Plant Operations, Maintenance, and Optimization (LF-5), JBLM McChord Field, Washington (TtEC 2012a)

A pilot study was performed at the downgradient edge of site MF-ALGT-LF-005. The study consisted of injection of approximately 440 gallons of emulsified vegetable oil (EVO), diluted at a 5 to 1 ratio, in groundwater monitoring well DA-32, and subsequent monitoring in nearby groundwater monitoring wells. The study concluded that reductive dechlorination did not occur, however the injection was successful in enhancing anaerobic conditions. It was noted that if there was more time to complete additional groundwater sampling, reductive dechlorination of contamination may have been observed.

First Installation-Wide Five-Year Review Report, Joint Base Lewis – McChord, Washington (U.S. Department of Army and U.S. Army Environmental Command 2012)

In 2012, the Army completed the first “installation-wide” Five-Year Review. The report stated that the remedy at the ALGT site is protective in the short term for human health and the environment, and exposure pathways that could result in unacceptable risks are being adequately controlled. In the off-Base area of the ALGT, groundwater meets remediation goals (drinking water criteria).

The report also stated that in order for the remedy to be protective in the long-term, the remediation goal of restoring the aquifer to its beneficial use by meeting remedial action objectives (RAOs) throughout the plume must be met in a reasonable timeframe.

Table 3 of the Five-Year Review report appears to have overstated the amount of TCE removed annually (and the corresponding efficiency of removal) by the GPT system by a factor of three.

Recommendations in the report included continuing to evaluate alternatives to reduce source area contamination and enhance dissolved plume remediation, including verifying that the source area conceptual site model is correct.

Well Installation and Source Zone Characterization: American Lake Garden Tract, Area D, Joint Base Lewis McChord, Washington (Pacific Northwest National Laboratory [PNNL] 2013)

Seven wells were installed near the downgradient edge of the source area as part of a study to support technology development and testing for a bioremediation approach using long-duration substrate and shear-thinning fluid (STF) additives to cut off the source area from the downgradient plume via an *in situ* permeable reactive barrier. Groundwater results indicated elevated TCE in a lower permeability silty gravel zone located approximately 50 to 70 feet bgs. TCE breakdown byproducts DCE and VC were also observed, suggesting biological reduction occurred in portions of the silty gravel zone.

Enhanced Amendment Delivery to Low-Permeability Zones for Chlorinated Solvent Source Area Bioremediation. ETCP Project No. ER-200913 (GSI Environmental, Inc. [GSI] and PNNL 2014)

The Environmental Security Technology Certification Program funded a demonstration project to further evaluate the effectiveness of *in situ* bioremediation to treat chlorinated solvents at the Site MF-ALGT-LF-005 source area. An amendment solution containing substrate (ethyl lactate) and tracer (chloride) in a STF (i.e., xanthan gum) was injected into existing well DA-37, followed by 8 months of groundwater monitoring. Results indicated some improved distribution of amendment to lower permeability zones using STF, reduction of TCE and daughter products, and enhanced persistence of amendment. When the report was published, groundwater samples had not been collected from the wells used in the STF demonstration to evaluate natural attenuation.

Technical Memorandum for Area D/American Lake Garden Tract Site Management Improvement Study, Joint Base Lewis McChord, Washington (TtEC 2015a)

This Technical Memorandum identified data gaps that needed to be addressed to support the Site Management Improvement Study Report. The memorandum documented that the GPT system would be temporarily shut off (for a duration of 12 to 24 months), six additional groundwater monitoring wells would be installed, and groundwater samples would be collected to monitor for a potential rebound in contaminant concentrations. The memorandum also identified that data would be collected to determine if MNA is a viable alternative to the GPT system for removing the residual TCE in groundwater.

Second Installation-Wide Five-Year Review, Joint Base Lewis McChord, McChord Field (JBLM Public Works 2017)

In 2017, the Army completed another Five-Year Review for all CERCLA sites at JBLM, including ALGT. This Five-Year Review identified that groundwater containing per- and poly-fluorinated alkylated substances (PFAS) may be present at the site as a result of site activities or broader, installation wide PFAS contamination. A protectiveness determination could not be made for ALGT at the time, and this report recommended investigating and evaluating the presence of PFAS at the site.

Site Management Improvement Study Report; Area D/American Lake Garden Tract, Groundwater Pump and Treat System, Joint Base Lewis McChord, Washington (TtEC 2018)

Field investigation activities were conducted to address data gaps, to evaluate if a rebound in groundwater contaminant concentrations was occurring following the shutdown of the GPT system, and to evaluate if MNA is a viable treatment technology to replace the GPT system. Results indicated that TCE concentrations in groundwater were stable post-GPT shutdown, no contaminant rebound was observed, and TCE was not migrating. Results also indicated that natural attenuation by reductive dechlorination was not occurring at a significant rate and that the plume would likely remain stable for a long time. The report concluded that injection of an amendment (hydrogen source) into groundwater that is designed to create a more favorable geochemical environment for native microorganisms to degrade TCE through reductive dechlorination could be used to expedite the cleanup timeframe.

Area D/ALGT Operations and Maintenance/Groundwater Monitoring Annual Reports

Operation and maintenance of the ALGT GPT system and associated groundwater monitoring data were documented in annual reports as follows, until the GPT was shut off in 2016:

- Calendar Year (CY) 1994 and CY 1995 by Hart-Crowser (1995 and 1996)
- CY 1996 through CY 1999 by URS Greiner Woodward-Clyde and Foster Wheeler Environmental Corporation (1997, 1998, 1999, and 2000)
- CY 2000 by FPM Group and Foster Wheeler Environmental Corporation (2001)
- CY 2001 and CY 2002 by Foster Wheeler Environmental Corporation (2002 and 2003)
- CY 2003 and CY 2004 by Tetra Tech FW, Inc. (2004 and 2005)
- CY 2005 through CY 2011 by TtEC (2006, 2007, 2008, 2009, 2010, 2011, and 2012b)
- CY 2012 and CY 2013 by Versar, Inc. (2013 and 2014)
- CY 2014 through 2016 by TtEC (2015b, 2016a, and 2017).

These reports described system performance and presented compliance monitoring results on an annual basis. As of the end of CY 2016, the GPT system had treated approximately 1.4 billion gallons of groundwater, removed approximately 108 pounds of TCE from the aquifer, and helped contain and decrease the footprint of the TCE plume (defined as groundwater with TCE concentrations above the MCL).

During GPT operation, groundwater was extracted from well DX-2 (with an average TCE concentration during CY 2016 of 2.65 µg/L), and from well DX-3 (with an average TCE concentration during CY 2016 of 8.95 µg/L). Well DX-1 has not been used since December 1999 because TCE levels in the well were below the MCL. The well was shut down with both

EPA and Ecology approval. The average influent concentration of TCE (water that is treated by the GAC system) was somewhat above the MCL with an average concentration of 8.0 µg/L during CY 2016. The maximum concentration of TCE reported in site groundwater monitoring wells during CY 2016 was 33 µg/L from well DA-21b, located between extraction well DX-3 and the source area (known as Site MF-ALGT-LF-005).

Following the shutoff of the GPT system in 2016, groundwater monitoring data associated with MNA were presented in the following annual report:

- CY 2018 by EA (2019).

The 2018 report concluded that reductive dechlorination was not occurring under ambient conditions at the site, except for one location where EVO had previously been injected. The report recommended that groundwater monitoring for MNA parameters be reduced from a quarterly to semiannual basis, while monitoring for VOCs continues on a quarterly basis. Changes to the monitoring program were implemented beginning in December 2019.

1.6 CURRENT SITE MONITORING PROGRAM

Under the current groundwater monitoring program at ALGT, groundwater sampling and analysis occurs at 25 monitoring wells. Sampling and analysis of VOCs (TCE, cis-1,2-DCE, 1,1-DCE, and VC) occurs on a quarterly basis in March, June, September, and December. Sampling and analysis of MNA parameters occurs on a semiannual basis in March and September and includes the following: alkalinity, anions (nitrate, sulfate, and chloride), ferrous iron (Fe[II]), dissolved hydrocarbon gases (methane, ethane, and ethene), total organic carbon, and dissolved metals (iron and manganese).

1.7 NATURE AND EXTENT OF CONTAMINATION

The RI (Ebasco Environmental 1991a) investigated possible contamination in Area D, focusing on the known groundwater plume and possible source areas. Source areas were defined as those with residual soil contamination. The following sections provide a summary of the RI findings.

1.7.1 Source Areas

The Area D/ALGT RI investigated soil, groundwater, surface water, and sediment at IRP Sites MF-LF-004, MF-ALGT-LF-005, MF-LF-006, MF-LF-007, MF-OT-026, MF-RW-035, and MF-OT-039. The investigation found that contamination was not above regulatory limits in soil, sediment, or surface water for any sites. The investigation did locate and define a groundwater plume of TCE and cis-1,2-DCE extending westward from the vicinity of site MF-ALGT-LF-005; groundwater contamination was not detected at the other six IRP sites.

A continuing source of groundwater contamination appears to be present at a depth of approximately 60 feet below ground surface (40 feet below the water table) at site MF-ALGT-LF-005. Wells screened just above the undifferentiated till layer had the highest concentrations of TCE and DCE on the site at the time of the RI, and the till was hypothesized in the RI to support a layer of separate phase solvent material acting as secondary source of contamination (Ebasco Environmental 1991a). Subsequent investigations confirmed elevated TCE concentrations in a lower permeability muddy gravel zone 50 – 70 feet below the surface, supporting the hypothesis of secondary contamination from matrix diffusion (PNNL 2013).

1.7.2 Extent of Contamination

The plume at the time of the RI was 3,500 feet long by 500 feet wide by 40 feet thick (Ebasco Environmental 1991a). As of 2019, the plume now measures 1000 feet long by 500 feet wide by approximately 20 feet thick (EA 2019). Plume extents and thickness were estimated based on a linear interpolation of contaminant concentration data, as well as an understanding of the site geology/hydrogeology to infer the vertical distribution of contaminants.

1.7.3 Current Remediation Impact

The GPT system operated from 1994 to 2016. The results of the 22 years of operation of the GPT system are summarized below:

- The GPT system treated approximately 1.4 billion gallons of water, while removing a relatively low total of approximately 108 pounds (the equivalent of roughly 9 gallons) of TCE from the aquifer.
- The GPT system removed approximately 4 to 5 pounds of TCE each year. The maximum annual amount of TCE removed was in 1995, when approximately 9 pounds were removed.
- Analysis of TCE concentrations over time suggest that the TCE plume reached asymptotic TCE concentration levels between approximately 2003 and 2008 (TtEC 2018).

1.8 CONTAMINANT FATE AND TRANSPORT

Multiple contaminant fate studies have been conducted at ALGT over the history of the site. The most recent study of the fate of chlorinated solvents was reported in the 2018 Site Management Improvement Study Report (TtEC 2018).

Much of the shallow aquifer beneath JBLM, including the ALGT site, is within the Vashon Recessional Outwash (Qvr). This outwash unit typically features low organic carbon content and a lack of reducing minerals, and therefore is not conducive to microbially mediated reductive dechlorination of TCE. However, consistent detections of TCE daughter products such as cis-1,2-DCE, 1,1-DCE, and VC suggest that some degradation has been occurring since monitoring began at the site.

Two different reducing agents were injected into the groundwater as part of pilot studies to test their ability to enhance natural attenuation. EVO was injected in 2011 in the upgradient portion of the plume (TtEC 2012b) and ethyl lactate with a shear-thinning fluid was injected in 2014, also in the upgradient portion of the plume (GSI and PNNL 2014). These injections altered a portion of the Site's groundwater chemistry by creating a reducing environment which stimulated the native microbial community and provided improved geochemical conditions for degrading TCE. Over a period of several years, a corresponding decline in TCE concentrations was observed in the vicinity of the electron-donor injections, as well as an increase in VC. *Dehalococcoides*, a microbe capable of complete dechlorination TCE, was also detected within the footprint of the injections. The data suggest that enhanced reductive dechlorination is occurring within the area of electron-donor injection (TtEC 2018).

Outside of the footprint of electron-donor injections, groundwater samples generally had low total organic carbon, high dissolved oxygen, high oxidation-reduction potential, high sulfate, low methane, moderately low alkalinity, low ferrous iron, and low levels of *Dehalococcoides*. These conditions are not favorable for reductive dechlorination, which is an important component of natural attenuation of TCE (TtEC 2018).

