# Feasibility Study Report – Public Review Draft
# Alexander Avenue Petroleum Tank Facilities Site
# Tacoma, Washington

Date: March 5, 2021

Prepared for

The Port of Tacoma

Landau Associates

130 2nd Avenue South
Edmonds, WA 98020
(425) 778-0907

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# Alexander Avenue Petroleum Tank Facilities Site
# Tacoma, Washington

This document was prepared by, or under the direct supervision of, the technical professionals noted below.


Document prepared by: ______________________ Piper Roelen, PE, CHMM
Primary Author

Document reviewed by: ______________________ Clint Jacob, PE
Quality Reviewer



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# EXECUTIVE SUMMARY

This remedial investigation (RI) and feasibility study (FS) has been prepared for the Alexander Avenue Petroleum Tank Facilities site (Site) pursuant to Agreed Order No. DE 9835 (Order) between the Washington State Department of Ecology (Ecology), the Port of Tacoma (Port), and Mariana Properties, Inc. (Mariana). The purpose of the RI/FS is to delineate the nature and extent of contamination at the Site and select a preferred cleanup alternative. This RI/FS was conducted consistent with both the Model Toxics Control Act (MTCA), Revised Code of Washington (RCW) 70.105D, and the federal National Contingency Plan (NCP).

## Site Discovery & Background

The Site was listed by Ecology in 1995 after a release was discovered when the City of Tacoma (City) notified Ecology that petroleum was infiltrating into a sanitary sewer line beneath Alexander Avenue. Additional information from investigations at the nearby former Occidental Chemical Corporation (OCC) Facility Site (Occidental Site) confirmed releases of hazardous substances associated with historical petroleum storage and distribution facilities previously located at 721 Alexander Avenue (721 property), owned by the Port, and the adjacent parcel at 709 Alexander Avenue (709 property) owned by Mariana. The Site is defined by the area where contaminants from releases from the 709 and 721 properties has come to be located, encompassing an area of approximately 19 acres that includes portions of four contiguous tax parcels east of Alexander Avenue, a portion of one parcel west of Alexander Avenue, and the section of the Alexander Avenue right-of-way (ROW) between these parcels. On October 3, 2013 the Port, Mariana, and Ecology entered into the Order, which required the Port and Mariana to conduct an RI/FS and prepare a draft cleanup action plan (dCAP) for the Site.

The Site is located on the Blair-Hylebos Peninsula, between the Blair and Hylebos Waterways, and is being administered under Ecology oversight pursuant to the MTCA. The Site is surrounded by other sites being cleaned up under MTCA as well as sites under US Environmental Protection Agency (EPA) oversight pursuant to the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Sites being cleaned up under MTCA include the Earley Business Center (EBC) site. Sites being cleaned up under CERCLA include the Head and Mouth of Hylebos Waterway (Problem Areas of the Commencement Bay Nearshore/Tideflats Superfund site). The Occidental Site is subject to both EPA and Ecology oversight.[1] Ecology and EPA coordinate with each other on all the sites on and adjacent to the peninsula.

[1] The Occidental Site has been, and continues to be, subject to an Administrative Order on Consent, EPA Docket No. 10-97-0011-CERCLA, as amended, Agreed Order No. DE 16943, Dangerous Waste Management Permit for Corrective Action No. WAD009242314, and the 2005 “Occidental Site Memorandum of Understanding Between -EPA and Ecology,” pursuant to CERCLA, MTCA, and the Washington Hazardous Waste Management Act.

The concentration of contaminated sites on the Blair-Hylebos Peninsula is in large part due to federal activities accomplished by instrumentalities of the United States (US) over several decades. The current location of the EBC and surrounding properties encompassing much of the peninsula have been the sites of World War I and World War II shipbuilding, the US Naval Station Tacoma, dismantling of US Navy ships, the US Army Reserve, and the US Navy and Marine Corps Reserve. Portions of the Occidental Site were taken over by the US government during World War II. As discussed below, petroleum operations at 721 Alexander Avenue were operated by the federal government during World War II and again from 1951–1966. The EBC Site is contaminated with petroleum and metals and is currently undergoing investigation. The Occidental Site is contaminated with chlorinated volatile organic compounds (cVOCs) and will be the subject of additional remedial action anticipated to include a hydraulic containment and treatment system. A sediment dredging, capping, and natural recovery remedy was implemented for the Head and the Mouth of Hylebos Waterway. Active dredging and capping were completed between 2002 and 2008. Natural recovery is still ongoing. Recent sediment, bioassay, and fish tissue sampling indicates remedial action goals are being met.

## Site History

Investigation into the operational history of the Site is ongoing, but available information establishes that both the 721 and 709 properties were first developed in the 1930s. The 709 property was developed by Norton and Mary Clapp as a petroleum storage and distribution facility, including vessel loading and unloading infrastructure on the Hylebos Waterway and several large aboveground storage tanks (ASTs). The facility changed hands several times until in 1981, when it was purchased by PRI Northwest. In addition to fuel storage and distribution, PRI Northwest also operated a tetraethyl leading plant for blending lead into gasoline, and the United Independent Oil Company operated a crude oil distillation plan on the property. The infrastructure at the property was demolished shortly before the parcel was sold in 1997 to OCC Tacoma Inc., which transferred the property to Mariana in 2001. Historical petroleum operations at these properties were active over seven decades.

The 721 property was developed by the Maxwell Petroleum Corporation (an ExxonMobil predecessor) in the 1930s. Similar to the 709 property, fuel was received by ship via a pier and dock on the Hylebos Waterway and stored in large ASTs within an earthen bermed area. One notable difference was that the 721 property had a large sludge pit (USAF Sludge Pit)[2] used to dispose of waste generated at the property including tank-bottom waste and spills. The USAF Sludge Pit was sloped like a swimming pool such that it was deepest at its west end where a tile field facilitated infiltration of liquids into the subsurface. The federal government leased the property during World War II, and again assumed operations when the US Air Force (USAF) bought the property in 1951. From 1951 to 1966 the facility was responsible for USAF fuel and petroleum products supply for the entire northwestern part of the

[2] Although the sludge pit appears to have been an original feature of the petroleum operations dating back to the 1930s, early environmental investigation documents from the 1990s labelled it the "Former USAF Sludge Area" and subsequent investigations, as well as Ecology, have continued to use that nomenclature.

United States. A notable change made to the facility during the USAF's ownership was the excavation of material from the USAF Sludge Pit to prepare for a proposed (but never built) AST, with the contaminated material from the sludge pit disposed of along the south-central property boundary (the Former Earthen Disposal Area). The Port purchased the property in 1966 and leased it to a variety of entities for petroleum storage and distribution until 1983 when all infrastructure was removed, and the property was paved.

In addition to the Occidental Site to the north, the 721 and 709 Alexander Avenue properties are surrounded by the Hylebos waterway to the east, the Port-owned 500 Alexander Avenue property to the west, and Port-owned property to the south that is currently leased to Puget Sound Energy. The Alexander Avenue ROW lies between the 721 and 709 Alexander Avenue properties and the 500 Alexander Avenue property, which terminates to the west at the Blair Waterway. The current Puget Sound Energy leasehold was part of the shipbuilding facilities owned and operated by the US government that occupied most of the Blair-Hylebos Peninsula during World War II. After the war, the property became part of Naval Station Tacoma for the berthing, maintenance, and dismantling of ships until it was acquired by the Port in 1959 for warehouse and logistics use. The portion of the 500 Alexander Avenue property onto which the Site extends was also part of the federal World War II shipbuilding activities and the post-war Navy Station until its sale to the Port in the 1960s for storage yard and warehouse use. The property was developed for its current use as a marine cargo terminal for Totem Ocean Trailer Express (TOTE) shipping lines in 1983.

Figure ES-1 shows the Site with parcel addresses.[3]

## Nature & Extent of Contamination

As part of the RI, soil and groundwater at the Site was sampled in order to determine the nature and extent of contamination. The RI considered all pertinent data, including data gathered under the Order and that gathered as part of the Occidental Site investigation. The RI confirmed that petroleum hydrocarbon contamination is present at the Site as light non-aqueous phase liquid (LNAPL), and in soil and groundwater. Based on sampling data and other analyses, the RI further determined the following:

- The Site has been impacted by releases from historical petroleum operations at the 721 and 709 Alexander Avenue properties resulting in elevated concentrations of benzene, gasoline-range organics, diesel-range organics and oil-range organics in soils and groundwater;[4]
- The primary source areas are on the 721 Alexander Avenue property;
- The Site is bisected by a groundwater divide that results in contamination originating on the east side of the 721 and 709 Alexander Avenue properties migrating toward the Hylebos

[3] The street addresses for several Port properties have been changed in recent years, including the 721 Alexander Avenue property which was combined with the parcel to the south. Figure ES-1 shows the historical street addresses of the various Site properties.

[4] The RI determined that cVOCs present at the Site are primarily attributable to releases from the neighboring Occidental Site.

Waterway, and contamination originating on the west side of the properties migrating toward the Blair Waterway.

Figure ES-2 shows the groundwater divide, the current extent of groundwater with indicator hazardous substances (IHS) above cleanup levels and the current extent of LNAPL.

The RI also identified two soil “hot spots,” the Blair Hot Spot and Hylebos Hot Spot, shown in Figure ES-3.

## Conceptual Site Model

Based on the data, including the locations of the soil hotspots and LNAPL, the primary source of contamination at the Site are the areas historically used for on-site waste disposal and containment; specifically, the USAF Sludge Pit and the Earthen Disposal Area. As shown in Figure ES-3, the Blair Hot Spot is beneath and downgradient of the deeper side of the USAF Sludge Pit, appearing to be the result of infiltration of wastes containing hazardous substances disposed in the pit and of spills contained in the pit. The Hylebos Hot Spot is beneath the Earthen Disposal Area where, during USAF ownership, material excavated from the USAF Sludge Pit was disposed. The Hylebos Hot Spot appears to be the result of infiltration of hazardous substances from the Earthen Disposal Area. Various leaks and spills during petroleum operations appear to be additional, but less significant, sources of contamination.

While cVOCs are present at the Site, they are found in limited areas and are primarily attributable to releases of chlorinated solvents on the adjacent Occidental Site, with less significant contributions from spills and leaks of solvents used during petroleum operations on the 721 property.

## Preferred Remedy

Because groundwater under the Blair-Hylebos Peninsula is not potable but discharges to the Hylebos and Blair Waterways, cleanup of the Site must remediate the groundwater to levels that are protective of human and aquatic life at the point where the groundwater flows to the waterways. Additionally, the cleanup must be protective of workers undertaking excavations and other activities who may come in contact with subsurface soils and groundwater, or LNAPL and petroleum vapors in adjacent sewer lines. While site conditions present vapor intrusion risks, the design and construction of future on-Site occupied buildings must include engineering controls to protect indoor air quality. An additional factor to be considered is the effect of the anticipated Occidental Site remedy, which is expected to have an effect on groundwater flow, attenuation of contaminant concentrations and other Site conditions. The FS evaluated six remedial alternatives, including a “no action” alternative (Alternative 1) as required by the NCP.[5] Alternatives 2 through 6 incorporated the most viable cleanup action technologies within the general response action categories of containment, source removal

[5] The alternatives evaluated in the FS were approved by Ecology based on a technical screening memorandum prepared by the Port and Mariana that evaluated remedial technologies and other factors.

(i.e., excavation), treatment, and institutional controls. All alternatives were designed to meet the requirements of the MTCA rules and to achieve a "CERCLA-quality cleanup" under both current conditions, prior to implementation of the Occidental Site remedy, and after the implementation of the Occidental Site remedy. The Occidental Site remedy was not relied upon for the efficacy of any of the alternatives evaluated in the FS.

Under MTCA the selected cleanup alternative must be the one that is "permanent to the maximum extent practicable." The six alternatives were evaluated through a disproportionate cost analysis that included the criteria of performance, protectiveness, long-term effectiveness, implementability, management of short-term risks, consideration of public concerns, and cost. The alternative that is determined, through the disproportionate cost analysis, to be permanent to the maximum extent practicable, is identified as the preferred remedial action for Site cleanup. The six alternatives were:

- Alternative 1: No Action (Monitoring Only).
- Alternative 2: Shoreline Enhanced *In Situ* Bioremediation (EISB), Site-Wide Monitored Natural Attenuation (MNA), and Institutional and Engineering Controls (I&ECs)[6].
- Alternative 3: Blair Hot Spot EISB and Bioventing, Hylebos Hot Spot Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs.
- Alternative 4: Hot Spot EISB and Bioventing, Site-Wide MNA, and I&ECs.
- Alternative 5: Hot Spot Excavation, Alexander Avenue EISB and Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs.
- Alternative 6: Extended Remedial Excavation, Alexander Avenue EISB and Bioventing, and MNA for Deep Groundwater.

Alternative 4 was selected as the preferred remedial alternative for the Site based on the outcome of the disproportionate cost analysis: Alternative 4 is permanent to the maximum extent practicable. Alternative 4 includes hot spot bioremediation (EISB and bioventing at both Blair and Hylebos Hot Spots) in addition to MNA and I&ECs. Figure ES-4 provides a conceptual drawing of the preferred remedial alternative.

[66]I&ECs are physical and administrative measure taken to ensure that workers are not exposed to contaminated soil and groundwater in a manner that would be unsafe. All other components of the alternatives (e.g., EISB, MNA) are remedial technologies that remediate Site contaminants.

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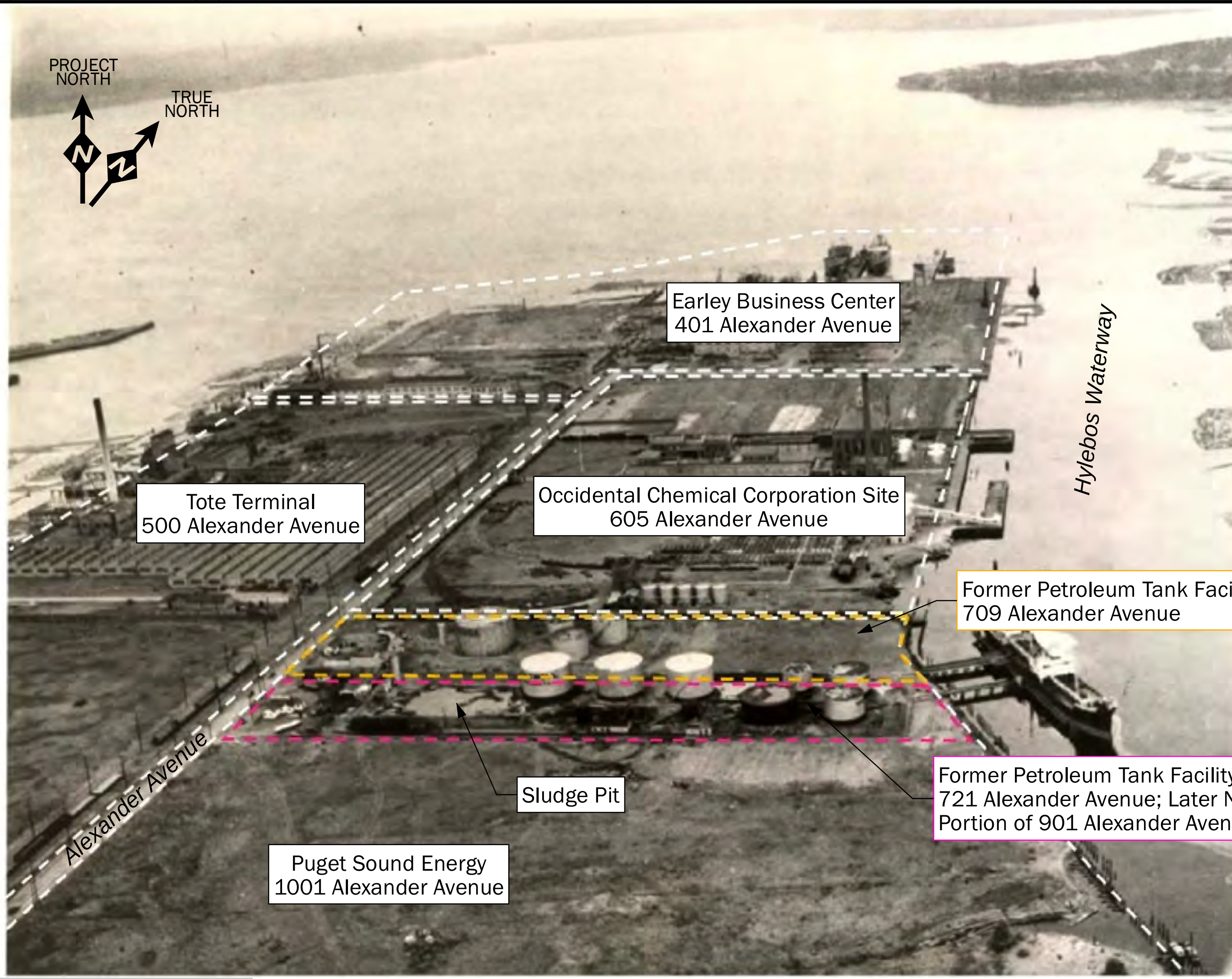


**Legend**

- Approximate Current Property Boundaries
- Approximate Historical Property Boundaries

Data Source: Occidental Chemical Corporation.

**Note**

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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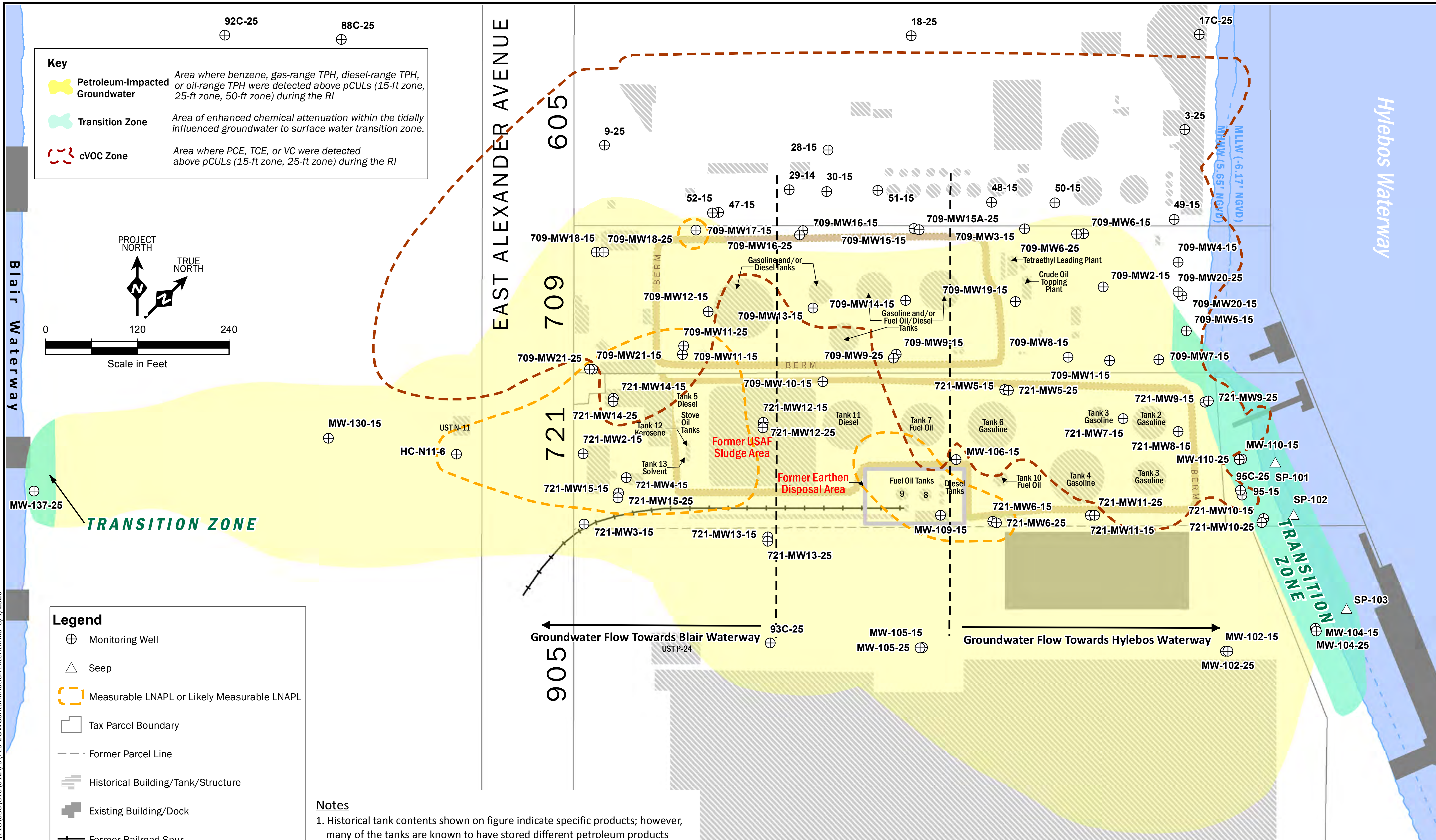
| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | **Historical Photo (Date 1936-1946)** | Figure ES-1 |
| --- | --- | --- |




Notes
1. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Port of Tacoma, 2017; Aspect Consulting, 2016; GHD, 2017b

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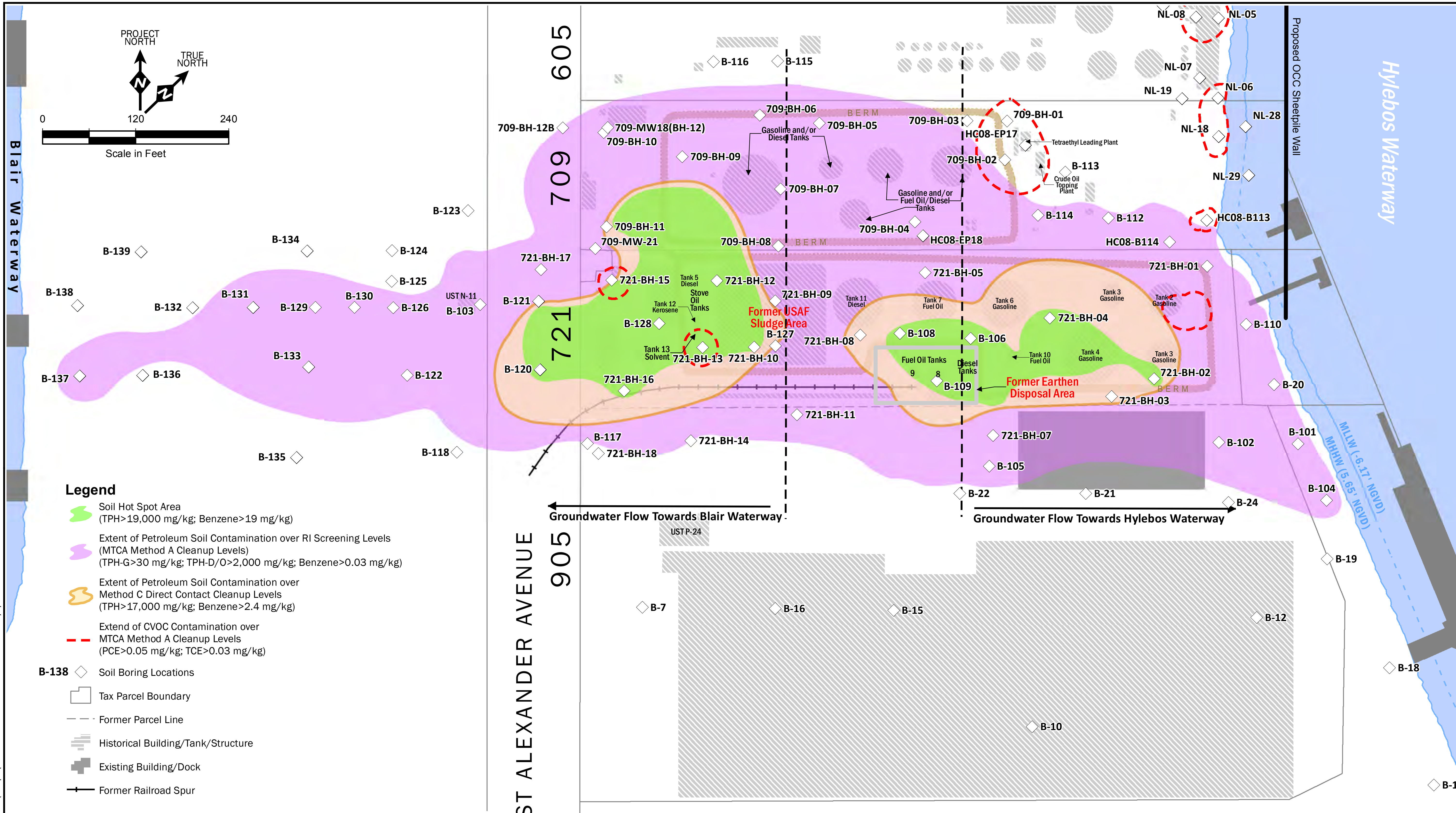
| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | **Extent of Groundwater Contamination (Petroleum Hydrocarbons and CVOCs)** | Figure ES-2 |
|---|---|---|




## Notes

1. RI soil screening levels are 0.02 mg/kg benzene, 30 mg/kg gasoline, and 2000 mg/kg diesel + oil.
2. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
3. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Aspect Consulting, 2016; Ecology, 2018.

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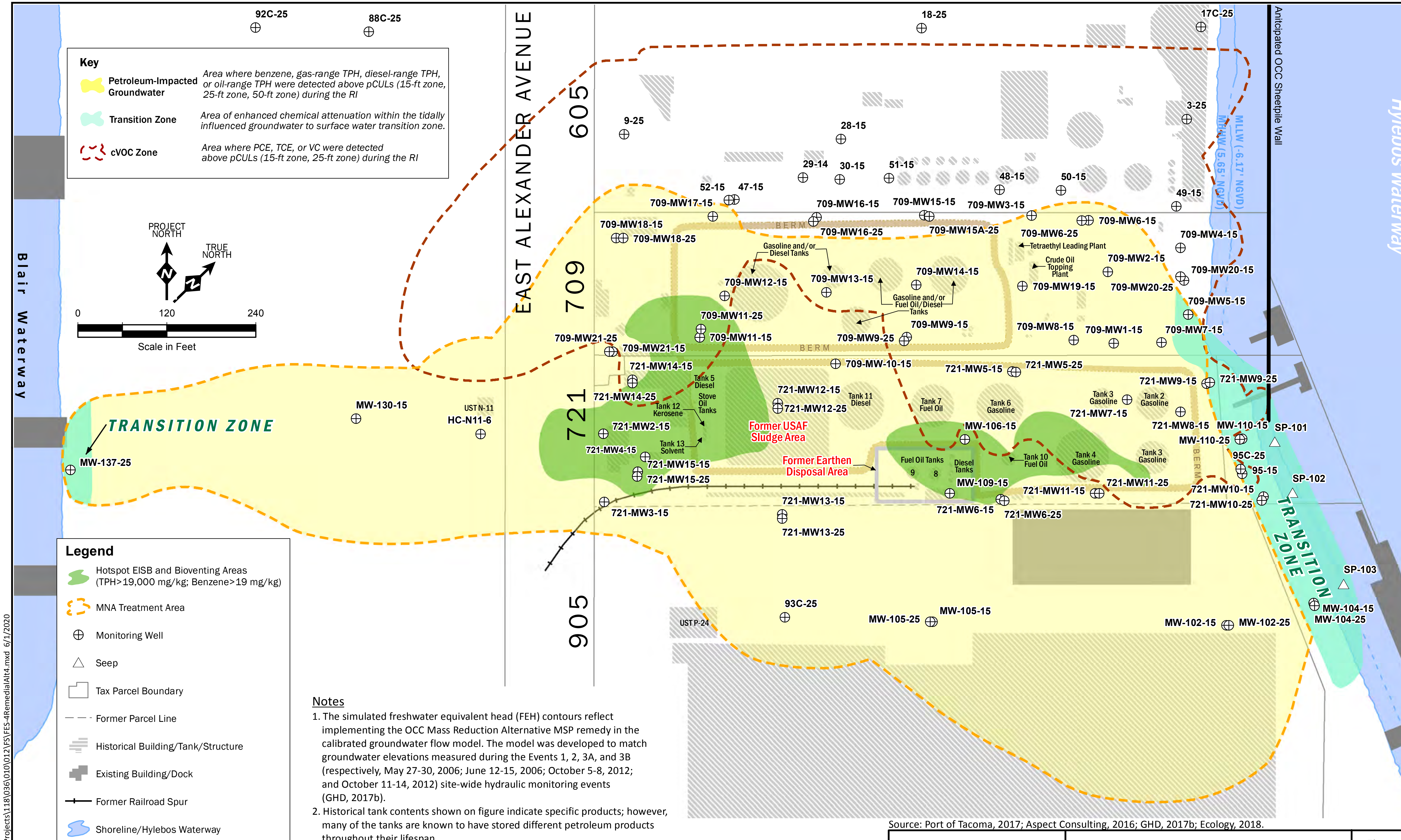
| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | Extent of Soil Contamination (Petroleum Hydrocarbons and CVOCs) | Figure ES-3 |
|---|---|---|




## Notes

1. The simulated freshwater equivalent head (FEH) contours reflect implementing the OCC Mass Reduction Alternative MSP remedy in the calibrated groundwater flow model. The model was developed to match groundwater elevations measured during the Events 1, 2, 3A, and 3B (respectively, May 27-30, 2006; June 12-15, 2006; October 5-8, 2012; and October 11-14, 2012) site-wide hydraulic monitoring events (GHD, 2017b).
2. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Port of Tacoma, 2017; Aspect Consulting, 2016; GHD, 2017b; Ecology, 2018.