Transport of dissolved chlorinated solvents is primarily affected by advection, dispersion, and adsorption/desorption. Groundwater contour maps show groundwater flowing to the northwest from the source and bending westward near the center of the plume (Figure 4). Excepting local effects of groundwater extraction wells when they were operating, groundwater flow direction for the site has not changed over the period of study. While hydraulic conductivity values in the study area are relatively high, hydraulic gradient is very low, yielding fairly low contaminant migration velocity estimates. Estimates of groundwater velocity have ranged from 0.5 feet/day in the 1991 RI (Ebasco Environmental 1991a) to as low as 0.02 feet/day in the 2018 Site Management Improvement Study (TtEC 2018). The retardation factor for TCE in site aquifer materials has been estimated at 2 (Ebasco Environmental 1991a).

1.9 HUMAN HEALTH RISK ASSESSMENT

A Human Health Risk Assessment (Ebasco Environmental 1990a) was conducted prior to the RI (Ebasco Environmental 1991a) and considered risks to human health from exposure to contaminants in soils, groundwater, surface water, and air for current and projected future off-post and on-post populations (receptors). For this FS, data presented in the Human Health Risk Assessment are still considered to be accurate and current.

1.10 ECOLOGICAL RISK ASSESSMENT

An Ecological Risk Assessment (Ebasco Environmental 1990b) was conducted prior to the RI (Ebasco Environmental 1991a) and considered risks to animals and plans resulting from exposure to contaminated surface water and sediments. For this FS, data presented in the Ecological Risk Assessment are still considered to be accurate and current.

1.11 CONCEPTUAL SITE MODEL

A conceptual site model (CSM) is a tool used in risk assessment to describe relationships between chemicals and potential receptors. The CSM is designed to identify exposure pathways that describe a chemical's transport from its source to a potentially exposed individual. The CSM must include a source, transport mechanism, exposed population, and point of entry into the body. The potentially exposed populations and exposure pathways selected for evaluation at ALGT identified below. The CSM presented was established in the RI (Ebasco Environmental 1991a) and updated by the Site Management Improvement Study Report (TtEC 2018). The CSM is presented in Figure 5. A summary of the CSM is presented in following subsections.

1.11.1 Identification of Potentially Exposed Population

The potentially exposed human populations for the site include the current and future residents in neighborhoods near ALGT, workers on or near the site, and site visitors (e.g., at Whispering Firs Golf Course). The CSM also includes potential impacts to terrestrial and aquatic biota.

1.11.2 Potential Routes of Migrations

Exposure to Chemicals in Air

Potential exposure to chemicals in air could occur during outdoor activities or indoors if vapor were to be trapped in a house or building through the volatilization of TCE from groundwater that migrates to the indoor space. Inhalation by residents, workers, site visitors, and terrestrial biota are all considered potential exposure pathways.

Exposure to Chemicals in Soil

Direct contact (incidental ingestion, dermal contact, inhalation of particulates/volatiles) with soils by workers is considered a potential exposure pathway. However, exposure is only considered possible in the landfill area at depths greater than 3 feet (Figure 5).

Exposure to Chemicals in Groundwater

Groundwater exposure is typically associated with ingestion by drinking, inhalation, or dermal contact by washing or showering. All private residences above and downgradient of the plume have been connected to public water supply. The historical and current boundaries of the plume are within the confines of JBLM property; no potable wells are utilized at the site. Therefore, this pathway is considered possible but unlikely (i.e., only possible if land use were to change) because there are currently no receptors within the TCE plume.

Exposure to Chemicals in Surface Water and Sediment

Groundwater may discharge to surface water bodies at ALGT, leading to contaminants in surface water and sediment. However, contamination at concentration levels requiring remediation has not been identified in surface water or sediment. As such, ingestion and dermal contact by biota are considered possible but unlikely exposure pathways; all human exposure pathways are considered incomplete.

2. REMEDIAL OBJECTIVES

2.1 REMEDIAL ACTION OBJECTIVES

According to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] §300.430[a][1][I]), the goal of the remedy selection process is "to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste." RAOs are medium specific (e.g., groundwater) goals that address the requirements from protecting human health and the environment (EPA 1988).

At ALGT, the objective of the remedial action is to restore groundwater to its beneficial use as a potential groundwater drinking source (EPA et al. 1991).

2.2 APPLICABLE, OR RELEVENT OR APPROPRIATE STATE AND FEDERAL LAWS

Applicable or Relevant and Appropriate Requirements (ARARs) are substantive federal and state environmental laws and regulations that specify cleanup levels or performance standards for CERCLA sites. Section 121(d) of CERCLA, as amended by Superfund Amendments and Reauthorization Act (SARA), states that on-site remedial actions must attain ARARs. ARARs may include regulations, standards, criteria, or limitations promulgated under federal or state laws. An ARAR may be either "applicable" or "relevant and appropriate," but not both.

Three categories of ARARs exist: chemical-, location-, and action-specific requirements. Chemical-specific ARARs are health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical cleanup values. These values establish the acceptable amount or concentration of a chemical that may be detected in or discharged to the ambient environment. Location-specific ARARs are restrictions on the concentrations of hazardous substances or on activities conducted at the Site that result from site characteristics or its immediate environment. For example, location of the Site or proposed remedial action in a flood plain, wetland, historic place, or sensitive ecosystem may trigger location-specific ARARs. Action-specific ARARs are technology- or activity-based requirements or limitations on actions taken. These requirements are triggered by the specific remedial activities selected. Action-specific ARARs do not in themselves determine the remedial alternative; rather, they indicate how an alternative must be conducted (EPA 1994).

In addition to the legally binding requirements established as ARARs, many federal and state programs have developed criteria, advisories, guidelines, or proposed "To Be Considered" (TBC) standards. TBC material may provide useful information or recommend procedures if no ARARs address a particular situation or if existing ARARs do not provide protection. In such situations, TBC criteria or guidelines should be used to set remedial action levels. TBC criteria are not legally binding and do not have the status of ARARs.

2.2.1 Chemical-specific ARARs

Safe Drinking Water Act of 1974 (SDWA), 42 United States Code (USC) 300f-300j-11; National Primary and Secondary Drinking Water Regulations, 40 CFR 141 143 (Applicable)

SDWA establishes MCLs, secondary MCLs, and non-carcinogenic MCL goals where groundwater is a current or future source of drinking water. The remediation goals as defined by the ROD (EPA et al. 1991) for TCE and cis-1,2-DCE are based on the MCLs established by the SDWA. Site groundwater may potentially serve as a future source of drinking water; therefore, these standards are considered applicable.

Model Toxics Control Act (MTCA), Ch. 70.105D; Revised Code of Washington (RCW) Regulations, Ch. 173-350 Washington Administrative Code (WAC) (Applicable)

MTCA is the key regulation governing site investigation and remediation in the state of Washington. MTCA describes the requirements for selecting cleanup actions, preferred technologies, policies for use of permanent solutions, the time for cleanup, and the decision-making process. Recently, MTCA was amended to achieve the following purposes: 1) promote the public's interest to efficiently use the finite land base, 2) integrate land use planning policies, 3) clean up and reuse contaminated industrial properties in order to minimize industrial development pressures on undeveloped land, and 4) make clean land available for future social use (RCW 70.105D.010(4)).

Recent amendments to MTCA exempt remedial actions conducted pursuant to a Consent Decree or an Agreed Order from the procedural requirements of certain state laws, regulations and permitting requirements, and laws requiring local government approvals or permits. The substantive requirements of applicable laws, regulations, and ordinances must still be met. However, permits and separate approvals within the exemption are not required for remedial actions at the site.

The remediation goals as defined by the ROD (EPA et al. 1991) for VC and 1,1-DCE are based on the MTCA Method B standards.

Water Pollution Control/Water Resources Act, Ch. 90.48 RCW/Ch. 90.54 RCW; Surface Water Quality Standards, Ch. 173-201A WAC (Potentially Applicable)

Surface water quality standards are set at levels protective of all potential surface water uses including human health, aquatic life, wildlife, and recreation. These water quality standards are applicable to all surface waters at the site where a discharge into surface water could occur, including those that either support or have the potential to support aquatic life. No activity can occur that would potentially violate any surface water quality standard including stormwater runoff, or anything that could potentially get into surface water or runoff that could discharge into a stream or lake or stormwater drain. These regulations may be applicable to any water discharged from the site.

2.2.2 Location-Specific ARARs

Washington State Shoreline Management Act (Ch. 90-58 RCW), Ch. 173-18 010-046 WAC (Potentially Applicable)

The Shoreline Management Act includes requirements for local jurisdictions to manage shorelines. Section 030 includes the Pierce County listing of Clover Creek from railway to Lake Steilacoom, excluding federal lands. This area may include the future location of remediation activities, including excavation or drilling operations.

Washington State Hydraulic Projects Approval (Ch. 77.55 010-320 RCW), Ch. 220-110-030 WAC (Not Applicable)

Under Section 030, the procedural requirements of this chapter shall not apply to any person conducting a remedial action at a facility pursuant to a Consent Decree, Order, or Agreed Order issued pursuant to Chapter 70.105D RCW (MTCA), or to Ecology when it conducts a remedial action under MTCA. Therefore, this chapter is not applicable.

2.2.3 Action-Specific ARARs

Utilization of a GPT was the existing remedial action as outlined by the ROD (EPA et al. 1991). Proposed new remedial alternatives are defined in Section 5 and are summarized as follows:

- No Action/Natural Attenuation
- MNA
- *In situ* reductive dechlorination through enhanced in-situ bioremediation (EISB)
- *In situ* reductive dechlorination through electron donor injection.

Based on these proposed alternatives, the following rules and regulations may be applicable or reasonably appropriate.

Comprehensive Environmental Response, Compensation and Liability Act, Emergency Planning and Community Right-to-Know Act Promulgated by 40 CFR 302.6(a), 40 CRF 355.40 (Potentially Applicable)

SARA amended CERCLA on October 17, 1986. The requirements of CERCLA/SARA would be potentially applicable if a hazardous substance release equal to or greater than a reportable quantity occurred or was identified during the remediation activities, including a previously unidentified historical release. Because the remedial activities are occurring under the IRP, CERCLA/SARA requirements and protocols for planned remedial activities would be followed, regardless of whether a new source or release is identified.

Water Well Construction, Ch. 18.104 RCW; Minimum Standards for Construction and Maintenance of Water Wells, Ch. 173-160 WAC (Applicable)

These requirements are applicable to remedial actions that include construction of wells used for groundwater extraction, monitoring, or injection of treated groundwater or wastes. These requirements also include standards for well abandonment. These requirements are applicable because wells are currently part of the monitoring network. In addition, well abandonment or construction are logical actions for any remediation scenario proposed.

Underground Injection Control Program, Ch. 173-218 WAC (Potentially Applicable)

The purpose of this chapter is to set forth the procedures and practices applicable to the injection of fluids through wells. Permits issued in accordance with the provisions of this chapter are designed to (a) satisfy the intent and requirements of Part C of the federal SDWA 42 USC § 300h et seq. as authorized by RCW 43.21A.445 and of the Water Pollution Control Act, Chapter 90.48 RCW and (b) preserve and protect groundwaters, including underground sources of drinking water, for existing and future beneficial uses. If injection wells were used as a remediation alternative this regulation would become applicable.

Clean Air Act of 1977, as amended 42 USC 7401 et seq. (Potentially Applicable)

The Clean Air Act (CAA) regulates emission of conventional and hazardous pollutants to the air. Controls for emissions are implemented through federal, state, and local programs. Pursuant to the CAA, EPA has promulgated National Ambient Air Quality Standards, National Emission Standards for Hazardous Air Pollutants, and new Source Performance Standards. Implementation of the CAA has been delegated to the State of Washington. The CAA would be applicable only if remedial action at the site created new sources of regulated air emissions, including fugitive dust and particulate matter.

Washington Clean Air Act, Ch. 70.94 RCW and Ch. 43.21A RCW; General Regulations for Air Pollution Sources, Ch. 173-400 WAC; Controls for New Sources of Air Pollution, Ch. 173-460 WAC (Potentially Applicable)

The Washington CAA is the state equivalent of the federal CAA. The regulation requires that all sources of air contaminants meet emission standards for visibility, particulate matter, fugitive dust, odors, and hazardous air emissions. Under WAC 173-340-710 (6)(b), air emissions are required to use best available control technology consistent with 70.94 RCW and its implementing regulations.

State Environmental Policy Act (SEPA), Ch. 43-21C RCW; SEPA Rules, Ch. 197-11 WAC; SEPA Procedures, Ch. 173-802 WAC (Potentially Applicable)

SEPA is triggered when a governmental action is taken on a public or private proposal. Under Ch. 197-11-784 WAC, a proposal includes both regulatory decisions of agencies and actions proposed by applicants. Under Ch.197-11-253 WAC, Ecology is the lead agency for site cleanup actions performed under MTCA.

If the proposal is not "exempt," Ecology requires the submission of the SEPA Environmental Checklist regarding how the proposal would affect elements of the environment such as air and water. If the proposal is determined by Ecology to have a "probably significant adverse environmental impact," an environmental impact statement is required. The environmental impact statement examines the potential environmental problems that would result from the proposed action, and options for mitigation of adverse effects.