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Alexander Avenue Petroleum Tank Facility Site Feasibility Study

**Preferred Remedial Alternative**
**Alt 4: Hotspot EISB and Bioventing, and MNA**

Figure ES-4

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## APPENDICES

# LIST OF ABBREVIATIONS AND ACRONYMS

µg/L ........ micrograms per liter
µg/m³ ........ micrograms per cubic meter
ARARs ........ applicable or relevant and appropriate requirements
AST ........ aboveground storage tank
BAF ........ bioaccumulation factor
bgs ........ below ground surface
CAP ........ cleanup action plan
CBNT ........ Commencement Bay/Nearshore Tideflats
CERCLA ........ Comprehensive Environmental Response, Compensation, and Liability Act
CFR ........ Code of Federal Regulations
$CH_4$ ........ methane
City ........ City of Tacoma
CLARC ........ Cleanup Level and Risk Calculation
$CO_2$ ........ carbon dioxide
COCs ........ constituents of concern
CPOCs ........ conditional points of compliance
CSM ........ conceptual site model
CULs ........ cleanup levels
cVOC ........ chlorinated volatile organic compound
DCA ........ disproportionate cost analysis
dCAP ........ draft cleanup action plan
DO ........ dissolved oxygen
EBC ........ Earley Business Center
Ecology ........ Washington State Department of Ecology
ED ........ exposure duration
EISB ........ enhanced *in situ* bioremediation
EPA ........ US Environmental Protection Agency
FCR ........ fish consumption rate
$Fe^{2+}$ ........ ferrous iron
Fletcher ........ Fletcher Oil Company
FS ........ feasibility study
ft ........ feet, foot
ft/day ........ feet per day
ft/ft ........ feet per foot
ft/year ........ feet per year
g/day ........ grams per day
GET ........ groundwater extraction and treatment
I&ECs ........ institutional and engineering controls

# LIST OF ABBREVIATIONS AND ACRONYMS (CON'T)

IHS ........ indicator hazardous substances
K ........ conductivity
LAI ........ Landau Associates, Inc.
Lilyblad ........ Lilyblad Petroleum, Inc.
LNAPL ........ light non-aqueous phase liquid
LNG ........ liquefied natural gas
Mariana ........ Mariana Properties, Inc.
Maxwell ........ Maxwell Petroleum Company
mg/kg ........ milligrams per kilogram
$Mn^{2+}$ ........ soluble manganese
MNA ........ monitored natural attenuation
MTCA ........ Model Toxics Control Act
Navy ........ US Navy
NCP ........ National Contingency Plan
NETI ........ New England Tank Industries
NGVD29 ........ National Geodetic Vertical Datum of 1929
$NO_{3-}$ ........ nitrate
NPDES ........ National Pollutant Discharge Elimination System
NSZD ........ natural source zone depletion
NTR ........ National Toxics Rule
O&M ........ operation and maintenance
OCC ........ Occidental Chemical Corporation
Occidental Site ........ Former OCC Facility Site
Order ........ Agreed Order No. DE 9835
PCE ........ tetrachloroethene
pCULs ........ proposed cleanup levels
PDCE ........ physical direct-contact exposure
PMI ........ Port Maritime and Industrial
POC ........ point of compliance
Port ........ Port of Tacoma
Port properties ........ 500, 717, and 1001 Alexander Avenue
PQLs ........ practical quantitation limits
PRB ........ permeable reactive barrier
PRI ........ PRI Northwest, Inc.
PSCAA ........ Puget Sound Clean Air Agency
RAOs ........ remedial action objectives
RCW ........ Revised Code of Washington
RI ........ remedial investigation

# LIST OF ABBREVIATIONS AND ACRONYMS (CON'T)

RLs .... remediation levels
ROW .... right-of-way
RSC .... relative source contribution
SEPA .... State Environmental Policy Act
SGC .... silica gel cleanup
Site .... Alexander Avenue Petroleum Tank Facilities site
SLs .... screening levels
$SO_4^{2-}$ .... sulfate
SWPPP .... stormwater pollution prevention plan
SWQS .... surface water quality standards
TCE .... trichloroethene
TEE .... Terrestrial Ecological Evaluation
TOTE .... Totem Ocean Trailer Express
TPH .... total petroleum hydrocarbons
TPH-D .... diesel-range total petroleum hydrocarbons
TPH-G .... gasoline-range total petroleum hydrocarbons
TPH-O .... oil-range total petroleum hydrocarbons
UIC .... underground injection control
USACE .... US Army Corps of Engineers
USAF .... US Air Force
USC .... United States Code
UST .... underground storage tank
VC .... vinyl chloride
VI .... vapor intrusion
VOC .... volatile organic compound
VPH .... volatile petroleum hydrocarbons
Vs .... seepage velocities
WAC .... Washington Administrative Code
WDFW .... Washington Department of Fish & Wildlife
$yd^3$ .... cubic yards

# 1.0 INTRODUCTION

This document presents the results of a feasibility study (FS) conducted for the Port of Tacoma (Port) and Mariana Properties, Inc. (Mariana) Alexander Avenue Petroleum Tank Facilities site (Site) pursuant to Agreed Order No. DE 9835 (Order). The Site is located along Alexander Avenue in the Port of Tacoma, Tacoma, Washington (Figure 1-1). The Site includes portions of the current properties located at 500 Alexander Avenue, 717 Alexander Avenue, and 1001 Alexander Avenue (Port properties), the current properties located at 605 Alexander Avenue and 709 Alexander Avenue (owned by Mariana), and a segment of the Alexander Avenue right-of-way (ROW; see Figure 1-2; owned by the City of Tacoma [City]).

The Site is located on the Blair-Hylebos Peninsula between the Blair and Hylebos waterways and includes property on both sides of Alexander Avenue. The Port and Mariana have conducted investigations to characterize soil and groundwater conditions at the Site, as documented in the remedial investigation (RI) report (Aspect 2016). The RI report concluded that remedial action evaluation was warranted for impacted soil, groundwater, surface water, and soil vapor at the Site. The RI and this FS have both been conducted under the Order between the Washington State Department of Ecology (Ecology), the Port, and Mariana (Ecology 2013). The Final RI was submitted to Ecology on December 30, 2016 and was determined by Ecology to be sufficient to proceed with the FS as documented in an email dated January 13, 2017 (Ecology 2017b).

This FS report documents the development and evaluation of remedial action alternatives to address contamination at the Site and identifies a preferred remedial alternative that will address the contamination at the Site as required by Washington Administrative Code (WAC) 173-340-360, under the Model Toxics Control Act (MTCA). To support the development of remedial alternatives to be evaluated in this FS report, a remedial technologies screening document was prepared and submitted to Ecology (Landau Associates, Inc. [LAI] 2018). The remedial technologies screening document served as a vehicle to focus discussion between the Port, Mariana, and Ecology and, as a result of those discussions, the parties agreed to proceed with preparation of the FS using the remedial technologies/alternatives included in Section 5 of this FS report. Ecology's review of the document also included a summary of key points of agreement between the parties, and outstanding issues to be addressed in the FS (Ecology 2018b). The FS report is responsive to those issues and documents the development of proposed soil, groundwater, surface water, and soil vapor cleanup levels (CULs) and identifies proposed points of compliance (POCs).

This FS, performed for Ecology and in accordance with MTCA guidance, is also consistent with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP). The final NCP rule (US Environmental Protection Agency [EPA] 1990) explains that a private party cleanup is consistent with the NCP if, when evaluated as a whole, it achieved “substantial compliance” with potentially applicable NCP requirements and resulted in a “CERCLA-quality cleanup.”[7]

This FS report also relies on RI, FS, and site characterization information presented on the neighboring Occidental Chemical Corporation (OCC) site subject to the Administrative Order on Consent among OCC, EPA, and Ecology in EPA Docket No. 10-97-0011-CERCLA, as amended 2005 and 2020, and subject to Agreed Order No. DE 16943 (Occidental Site). A review of the Occidental Site Feasibility Study Report (GHD 2017b) indicates that the implementation of any of the remedial action alternatives evaluated for the Occidental Site will impact the fate of Site contamination and remedy implementation. For the purposes of this FS, the future impacts of the Occidental Site remedy are considered an existing condition for the Site remedy. A brief description of the Occidental Site alternatives analysis and the anticipated effects of the Occidental Site preferred remedy on Site hydrogeology are presented in Section 1.6. OCC and Ecology are currently in the process of preparing a draft cleanup action plan (dCAP) for the Occidental Site pursuant to Agreed Order DE 16943.

## 1.1 Site Description and Background

The Site is located along Alexander Avenue between the Blair Waterway and the Hylebos Waterway. Note that, although Alexander Avenue is situated in a northwest-southeast orientation, for ease of direction identification, discussion of relative locations of various Site features in this report, “project directions” will be referenced. As such, Alexander Avenue will be considered to run north-south, the Occidental Site will be referenced as north of the Site, the Blair Waterway will be referenced as west of the Site, and the Hylebos Waterway will be referenced as east of the Site. Both true north and project north are shown on report figures.

MTCA defines a contaminated “site” or “facility” as any “area where a hazardous substance, other than a consumer product in consumer use, has been deposited, stored, disposed of, or placed, or otherwise come to be located.” By this definition, the Site encompasses an area of approximately 19 acres and includes portions of four contiguous tax parcels east of Alexander Avenue, a portion of one parcel west of Alexander Avenue, and the section of the Alexander Avenue ROW between these parcels (see Figure 1-2) including:

- 500 Alexander Avenue (owned by the Port, also known as the Totem Ocean Trailer Express [TOTE] Maritime Alaska Terminal property; “500 property” or “TOTE property”),
- 605 Alexander Avenue (southern end of the former OCC facility; owned by Mariana; “605 property”),
- 709 Alexander Avenue (owned by Mariana; “709 property”),
- 717 Alexander Avenue (owned by the Port; “717 property”),

[7] A CERCLA-quality cleanup is defined as one that protects human health and the environment, utilizes permanent solutions and alternative technologies to the maximum extent practicable, and is cost effective; these are also requirements under MTCA.

- 1001 Alexander Avenue (owned by the Port; "1001 property"), and
- A roughly 300-foot (ft) segment of the Alexander Avenue ROW (owned by the City) located adjacent/between to the parcels identified above.

The properties east of Alexander Avenue that contained the original sources of Site petroleum contamination, or were most impacted by releases, coincide with historical properties (see Figures 1-3a and 1-3b) at the following addresses:

- 709 Alexander Avenue, and
- 721 Alexander Avenue ("721 property;" together with the 709 property the "former petroleum tank farm properties").

The 709 and 721 properties were both developed as petroleum fuel terminals in the 1930s. The parcel boundary of the 4.59-acre 709 property has not changed since the property was first developed. The 4.5-acre 721 property was divided into two parcels in 1965 under US Air Force (USAF) ownership, 0.71 acres along the Hylebos Waterway were transferred to the US Navy (Navy). The 0.71-acre parcel was assigned the address 717 Alexander Avenue. The reduced 3.71-acre 721 property, after being purchased by the Port in 1966, was combined with parcels to the south. The property adjacent to the south of the 721 property was previously identified as 905 Alexander Avenue ("905 property"). The 721 property and the 905 property became the northern and central portions of a larger parcel known as 901 Alexander Avenue ("901 property") in the mid-1980s.In turn, the 901 property recently became part of the current 32-acre parcel known as 1001 Alexander Avenue. In 2011 the Port acquired the title for the 0.71-acre 717 property.

As described in the RI, the sources of current Site contamination were multiple historical releases of hazardous substances. Releases of hazardous substances including gasoline, diesel, and/or oil occurred during storage (including on-Site disposal of wastes generated through storage and handling activities), processing, and distribution activities on the former petroleum tank properties (709 and 721 properties), resulting in total petroleum hydrocarbon (TPH) contamination of soil and groundwater. Historical releases of chlorinated solvents on the adjacent Occidental Site to the north appear to be the primary source of chlorinated volatile organic compounds (cVOCs) present in the northeastern portion of the Site. However, other potential sources of chlorinated solvent contamination associated with historical operations include placement of embankment fill, a 5,000-gallon solvent tank identified on the 1950 Sanborn map of the 721 property, probable use of unknown solvents and other materials for various purposes, including cleaning of tanks and equipment, and a documented spill in 1981 of Safety-Kleen aliphatic solvent associated with Lilyblad Petroleum, Inc. (Lilyblad) on the 721 property (unknown volume and location; CRA 2013).

The RI identified indicator hazardous substances (IHS) for the Site as benzene, gasoline-range TPH (TPH-G), diesel- and oil-range TPH (TPH-D/O), and the cVOCs tetrachloroethene (PCE), trichloroethene (TCE), and vinyl chloride (VC). Light non-aqueous phase liquid (LNAPL) petroleum has also been identified in monitoring wells and soil borings at the Site. The estimated extent of LNAPL, based on LNAPL measured in wells and sheen observed in soil boring samples during the RI, is shown on Figure 1-4.

As described in the RI report, the Site and surrounding area is zoned Port Maritime and Industrial (PMI), which is consistent with the MTCA definition of industrial property (Aspect 2016).

## 1.2 Site History

The history of ownership and operations of the Site properties and adjacent properties, as well as the development of the Blair-Hylebos Peninsula in general, is described in some detail in the RI report (Aspect 2016) and elsewhere, including the Data Summary Report – 709 and 721 Alexander Avenue (CRA 2012 and 2013) and Final Report, 721 East Alexander (GeoEngineers 2010). Below is a short historical summary of the historical Site properties.[8] The Site is shown relative to historical parcels on Figures 1-3a and 1-3b.

### 1.2.1 709 Property

Prior to 1920, the 709 property and adjacent area were undeveloped tidal mudflats. Between 1920 and 1931, the area was filled with approximately 16 ft of dredge material, primarily sand, as part of an upland expansion project. Known historical ownership and usage of the 709 property are summarized below; referenced historical aerial photographs and site maps are included in Appendix A.

- Norton and Mary Clapp ownership, 1930s (?) to 1938: Sometime between 1931 and 1940 the property was developed as a fuel storage and distribution facility (see aerial photography—1931 and 1940). In 1938 the property was sold to Fletcher Oil Company (GeoEngineers 2010).
- Fletcher Oil Company ownership, 1938 to 1979: The Fletcher Oil Company (Fletcher) operated a gasoline and diesel-fuel storage and distribution facility at the 709 property. Aerial photography and early Sanborn maps show four large aboveground storage tanks (ASTs) surrounded by an earthen berm. In the 1950 Sanborn map, the four tanks are labelled as storing gasoline, with a total combined capacity of 45,000 barrels or 1.89 million gallons (GeoEngineers 2010). Aerial photography from 1953 shows a new large tank added to the east of the existing infrastructure. Fletcher operated under several names during its tenure at the site: Fletcher Oil Company, Fletcher Oil Inc., and F.O. Fletcher, Inc. Tenants operated on the property in the 1970s: Tesoro Petroleum, Inc., and United Independent Oil Company, Inc. (CRA 2013).
- PRI Northwest, Inc. ownership, 1981 to 1997: PRI Northwest, Inc. (PRI) began leasing the 709 property in 1979 and purchased it in 1981 for use as a storage and distribution facility for unleaded gasoline, leaded gasoline, diesel fuel, and fuel alcohol. Additionally, PRI operated a tetraethyl leading plant for blending lead into gasoline, a process that involves reacting chloroethane with a sodium-lead alloy. And the United Independent Oil Company operated a crude oil distillation plant (CRA 2013). In the 1978 aerial photograph, the new infrastructure

[8] This report and other reports contain partial information about the history of ownership and operations relevant to the Site, and it is anticipated additional information will be obtained through ongoing research activities and efforts to obtain information from other sources.

can be seen in the eastern portion of the property. The crude oil distillation plant was removed from the property in 1985. The ASTs, a lead waste underground storage tank (UST), and associated soils were removed from the property in 1989. All other tanks and structures were removed from the property by PRI prior to the sale of the property in 1997, except for the office building located near Alexander Avenue (CRA 2013, Ecology and Environment 1990).

- OCC Tacoma, Inc. ownership, 1997 to 2001: In 1997 the 709 property was purchased by OCC Tacoma, Inc. (a former subsidiary of OCC) and in 2001 it was transferred to Mariana (CRA 2013).
- Mariana Properties, Inc. ownership, 2001 to present: The 709 property was used briefly during the winter of 2002–2003 to temporarily stage treated sediments removed by OCC from the Hylebos Waterway (Area 5106 Removal Action) under EPA oversight (EPA 2020). Dredged sediments were stored and treated on the adjacent 605 property then stockpiled on the 709 property prior to being loaded onto barges for final disposal in the confined disposal facility located at Slip One. The sediment storage area is visible in a 2003 aerial photo. In addition to the historical industrial infrastructure of the 709 property, industrial material including wastes and debris (e.g., bricks, fibrous material, and graphite anodes) from the former OCC facility located at 605 Alexander Avenue, among other sources, was used as embankment fill in a portion of the 709 property adjacent to the Hylebos Waterway (CRA 2012). The dates of this fill placement are uncertain. The fill area is listed as facility-site number 1246 in Ecology's cleanup site database and is subject to Agreed Order DE 16943 as part of the Occidental Site. The office building located on the 709 property near Alexander Avenue was removed during the removal of buildings and structures at 605 Alexander Avenue between 2006 and 2008.

The 709 property is currently secured by fencing, without structures, and largely unpaved (except for a gravel road and small asphalt pad).

### 1.2.2 721 Property (Including 717 Property)

Prior to 1920, the 721 property and adjacent area were undeveloped tidal mudflats. Between 1920 and 1931, the area was filled with approximately 16 ft of dredge material, primarily sand, as part of an upland expansion project. Known historical ownership and usage of the 721 property are summarized below; referenced historical aerial photographs and site maps are included in Appendix A.

- H.D. Maxwell and Josephine E. Maxwell ownership, 1935 to 1951: In 1935, H.D. Maxwell announced plans to develop a 4.5-acre parcel along Hylebos Waterway for his company, the Maxwell Petroleum Corporation (Maxwell), to operate a gas and oil distribution facility (Tacoma Sunday Ledger 1935). In 5 years, H.D. Maxwell had grown the fuel terminal at 721 Alexander Avenue to a capacity of 5 million gallons. The company had become the state's largest independent petroleum distributor, providing service to 165 service stations (The Daily Chronicle 1941, Guthrie 1942). The terminal mostly handled gasoline but also offered products for wholesale, including stove oil, diesel, industrial fuel oil, and road oils. Shipments were received by tanker from Los Angeles and split between Maxwell and Fletcher Oil Company. Fletcher Oil Company occupied the fuel terminal adjacent to the north on the 709 Alexander Avenue property (Guthrie 1942). During World War II Maxwell leased the facility to the US government.

The earliest known photographs of the 721 facility, taken some time between 1936 and 1946, show seven large ASTs, a fuel tanker docked on the Hylebos Waterway with an oil sheen visible in the water, and a large pit filled with liquid in the bermed area at the western end of the property. A feature that appears to be a berm in a semi-circular shape is present to the south of the parcel. An appraisal drawing from 1940 shows the large ASTs labeled "diesel, fuel, 1st grade, 3rd grade, ethyl, and stove oil." The drawing includes an office, garages, several pump houses, several smaller ASTs, a fire house, a spur track, a car loading and truck loading rack, a dock, and a fire wall, or dike, surrounding the large ASTs (Appendix A; Maxwell Petroleum Corp. "Site Plan" 1940). Available evidence indicates the unlined pit visible in the photographs was used to manage waste disposal and containment (including tank-bottom wastes and spills) and to manage stormwater. Open air pits, sludge pits, or atmospheric treatment ponds (these terms are synonymous) were historically used to manage waste at facilities storing and distributing fuels, oils, other petroleum products, and other hazardous substances. Operators used sludge pits when they were trying to keep fuel quality high and did not have time to dispose of tank bottoms by other means. Lighter petroleum waste was removed by volatilization and the remaining heavier petroleum residue was skimmed off and burned. The remaining impacted water would have been discharged or allowed to infiltrate (Lidiak 2019).

In 1943 Maxwell Petroleum Corporation merged with the General Petroleum Corporation, (Seattle Daily Times 1943).[9] General Petroleum Corporation was a fully owned subsidiary of Socony (acronym for Standard Oil Company of New York) and the merger created one of the largest gasoline distributers in the Unites States (APS 2019). In November 14, 1951, General Petroleum Corporation purchased the parcel from H.D. Maxwell and Josephine E. Maxwell and sold the property to the US government a week later (Chicago Title 2009).

- US Air Force ownership, 1951 to 1966: The US government purchased the 721 property from General Petroleum on November 14, 1951. The facility's operation was managed by the USAF and was most commonly referred to as the "Tacoma Air Force POL Retail Distribution Station."[10] The facility was responsible for USAF fuel and petroleum products supply for the entire northwestern part of the United States, including McChord Air Force Base. In 1952 up to 1.5 million gallons of aviation gasoline were being handled each month (USAF 1952). Facility operation was contracted with New England Tank Industries (NETI) and Pacific Terminal Company (USAF 1954, NETI 1960).

  During USAF ownership, 1951 to 1966, the configuration of the 721 property appears to have remained largely unchanged from Maxwell and General Petroleum operations; however, USAF records indicate new tanks were considered and some improvements were completed. In 1952, USAF approved funds to decontaminate and paint some of the tanks. The same year additional funds were requested to rehabilitate the entire facility. Language in the request suggests infrastructure was in poor condition at the time of the property transfer, "the proposed project has been reduced to bare necessities for the successful and safe operation of the plant" (USAF 1952).[11] It is unclear from the documents available if facility rehabilitation

[9] General Petroleum Corporation, via mergers and acquisitions, eventually became part of Exxon Mobil Corporation in 1999 (State of New York 1959, 1966, and 1976, Moody's 1960, State of New Jersey 1999).

[10] Available documents also refer to the facility as the "Aviation Gasoline Terminal," and the "Tacoma P.O.L. Depot."

[11] The letter includes the following description of work, *"…Reference is made to Project 02B115 recently approved in the amount of $9,937, which covers only the decontamination and painting where necessary of the four remaining unusable tanks and the minor rehabilitation of the main office building. This prove proposed the complete remaining rehabilitation of the entire plant, including the following: Repair of seams, etc. on Tank #4; removing where necessary and rerouting the piping*

was completed. Aerial photography from July 1953 shows what appear to be freshly painted tanks.

In 1956, the USAF proposed increasing the facility's fuel storage capacity by erecting an 80,000-barrel tank in the sludge pit area (US Army Corps of Engineers [USACE]a). However, the large tank would have been too close to the adjacent 709 property to the north and too close to the rail line to the south to meet safety standards. The tank size was reduced to 30,000-barrels (USAF 1956, 1957a and b). Updated plans for the smaller tank included abandoning the sludge pit (labeled "old tile field," with a note regarding excavation volumes) and disposing of the excavated material outside the berm (labeled "Former Earthen Disposal Area;" USACE b and c). A review of available aerial photographs indicates that the preparatory earthwork was completed by 1960: the soil in the sludge pit area is lighter in color than in earlier historical photographs and the boundaries inside the berm are more sharply defined, indicating abandonment was completed and the surface regraded; and in the "Former Earthen Disposal Area" six smaller ASTs were removed, and the area appears empty except for bare dirt (1960 and 1961 aerial photography; Appendix A). The new tank was never installed. The work was completed sometime between 1958 and 1960.[12] Even after the sludge pit was abandoned the area remained the de facto catchment for stormwater and spills since the berm remained in place and no surface drainage infrastructure was added to the facility. A 1959 inventory sheet listed an incinerator, which may have been used to burn off petroleum residue skimmed from the sludge pit (Unknown 1959). In 1990 the same area was identified by EPA contractors as the "Former USAF Sludge Area," but a source for this information is not listed (Ecology & Environment 1990). Available evidence indicates that the unlined sludge pit continued to be used by USAF and its contractors to manage waste disposal and containment (including tank-bottom wastes and spills) and to manage stormwater.

In 1957 a few of the tanks were deemed "unsafe due to obsolete design, [and] are in poor condition," (USAF 1957a), and by 1959 Tanks 1, 2, and 3, were leaking (Unknown 1959). USAF continued to use the facility to store aviation and jet fuels until approximately 1964, when the cost to take care of deferred maintenance became too great. In 1965, the USAF transferred 0.71 acres of the former 721 property along the Hylebos Waterway (including the shoreline and a dock) to the Navy, which became present-day Parcel 2275200532 (717 property). By 1966, USAF had determined the facility was surplus and sold the property to the Port. At the time of the sale, the four riveted tanks (tanks 1, 2, 3, and 4) were not usable. Tanks 6, 7, and 11 were in good condition (Steel 1966; tank numbers are presented in Figure 1-4).

- <u>Port of Tacoma ownership, 1966 to present</u>: Between 1969 and 1982, the Port leased the former 721 property to Fletcher, a wholly owned subsidiary of Sinclair Oil Corporation, for operation as a gasoline and diesel fuel terminal. Fletcher leased tanks 4, 6, 7, and 11 and 4.1 acres of land. United Independent Oil, a wholly owned subsidiary of Fletcher, operated the facility.[13] In 1973 tanks 1, 2, and 3 were removed by Don Oline Trucking Co. Fletcher sub-leased tank 4 to Lilyblad. In 1980, the Port required that Lilyblad lease tank 4 directly from the

*system; installation of new fencing; installation of new truck fill stands and appurtenant facilities; installation of new car loading facilities; repairs and rehabilitation of the dock including walkways and dolphins; installation of fire protection system, and other minor construction, rehabilitation and fire protection items."*

[12] The drawing, USACEb, is not dated; however, it includes soil boring explorations completed in 1958 and aerial photographs. Changes are visible in a 1961 aerial photograph.

[13] Also referred to as United Industrial Refining in the Port of Tacoma Real Estate file.

Port.[14] Lilyblad initially used tank 4 for diesel fuel storage, after 1981 it was used to store calcium chloride (AGI Technologies 1995).

In 1979 PRI Northwest (PRN), a subsidiary of Pacific Resources Inc. (PRI),[15] assumed control of Fletcher's wholesale fuel oil assets and began operating the Fletcher facility at 721 Alexander. The lease with the Port was not transferred to PRN until 1982.

In 1983 operation of the property as a fuel terminal ended. The ASTs, buildings, and associated infrastructure were removed from the property and the property was paved. Since 1983, the Port has leased the property to multiple organizations for aboveground commercial storage (primarily trucks and shipping containers).[16]

In 2011 the Port acquired the title for the shoreline 0.71-acre 717 property parcel.

Today, the former 721 property is part of an approximately 33-acre leasehold granted to Puget Sound Energy for the development of a liquefied natural gas (LNG) storage and distribution facility. Plant infrastructure is being constructed on the southern two-thirds of what is now the 1001 property. No construction activities are planned for the approximately 4.5 acres that were formerly the 721 Alexander Avenue petroleum tank farm, except for the addition of landscaping along the Hylebos Waterway. The former 721 property is currently used for parking and construction storage.

### 1.2.3 500 Property/Alexander Avenue ROW

Prior to 1920, the 500 property, adjacent Alexander Avenue ROW, and surrounding area were undeveloped tidal mudflats. Between 1920 and 1931, the area was filled with approximately 16 ft of dredge material, primarily sand, as part of an upland expansion project. Known historical ownership and usage of the 500 property are summarized below; referenced historical aerial photographs and site maps are included in Appendix A.

- Alexander Avenue ROW: The Alexander Avenue roadway has been present since at least the 1930s and the associated rail lines have also been present since at least the 1940s. The Alexander Avenue ROW currently includes a paved two-lane motor vehicle roadway and a three-track rail line system operated by Tacoma Rail.
- Peterman Manufacturing Company/US Navy ownership, 1926 to 1960s: The 500 property (TOTE property; Figure 1-2) was historically part of the US Naval Station in the 1940s and 1950s. Prior to development as a Naval Station, the northern half of the 59-acre parcel was owned by the Peterman Manufacturing Company. The company bought 25 acres in 1926 and built a plywood mill and door plant, the plant can be seen in the 1931 aerial photograph. In 1942 the Federal Government ordered Peterman to vacate for conversion of the site into a shipyard for baby flat-tops (Plywood Pioneers Association 1969).