If the action is performed under an Agreed Order or Consent Decree, any public comment period required under SEPA must be combined with any comment period under MTCA in order to expedite and streamline public input. If it is determined that there would be no significant adverse environmental impact, Ecology issues a Determination of Nonsignificance, and no environmental impact statement is required. According to Ch.197-11-259 WAC, if Ecology makes a Determination of Nonsignificance, this can be issued with the draft Cleanup Action Plan.

Emission Standards and Controls for Sources Emitting VOCs, Ch. 173-490 WAC (Potentially Applicable)

It is the policy of Ecology, under the authority vested in it by Ch. 43.21A RCW, to provide for the systematic control of air pollution from air contaminant sources and for the proper development of the state's natural resources. It is the purpose of this chapter to establish technically feasible and reasonably attainable standards for sources emitting VOCs and revise such standards as new information and better technology are developed and become available. Because all proposed remediation technologies would involve in-situ remediation, and because of low levels of VOCs in the soil, it is unlikely that thresholds or standards would be exceeded as a result of the remediation activities at the site.

Hazardous Materials Transportation Act, 49 USC 1801, et seq.; Hazardous Materials Transportation Regulations, 49 CFR 171 and 172 (Potentially Applicable)

This act and associated regulations apply to transportation of hazardous materials. These requirements would be applicable only if hazardous waste or other hazardous materials (as defined in the regulations) were generated during site remediation for off-site transportation on public roadways. This would apply to any hazardous materials on a public roadway that would be transported for remediation or disposal, possibly including sampling fluids, decontamination fluids, calibration gases, etc.

Resource Conservation and Recovery Act (RCRA) Definitions and General Requirements, 40 CFR 260 and 261; Generator Standards, 40 CFR 262 (Potentially Applicable)

RCRA's primary goals are to protect human health and the environment from the potential hazards of waste disposal, to conserve energy and natural resources, to reduce the amount of waste generated, and to ensure that wastes are managed in an environmentally sound manner. EPA has granted the state of Washington the authority to implement RCRA through Ecology's dangerous waste program (Ch. 173-303 WAC). RCRA would be applicable only if hazardous waste were generated during remedial action.

Hazardous Waste Management Act, 70.105 RCW; Dangerous Waste Regulations, Ch. 173-303 WAC; Standards for Solid Waste Handling, Ch. 173-304 WAC; Minimal Functional Standards for Solid Waste Handling, Ch. 173-304 WAC (Potentially Applicable)

These requirements would be applicable for any waste that is generated as a result of remedial investigation and remedial action activities, including hazardous or dangerous waste and solid waste. Certain wastes may also be exempt from regulation pursuant to MTCA if the final cleanup is performed under a Consent Decree.

Clean Water Act, 33 USC 1251 et seq.; General Pretreatment Regulations for Existing and New Sources of Pollution, 40 CFR 403; Stormwater Discharge Regulations, 40 CFR 122.26; Disposal of Pollutants into POTWs, 40 CFR 122.50; Urban Area Pretreatment Program, 40 CFR 125.65; Toxics Control Program, 40 CFR 125.66 (Potentially Applicable)

These regulations may be applicable if there is wastewater generated that meets the requirements of the Clean Water Act and Washington Pollution Control Act for disposal into a publicly owned treatment works. Permitting and licensing have been delegated to the states under Sections 401 and 402 of the Clean Water Act.

Native American Grave Protection and Repatriation Act (25 USC 3001-3013; 43 CFR Part 10) (Potentially Applicable)

This statute requires that any federal agency discovering Native American cultural items (i.e., human remains and associated funerary objects) notify in writing the U.S. Department of the Interior and the appropriate Indian tribe. The federal agency must cease activity in the area of the discovery, make a reasonable effort to protect the items discovered before resuming such activity, and provide notice as described above. These requirements apply only if cultural items are discovered during implementation of the selected remedy.

Archaeological Resources Protection Act (16 USC 470aa et seq.; 43 CFR Part 7) (Potentially Applicable)

This statute sets forth requirements that are triggered when archaeological resources are discovered on federal lands. It requires that excavation of these resources be conducted under a permit by professional archaeologists. These requirements apply only if archaeological items are discovered during implementation of the selected remedy.

2.3 REMEDIATION GOALS

Based on the ARARs review in Section 5.1 and continued agreement by both EPA and Ecology, the regulatory driver for ALGT continues to be the MTCA Cleanup Regulation, Chapter 173-340 WAC. Therefore, the remediation goals will remain the same as those determined under the MTCA in the previous FS.

Per MTCA, cleanup standards are based on the following:

- Selection of compound-specific clean up levels (CULs)
- Determination of the points of compliance
- Compliance with applicable requirements under state and federal laws.

WAC 173-340-720 (1)(a) states that, "Groundwater CULs shall be based on estimates of the highest beneficial use and the reasonable maximum exposure expected to occur under both current and potential future site use conditions."

Remediation goals, which serve as CULs, are defined in the ROD as the federal MCLs or MTCA Method B cleanup levels (EPA et al. 1991). The federal MCLs were used to determine the remediation goals for TCE and cis-1,2-DCE at 5 µg/L and 70 µg/L, respectively. The MTCA Method B CULs were used to determine the remediation goals for 1,1-DCE and VC at 0.07 µg/L and 0.04 µg/L, respectively.

The point-of-compliance for groundwater is defined in WAC 173-340-720(8). According to this section, "Groundwater CULs shall be attained in all groundwaters from the point of compliance to the outer boundary of the hazardous substance plume." Subsection (b) states that "The standard point of compliance shall be established throughout the site from the uppermost level of the saturated zone extending vertically to the lowest depth which could potentially be affected by the site." The lowest practicable depth for the site is the underlying confining aquitard composed of the Qvt layer approximately 100 feet below the surface.

If, based on this FFS, the selected remedy for ALGT is revised, additional location- and action-specific ARARs and compliance requirements may be considered.

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3. IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

3.1 INTRODUCTION

This section presents and screens a list of remedial technologies potentially applicable to the contaminated groundwater at the site.

In general, the technologies fit into one or more categories of general response actions (GRAs). GRAs are generic, medium-specific, remedial actions that will satisfy the RAOs discussed earlier. GRAs may include no action, institutional controls, containment, removal, treatment, disposal, monitoring, or a combination thereof (EPA 1988). The development of remedial alternatives begins with the identification of GRAs that can meet RAOs, which are then screened and developed into remedial alternatives to address all contaminated media at the Site.

3.1.1 Key Engineering Considerations

A GPT system operated at the site from 1994 to 2016. The system has demonstrated limited effectiveness at progressing the site towards closure through the reduction of TCE concentrations to a level below MCL as designated by the ROD (EPA et al. 1991).

3.1.2 General Response Actions

No Further Action
As required by the NCP (40 CFR § 300.430 [e][6]), remedial alternatives must include the No Further Action alternative to be used as the baseline alternative against which the effectiveness of all other remedial alternatives is judged.

Removal
For groundwater, removal entails physical extraction of groundwater for *ex situ* treatment. Once groundwater is extracted, treatment technologies for groundwater impacted by organic compounds could include air stripping, carbon adsorption, biological reactor, among others.

Treatment
Injections are considered potential *in situ* treatment technologies. A number of chemicals are available to facilitate and accelerate the breakdown of dissolved-phase TCE into harmless daughter products. These include chemical oxidants that react with organic contaminants, mineralizing them to carbon dioxide, water, and inorganic salts; small particles that physically isolate organic contaminants through adsorption; electron donor chemicals that create redox conditions favorable for reductive dechlorination; and biological agents that enhance anaerobic biological degradation of organic contaminants. These technologies can be used individually or in specific mixtures designed to affect the breakdown of TCE.

Monitored Natural Attenuation
MNA allows natural processes to achieve site-specific remedial objectives without enhancement or aggressive treatment. The "natural attenuation processes" that are at work in such a remediation approach include physical, chemical, or biological processes that, under favorable

conditions, reduce the mass, toxicity, mobility, volume, or concentration of contaminants in the groundwater. Natural attenuation processes that could occur include biodegradation (aerobic or anaerobic), abiotic transformation (e.g., hydrolysis), adsorption, dispersion, or dilution.

3.2 SCREENING OF REMEDIAL TECHNOLOGIES

Three preliminary screening criteria (effectiveness, implementability, and cost) were used to screen remedial technologies. Definitions of each criterion and a brief discussion of the screening results are described below.

3.2.1 Effectiveness

This criterion is a measure of the ability of an option to: (1) reduce toxicity, mobility, or volume; (2) minimize residual risks; (3) afford long-term protection; (4) comply with ARARs; (5) minimize short-term impacts; and (6) achieve protectiveness in a limited duration. Technologies that offer significantly less effectiveness than other proposed technologies may be eliminated from the alternative development process. Options that do not provide adequate protection of human health and the environment likewise are eliminated from further consideration.

3.2.2 Implementability

Implementability is a measure of the technical feasibility and availability of the option and the administrative feasibility of implementing it (e.g., obtaining permits for off-site activities, rights-of-way, or construction). Options that are technically or administratively infeasible or that would require equipment, specialists, or facilities that are not available within a reasonable period may be eliminated from further consideration.

3.2.3 Cost

Qualitative relative costs for implementing the remedy are considered. Technologies that cost more to implement, but that offer no benefit in effectiveness or implementability over other technologies, may be excluded from the alternative development process.

3.3 TECHNOLOGIES NOT RETAINED FOR FURTHER ANALYSIS

GPT was conducted at the site for 22 years. While the system removed small amounts of contaminant annually, the rate of contaminant removal was not driving the site towards closure in an expedient manner. Furthermore, the plume is in a steady-state condition without the extraction system running (TtEC 2018). With a removal of only 108 pounds of TCE in 22 years, the GPT is ineffective and costly to operate and maintain and is not considered for further operation.

Thermal destruction of TCE is a technology that continues to grow in sophistication and effectiveness. The electrical induction and related systems are very expensive relative to other alternatives to design and implement but are effective at rapidly driving highly contaminated sites with small footprints towards closure. Due to the size of the site, the low concentrations of contaminants present at the site, and the high cost relative to other technologies, thermal treatment is not retained for further analysis.

In Situ Chemical Oxidation (ISCO) is an aqueous process that reacts chemical oxidants with dissolved organic contaminants to break down those organic constituents. ISCO works well in environments that are naturally low in organic carbon and reduced-state minerals, as the chemical oxidant can be spent on the target organic contaminants. At first this approach sounds promising for the ALGT site, which has naturally low organic carbon. However, experience at a nearby site at JBLM (SS-34N) with very similar subsurface geology has shown that ISCO is not highly effective for achieving MCLs across a diffuse, low concentration plume, and may degrade injection well quality with subsequent injections. Based on this relevant experience with the effectiveness of ISCO on dissolved TCE in the Upper Vashon aquifer located in the Quaternary Vashon Recessional Outwash (Qvr), ISCO injection treatment is not retained for further analysis.

3.4 TECHNOLOGIES RETAINED FOR FURTHER ANALYSIS

Technologies that passed through screening and will be retained to create focused remedial alternatives for the Site are listed below:

- No further action
- MNA
- *In situ* reductive dechlorination through EISB
- *In situ* reductive dechlorination through electron donor injection.

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4. DEVELOPMENT OF REMEDIAL ALTERNATIVES

Technologies that were retained after screening (Section 3.4) were developed into four remedial alternatives. The alternatives are described in detail within this section.

4.1 ALTERNATIVE 1: NO FURTHER ACTION / NATURAL ATTENUATION

As required by the NCP (40 CFR § 300.430 [e][6]), the alternatives evaluated must include the No Further Action alternative. No Further Action is to be used as the baseline alternative against which the effectiveness of all other remedial alternatives are judged and is not presented as a viable alternative. Under Alternative 1, no remedial actions would be conducted at the Site. Groundwater contaminants would remain in place and would be subject to environmental influences. This alternative would not include monitoring of the site or implementation of institutional controls and, thus, would incur no cost.

4.2 ALTERNATIVE 2: MONITORED NATURAL ATTENUATION

This alternative includes natural attenuation by dilution and dispersion, continuing effort to collect data from groundwater well sampling, and maintaining existing institutional controls with the aim of minimizing risks to human health and the environment. The primary objective of MNA is to allow natural attenuation processes to reduce dissolved-phase contaminant concentrations via contaminant mass degradation. The progress of this approach is continually monitored through regular sampling of groundwater until after it has been statistically determined that the dissolved phase concentrations of the contaminants in groundwater have fallen below the remediation goals. During the MNA process, existing institutional controls are maintained to protect human and ecological receptors.