  Sometime between 1940 and 1944 the acreage to the south, between Peterman Manufacturing Company and East 11th Street, was developed into a warehouse and rail-supported storage yard. The warehouse and railyard were either originally developed as part

[14] Source: Port of Tacoma Real Estate files.
[15] In 1989 PRI was acquired by The Broken Hill Proprietary Company Limited (BHP). Source: https://www.upi.com/Archives/1989/01/09/Pacific-Resources-to-merge-with-Australian-company/9370600325200/
[16] Source: Port of Tacoma Real Estate files.

of the Naval Station, or was the property was acquired by the Navy soon after site development (see 1953 photograph of warehouse and baby flat-tops).

- Port of Tacoma ownership, 1960s to present: The Port purchased all 59 acres from the Navy in the 1960s and used it as a storage yard and warehousing facility into the 1970s. In 1983, the property was developed for its current use, a maritime cargo terminal for TOTE.

Navy drawings depict a UST, "Oil Tank 11," directly across Alexander Avenue from the 709/721 property boundary (Navy 1949). A prior investigation of the UST, identified as "N-11" by the Port, did not identify the presence of the UST; however, petroleum impacts were detected in the soil and groundwater in the vicinity of the former tank pit (Aspect 2016, Hart Crowser 2012). Contamination on this property and ROW is concluded to have originated from the former petroleum tank farm properties (709 property and former 721 property; Aspect 2016). However, it is conceivable that if the UST N-11 did leak, the release is indistinguishable from the release from the tank farm properties.

### 1.2.4 1001 Property

This current address, 1001 Alexander Avenue, includes what used to be three separate parcels: 721 Alexander Avenue (see section 1.2.2), 905 Alexander Avenue, and 901 Alexander Avenue (Figure 1-2). The former 905 and 901 parcels were part of the shipbuilding facilities owned and operated by the US government on most of the Hylebos Peninsula during World War II. Post-war the properties became part of the Naval Station for the berthing, maintenance, and dismantling of ships (Navy 1949). The property was acquired by the Port in 1959.

Today, the 1001 property is currently a leasehold granted to Puget Sound Energy for the development of an LNG storage and distribution facility. Plant infrastructure is being constructed on the property.

## 1.3 Site Hydrogeology

A full description of the environmental setting of the Site (including topography, geology, hydrogeology, climate, ecological, cultural resources, existing infrastructure, and potential sources of contamination) is described in detail in the RI report. Relevant information regarding the hydrogeologic setting of the Site is summarized here. The Site is located within the historical Tacoma Tideflats. The ground surface at the Site is mostly flat and at an average elevation of approximately 12 ft National Geodetic Vertical Datum of 1929 (NGVD29). Subsurface soil at the Site is comprised of dredged fill material underlain by native tideflat deposits underlain by stratified deltaic deposits underlain by Vashon-age glacial deposits. The dredged fill material is approximately 16–20 ft thick; the native tideflat deposits are approximately 5 ft thick and include a clayey unit that is between approximately 0.5 and 3 ft thick; the native deltaic deposits extend to a depth of between 180 and 220 ft below ground surface (bgs); and the glacial deposits extend to an estimated depth of at least 800 ft bgs. For the purposes of the RI report (and following the Occidental Site characterizations), the subsurface soil relevant to soil and groundwater contamination at the Site was characterized by three distinct depth zones as follows:

- 15-ft zone: The 15-ft zone is the uppermost unconfined (water table) water-bearing unit, which occurs between the water table and the native tideflats deposit. The water table generally occurs in the elevation range of 2–6 ft NGVD29 (5–9 ft bgs). The native tideflat deposits represent a leaky aquitard unit and are present at approximately -5 ft NGVD29. The 15-ft zone is at the approximate same elevation as the intertidal zone near the Hylebos waterway. During lower low-tide stages, generally diffuse, low-volume seepage is visible on the intertidal beach at the base of this zone, just above the native tideflat deposits, at approximately -5 ft NGVD. This zone is comprised primarily of dredged fill material. The fill material is generally fine-grained sand with trace silt.
- 25-ft zone: The 25-ft zone includes the native tideflats deposits (approximately -5 to -10 ft NGVD29), and the uppermost sandy deltaic deposits beneath the native tideflats deposits, to the top of a deeper silt-clay later at approximately -20 ft NGVD29. Monitoring wells in this zone are generally screened from -10 to -20 ft NGVD29. The 25-ft zone generally include elevations within the subtidal zone near the Hylebos waterway, through the uppermost 2–3 ft of the 25-ft zone can be intertidal during periods of tidal extremes. The native tideflats deposits consist of silty sands, sandy silty, or clays, and have a slightly higher organic content (wood fibers) compared to the fill unit.
- 50-ft zone: The 50-ft zone consists of native sandy deltaic deposits located below a deeper silt/clay confining unit present at -20 to -25 ft NGVD29. The silt/clay confining unit range in thickness between 9.5 and 25 ft and is present in all 50-ft zone monitoring well logs within the 709 and 1001 properties. The 50-ft zone generally extends from -30 to -40 ft NGVD29.

Geologic cross sections displaying these intervals are shown on RI Figures 6.4-6A and 6.4-6B. For consistency with the RI report, the naming conventions for these hydrostratigraphic unit distinctions have been adopted for the FS report.

Groundwater flow across the Site is generally toward the water bodies in the east (Hylebos Waterway) and west (Blair Waterway) from a groundwater divide running approximately north-south across the western portion of the 709 and 1001 properties. Horizontal hydraulic gradients in the 15-ft zone are between 0.001 and 0.003 feet per foot (ft/ft) and those for the 25-ft zone are between 0.003 and 0.007 ft/ft. A downward vertical hydraulic gradient between the 15-ft and 25-ft zones is reported in the RI between 0.1 and 0.3 ft/ ft in the western and central portions of the 709 property and former 721 and 905 properties, indicating groundwater recharge from the surface. A larger downward vertical gradient (up to 0.6 ft/ft) between the 15-ft and 25-ft zones toward the eastern edge of the Site is likely influenced by tidal fluctuations in the Hylebos Waterway. According to the RI report, there appears to be a minimal or neutral vertical hydraulic gradient between the 25-ft and 50-ft zones.

Horizontal hydraulic conductivity (K) values at the Site are reported in the RI (CRA 2015, Aspect 2016) to be between approximately 0.3 and 30 feet per day (ft/day) for the 15-ft zone and approximately 0.03 and 30 ft/day for the 25-ft zone.[17] Based on literature values (McWhorter and Sunada 1977), the

[17] These ranges of hydraulic conductivity are based on slug tests (Aspect 2016) performed on various monitoring wells and represent estimates at the specific locations and depths of the monitoring well screens; they are assumed to be generally

fine- to medium-grained SP sand predominant at the Site could be expected to exhibit a K of 10–20 ft/day; the average of 15 ft/day is near the middle of the K range from the RI. A coarse SP sand would have a K near 30 ft/day, the upper end of the K range presented in the RI.

Estimated average seepage velocities (Vs) reported in the RI report range from 0.3 to 160 feet per year (ft/year; cited average of 8 ft/year) for the 15-ft zone and from 0.09 to 380 ft/year (cited average of 7 ft/year) for the 25-ft zone. The "average" Vs values presented in the RI are very near the low end of the presented ranges. LAI's further evaluation of Vs within the 15-ft zone as a basis for bioremediation design and costing (i.e., for estimation of the downgradient transport of injected substrates) utilized the middle-range K value of 15 ft/day (described above) and values for hydraulic gradient (0.0014–0.002 ft/ft)[18] and effective porosity (20–35 percent, 25 percent assumed average) as presented in the RI. Our evaluation results in a somewhat higher Vs of 31–44 ft/year. A summary of hydraulic properties of the subsurface materials beneath the Site is included in the table below.

**Summary of Hydraulic Parameters**

| Variable | Aquifer Zone | RI | Literature Values | Values Applied in the FS |
|---|---|---|---|---|
| **Hydraulic Conductivity (K)** | 15-ft | 0.3 to 30 ft/day | 10 to 20 ft/day (fine to medium grained sand) | 15 ft/day |
| | 25-ft | 0.03 to 30 ft/day | 30 ft/day (coarse sand) | 30 ft/day |
| **Hydraulic gradient (i)** | 15-ft | 0.001 to 0.003 ft/ft | -- | 0.0014 to 0.002 |
| | 25-ft | 0.003 to 0.007 f/ft | -- | NA |
| **Effective porosity (n_eff)** | 15-ft | 20 – 35%, literature derived, 25% assumed average | -- | 25% |
| | 25-ft | 20 – 35%, literature derived, 25% assumed average | | 25% |
| **Seepage velocity (Vs) Vs = (K*i)/n_eff** | 15-ft | 0.3 to 160 ft/year, average 8 ft/year | -- | 31 to 44 ft/year |
| | 25-ft | 0.09 to 380 ft/year, average 7 ft/year | -- | NA |

applicable to the respective depth zones but can vary from actual *in situ* hydraulic conductivity values which can be affected by local silt or clay lenses.

[18] This gradient is based on calibrated simulated groundwater level contours in the western portions of the 709 and 721 properties (GHD 2017a).

## 1.4 Previous Site Investigations

Environmental investigations at the Site to date have been conducted to characterize and evaluate the chemical quality and physical condition of soil, groundwater, and sediment. Investigations were conducted from 1989 to 2015, culminating in preparation of the RI report (Aspect 2016). These investigations are detailed in the RI report and not repeated here. Site features and all investigation locations are shown on RI Figure 4.1.

## 1.5 Previous Interim Actions/Remedial Actions

Two individual UST removals on the 709 property are known to have occurred at the Site:

- A leading plant waste UST and associated soils were removed in 1989 and four soil samples were collected from the sidewalls of the excavation (Hart Crowser 1990).
- A heating oil UST located adjacent to the 709 property office building was removed in 1996 (CRA 2013). No soil samples were reportedly collected from the UST removal.

While no documentation of removal of the UST on the 500 property has been identified, a geophysical survey and push probe investigation in 2012 confirmed that the UST is no longer present (Hart Crowser 2012).

No other interim actions or remedial actions are documented for the Site.

## 1.6 Anticipated Impacts of Occidental Site Remedy to Site Hydrology and Contaminant Fate and Transport

Modifications to Site hydrology and contaminant fate and transport caused by implementation of the Occidental Site remedy are recognized as an “existing condition” for the purposes of this FS. This existing condition is taken into consideration as part of the evaluation of Site remedial technologies and alternatives; however, it is not relied upon for the efficacy of any of the alternatives. All alternatives were designed to meet the requirements of the MTCA rules and to achieve a “CERCLA-quality cleanup” under both current conditions, prior to implementation of the Occidental Site remedy, and after the implementation of the Occidental Site remedy. However, some technologies incorporated in the alternatives do rely on groundwater transport to deliver amendments to the subsurface. For these components the timing of the Occidental Site remedy and establishment of steady state groundwater flow conditions may need to be considered during design.

The Occidental Site FS evaluates more than 20 remedial alternatives, including 3 hydraulic containment alternatives, 11 volatile organic compound (VOC) mass removal alternatives, and 6 additional alternatives to reduce or enhance the containment of the pH plume. The Occidental Site FS’s preferred alternative consists of VOC source area mass reduction by strategic groundwater pumping combined with appropriate containment technologies from the containment alternative utilizing 50 percent more pumping than the base hydraulic containment alternative. Elements of the preferred alternative include institutional controls; groundwater quality monitoring; soil vapor monitoring; a physical direct-contact exposure (PDCE) barrier for the 605 and 709 properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile vertical barrier wall between the Site and the Hylebos Waterway; groundwater pumping from 11–13 extraction wells (9 for VOC source area mass reduction by strategic groundwater pumping plus 2–4 additional wells); and *ex situ* treatment of extracted groundwater through a newly constructed conveyance and treatment system.

Ecology has prepared a responsiveness summary based on public comments regarding the Occidental Site FS. Ecology has not yet selected a remedy for the Occidental Site. OCC and Ecology are currently in the process of preparing a dCAP for the Occidental Site pursuant to Agreed Order DE 16943. Whichever remedy is ultimately selected, several consistent components across all remedial alternatives will alter the area's groundwater flow regime and will have a positive impact on the fate and transport of both VOC and TPH contamination currently present on the Site (i.e., will enhance flushing and natural attenuation).

A summary of the planned components of the Occidental Site FS's preferred alternative is shown on Figure 1-5. The components will consist of a 2,200-ft long sheet pile wall (70–75 ft deep) at the shoreline and between 11 and 13 groundwater extraction wells.[19] The sheet pile wall will extend along the Hylebos Waterway shoreline at the Occidental Site and at the Site; the wall will extend along the entire shoreline of the Mariana property (709 property) and approximately 60 ft along the Port property (current 717 property/former 721 property). The groundwater extraction wells for the Occidental Site FS's preferred alternative will be located on the 605 property and on the TOTE property and will be operated for cVOC mass removal and containment. Two additional wells may be located in the northern portion of the 709 property for enhanced containment.

Once implemented, the Occidental Site remedy components (planned to commence around 2022-2023 based on current estimated project schedule) are predicted to capture and remediate the Occidental Site groundwater plumes. Based on groundwater modeling data provided by the Occidental Site design team, the combination of the sheet pile wall and extraction wells is anticipated to result in modified hydraulic conditions at the Site. Simulated groundwater elevation contours and groundwater flow directions from the Occidental Site calibrated groundwater flow model for the preferred alternative are presented on Figure 1-5 (GHD 2017a); groundwater contours for the site under non-pumping conditions are shown in the Occidental Site Characterization report (CRA 2015; Figure 3.77). Operation of the Occidental Site groundwater extraction and treatment (GET) system is expected to shift groundwater flow directions across much of the Site from the current easterly and westerly flows toward the Hylebos and Blair Waterways, respectively, to northerly flow patterns toward the Occidental Site extraction wells, as well as steepen hydraulic gradients in the new northerly flow directions. The Occidental Site groundwater flow model predicts that 79 percent of

[19] Figure 1-5 shows the 11 extraction wells pertaining to the Occidental Site FS's preferred remedy.

benzene in the 15-ft zone will be captured under the pumping configuration of the Occidental Site FS's preferred alternative (Massman 2018).[20] Plume capture analysis is presented in Appendix B.