The historically known extent of the plume, including after the GPT system was shut off in 2016, lies entirely within the Base property. As such remediation goals for groundwater have been achieved off-Base. The current TCE plume is stable and shows no evidence of mobility (EA 2019). Recent data indicates that TCE concentrations are generally stable or decreasing in site wells since termination of the GPT system. Institutional controls in use on Base property at the site control potential risk pathways.

For cost estimation, with the available data, concentration trends cannot accurately predict when Alternative 2 would successfully reach cleanup levels. An estimate of 30 years was utilized in costing, per FS guidance (EPA 1988).

4.3 ALTERNATIVE 3: ENHANCED IN-SITU BIOREMEDIATION WITH ORGANIC CARBON PLUS ACTIVATED CARBON AND ZERO-VALENT IRON

Alternative 3 addresses recalcitrant areas of TCE-contaminated soil and groundwater through the injection of a mixture of chemicals that is intended to both arrest TCE movement and degrade the chemical to harmless byproducts through the reductive dechlorination process. These chemical mixtures target the compound of interest (TCE) and are optimized for the subsurface conditions in which they are injected. This technique is often referred to as EISB. When properly implemented, EISB can rapidly address recalcitrant areas of contamination and move a site swiftly to closure. While a variety of commercially available products and application techniques can be used at sites contaminated with TCE, for this FFS, EHC® Plus injected into existing injection wells was used for costing purposes. EHC® Plus is composed of controlled-release organic carbon to stimulate biological activity, zero-valent iron for chemical reduction, and powdered activated carbon to reduce mobility of the contaminants. Alternative materials and application techniques may be selected during the remedial design, including the addition of bioaugmentation to enhance the available microbial community. If this alternative is selected, bench and pilot tests are recommended to identify the appropriate chemical suite, quantity, and application method for this site.

For the ALGT area, seven existing PNNL injection wells and one additional upgradient monitoring well with an elevated TCE concentration would be used for a chemical injection. These wells are screened at approximately 48 to 68 feet below the surface (PNNL 2013). Additional injections would also be performed in the mid-plume area and lower plume areas and would target lithologies identified in the pilot test as containing residual contamination. If subsequent performance monitoring shows that sources have not been adequately addressed, additional chemical injections will be required to treat the contamination.

Before beginning remediation activities, the following site preparation tasks would be performed:

- A bench test would be completed to select the reductive dechlorination chemical mixture that will most efficiently address the TCE within the subsurface conditions present at the Site.
- A pilot test will be completed to determine lithology and contamination depth at potential boring locations.
- Secure storage facilities at the site would be identified or set up to store chemicals during remediation activities.
- Necessary permits would be obtained (if required).

To implement this alternative at the site, a chemical or mixture of chemicals would be injected into the dissolved phase contamination plume shown in Figure 4. The injections would push the EISB product out the screened intervals of the injection wells. The seven PNNL injection wells were installed as part of a previous pilot study, downgradient of the source zone in a zone of lower hydraulic conductivity muddy gravel that is suspected of serving as a continuing source of TCE to groundwater through diffusion into higher hydraulic conductivity zones of subsurface strata (PNNL 2013). These seven wells (DA-33, DA-35, DA-36, DA-37, DA-38, DA-39, and DA-41), along with the nearby upgradient monitoring well DA-31, define the upgradient portion of the remaining (as of September 2019) area of contaminant mass shown in Figure 4, and as such would make ideal injection locations to address the recalcitrant contaminant mass. The line of seven injection wells would create a permeable reactive barrier, similar in configuration to that implemented during the PNNL pilot study. The injection of activated carbon along with organic carbon in the barrier would improve effectiveness by retaining the contaminants within the barrier's treatment zone. The addition of zero-valent iron would further promote reducing conditions appropriate for microbial reductive dechlorination and chemical reduction of the contaminants within the barrier.

Given the relatively flat hydraulic gradient at the site and correspondingly low groundwater flow velocities (Section 1.8), two additional lines of injections are recommended to decrease the treatment time and associated monitoring costs. One line would be established in the mid-plume area upgradient of monitoring wells DA-21b and DA-43. This mid-plume line would consist of approximately eight injection points advanced by a direct push probe with product injected through retractable screens in the boring probe. Another line would be established in the lower plume area upgradient of monitoring wells DA-29 and DB-6. This lower plume line would consist of approximately seven injection points applied in the same manner as the mid-plume line. A pilot study would vertically profile the lithology and contamination at these two transect lines to determine the appropriate injection depths.

For cost estimation, it was assumed that a single chemical application would be made into each injection well boring point. The total volume of EHC® Plus required was estimated at 17,250 pounds. The implementation time of this field effort was assumed to be 16 days, and it was assumed that post-remediation monitoring would be required for 10 years prior to site closure. Existing downgradient monitoring wells would be utilized to monitor for potential downgradient migration of EHC® Plus, and to monitor the progress and effectiveness of the remediation. If post-remediation monitoring determined that applied injections were insufficient, additional injections and monitoring time could be necessary to achieve site closure.

4.4 ALTERNATIVE 4: ENHANCED IN-SITU BIOREMEDIATION WITH ELECTRON DONOR INJECTION

Alternative 4 addresses recalcitrant areas of TCE-contaminated soil and groundwater through the injection of an organic chemical that acts as an electron donor, enhancing degradation of TCE to harmless byproducts through the reductive dechlorination process. A typical example of such an organic chemical that would act as an electron donor is EVO, although several similar organic materials could be used. When properly implemented, injection of an electron donor can jump start or accelerate reductive dechlorination and thus address recalcitrant areas of contamination. While a variety of commercially available products and application techniques can be used at sites contaminated with TCE, for this FFS, EVO injected into existing injection wells was used for costing purposes. Alternative materials and application techniques may be selected during the remedial design. A pilot test in which EVO was injected into groundwater has been previously conducted at this site (TtEC 2012a), as well as a pilot test involving injection of ethyl lactate (another electron donor) with chloride (a tracer) and xanthan gum (a shear-thinning fluid) (GSI and PNNL 2014).

Before beginning remediation activities, the following site preparation tasks would be performed:

- A review of the EVO pilot study and ethyl lactate with chloride and xanthan gum pilot study previously performed at the ALGT site would be conducted. The review will consider the materials and application techniques utilized, as well as immediate and long-term sampling data to determine the most effective electron donor. Previous reports indicate that subsurface chemistry has remained favorable to reductive dechlorination several years after the injection of an electron donor (TtEC 2018).

- A pilot test will be completed to determine lithology and contamination depth at potential boring locations.
- Secure storage facilities at the site would be identified or set up to store chemicals during remediation activities.
- Necessary permits would be obtained (if required).

To implement this alternative at the Site, an electron donor would be injected into areas of the dissolved phase contamination shown in Figure 4. Injections of the electron donor would occur in the seven previously established PNNL injection wells, as well as one upgradient well that has reported TCE concentrations exceeding the remediation goal. The injections would push the organic chemical out the screened intervals of the injection wells. The seven PNNL injections wells were installed as part of a previous pilot study, downgradient of the source zone in a zone of lower hydraulic conductivity muddy gravel that is suspected of serving as a continuing source of TCE to groundwater through back diffusion into higher hydraulic conductivity zones of subsurface strata (PNNL 2013). These seven wells, along with the nearby upgradient monitoring well DA-31, define the upgradient portion of the remaining (as of September 2019) area of contaminant mass shown in Figure 4, and as such would make ideal injection locations to address the recalcitrant contaminant mass. The line of seven injection wells would create a permeable reactive barrier, similar in configuration to that implemented during the PNNL pilot study (GSI and PNNL 2014).

As in Alternative 3, a mid-plume injection line and a lower plume injection line are recommended to accelerate treatment of the downgradient portion of the plume and would be comprised of a similar quantity of injection points advanced by a direct push probe with a retractable screen. A pilot study would vertically profile the lithology and contamination at these two transect lines to determine the appropriate injection depths.

For cost estimation, it was assumed that a single chemical application would be made into each injection well and boring point. The total volume of EVO to use was estimated at 13,800 pounds. The implementation time of this field effort was assumed to be 16 days, and it was assumed that post-remediation monitoring would be required for 10 years prior to site closure. Existing downgradient monitoring wells would be utilized to monitor for potential downgradient migration of EVO, and to monitor the progress and effectiveness of the remediation. If post-remediation monitoring determined that applied injections were insufficient, additional injections and monitoring time could be necessary to achieve site closure.

5. EVALUATION OF REMEDIAL ALTERNATIVES

In this section, remedial alternatives presented in Section 4 are evaluated in detail using EPA's RI/FS guidance (EPA 1988). The comparison criteria and evaluation process are discussed below. Table 4 presents the evaluation of four remedial alternatives against these criteria.

5.1 EVALUATION CRITERIA

As stated in EPA guidance (EPA 1988), remedial actions must accomplish the following:

- Be protective of human health and the environment
- Attain ARARs (or provide grounds for invoking a waiver)
- Be cost-effective
- Utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable
- Satisfy the preference for treatment that reduces toxicity, mobility, or volume as a principle element (or provide an explanation why it does not).

The nine criteria used to evaluate each alternative are listed below and are discussed in the paragraphs that follow:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction in toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance.

The first two criteria in the list above are referred to as the threshold criteria and must be met. The next five are considered balancing criteria and are addressed in this evaluation. The final two criteria (state and community acceptance) will be evaluated following receipt of feedback from the state and community. These nine criteria are described in the following paragraphs.

5.1.1 Overall Protection of Human Health and the Environment

The criterion evaluates how the alternative, achieves and maintains protection of human health and the environment. The overall assessment of protection considers the alternative's long-term effectiveness, permanence, short-term effectiveness, and compliance with ARARs. The evaluation of protectiveness focuses on the reduction or elimination of site risks by the proposed remedial alternative. This criterion is considered a threshold and must be met by the selected alternative.

5.1.2 Compliance with ARARs

The criterion evaluates whether each alternative will meet the federal and state ARARs identified or whether there is justification for waiving one or more ARARs. This criterion is also a threshold that must be met by the alternative selected.

5.1.3 Long-term Effectiveness and Permanence

The criterion evaluates the long-term effectiveness of alternatives in maintaining protection of human health and the environment after remedial action objectives have been met. The primary focus of this evaluation is the extent and effectiveness of controls used to manage the risk posed by treatment residuals or untreated wastes. Long-term effectiveness is one of the balancing criteria. The following factors will be considered in evaluating this criterion:

- Adequacy of remedial controls
- Reliability of remedial controls
- Magnitude of residual risk.

5.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

The criterion addresses the CERCLA statutory preference for treatment options that permanently and significantly reduce the toxicity, mobility, or volume of the contaminants. The preference is satisfied when treatment reduces the principal threats through the following:

- Destruction of toxic contaminants
- Reduction in contaminant mobility
- Reduction in the total mass of toxic contaminants
- Reduction in the total volume of contaminated media.

Although CERCLA includes a statutory preference for treatment, this criterion is not a threshold that must be met.

5.1.5 Short-term Effectiveness

The criterion evaluates the effectiveness of alternatives in protecting human health and the environment during the construction and implementation of a remedy until response objectives have been met. The following factors are considered:

- Exposure of the community during implementation
- Exposure of workers during construction
- Environmental impacts
- Time to achieve RAOs.

5.1.6 Implementability

Evaluates the technical and administrative feasibility of alternatives and the availability of required goods and services. The following factors are considered:

- Ability to construct the technology
- Monitoring requirements
- Availability of equipment and specialists
- Ability to obtain approvals from regulatory agencies.

5.1.7 Cost

Generally, the cost for each alternative is calculated from estimates of capital and operation and maintenance costs. Capital costs consist of direct and indirect costs. Direct costs include the purchase of equipment, labor, and materials necessary to implement the alternative. Indirect costs include engineering, financial, and other services such as testing and monitoring. Annual operation and maintenance costs for each alternative include operating labor, maintenance materials and labor, auxiliary materials, and energy.

A cost estimate in a CERCLA FFS is normally expected to fall within the range of 50 percent above to 30 percent below the actual project cost (accuracy of -30% and +50%) (EPA 2000). The FFS should indicate when it is not realistic to achieve this degree of accuracy based on existing data collected during the RI (EPA 1988).

5.1.8 State Acceptance

This criterion evaluates the state's apparent preferences among or concerns about alternatives. (Cannot be fully evaluated until the state has reviewed and commented on the alternatives in this evaluation.)

5.1.9 Community Acceptance

This criterion evaluates the community's apparent preferences among or concerns about alternatives. (Cannot be fully evaluated until the community has reviewed and commented on the alternatives in this evaluation.)

5.2 COMPARATIVE ANALYSIS

Table 4 presents a comparative analysis of the alternatives, in which the alternatives are evaluated in relation to each other for each of the evaluation criteria. A more detailed discussion of the result of each evaluation criterion is presented below. Cost estimates for Alternatives 2, 3, and 4 are presented in Tables 5, 6, and 7, respectively.

5.2.1 Overall Protection of Human Health and the Environment

Implementation of Alternatives 2 through 4 would result in the protection of human health and the environment. Alternative 1, the no action alternative, does not ensure protection of human health or the environment because chemicals exceeding the remediation goals would remain on-site.

5.2.2 Compliance with ARARs

Alternatives 2 through 4 would comply with ARARs. However, Alternative 1, the no action alternative, would not, because chemicals exceeding the MCLs would remain on-site, with potential exposure to human and ecological receptors (Table 4).

5.2.3 Long-term Effectiveness and Permanence

Alternatives 3 and 4 are the most effective over the long term since they destroy the contaminants of concern in the groundwater. Alternative 3 may be more effective than Alternative 4, due to the addition of activated carbon to reduce contaminant mobility and zero-valent iron to promote direct chemical reduction in Alternative 3. Alternative 2 would also be effective in the long term, although it relies on the slower processes of natural attenuation to remove or destroy contamination. These alternatives would also include monitoring to assess remedial progress and, if necessary, to recognize remedy failure and allow implementation of an alternative remedy.

5.2.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternatives 3 and 4 would use treatment to address the dissolved phase contaminants. Alternative 4 would reduce the volume of contaminants in the groundwater through dechlorination, while Alternative 3 would arrest the mobility of contaminants through physical adsorption and also reduce the volume through dechlorination. Alternatives 3 and 4 both have the potential to temporarily increase toxicity of the contaminant mass as daughter products of TCE are created through reductive dechlorination; however, the remedial design for Alternative 3 would attempt to minimize the accumulation of toxic daughter products, and the pilot studies associated with Alternative 4 did not show an appreciable increase in TCE daughter products.

Alternatives 1 and 2 would not affect the mobility of contaminants. Alternatives 1 and 2 would reduce the volume of contaminants through the processes of natural attenuation. Natural attenuation would result in a slower reduction of volume in Alternatives 1 and 2 than the active remediation processes contained in Alternatives 3 and 4. Natural attenuation includes the processes of advection, dispersion, and possibly degradation via reductive dechlorination. If advection and dispersion are the only mechanism present, toxicity will not be affected. If degradation through reductive dechlorination is present (either naturally or as a result of remaining product from the pilot studies creating a reducing environment), toxicity could be increased if TCE daughter products are created.

5.2.5 Short-term Effectiveness

Alternative 1, the no action alternative, would not offer any additional short-term risk to the community, workers, or the environment and would take no time since no actions would be required. Alternative 2 would involve a minimal short- and long-term risk to workers who continue to sample groundwater at regular intervals and would not involve a risk to the community or the environment. Alternatives 1 and 2 would not offer short-term effectiveness, as they rely on long-term natural attenuation to achieve RAOs.

Alternative 3 and 4 involve similar short-term risks to workers, the community, and the environment. The greatest short-term risk is to the workers that would handle the injection of chemicals, a smaller short-term risk exists for the off- and on-Base community, as well as the environment involving a product release. Short-term effectiveness is greatest with Alternatives 3 and 4, as they have a much shorter duration to achieve RAOs through active remediation than Alternatives 1 and 2. Alternative 3 is likely to achieve RAOs faster than Alternative 4 due to additional enhancements and thus has the greatest short term effectiveness, although for costing purposes both proposed remedies are assumed to up to eight years to meet RAOs for all locations that are currently above the Site CUL, after which attainment monitoring will add two additional years to reach site closure.

5.2.6 Implementability

All of the alternatives are considered implementable, though Alternatives 1 and 2 require very limited action and could be implemented more easily than Alternatives 3 and 4.

5.2.7 Cost

Detailed FS level cost estimates were prepared as described in Section 5.1.7 for each remedial technology. The present worth costs of remedial technologies were summed as appropriate to calculate the total estimated costs for each remedial alternative. These costs are presented in Table 4. The detailed cost estimates for each technology are provided in Tables 5 through 7.

Alternative 1 would have no costs. Alternative 2 would have the lowest cost of the action alternatives, estimated at $577,000 (Table 5). The estimated costs for Alternatives 3 and 4 are within 10% of Alternative 2, with Alternative 3 estimated at $627,000 (Table 6) and Alternative 4 estimated at $598,000 (Table 7).

With the available data, concentration trends cannot accurately predict when Alternative 2 would successfully reach cleanup levels. An estimate of 30 years was utilized in costing, per FS guidance (EPA 1988). Costs for injection programs (Alternatives 3 and 4) were estimated based on available site data; however, it should be noted that these Alternatives carry a certain amount of risk associated with scope and cost. If post-remediation monitoring determined that applied injections were insufficient, additional injections and monitoring time could be necessary to achieve site closure.

5.3 PREFERRED REMEDY

Considering the results of the comparative analysis of the alternatives presented in Section 5.2 and Table 4, Alternative 2 is recommended as the preferred remedy. The current TCE plume is stable and shows no evidence of mobility (EA 2019). Natural attenuation appears to be occurring at the site primarily via dispersion and dilution. Recent data indicates that TCE concentrations are generally stable or decreasing in site wells since termination of the GPT system. One monitoring well also exhibits reductive dechlorination conditions as a result of remaining product from a previous injection.

Alternative 2 is protective of human health and the environment. Alternative 2 has the lowest threshold for implementability, as well as the lowest cost and associated risk. Monitoring provides a means to continually evaluate the downward trend of concentrations for effectiveness, as well as potential contaminant migration. Based on this analysis, Alternative 2 is the preferred remedy.

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FIGURES

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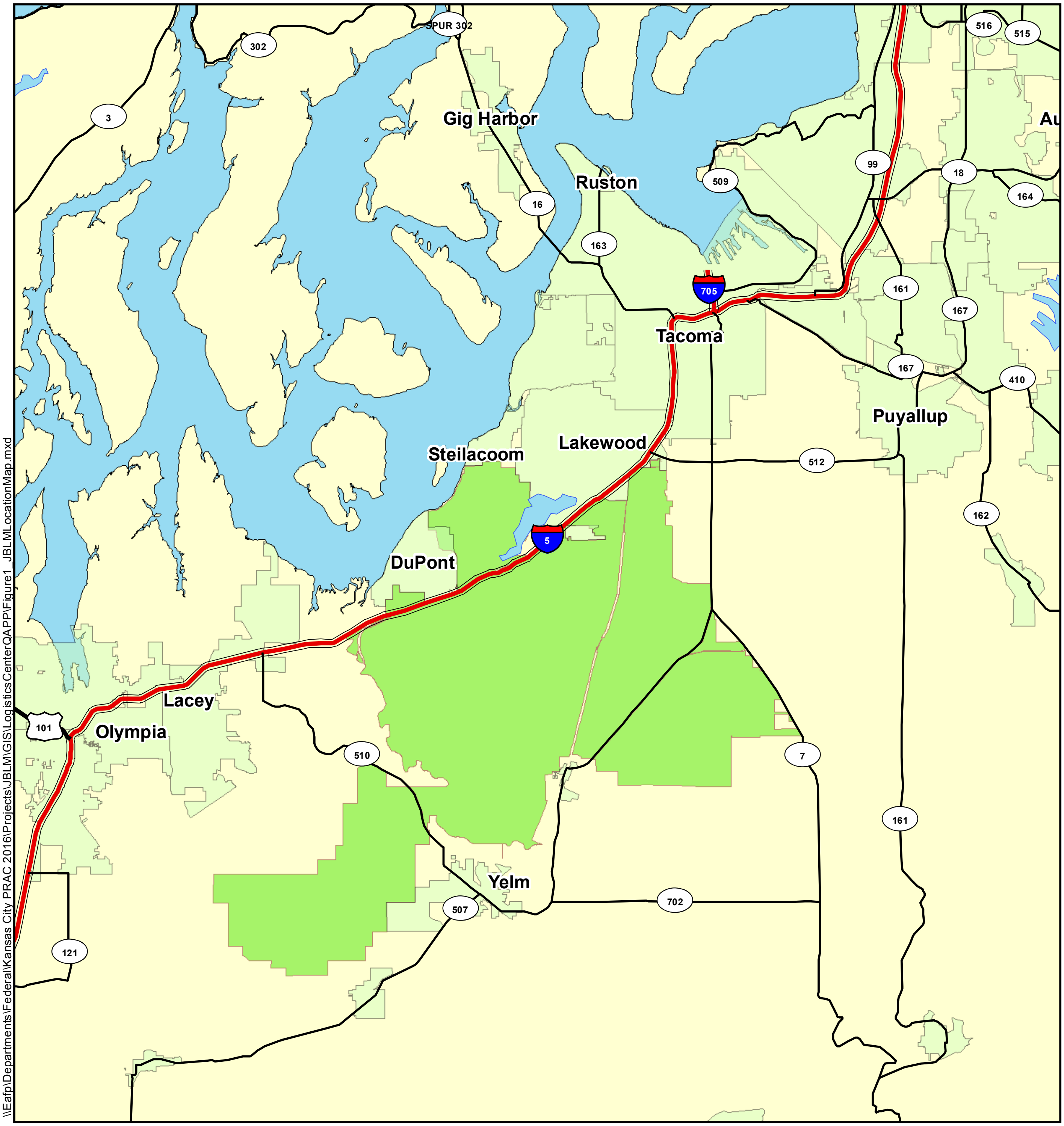

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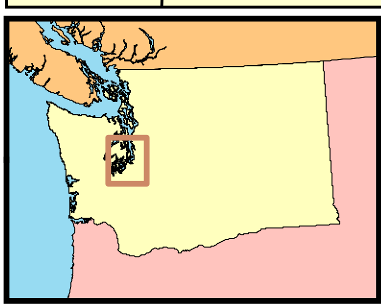

0 2.5 5 10
Miles

1 inch = 5 miles

N

Legend

- Joint Base Lewis-McChord
- City Limit
- Interstate
- State Route
- US Route
- Waterbody

FIGURE 1
JOINT BASE LEWIS-MCCHORD LOCATION MAP

AMERICAN LAKE GARDEN TRACT
FOCUSED FEASIBILITY STUDY

Map Date: 3/21/2018
Coordinate System: UTM Zone 10
Horizontal Datum: WGS 84

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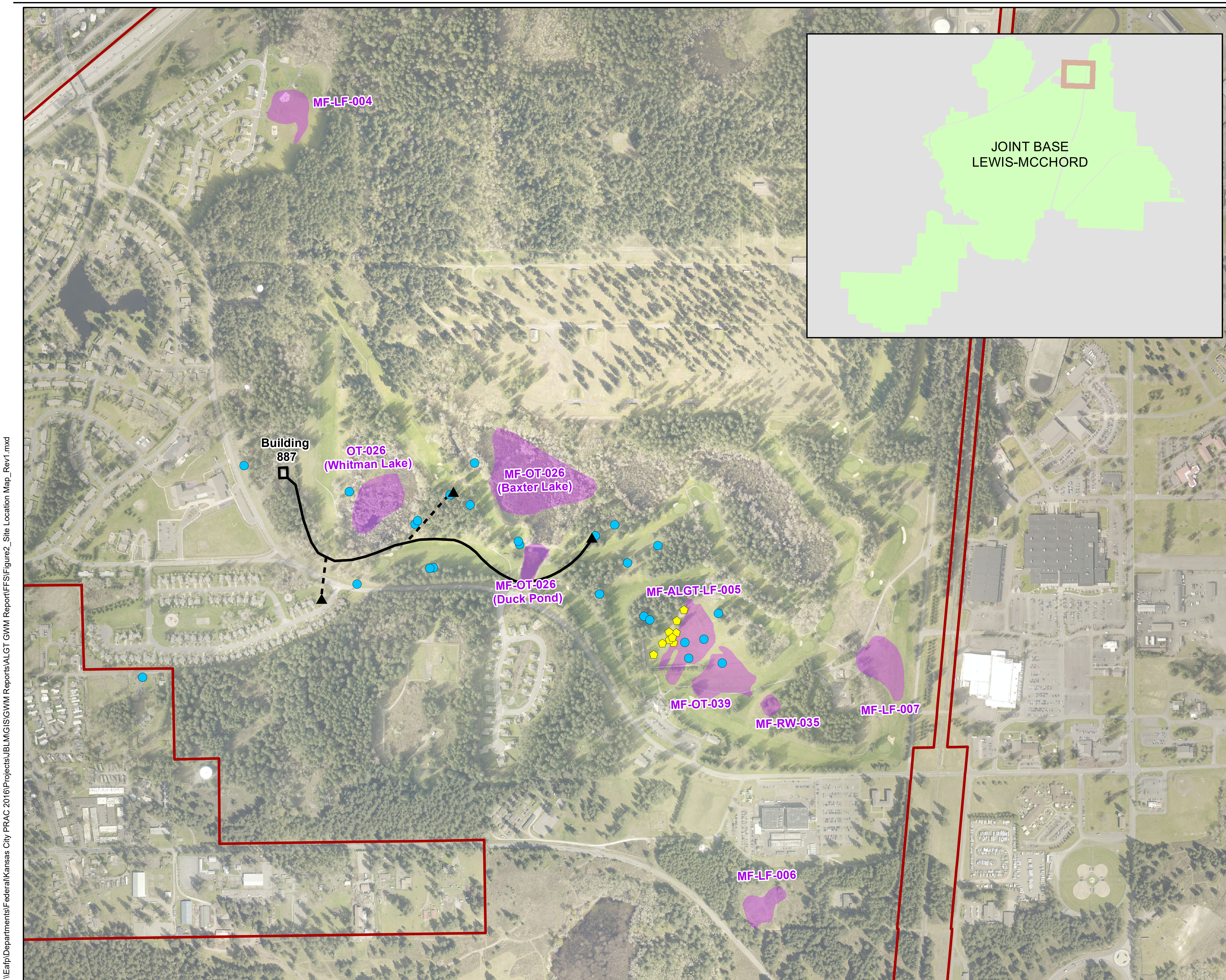