As a result of the changed hydraulic conditions, the Occidental Site GET system is anticipated to result in enhanced attenuation of Site cVOCs and TPH through increased groundwater flushing across most of the Site, thereby increasing advective transport and enhancing contaminant mass removal from the Site. The new northerly groundwater flow direction is also expected to enhance comingling and bioremediation of TPH and cVOCs where cVOCs are present in the northeast portion of the Site and on the 605 property. Microorganisms require both electron acceptors for respiration and electron donors as food for metabolism. Bioremediation of Site IHS involves microbial metabolism of TPH (electron donor) and cVOCs (electron acceptor), resulting in enhanced bioremediation of both contaminants. Additionally, the change in groundwater flow resulting from Occidental Site GET will draw clean groundwater through the TPH plume, adding electron acceptors naturally present in groundwater outside the petroleum plume (primarily sulfate and potentially nitrate and dissolved oxygen).[21] The addition of these electron acceptors and the increase in flushing is expected to enhance current petroleum attenuation rates at the Site.

Two areas of Site contamination are predicted not to be affected by the Occidental Site remedy. South of the end of the Occidental Site sheet pile wall, a shoreline wedge of the Site near the Hylebos Waterway is predicted not to be significantly influenced by the Occidental Site GET system and groundwater will continue to flow to the Hylebos Waterway. Groundwater near the distal portion of the plume extending west to the Blair Waterway is also predicted not to be significantly influenced by operation of the GET system; see figures presented in Appendix B.

[20] The capture analysis assumes that benzene travels with the velocity of the groundwater. It should be noted that the capture analysis does not consider sorption, other retardation processes, or contaminant degradation.

[21] Geochemical evaluation of the Site groundwater data found that electron acceptors nitrate, nitrite, and sulfate have been consumed and are depleted in the petroleum-impacted area (Port 2017).

# 2.0 CONCEPTUAL SITE MODEL

This section summarizes the nature and extent of contamination, as documented in the RI report (Aspect 2016). The RI identified IHS for the Site as benzene, TPH-G, TPH-D/O, and the cVOCs PCE, TCE, and VC. The more detailed documentation of the nature and extent of contamination as presented in the RI is not repeated here. Petroleum hydrocarbon contamination is present at the Site as LNAPL. Benzene, TPH-G and TPH-D/O are present in soil and groundwater. The Site does not include intertidal/subtidal areas in the Hylebos Waterway because they are part of the larger Commencement Bay/Nearshore Tideflats (CBNT) Superfund Site. Sediments were investigated in the RI, and sediment quality was determined not be a threat to aquatic life based on bioassays. Chlorinated VOCs are present in groundwater in the north/northeast portion of the Site and will be addressed by the Occidental Site remedy.

Since the drafting of the RI, the conceptual site model (CSM) has evolved as new data and historical documents are added to the project library. Five key efforts have advanced the CSM since finalization of the RI:

- Additional groundwater and seep sampling and analysis (Port 2017),
- Natural attenuation and restoration time frame analysis (Port 2017; Appendix F),
- Hot Spot analysis (Appendix C),
- Ongoing research into corporate ownership and operational history at the Site (Cited Documents), and
- Video inspection of the Alexander Avenue sanitary sewer.

Most noteworthy are the overall Site data, the results of the hot spot analysis (analytical methodology is presented in Section 2.1 and 2.3), and the operational history research, all of which indicate that the soil hot spots are the result of on-Site management and disposal of wastes containing hazardous substances. The CSM is depicted in cross-section on Figure 2-1.

## 2.1 Extent and Sources of Site Contamination

The Site, as defined per MTCA in Section 1.1, includes various parcels where hazardous substances have come to be located. The extent of Site contamination is presented relative to current and historical parcels on Figures 1-2 and 1-3a (black, dashed line), respectively. The Site covers more than 18 acres.

Sediment quality was investigated during the RI by sample collection and analysis as well as confirmatory bioassay testing. All sediment samples evaluated with bioassay testing passed by overall determination and by individual biological tests. Therefore, Ecology determined that sediments would not be included in cleanup actions at the Site. Additionally, intertidal/subtidal areas in the Hylebos Waterway were addressed under the CBNT Superfund Site, which is under EPA jurisdiction. The remainder of this section provides background on the extent and sources of contamination in Site soil and groundwater.

Considering the large area of the plume and difficulty inherent in designing cleanups at sites with large footprints, Ecology conducted ArcMap Geostat Hot Spot Analysis to identify areas of concentrated petroleum mass that could be targeted as part of the remedy (Ecology 2018a; Appendix C). Hot Spot Analysis of TPH soil data identified two distinct hot spots, one in the central-eastern area of the 721 property, and the second at the west end of the 721 property extending north beneath the 709 property and underneath the Alexander Avenue ROW. The groundwater divide runs generally north-south, and roughly between the two hot spots. Based on groundwater flow direction, the hot spot to the east of the divide is referred to as the Hylebos Hot Spot, and the hot spot to the west as the Blair Hot Spot. There is some uncertainty, and likely some seasonal variability, as to the specific location of the hydraulic groundwater divide.

In addition to storage and distribution of petroleum products, the Blair Hot Spot and the Hylebos Hot Spot are specifically in areas historically used to manage onsite waste disposal and containment. The 721 property historically included an unlined pit that was used to manage waste disposal and containment (including tank-bottom waste and spills) and to manage stormwater. The Blair Hot Spot is beneath and downgradient of the deeper side of the pit, appearing to be the result of infiltration of wastes containing hazardous substances disposed in the pit and of spills contained in the pit. During USAF ownership, the sludge pit was excavated to prepare for a proposed aboveground tank, and contaminated soil was disposed of along the south-central property boundary. The Hylebos Hot Spot is beneath the disposal area.

The Blair Hot Spot intersects with the City sanitary sewer line in the Alexander Avenue ROW. In January 2018 the City received a complaint of fuel in the downgradient pump station at the intersection of Alexander Avenue and Lincoln Avenue.[22] The City traced the petroleum upgradient to a section of pipe between Manhole 30 (currently named Manhole 6773134) and Manhole 31 (currently named Manhole 6773138). A video survey completed by the City on May 9, 2019 shows discoloration around a sanitary sewer cleanout joint that enters the line from the 721 property, 110 ft down pipe from Manhole 30, within the footprint of the Blair Hot Spot. This same location was identified as having a leaky joint by a 1991 survey (Aspect 2016).

Other potential sources of contamination associated with historical operations include leaks at pipe connections, valves, pump houses, and loading racks. Additionally, the 709 property included the leading plant and crude oil topping plant, two USTs on the 709 property (one used to collect waste material from the tetraethyl leading facility; these USTs and associated soils were removed in 1989), and documented spills (CRA 2012, Aspect 2016):

[22] Petroleum sheen was discovered in this sewer line in 1984, which resulted in the initial environmental investigations at the 709 and 901 properties. Section 6.2 of the RI provides additional information on historical releases to the sanitary sewer.

- a 1979 gasoline spill (69 gallons);
- spills during 1981 from leaking valves (gasoline, diesel, and/or fuel oil); and
- a 1981 diesel spill (300 gallons).

Historical releases of chlorinated solvents on the adjacent Occidental Site to the north appear to be the primary source of cVOCs that are primarily present in the north and northeastern portions of the Site. However, other potential sources of chlorinated solvent contamination associated with historical operations on the Site include placement of embankment fill, a 5,000-gallon solvent tank identified on the 1950 Sanborn map of the 721 property, probable use of unknown solvents and other materials for various purposes, including cleaning of tanks and equipment, and a documented spill in 1981 of Safety-Kleen aliphatic solvent associated with Lilyblad on the 721 property (unknown volume and location; CRA 2013).

The RI identified IHS for the Site as benzene, TPH-G, TPH-D, TPH-O, and the cVOCs PCE, TCE, and VC.

## 2.2 Light Non-Aqueous Phase Liquids

Petroleum hydrocarbons are present as LNAPL over a significant portion of the Site. The LNAPL footprint is nearly identical in location and extent to the Blair Hot Spot and Hylebos Hot Spot. The estimated extent of LNAPL or potential LNAPL, based on LNAPL measured in wells and sheen observed in soil boring samples during the RI, is presented in Figure 1-4.[23]

## 2.3 Soil Quality

Soil exceeding RI screening levels (SLs) for TPH compounds extends over most of the Site. RI SLs consist of MTCA Method A CULs for TPH-G (30 milligrams per kilogram [mg/kg]), total TPH D/O (2,000 mg/kg), and benzene (0.03 mg/kg). The extent of soil with total petroleum hydrocarbon concentrations exceeding the RI SLs and the extent exceeding CULs proposed in this FS (17,000 mg/kg total TPH and 2.4 mg/kg benzene; see Section 3.4.2) are presented on Figure 2-2.

Soil contamination is predominant in the vadose zone (0–5 ft bgs) and smear zone/shallow saturated zone (5–15 ft bgs), and present to a lesser degree in the deep saturated zone (15–30 ft bgs). The removal of the accessible area of TPH soil contamination over site SLs (smear zone) from 0 to 9 ft bgs provides the basis for Remedial Alternative 6 (see Section 5). [24]

[23] This LNAPL extent is based on all of the boring observations and monitoring well LNAPL measurements conducted during the course of the RI. The resulting extent is somewhat greater than the LNAPL extent presented in RI Figure 6.2-2, which was based on a single monitoring event in October 2014.

[24] The smear zone at the Site is generally between 5 and 9 ft bgs and is on average approximately 2 ft thick (Aspect 2016). The majority of contaminant mass is in the smear zone. For this reason, and because excavation would be limited to roughly 9 ft bgs (2 ft below average dry season water table), the hot spot data analysis included samples collected between 5 and 10 ft bgs.

TPH soil data collected to date at the Site was evaluated by Ecology (Ecology 2018a) using ArcMap Geostat Hot Spot Analysis, which identified distinct "hot spots" (statistically significant spatial clusters of high concentrations of TPH in soil samples in smear zone/shallow saturated soils; see Appendix C). This analysis was also supplemented by an evaluation by the Port of benzene in soil samples (also included in Appendix C). Based on these hot spot evaluations, hot spots are defined by a sum total of TPH (TPH-G plus TPH-D/O) concentrations of 19,000 mg/kg or higher and/or benzene concentrations of 19 mg/kg or higher. Soil hot spots are shown on Figure 2-3. This hot spot definition provides the basis for the areas of the hot spot remedial actions proposed in Remedial Alternatives 3 and 4.[25]

Low levels of chlorinated solvents, primarily PCE, have been detected sporadically in soil at the Site (see RI Figures 6.3-10 through 6.3-15). The concentrations detected are low and not considered risk drivers,[26] nor are they expected to affect the scope of potential Site remedial actions. Detection of PCE and TCE in soil above MTCA Method A soil CULs for industrial properties, 0.05 mg/kg and 0.03 mg/kg, respectively, are presented on Figure 2-2.

## 2.4 Groundwater Quality

Site groundwater is impacted by petroleum hydrocarbons and cVOCs. The following sections summarize the nature and extent of these contaminants and other applicable hydrologic considerations.

### 2.4.1 Petroleum Hydrocarbons in Groundwater

Petroleum hydrocarbons in groundwater exceed RI SLs and/or groundwater CULs proposed in this FS (see Section 3.2.1) over most of the Site and extend to the Hylebos Waterway and potentially to the Blair Waterway, as summarized below. RI SLs (and proposed cleanup levels [pCULs]) for TPH-G and TPH-D/O consist of MTCA Method A CULs (800 micrograms per liter [µg/L] for TPH-G and 500 µg/L for TPH-D/O). The RI SL for benzene for groundwater for the vapor intrusion (VI) pathway is 24 µg/L; however, the pCUL for benzene is 1.6 µg/L.[27] The combined areas of groundwater level exceedance for TPH for the 15-ft zone and 25-ft zone (with TPH-D/O analysis with and without silica gel cleanup [SGC]) are shown in Figures 2-4A through 2-4D; and the areas of benzene contamination are shown for the 15-ft zone, 25-ft zone, and 50-ft zone in Figures 2-4E through 2-4G. The following conclusions are based on observations made from these figures:

- When analyzed with SGC, the area with TPH-G and/or TPH-D/O concentrations above the CULs extends over most of the Site and to the Hylebos in the 15-ft zone, but TPH-G and TPH

[25] The total TPH hot spots comprise an estimated 44 percent of the TPH mass between 5 and 10 ft bgs and 25 percent of the area and volume of soil exceeding TPH MTCA CULs. The benzene hot spot comprises approximately 55 percent of the benzene mass between 5 and 10 ft bgs and 5 percent of the soil volume greater than the MTCA CUL.

[26] All soil concentrations of TCE and PCE were below the Method C calculated SL values for direct contact (Aspect 2016).

[27] For protection of marine surface water. The SL was listed as 58 µg/L in the RI; however, the marine surface water criteria has since been updated based on protection of human health and was promulgated under WAC 173-201A (effective September 1, 2016).

D/O are not detected above CULs in the three seep sample locations along the Hylebos, and are present in only a small area of groundwater around the Blair Hot Spot in the 25-ft zone.

- When analyzed without SGC, the area with TPH-G and/or TPH-D/O concentrations above the CULs extends over most of the Site and to the Hylebos in both the 15-ft and 25-ft zones and TPH-D/O been detected above the CULs at each of the three seep locations.
- The CUL for benzene is exceeded over most of the Site in both the 15-ft and 25-ft zones, extending to the Hylebos. The benzene CUL is exceeded consistently only at one of the three seeps. In the 50-ft zone, benzene is the only constituent to exceed CULs and occurs in five upland locations (Figure 2-4G).
- Groundwater quality at the western extent of the plume near the Blair Waterway may be currently protective of surface water CULs at the point it flows into surface water (see Section 2.4.5).

It is important to note that when analyzed with SGC, the TPH-D and TPH-O results are much lower and show a much smaller CUL exceedance area in the 15-ft zone and all SGC results for TPH-D and TPH-O in the 25-ft zone are below the proposed groundwater CUL (Method A drinking water CUL). The substantial difference between the non-SGC and SGC results is because SGC is a lab cleanup method that removes polar metabolites (breakdown products) of diesel and oil that have resulted from the natural biodegradation of petroleum hydrocarbons in the ground, while non-SGC results include those metabolites in the final result. The polar metabolites are not petroleum hydrocarbons, but include alcohols, acids, esters, ketones, aldehydes, and phenols, which have lower toxicity than the parent petroleum hydrocarbons (Zemo et al. 2017). Ecology is not currently allowing the use of SGC results for comparison to site SLs and CULs. Ecology requires the comparison of non-SGC results to site SLs and CULs, which is considered by the Port and LAI to be highly conservative and to over-predict the extent of petroleum hydrocarbon contamination for which the SL and CUL were developed.