FIGURE 2
SITE LOCATION MAP

AMERICAN LAKE GARDEN TRACT
FOCUSED FEASIBILITY STUDY

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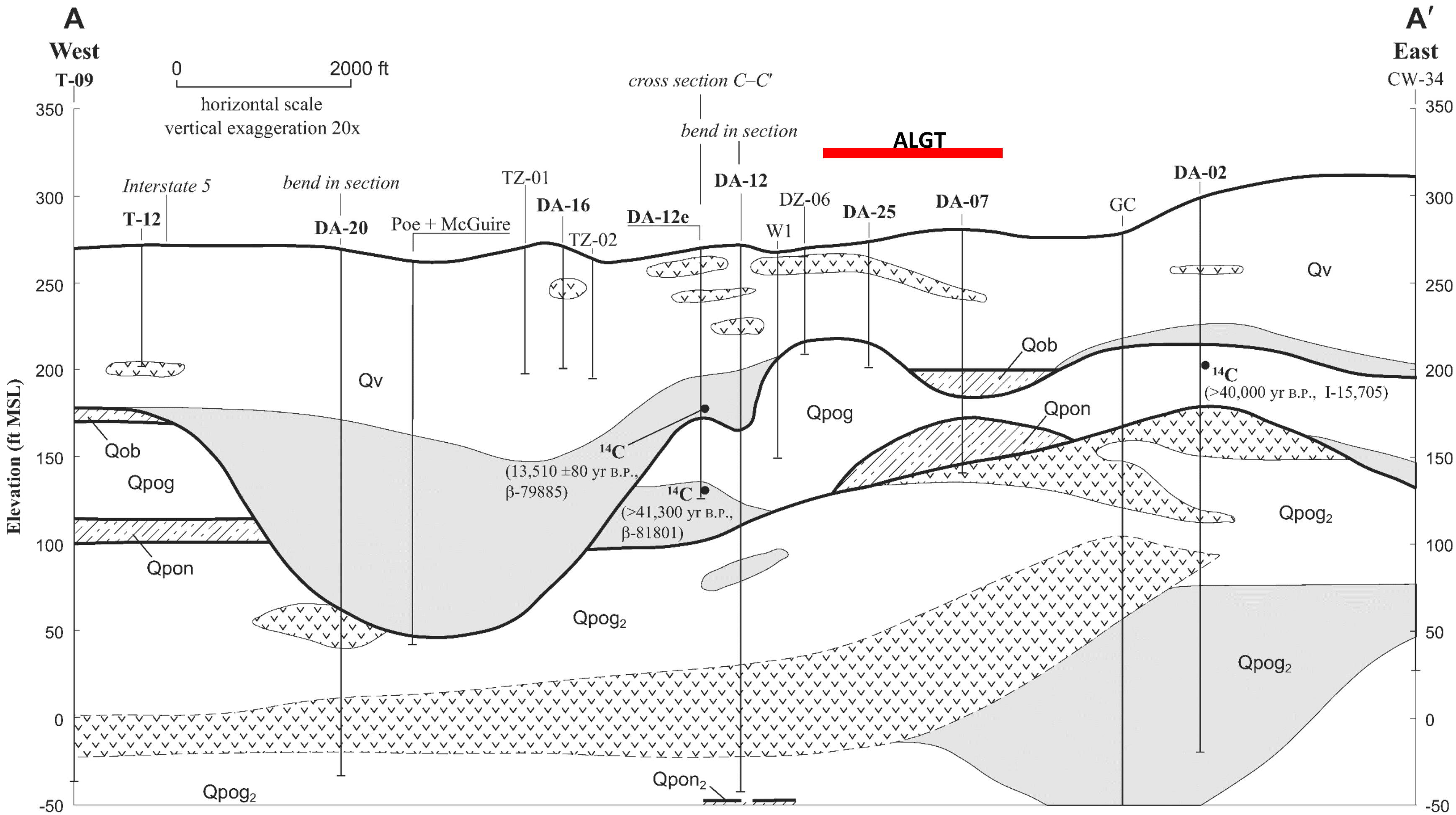

FIGURE 3

CROSS SECTION OF ALGT

(ADAPTED FROM BORDEN AND TROOST 2001)

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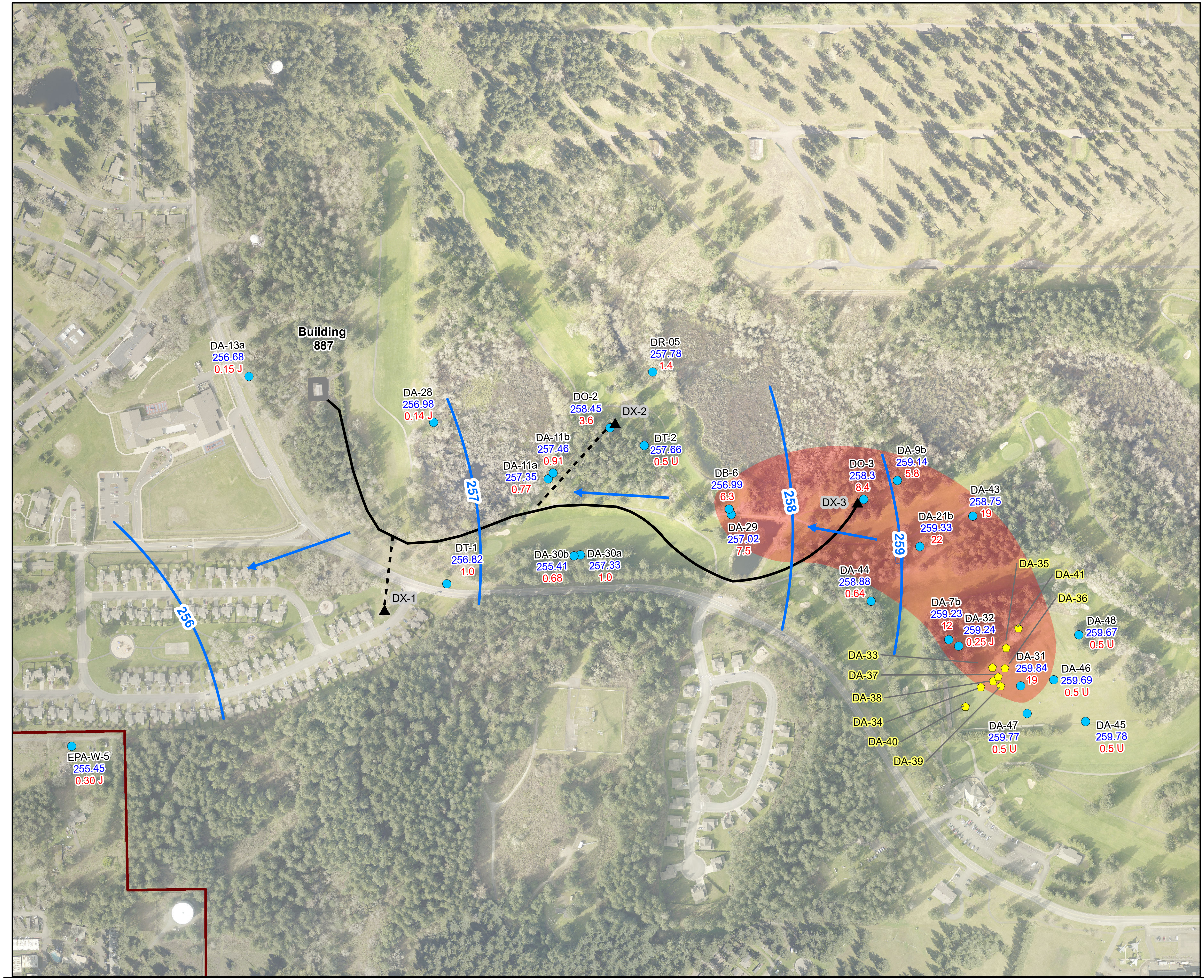

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Legend

- PNNL Injection Well
- Groundwater Monitoring Well
- Extraction Well
- Base Boundary
- GPT System 2" Pipe
- GPT System 6" Main Pipe
- Inferred Residual TCE Plume Above 5 µg/L
- Inferred Groundwater Elevation Contours
- Inferred Seasonal Groundwater Flow Direction
- 258.75 September 2019 Groundwater Elevation (ft AMSL)
- 19 September 2019 TCE Concentration (µg/L)

Notes:
ROD Cleanup Level for TCE = 5 µg/L
J = The result is an estimated value.
U = Analyte not detected above practical quantification limit. Value listed is reporting limit.

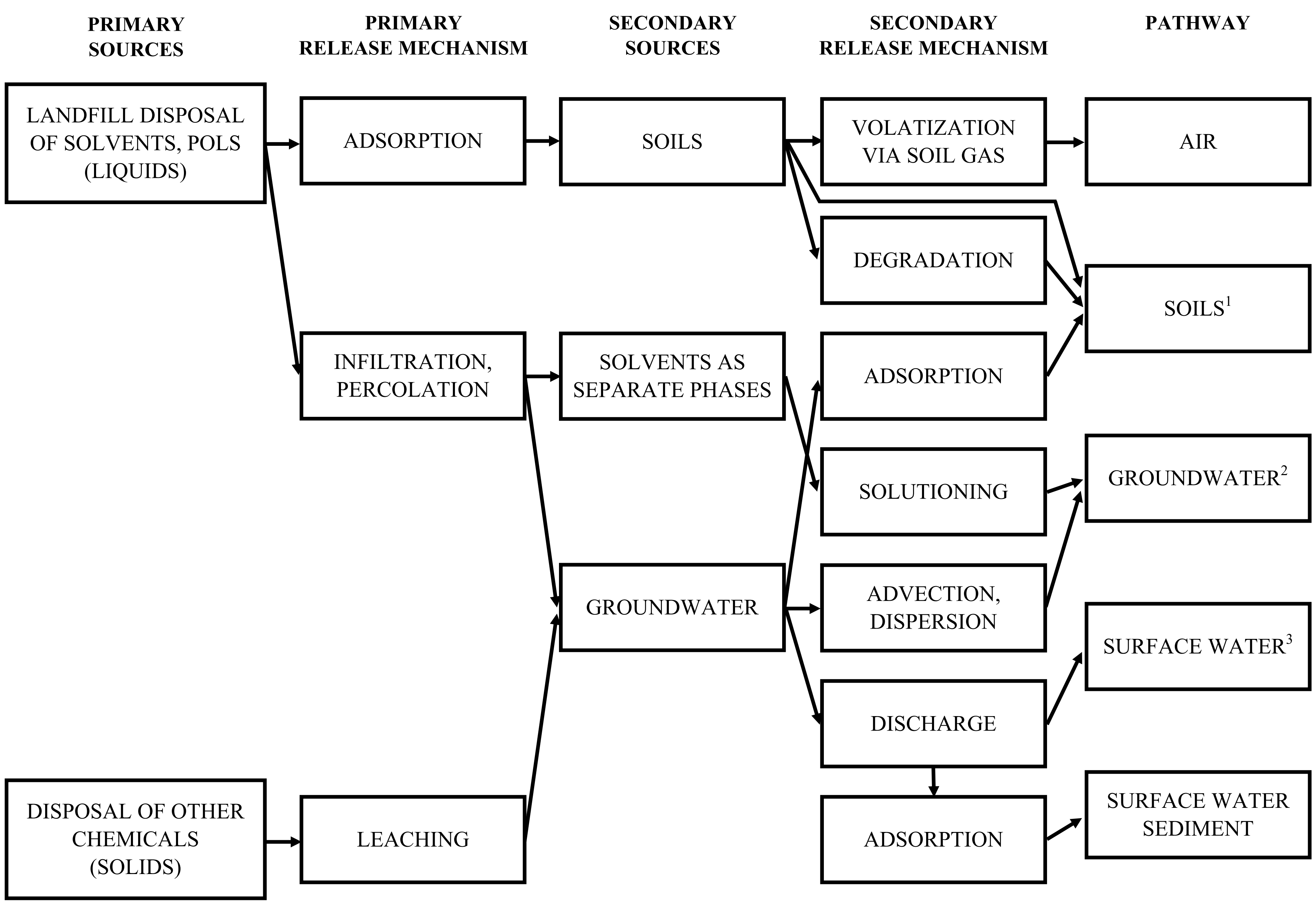
N

0 335 670
Feet

Map Date: 4/13/2020
Coordinate System: UTM Zone 10
Horizontal Datus: WGS 84

FIGURE 4
GROUNDWATER ELEVATIONS AND TCE CONCENTRATIONS (SEPTEMBER 2019)

AMERICAN LAKE GARDEN TRACT
FOCUSED FEASIBILITY STUDY



RECEPTOR

	HUMAN			BIOTA	
EXPOSURE ROUTE	RESIDENTS	WORKERS	SITE VISITORS	TERRESTRIAL	AQUATIC
INHALATION	●	●	●	●	
INGESTION					
DERMAL CONTACT					

INHALATION		●			
INGESTION		●			
DERMAL CONTACT		●			

[1] Only in landfill proper and below 3 feet in depth.

INHALATION	○				
INGESTION	○				
DERMAL CONTACT	○				

[2] All private wells in and downgradient to the plume have been connected to the private water supply.

INHALATION					
INGESTION				○	○
DERMAL CONTACT				○	○

[3] Post-RI sampling confirms surface water contamination levels below action levels.

INHALATION					
INGESTION				○	○
DERMAL CONTACT				○	○

● POTENTIAL EXPOSURE PATHWAYS
○ POSSIBLE BUT UNLIKELY EXPOSURE PATHWAYS (POTENTIAL FUTURE LAND USE)

FIGURE 5

CONCEPTUAL SITE MODEL

(ADAPTED FROM ORIGINAL RI/FS CSM)

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TABLES

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Table 1. Contaminants of Concern and Cleanup Levels

Contaminant	Cleanup Level[1] (µg/L)
TCE	5
cis-DCE	70
1,1-DCE	0.07
VC	0.04

Notes:

[1] Cleanup levels were established in the ROD (EPA et al. 1991).

Abbreviations and Acronyms:

1,1-DCE – 1,1-dichlorethene

µg/L – micrograms per liter

cis-DCE – cis-1,2-dichloroethene

EPA – United States Environmental Protection Agency

MTCA – Model Toxics Control Act

ROD – Record of Decision

TCE – trichloroethylene

VC – vinyl chloride

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Table 2. Generalized Stratigraphic and Hydrostatic Column for West-Central Pierce County

Geologic/Climatic Unit	Geologic Unit	Symbol	Lithologic Description	Regional Hydrogeologic Designation	Thickness (feet)	Hydrogeologic Designation
Recent	Fill	f	Predominantly silty gravel with varying amounts of rubble	AL	0–20	Aquifer where saturated
	Recent Deposits	Qr	Predominantly alluvium and colluvium, silt, sand and gravel with lesser amounts of organic depression fillings	AL	0–10	
Vashon Drift	Vashon recessional outwash	Qvr	Interbedded, brown to gray sandy gravel and sand with minor silt interbeds. Locally represented by a coarse open-work gravel facies of the Steilacoom Gravel (Qvs)	A1	0–70	Vashon unconfined aquifer
	Vashon till and ice contact deposits	Qvt	Dense, gray, silty sandy gravel and gravelly sandy silt, generally matrix supported	A2	5–100; laterally discontinuous	
	Vashon advance outwash	Qva	Interbedded uniformly graded gravelly sand and sandy gravel with silt lenses, typically dense to very dense	A3	5–150	
	Glaciolacustrine silt/clay (Lawton Clay)	Qvlc	Gray, laminated to massive silt and clayey silt with minor fine sand interbeds	B	0–50	
Non-glacial deposits	Olympia Beds	Qob	Mottled, massive, organic-rich, clayey, sandy gravel (mudflows) or lavender silt, peat, sand, and gravelly sand (fluvial and overbank deposits)	B	0–30	
Pre-Olympia Drift (may correlate with Possession Drift)	Possibly Possession Drift	Qpog	Gray-brown, fine to medium-grained sand with minor sandy gravel interbeds, oxidized at top; common silt interbeds at base, rare and discontinuous till	A	0–90	
Second nonglacial deposits	Possibly Whidbey Formation	Qpon	Mottled, massive, organic-rich, clayey, sandy gravel (mudflows) or lavender silt, peat, sand, and gravelly sand (fluvial and overbank deposits)	B	5–150; laterally discontinuous	Aquitard (locally breached by unit Qv and Qpog erosional features)
Third glacial drift	Salmon Springs Till	$Qpog_2$	Interbedded, orange to dark gray sandy gravel and sand with minor silt interbeds, intensely iron-oxide stained at top	C	10–150	Sea level aquifer
			Dense, gray silty, sandy gravel and gravel, sandy silt, generally matrix supported (till)			
			Interbedded, gray-brown to dark gray sandy gravel and sand with minor silt interbeds			
Third nonglacial deposits	Not applicable	$Qpon_2$	Lavender silt, peat, sand, and gravelly sand (fluvial and overbank deposits)	D	0–25	Aquitard
Puyallup Interglacial	Puyallup Formation	Qpy	Alluvial deposits of interbedded silt and coarse-grained sediment with mudflow deposits and ash	D	up to 135	Puyallup aquitard

Sources: Ebasco Environmental (1991b), Borden and Troost (2001)

Table 3. Hydrogeologic Units and Correlation with Geologic and Hydrostratigraphic Units from Previous Investigations

Period	Epoch	Regional Hydrogeologic Designation	Hydrogeologic Units	Geologic Units in Borden and Troost (2001), and Troost and Booth (2008)	Geologic Units in Schasse (1987) and Walsh (1987)	Hydrostratigraphic Units in Robinson & Noble, Inc., and others (2003)	Stratigraphic units
Quaternary	Holocene, Pleistocene	Aquifer where saturated	AL alluvial valley aquifer	Qal, af, Qp	Qa, Qvl(e)	Aquifer A: includes Steilacoom gravel, Vashon Till, Vashon Advance Outwash, Esperance Sand	Recent alluvium, mudflows/ lahars and marine deposits
		Vashon Unconfined Aquifer	A1 aquifer	Qv, Qvr, Qvry, Qvs, Qw	Qa, Qgd, Qgo, Qgog, Qgos, Qp, Qvl(lc), Qvl(o)		Vashon Drift (Steilacoom gravel, recessional outwash
			A2 confining unit	Qvi, Qvt, Qvrl	Qgm, Qgt, Qgl		Vashon Drift (Vashon Till), ice-contact and moraine deposits
			A3 aquifer	Qva, Qpfc	Qga		Vashon Drift (advance outwash)
			B confining unit	Qob, Qpdc, Qpf, Qpoc, Qpon, Qtf, Qvlc, Qwbc	Qc(k)	Layer B	Olympia Beds (Kitsap Formation), Lawton Clay
		Sea Level Aquifer	C aquifer	$Qpog_2$, Qpogc	Qgp	Aquifer C	Salmon Springs Drift, Penultimate Drift, Hayden Creek Drift, Wingate Hill Drift
		Puyallup Aquitard	D confining unit	$Qpon_2$	Not applicable	Layer D	Puyallup Formation
		Stuck Aquifer	E aquifer	Not applicable	Not applicable	Aquifer E	Stuck Drift
		Not applicable	F confining unit	Not applicable	Not applicable	Layer F	Alderton Formation
		Not applicable	G Undifferentiated deposits	Not applicable	Not applicable	Aquifer G	Orting Drift
Tertiary	Miocene to Eocene	Not applicable	Bedrock Unit	Not applicable	Qap, Qap(fl), Qapt(fl), Qap(wh), Qapt(wh), and all pre-Quaternary deposits		Basement confining unit and some alpine glacial deposits

Table 4. Alternatives Evaluation Summary

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Criterion	No Further Action	Monitored Natural Attenuation (MNA)	Enhanced In-Situ Bioremediation (EISB) with Organic Carbon Plus Activated Carbon and Zero-Valent Iron	EISB with Electron Donor Injection
(1) Overall Protection of Human Health and the Environment				
Minimize Potential Exposure to Contaminants in Groundwater	There is no reduction of risk with this alternative.	Institutional controls would be maintained, limiting exposure to soil and groundwater until natural attenuation factors lower TCE concentrations below cleanup levels. Monitoring would provide a warning system for contaminant migration or increase.	There would be no unacceptable risk to human health or the environment from ground water once the EISB is complete.	There would be no unacceptable risk to human health or the environment from ground water once the electron donor injections are complete.
(2) Compliance with ARARs				
Comply with Chemical, Location, and Action-Specific ARARs and TBCs	May not meet chemical-specific ARARs. No action-specific ARARs are applicable to this alternative.	May not meet chemical-specific ARARs, as contaminant of concern concentrations would remain above applicable cleanup levels in some areas of the site. However, continued implementation of institutional controls would limit potential exposure to soil and groundwater. Aniticipated to comply with all location and action-specific ARARs.	Anticipated to comply with chemical-specific ARARs by reducing contaminant of concern concentrations to below applicable cleanup levels. Anticipated to comply with all location-specific and action-specific ARARs.	Anticipated to comply with chemical-specific ARARs by reducing contaminant of concern concentrations to below applicable cleanup levels. Anticipated to comply with all location-specific and action-specific ARARs.
(3) Long-Term Effectiveness and Permanence				
Permanently Address Contamination and Control any Residual Risk in the Long-Term	This alternative may provide long-term effectiveness and permanence. Evidence of natural attenuation at this site suggests that over an unknown timeframe the plume may reduce in size and concentration below clean up levels. However with no monitoring in place it could not be determined when or if that occurs, or determine if the plume is expanding or changing in nature.	This alternative should provide long-term effectiveness and permanence, as natural attenuation slowly degrades the remaining dissolved plume while existing institutional controls safeguard against human health risks. Continual periodic sampling would monitor for stalling in natural attenuation and for regressive changes in plume extent and concentration.	This alternative would provide long-term effectiveness and permanence. Reductive dechlorination will permanently destroy contaminants in groundwater. Monitoring would provide a means to recognize remedy failure and implement a more aggressive remedy, if necessary.	This alternative would provide long-term effectiveness and permanence. Reductive dechlorination will permanently destroy contaminants in groundwater. Monitoring would provide a means to recognize remedy failure and implement a more aggressive remedy, if necessary.
(4) Reduction of Toxicity, Mobility, or Volume through Treatment				
Amount of Hazardous Materials Destroyed or Treated	Natural attenuation is expected to break down organic contaminants in the dissolved plume over time.	Natural attenuation is expected to break down organic contaminants in the dissolved plume over time.	EISB would destroy contaminants in the dissolved groundwater plume.	Reductive dechlorination would destroy contaminants in the dissolved groundwater plume.
Degree of Expected Reductions in Toxicity, Mobility, or Volume	Unknown. Natural attenuation is expected to reduce volume and toxicity of contaminants over time.	MNA is expected to reduce the volume and toxicity of contaminants over time due.	Reduction of toxicity, mobility, and volume of contaminants is expected to be achieved through EISB. Commercially-available injectates physically trap contaminants through adsorption (typically with colloidal carbon), then use a combination of organic carbon and electron donors (such as zero-valent iron) to enhance an existing or injected microbial population that dechlorinates contaminants such as TCE into non-toxic daughter products.	Reduction of toxicity and volume of contaminants is expected to be achieved through electron donor injection. Similar to Alternative 3, an electron donor such as emulsified vegetable oil (EVO) would enhance existing microbial populations to dechlorinate contaminants such as TCE into non-toxic daughter products, thus reducing toxicity and volume. However, Alternative 4 does not provide a targeted adsorption pathway to reduce mobility of contaminants.
Irreversible Treatment?	N/A	N/A	Yes	Yes
Residuals Remaining After Treatment	N/A	N/A	Trace residuals or chemical breakdown products may remain. Additional treatments beyond those proposed in Alternative 3 may be required to address residual contamination.	Trace residuals or chemical breakdown products may remain. Additional treatments beyond those proposed in Alternative 4 may be required to address residual contamination.
(5) Short-Term Effectiveness				
Community Protection	No additional risk to the community.	No additional risk to the community.	No additional risk to the community.	No additional risk to the community.