### 2.4.2 Chlorinated Volatile Organic Compounds in Groundwater

Groundwater cVOC concentrations exceed the RI SLs for PCE (8.9 µg/L), TCE (7 µg/L), and VC (1.6 µg/L) in a number of areas of the Site (see RI Figures 6.4-11 through 6.4-16). Areas of the Site where the CULs proposed in this FS (see Section 3.2.4) for PCE (7.1 µg/L), TCE (0.86 µg/L), and VC (0.26 µg/L) are exceeded occur in both the 15-ft and 25-ft zones (see Figures 2-5A and 2-5B). The following conclusions are based on observations made from these figures:

- CUL exceedances for PCE and TCE occur primarily in the northeastern portion of the Site
- VC in the 15-ft and 25-ft zones extends over the northern and parts of the eastern portions of the Site.

Nearly all locations with PCE, TCE, and/or VC exceedance of proposed CULs are within the predicted capture zone of the Occidental Site remedy and most of it coincides with the area of TPH contamination. Where cVOCs and TPH are comingled, which includes limited areas of the Site where cVOCs are present outside the predicted capture zone of the Occidental Site remedy (generally in the southeast portion of the Site), rapid natural biodegradation of both compounds is likely occurring through beneficial cometabolic processes. Biodegradation of these compounds consists of microbial respiration of the cVOCs as electron acceptors and utilization of TPH as electron donor (i.e., as food), resulting in enhanced bioremediation and natural attenuation of both groups of contaminants.

### 2.4.3 Groundwater to Vapor Intrusion Pathway

Groundwater concentrations of benzene identified in shallow groundwater during the RI exceed the Ecology VI SL for protection of Method C indoor air quality for industrial sites (i.e., benzene concentrations greater than 24 µg/L) across much of the Site. The most recent shallow groundwater sample results (collection dates ranging from 2004 to 2015) indicated that concentrations of PCE, TCE, and/or VC have exceeded their respective Ecology VI SLs (95 µg/L PCE, 8. 4 µg/L TCE, and 3.5 µg/L VC) in a number of locations in the northeastern portion of the Site (see Figure 2-5A). There are currently no ***occupied*** buildings on the Site located above groundwater where VI SL exceedances have been identified;[28] therefore, there is no immediate associated risk to human health from the VI pathway (Port 2016 and Ecology 2016).

### 2.4.4 Groundwater Potability

Site groundwater is non-potable as described in the RI (Aspect 2016).

### 2.4.5 Impacted Groundwater Flow to Surface Water

Based on the findings from the RI (Aspect 2016), groundwater impacted with petroleum hydrocarbons has been confirmed to flow into surface water from groundwater seepage along the Hylebos Waterway shoreline, which is evident from three seeps which have been observed emanating below the rip-rap on the embankment at the approximate elevation of the native tideflat material underlying the dredge fill. This groundwater to surface water flow is assumed to originate from the 15-ft groundwater zone. Impacted groundwater from the 25-ft groundwater zone also likely emanates to the Hylebos at depth below the lowest tidal elevations in the Hylebos Waterway, but this has not been empirically demonstrated. Groundwater data for the 50-ft zone indicate that petroleum hydrocarbon impacts do not extend to the Hylebos Waterway. Groundwater data on the Blair Waterway side of the Site indicate that petroleum hydrocarbon impacts (specifically benzene) may extend to the Blair Waterway in the 25-ft zone, but are not as likely to be present in the 15-ft zone.[29] Groundwater data for the 50-ft zone indicates that petroleum hydrocarbon impacts do not extend to the Blair Waterway.

[28] Port Building 845 is located within the footprint of groundwater exceeding VI-based SL; however, under current site conditions and building use (unoccupied warehouse with large doors/openings creating high air exchange rates), there is no threat to human health for the VI pathway (Port 2016, Ecology 2016).

[29] The extent of petroleum hydrocarbon impacts in the 15-ft zone toward the Blair Waterway has not been delineated between monitoring well MW-120-15 and the Blair Waterway shoreline, but lateral attenuation trends based on existing data suggests that petroleum hydrocarbon impacts in the 15-ft zone likely do not extend to the Blair Waterway (Port 2017).

Concentrations of petroleum hydrocarbons that extend to the shorelines of the Blair and Hylebos Waterways do not exceed concentrations that would be anticipated to impact sediment in the waterways as indicated by RI bioassay testing results.[30]

## 2.5 Identification of Areas or Volumes of Media that Require Remedial Action

The Site media requiring remedial action include LNAPL, soil, groundwater, and soil vapor, as follows:

### 2.5.1 Light Non-Aqueous Phase Petroleum Liquids

As shown on Figure 1-4, the potential presence of LNAPL may be located over an estimated area of approximately 2 acres. The area with observed LNAPL greater than 0.10 ft in monitoring wells is estimated at approximately 0.8 acres in the Blair Hot Spot. No LNAPL thickness greater than 0.10 ft was observed at the Hylebos Hot Spot. Because of the significant uncertainty in estimating the LNAPL thickness in the aquifer from LNAPL thickness measurement in individual wells, an estimate of LNAPL volume is not attempted by this method. However, based on the calculated TPH concentration in the Blair Hot Spot of approximately 28,000 mg/kg from Ecology's hot spot evaluation (Appendix C), and the estimated area and depth of the Blair Hot Spot smear zone, it is estimated that the LNAPL volume in the Blair Hot Spot area is approximately 95,000 gallons. Results from LNAPL recoverability testing performed during the RI indicated that direct recovery of LNAPL is not practicable.

### 2.5.2 Soil

As shown on Figure 2-2, shallow (0–15-ft depths) soil with TPH concentrations above pCULs extends over an area of approximately 3 acres, and the area of shallow soil with TPH concentrations above the RI SLs extends over approximately 8 acres. The corresponding estimated volumes of impacted shallow soil are approximately 38,000 cubic yards ($yd^3$) and 79,000 $yd^3$, respectively. These volumes are based on contaminated soil from 5 to 10 ft bgs within the respective areas of concern (includes the smear zone), plus an assumed 70 percent of the soil from 0 to 5 ft bgs within the hot spot areas (see Section 2.3).

There are no sources of TPH contamination in deeper soil, because of the water table presenting a density barrier to downward migration of LNAPL. Concentrations of TPH-G and benzene in deeper saturated soil reflect contaminated groundwater (i.e., soil pore water) and equilibrium partitioning of contamination from groundwater onto soil. Deeper soil is evaluated in terms of groundwater concentrations, as direct contact with deeper soil is not a complete pathway and cleanup of deeper saturated soil is based on protection of groundwater.

[30] As documented in the RI report, even with some detections of benzene, TPH-D/O, and some cVOCs in sediment samples, the results of bioassay testing indicate that sediments adjacent to the Site are not toxic to marine biota.

Although there are limited areas where concentrations of cVOCs present in soil are above MTCA Method A CULs, they are not sufficiently prevalent to be considered constituents of concern (COCs) or IHS for Site soil. Additionally, cVOCs in saturated soil (and groundwater) will continue to undergo cometabolic biodegradation where comingled with TPH (see Section 2.3) and are located within the zone of influence of the Occidental Site remedy. The Occidental Site remedy is considered an existing condition for the Site FS. Therefore, the area and volume of cVOC contamination is not considered to require separate remedial action under this FS.

### 2.5.3 Groundwater

Groundwater with TPH-G and/or TPH-D/O concentrations above CULs is present in the 15-ft zone and to a much lesser degree in the 25-ft zone; benzene is the only petroleum-related constituent present in the 50-ft. The extent of these exceedances is as follows:

- As shown on Figure 2-4A and 2-4E, TPH-G and/or TPH-D (with SGC) and benzene above pCULs extends over approximately 10 acres in the 15-ft zone.
- As shown on Figure 2-4C and 2-4F, TPH-G and/or TPH-D (with SGC) and benzene above pCULs extends over approximately 17 acres in the 25-ft zone.
- As shown on Figure 2-4G, benzene above pCULs extends over approximately 4 acres in the 50-ft zone.

While Ecology currently requires demonstration of compliance for TPH contamination based on non-SGC concentrations, the extent of Site TPH concentrations based on SGC concentrations is presented on the figures referenced above to illustrate areas of greatest concern (areas where non-polar petroleum compounds remain), indicating that these are the core areas of the dissolved diesel-range TPH plume in groundwater. Figures 2-4A and 2-4B (15-ft zone) and 2-4C and 2-4D (25-ft zone) show the difference in the extent of TPH plumes with and without SGC for TPH-D analysis, respectively.

Protective measures to prevent leakage of contaminated groundwater and vapor into the sewer line may be required until the surrounding groundwater is remediated.

Treatment of cVOCs present in groundwater (Figures 2-5A and 2-5B) will be addressed by the Occidental Site remedy and naturally occurring biodegradation. The Occidental Site remedy is considered an existing condition for the Site FS. Therefore, the area and volume of cVOC contamination is not considered to require separate remedial action under this FS. Occidental Site remedy capture zone projections indicate that a small area of cVOC contamination in the southeastern portion of the Site may not be captured by the Occidental Site remedy (Appendix B). The area of cVOC contamination at the Site also occurs where it is commingled with TPH contamination. Where cVOC contamination is comingled with TPH, beneficial cometabolic biodegradation is occurring, resulting in natural attenuation of both groups of contaminants as described in Section 2.3.

### 2.5.4 Soil Vapor

Impacted soil vapors may occur in areas where vadose soil, smear zone soil, and/or shallow groundwater are contaminated with volatiles (e.g., volatile petroleum hydrocarbons [VPH] and benzene). The combined area where shallow (15-ft zone) groundwater concentrations exceed VI SLs for benzene (24 µg/L)[31] would provide a reasonable estimate of where soil vapor treatment or mitigation may be required. Groundwater VPH concentrations have not been measured at the Site; however, for the purposes of this FS, areas where benzene concentrations exceed the groundwater VI SL (see Figure 2-4E) are considered to be representative of areas of the Site where impacted soil vapor may be a concern.

## 2.6 Site Use—Potential Exposure Pathways and Receptors

The Site qualifies as an industrial property under MTCA (WAC 173-340-200) and Site groundwater is non-potable as described in the RI (Aspect 2016). Under the current and future industrial land use of the Site, the following potentially complete exposure pathways and receptors are identified:

1) Migration of contaminated groundwater to surface water (Hylebos Waterway and potentially the Blair Waterway), which could impact marine benthic and aquatic organisms as well as humans and ecological receptors that may consume the organisms.
2) Exposure of Site workers to surface soil during the normal course of Site activities, and to soil and groundwater during subsurface construction, maintenance, and/or utility work; exposure scenarios include incidental ingestion, dermal contact, and inhalation of volatile compounds.
3) Potential for occupants of future buildings at the Site to be exposed to volatile compounds through VI to indoor air.[32]
4) Migration of contaminated groundwater and/or vapor into sanitary sewer or storm drain lines where utility workers may be exposed to vapors.

[31] This screening level is considered conservative relative to the 5,000 µg/L threshold for benzene and 30,000 µg/L threshold for TPH associated with recommended vertical separation distances of 6 ft (for concentrations below the thresholds) and 15 ft (for concentrations greater than the threshold values) between contaminated groundwater and building basement floor, foundation, or crawlspace surface of Ecology's Toxics Cleanup Program Implementation Memo #14 (Ecology 2016).

[32] Under existing site conditions, this is an incomplete pathway because existing Port building 845 is not an occupied building (see Section 2.4.3).

# 3.0 PROPOSED CLEANUP STANDARDS

Proposed cleanup standards are presented in this FS report for IHS identified by the RI (i.e., TPH-D/O, TPH-G, benzene, PCE, TCE, and VC) and are summarized in Section 2.0 of this report. Per WAC 173-340-700, a cleanup standard is defined by establishing the following components of the standard: (1) CUL; (2) POC; and (3) other applicable, relevant, and appropriate requirements (ARARs) under state and federal laws. A CUL is the concentration of a hazardous substance that must be met to avoid risks to human health and the environment through a specified exposure pathway. POCs designate the location on the Site where the CULs must be met. Standard POCs are generally throughout a site for each media of concern, whereas conditional POCs (CPOCs) are a specific location (e.g., a property line). CPOCs for site groundwater may be allowed by Ecology if it is determined that no practicable remedial alternatives exist that would be able to clean up groundwater at the standard POC in a reasonable time frame, provided that all practicable methods of treatment are to be used in the cleanup. ARARs are other regulatory requirements that apply to a site because of the type of action that will be taken and/or the location of the site.

The pCULs for the Site are based on preliminary SLs as established in the RI, but revised, as appropriate, to account for applicable migration and exposure pathways, practical quantitation limits (PQLs), background values, and new or revised ARARs. The pCULs used in the FS are presented in Table 3-1. The following sections evaluate, by media, applicable CULs and POCs for the purpose of defining the area or volume of contaminated media at the Site that must be addressed by the cleanup actions, evaluating viable cleanup actions (i.e., alternatives), and evaluating the potential need for CPOCs and remediation levels (RLs). Standard POCs and CPOCs are both included under various remedial alternatives.

Figures 2-2, 2-4(A through G), and 2-5(A and B) present the areas of the Site where soil and groundwater concentrations are above their pCULs. These are the areas identified for evaluation of remediation action alternatives, as presented in Section 5.

## 3.1 Surface Water Cleanup Standards

Under MTCA (WAC 173-340-730), surface water CULs, when appropriate, are to 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. Given that surface waters of the Hylebos and Blair Waterways are saline marine waters, the water is non-potable and the drinking water usage scenario is not an applicable exposure pathway at this Site. It is possible that people may consume fish (or other aquatic organisms) that are present in the Hylebos and Blair Waterways during certain fish life stages. Therefore, the applicable human health and ecological SLs were evaluated and are presented in Table 5-3 of the RI report.

IHS for surface water at the Site include TPH-D/O, TPH-G, benzene, PCE, TCE, and VC. Surface water SLs and pCULs were introduced in the RI report and preliminary draft of the FS report, respectively, for these compounds. However, based on further discussion with Ecology related to the method and location for demonstrating that groundwater cleanup is protective of surface water, it was determined that compliance sampling in surface water is not practicable at the Site and, therefore, surface water pCULs are not applicable. Instead, using surface water quality standards and ARARs, groundwater CULs protective of surface water are proposed, in accordance with WAC 173-340-720(8) and (9), and discussed in Section 3.2.