Table 4. Alternatives Evaluation Summary

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Criterion	No Further Action	Monitored Natural Attenuation (MNA)	Enhanced In-Situ Bioremediation (EISB) with Organic Carbon Plus Activated Carbon and Zero-Valent Iron	EISB with Electron Donor Injection
Worker Protection	No action and therefore no workers present.	Minimal short- and long-term risk to workers who continue to sample groundwater at regular intervals.	Increased short term risk to workers that perform chemical injections. Minimal short- and long-term risk to workers who continue to sample groundwater at regular intervals.	Increased short term risk to workers that perform chemical injections. Minimal short- and long-term risk to workers who continue to sample groundwater at regular intervals.
Environmental Impacts	No short-term impacts to the environment.	Waste produced would included contaminated PPE and contaminated water, which would be managed in compliance with ARARs. Limited short-term environmental impact associated with implementation.	Waste produced would included contaminated PPE and contaminated water, which would be managed in compliance with ARARs. Limited short-term environmental impact associated with implementation.	Waste produced would included contaminated PPE and contaminated water, which would be managed in compliance with ARARs. Limited short-term environmental impact associated with implementation.
Time Until Action Complete (Field Construction Time)	No action taken.	Approximately 4 months to begin monitoring, indefinite timeframe to complete.	Approximately 18 months to complete.	Approximately 18 months to complete.
(6) Implementability				
Ability to Construct and Operate	Not applicable.	Monitoring well network already installed.	EISB is implementable and has been used nationally. May require onsite pilot test.	Electron donor injection is implementable. A pilot study of electron donor injection has already been performed at this site.
Monitoring Requirement	Not applicable.	MNA requires LTM until groundwater cleanup is confirmed	EISB requires periodic groundwater monitoring until cleanup confirmed.	EISB requires periodic groundwater monitoring until cleanup confirmed.
Availability of Equipment and Specialists	Not Applicable.	Equipment and specialists are available for the implementation of this alternative.	Equipment and specialists are available for the implementation of this alternative.	Equipment and specialists are available for the implementation of this alternative.
Ability to Obtain Approvals and Coordinate with Other Agencies	Not Applicable.	Ability to obtain approvals and coordinate with other agencies assumed to be possible.	Ability to obtain approvals and coordinate with other agencies assumed to be possible.	Ability to obtain approvals and coordinate with other agencies assumed to be possible.
(7) Cost (Present Worth)				
	$0	$577,000	$627,000	$598,000
(8) State Acceptance				
	TBD	TBD	TBD	TBD
(9) Community Acceptance				
	TBD	TBD	TBD	TBD

Notes:
ARAR - Applicable Relevant or Appropriate Requirement
EISB - Enhanced In-Situ Bioremediation
LTM - Long-Term Monitoring
MNA - Monitored Natural Attenuation
PPE - Personal Protective Equipment
TBD - To be determined. Cannot be fully evaluated at this time.
TBC - To Be Considered

Table 5. Alternative 2 Cost Estimate

ALTERNATIVE 2: MONITORED NATURAL ATTENUATION		LOCATION	Total Cost		$577,000
Alternative 2 includes natural attenuation by dilution and dispersion, continuing effort to collect data from groundwater well sampling, and maintaining existing institutional controls with the aim of minimizing risks to human health and the environment.		ALGT	Implementation Time:	N/A	
			Post Remediation Monitoring:	30	Years
		Quantities		Combined Unit Costs	
Description	Data Source	Quantity Amount	Quantity Unit	Unit Cost	Option Total Cost
Implementation Costs					
Reporting					
UFP-QAPP	Professional est	1	ea	$ 20,000.00	$20,000
Sub-Total Implementation Costs					**$20,000**
Long-Term Operation and Maintenance Annual Cost					
Monitoring					
Sampling Equipment (PDBs)	ALS Kelso	12	ea	$ 35.00	$420
Sampling Supplies (Hanging wire, gloves, zipties, etc.)	Professional est	1	LS	$ 100.00	$100
Shipping (per cooler)	Professional est	1	ea	$ 50.00	$50
Laboratory Fee for VOC Analysis (10 primary samples, 1 duplicate, 1 matrix spike, 1 matrix spike duplicate)	ALS Kelso	13	ea	$ 49.00	$637
Sampling Team					
Field Manager (includes field prep, travel, sampling, wrap-up)	Professional est	6	hr	$ 140.00	$840
Field Technician (includes field prep, travel, sampling, wrap-up)	Professional est	6	hr	$ 100.00	$600
Travel	Professional est	1	LS	$ 150.00	$150
Reporting					
Annual Groundwater Monitoring Report	Professional est	1	ea	$ 20,000.00	$20,000
30 Years of Operation					
3% Discount Factor					
Sub-Total Long-Term Operation and Maintenance Cost (Net Present Value)					**$446,832**
Sub-Total					**$466,832**
Bid Bond (1%)					**$4,668**
7.5% Governement Administration					**$35,012**
10% Professional/Technical Services					**$46,683**
5% Contingency					**$23,342**
Total Cost				**$577,000**	

Assumptions

Assumes sampling will be conducted annually at 10 existing site wells for volatile organic compounds via passive diffusion bag (PDB).

Assumes sampling team (2 people) would need approximately 4 hours to complete sampling.

Assumes PDBs will be re-deployed at the time of sampling.

References

1 Source is 2018 CostWorks, RS Means
2 Day is assumed to be a 10 hour work day

Table 6. Alternative 3 Cost Estimate

ALTERNATIVE 3: IN-SITU REDUCTIVE DECHOLORINATION THROUGH ENHANCED IN-SITU BIOREMEDIATION		LOCATION	Total Cost		$627,000
Alternative 3 addresses recalcitrant areas of TCE-contaminated soil and groundwater through the injection of a mixture of chemicals that are intended to arrest TCE movement and degrade the chemical to harmless byproducts through the reductive dechlorination process.		ALGT	Implementation Time:	16	Days
			Post Remediation Monitoring:	10	Years
		Quantities		Combined Unit Costs	
Description	Data Source	Quantity Amount	Quantity Unit	Unit Cost	Option Total Cost
Implementation Costs					
In-situ Injections					
Pilot Test	Professional est	1	LS	$ 12,000.00	$12,000
In-situ Injections					
Mobilization/Demobilization	Vendor est	1	LS	$ 10,000.00	$10,000
Product Injection Point (new borehole, drill rig, injection mixer/pump, labor)	Vendor est	15	ea	$ 5,800.00	$87,000
Product Injection Point (existing well, injection mixer/pump, labor)	Vendor est	8	ea	$ 2,600.00	$20,800
Product (e.g. EHC Plus)	Vendor est	17,250	lb	$ 4.50	$77,625
Water Truck	Professional est	3	week	$ 750.00	$2,250
Field Manager (oversight)	Professional est	160	hr	$ 140.00	$22,400
Travel	Professional est	1	LS	$ 300.00	$300
Per Diem (Du Pont, WA)	Dept. of Defense	16	day	$ 195.00	$3,120
Reporting					
Work Plan	Professional est	1	ea	$ 30,000.00	$30,000
Final Construction Report	Professional est	1	ea	$ 20,000.00	$20,000
Sub-Total Implementation Costs					**$285,495**
Long-Term Operation and Maintenance Annual Cost					
Monitoring					
Sampling Equipment (PDBs)	ALS Kelso	12	ea	$ 35.00	$420
Sampling Supplies (Hanging wire, gloves, zipties, etc.)	Professional est	1	LS	$ 100.00	$100
Shipping (per cooler)	Professional est	1	ea	$ 50.00	$50
Laboratory Fee for VOC Analysis (10 primary samples, 1 duplicate, 1 matrix spike, 1 matrix spike duplicate)	ALS Kelso	13	ea	$ 49.00	$637
Sampling Team					
Field Manager (includes field prep, travel, sampling, wrap-up)	Professional est	6	hr	$ 140.00	$840
Field Technician (includes field prep, travel, sampling, wrap-up)	Professional est	6	hr	$ 100.00	$600
Travel	Professional est	1	LS	$ 150.00	$150
Reporting					
Annual Groundwater Monitoring Report	Professional est	1	ea	$ 20,000.00	$20,000
10 Years of Operation					
3% Discount Factor					
Sub-Total Long-Term Operation and Maintenance Cost (Net Present Value)					**$194,464**
Sub-Total					**$479,959**
Bid Bond (1%)					**$4,800**
7.5% Governement Administration					**$35,997**
10% Professional/Technical Services					**$47,996**
12% Contingency					**$57,595**
Total Cost				**$627,000**	

Assumptions

Assumes a 3-day pilot test will be conduted on both mid and lower injection lines to determine lithology and contamination depth in order to determine the target injection depths, and to determine soil characteristics for product selection and sizing.

Assumes a production rate of 1.5 points per day at new injection boreholes.

Assumes a production rate of 4 points per day at existing injeciton wells.

Assumes sampling will be conducted annually at 10 existing site wells for volatile organic compounds.

Assumes sampling team (2 people) would need approximately 4 hours to complete sampling.

Assumes PDBs will be re-deployed at the time of sampling.

References

1 Source is 2018 CostWorks, RS Means
2 Day is assumed to be a 10 hour work day

Table 7. Alternative 4 Cost Estimate

ALTERNATIVE 4: IN-SITU REDUCTIVE DECHOLORINATION THROUGH ELECTRON DONOR INJECTION		LOCATION	Total Cost		$598,000
Alternative 4 addresses recalcitrant areas of TCE-contaminated soil and groundwater through the injection of an organic chemical that acts as an electron donor, enhancing degradation of TCE to harmless byproducts through the reductive dechlorination process.		ALGT	Implementation Time:	16	Days
			Post Remediation Monitoring:	10	Years
		Quantities		Combined Unit Costs	
Description	Data Source	Quantity Amount	Quantity Unit	Unit Cost	Option Total Cost
Implementation Costs					
In-situ Injections					
Pilot Test	Professional est	1	LS	$ 12,000.00	$12,000
In-situ Injections					
Mobilization/Demobilization	Vendor est	1	LS	$ 10,000.00	$10,000
Product Injection Point (new borehole, drill rig, injection mixer/pump, labor)	Vendor est	15	ea	$ 5,800.00	$87,000
Product Injection Point (existing well, injection mixer/pump, labor)	Vendor est	8	ea	$ 2,600.00	$20,800
Product (e.g. EVO)	Vendor est	13,800	lb	$ 4.00	$55,200
Water Truck	Professional est	3	week	$ 750.00	$2,250
Field Manager (oversight)	Professional est	160	hr	$ 140.00	$22,400
Travel	Professional est	1	LS	$ 300.00	$300
Per Diem (Du Pont, WA)	Dept. of Defense	16	day	$ 195.00	$3,120
Reporting					
Work Plan	Professional est	1	ea	$ 30,000.00	$30,000
Final Construction Report	Professional est	1	ea	$ 20,000.00	$20,000
Sub-Total Implementation Costs					**$263,070**
Long-Term Operation and Maintenance Annual Cost					
Monitoring					
Sampling Equipment (PDBs)	ALS Kelso	12	ea	$ 35.00	$420
Sampling Supplies (Hanging wire, gloves, zipties, etc.)	Professional est	1	LS	$ 100.00	$100
Shipping (per cooler)	Professional est	1	ea	$ 50.00	$50
Laboratory Fee for VOC Analysis (10 primary samples, 1 duplicate, 1 matrix spike, 1 matrix spike duplicate)	ALS Kelso	13	ea	$ 49.00	$637
Sampling Team					
Field Manager (includes field prep, travel, sampling, wrap-up)	Professional est	6	hr	$ 140.00	$840
Field Technician (includes field prep, travel, sampling, wrap-up)	Professional est	6	hr	$ 100.00	$600
Travel	Professional est	1	LS	$ 150.00	$150
Reporting					
Annual Groundwater Monitoring Report	Professional est	1	ea	$ 20,000.00	$20,000
10 Years of Operation					
3% Discount Factor					
Sub-Total Long-Term Operation and Maintenance Cost (Net Present Value)					**$194,464**
Sub-Total					**$457,534**
Bid Bond (1%)					**$4,575**
7.5% Governement Administration					**$34,315**
10% Professional/Technical Services					**$45,753**
12% Contingency					**$54,904**
Total Cost				**$598,000**	

Assumptions

Assumes a 3-day pilot test will be conduted on both mid and lower injection lines to determine lithology and contamination depth in order to determine the target injection depths, and to determine soil characteristics for product selection and sizing.

Assumes a production rate of 1.5 points per day at new injection boreholes.

Assumes a production rate of 4 points per day at existing injeciton wells.

Assumes sampling will be conducted annually at 10 existing site wells for volatile organic compounds.

Assumes sampling team (2 people) would need approximately 4 hours to complete sampling.

Assumes PDBs will be re-deployed at the time of sampling.

References

1 Source is 2018 CostWorks, RS Means
2 Day is assumed to be a 10 hour work day