## 3.2 Groundwater Cleanup Standards

The following sections discuss the pCULs and POC for groundwater at the Site.

### 3.2.1 Groundwater Cleanup Levels

Under MTCA (WAC 173-340-720), groundwater CULs are to 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. As described in the RI, groundwater at or potentially affected by the Site is not considered potable in accordance with WAC 173-340-720(2). Contaminated groundwater from the Site discharges into the Hylebos Waterway and potentially to the Blair Waterway; therefore, groundwater pCULs at the Site are based on protection of surface water beneficial uses in the marine waterways.

It should be noted that, per WAC 173-340-720(4)(b)(ii), groundwater must be protective of surface water beneficial uses “unless it can be demonstrated that the hazardous substances are not likely to reach surface water.” This means that pCULs developed under this section are applicable only to groundwater that has the potential to emanate into surface water, and contains IHS concentrations above those established in accordance with the surface water cleanup standards methods in WAC 173-340-730 (Washington Surface Water Quality Standards [SWQS; WAC 173-201A]).

In order to determine appropriate actions for all Site groundwater, exposure pathway and location-specific RLs are also proposed for various phases of Site cleanup. RLs are used to identify the concentration at which a particular cleanup action component will begin or end (WAC 173-340-355[2]). RLs will be based, in part, on loss of contaminant mass and reductions in concentration along the flow path from upland to where groundwater discharges to surface water at the shoreline (see further discussion in Section 3.2.2). Specific RLs are proposed for various phases of Site cleanup as described in Section 5 and summarized in Table 3-2.

Because there are no other applicable regulatory limits for upland groundwater at the Site (i.e., for areas where IHS in groundwater do not flow into surface water),[33] groundwater pCULs are based on protection of surface water as discussed in Sections 3.1 and 3.4. IHS for groundwater at the Site include TPH-D/O, TPH-G, benzene, PCE, TCE, and VC. The pCULs for benzene, PCE, TCE, and VC were

[33] For example, regulatory cleanup levels for groundwater as drinking water are not applicable because groundwater at the Site is considered non-potable (per WAC 173-340-720[2]).

revised from the RI report SLs based on the promulgation of new human health criteria for surface water under the Washington SWQS (WAC 173-201A) in August 2016, [34] resulting in more conservative values than the RI SLs. PCULs for TPH were revised upward from the RI SLs to the MTCA Method A CULs. This change for TPH is based on whole effluent toxicity testing data from Ecology demonstrating that the concentrations of TPH that are protective of aquatic receptors are higher than the Method A CULs (Ecology 2019a and b); therefore the Method A TPH values for protection of human health are used (WAC 173-340-730(3)(b)(c)(iii)). The following pCULs apply to groundwater at the Site (equivalent to marine surface water ARARs or Method A groundwater CULs):

- **Benzene = 1.6 µg/L**, based on human health criteria, consumption of organisms (SWQS; WAC 713-201A)[35]
- **PCE = 7.1 µg/L**, based on human health criteria, consumption of organisms (WAC 713-201A)[36]
- **TCE = 0.86 µg/L**, based on human health criteria, consumption of organisms (WAC 713-201A)[37]
- **VC = 0.26 µg/L**, based on human health criteria, consumption of organisms (WAC 713-201A)[38]
- **TPH-G (gasoline) = 800 µg/L**, based on MTCA Method A[39]
- **TPH-D/O (diesel/oil) = 500 µg/L**, based on MTCA Method A.

Groundwater data from the RI indicate that Site COCs in the 50-ft zone do not discharge to surface water above pCULs.

Groundwater SLs protective of the VI pathway for potential future occupied buildings were also considered. However, the groundwater VI SLs presented in Ecology's Cleanup Level and Risk Calculation (CLARC) database[40] are not intended to be translated into groundwater CULs because of the inherent variability in the vapor transport pathway. To address potential VI, institutional controls establishing requirements for implementation of engineering controls (e.g., vapor barriers) are

[34] August 1, 2016 rulemaking for WAC 173-201A established new human health criteria under part 240 (became effective September 1, 2016). During the EPA approval process, the state water quality criteria were revised for some COCs by the EPA's November 15, 2016 response and codified under NTR (40 CFR 131.45) on November 28, 2016. However, as of April 16, 2020 EPA withdrew most of the human health criteria for Washington found in the NTR. This rulemaking resulted in official approval of most of the original human health criteria from WAC 172-201A-240. Ecology has since filed suit against EPA for withdrawing the NTR human health criteria values and has issued Interim Policy 720 (January 2021) encouraging potentially liable parties to take into account the withdrawn NTR criteria (PCE = 2.9 µg/L; TCE = 0.7 µg/L; VC = 0.18 µg/L).

[35] The human health criteria were calculated using a fish consumption rate (FCR) of 175 grams per day (g/day), using a cancer risk level equal to one-in-one-million, and exposure duration (ED) up to 70 years (Ecology 2016).

[36] EPA federally promulgated human health criteria, consumption of organisms. EPA's revised human health criteria were based on the same FCR, cancer risk, and ED as used by Ecology, but used more conservative bioaccumulation factors (BAF) and relative source contribution (RSC) factors (EPA 2016).

[37] *Id.*

[38] *Id.*

[39] The SWQS and the NTR do not provide numerical criteria for TPH mixtures (TPH-G, TPH-D, or TPH-O). The pCULs for TPH-G and TPH-D/O were set as allowable under WAC 173-340-730(3)(b)(iii)(C); Method A CULs would be protective of both human and ecological receptors based on information from published bioassay testing results for unweathered gasoline protective of marine surface water of 1,700 µg/L (Ecology 2019a) and preliminary bioassay testing results for weathered diesel protective of marine surface water of 1,200 µg/L (Ecology 2019b).

[40] https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx.

included as an element of the applicable final remedy alternatives in the event that future occupied buildings are constructed at the Site. However, groundwater VI SLs are used to identify RLs and are discussed in Section 3.6 below.

### 3.2.2 Groundwater Point of Compliance

The standard POC for groundwater is throughout the Site. As demonstrated in the subsequent sections, it is not practicable to meet groundwater pCULs throughout the Site within a reasonable restoration time frame given current extent of contamination, contaminant concentrations, estimated degradation rates, and the conservative application of SWQS as pCULs for groundwater.

As such, a CPOC is proposed for most of the alternatives. For properties abutting a surface water body, a CPOC may be “located within the surface water as close as technically possible to the point or points where ground water flows into the surface water” (WAC 173-340-720[8][d][i]). In addition, WAC 173-340-720(8)(e)(i&ii) also states that “The department may require or approve the use of upland monitoring wells located between the surface water and the source of contamination where a conditional point of compliance has been established [and] Where such monitoring wells are used, the department should consider an estimate of natural attenuation between the monitoring wells and the point or points where groundwater flows into the surface water in evaluating whether compliance has been achieved.” Ecology’s Implementation Memo #16 (Ecology 2017a) further clarifies that “an estimate of natural attenuation between the upland well and the CPOC is necessary in order to demonstrate that groundwater at the POC meets cleanup levels” and “using upland wells for compliance monitoring purposes requires extrapolation.”

Because it is difficult to measure compliance at the groundwater-surface water interface at the Site (most of the shoreline slope is under water and the shoreline is heavily armored with rock), Ecology is approving the use of upland monitoring wells (angled shoreline wells) along the Hylebos Waterway, where groundwater concentrations will be measured to establish compliance with the groundwater pCULs at the CPOC, taking into consideration estimated natural attenuation rates between the wells and point where groundwater flows into the surface water. Similar compliance monitoring will be performed on the Blair Waterway side of the Site, with upland angled or vertical wells, and in accordance with WAC 173-340-720(8).

Based on these requirements and conditions, the proposed CPOC for groundwater that flows to the Hylebos Waterway is the point or points at which groundwater emanates into the surface water. Compliance with cleanup levels at the CPOC is proposed to be measured at proposed upland angled wells; and the concentrations that will be used to demonstrate compliance at the CPOC will be determined based on estimated nearshore attenuation in the groundwater-surface water transition zone. These angled wells will be installed between existing vertical shoreline wells and the shoreline so that the attenuation rate between the existing wells and the angled wells can be established. The attenuation rate will then be used to extrapolate from the CPOC back to the angled wells to determine the concentration that are projected to meet the pCULs at the CPOC (as allowable under WAC 173-340-720[8][e][ii]). Angled wells will be installed at 45 degrees from vertical, extending toward the waterway and beneath the existing bulkheads as depicted conceptually on Figure 3-1.[41] On the Blair Waterway side of the Site, vertical or angled wells that will be used to demonstrate compliance with pCULs at the CPOC will be installed along the shoreline or at locations closer to the source, as determined based on the results of the pre-remedial design investigation. For simplicity, for the remainder of this FS report, the upland wells proposed to be used to demonstrate compliance with pCULs at the CPOC for both waterways are referred to as 'angled wells' or 'proposed angled wells.' Proposed angled wells would functionally constitute a screening network for evaluation of cleanup effectiveness.

Based on data from existing shoreline monitoring wells and shoreline seeps, the preliminary groundwater concentrations at proposed angled wells used to demonstrate that pCULs will be met at the Hylebos Waterway CPOC (15-ft zone) are as follows and provided in Table 3.1 (and summarized in Appendix D):

- **Benzene:** 4.0 µg/L at 15-ft zone angled well (for groundwater protection of surface water CUL of 1.6 µg/L)
- **TPH-D/O without SGC:** 680 µg/L at 15-ft angled well (for groundwater protection of surface water CUL of 500 µg/L)
- **TPH-G:** 2,200 µg/L (for groundwater protection of surface water CUL of 800 µg/L)
    - Note: This TPH-G concentration is already being met at shoreline wells upgradient of proposed angled wells, and the pCULs are currently being met at shoreline seeps.

The groundwater concentrations in proposed angled wells to demonstrate compliance in the 15-ft zone at the Hylebos Waterway CPOC are based on limited data and are therefore considered preliminary and are being used in this FS for planning purposes only.

There is currently insufficient data available for a similar evaluation for the 25-ft zone at the Hylebos shoreline or the 15- or 25-ft zones at the Blair shoreline. The final groundwater concentrations to be used to demonstrate compliance at both the Hylebos and Blair CPOCs (15-ft and 25-ft zones) will be developed based on data to be collected from existing and planned upland and angled boring wells during the pre-remedial design investigation for the final cleanup. The number and location of additional upland monitoring wells (angled and vertical) required on both the Hylebos and Blair sides of the Site will also be determined during the pre-remedial design investigation. Groundwater data from the RI indicate that Site COCs in the 50-ft zone do not discharge to surface water above pCULs at either waterway.

[41] The angled wells installed in the 15-ft and 25-ft depth zones will be an estimated 15 ft and 20 ft, respectively, laterally from the point of groundwater discharge to surface water in each zone. Depending on actual location of the wells and the associated shoreline geometry, other angles of installation (between 0 and 45 degrees) may be appropriate.

As required by MTCA (WAC 173-340-720[8][c]), the description of each remedial alternative includes details of the proposed POC and a demonstration that it is not practicable to meet the CULs throughout the Site in a reasonable restoration time frame and that all practicable methods of treatment are to be used in the Site cleanup.

## 3.3 Soil Cleanup Standards

The following sections discuss the pCULs and POC for soil at the Site.

### 3.3.1 Soil Cleanup Levels

Under MTCA (WAC 173-340-745), soil CULs for industrial properties are to 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. The pCULs for soil are based on Method C direct contact for industrial and construction workers for IHS in soil at the Site. Empirical demonstration that soil concentrations are protective of the groundwater leaching pathway will be made by measuring groundwater contaminant concentrations directly. As discussed in Section 3.3.2 of the RI Report, the Simplified Terrestrial Ecological Evaluation (TEE) found that land use at the Site and surrounding area make substantial wildlife exposure unlikely. The need for institutional controls such as environmental covenants to provide long-term worker protection related to direct contact with residual contaminated soil and groundwater is discussed in Section 5.

Unlike for benzene, there are no standard Method C CULs for protection of direct contact exposure for TPH-D/O and TPH-G in Ecology's CLARC database. However, a preliminary pCUL for TPH (gasoline + diesel + oil ranges) in soil was calculated using MTCA Equation 745-3 (WAC 173-340-745[5][iii][B][III]), which takes into account the effects of petroleum fractions and accounts for concurrent exposure due to ingestion and dermal contact; the equation inputs and calculation for TPH are presented in Appendix E. The following preliminary pCULs apply to soil at the Site:

- **Benzene = 2,400 mg/kg**, human health, direct contact for industrial and construction workers.
- **TPH (gasoline + diesel + oil ranges) = 17,000 mg/kg**, human health, direct contact for industrial and construction workers.[42]

Protection of groundwater is not incorporated into these CULs. Instead, groundwater contaminant concentrations will be measured directly to assess the success of cleanup actions for soil to address the leaching to groundwater pathway. Possible modification to the pCUL for soil TPH may be determined for the cleanup action plan or during the pre-remedial design investigation.

Low levels of chlorinated solvents, primarily PCE, have been detected sporadically in soil at the Site. The concentrations detected are low and not considered risk drivers, nor are they expected to affect

[42] Calculation provided in Appendix E was originally provided by Ecology (Ecology 2016) and assumes "entire petroleum fraction is associated with the Aromatic 10-12 carbon range fraction."

the scope of potential Site remedial actions. Detection of PCE and TCE in soil above MTCA Method A soil CULs for industrial properties, 0.05 mg/kg and 0.03 mg/kg, respectively,[43] are presented on Figure 2-2.

### 3.3.2 Soil Point of Compliance

The proposed soil standard POC will be from the ground surface to 15 ft bgs. Until pCULs are met, human direct contact risks will be addressed through institutional controls and protectiveness will be demonstrated through monitoring and the 5-year review process.

## 3.4 Applicable or Relevant and Appropriate Requirements

In accordance with MTCA, all cleanup actions must comply with applicable state and federal laws (WAC 173-340-710[1]). MTCA defines applicable state and federal laws to include legally applicable requirements and those requirements that are relevant and appropriate. Collectively, these requirements are referred to as ARARs. This section provides a brief overview of potential ARARs for the Site cleanup. The primary ARAR is the MTCA cleanup regulation (Chapter 173-340 WAC), which outlines requirements for the development of cleanup standards, and procedures for development and implementation of a cleanup under MTCA. The other ARARs that may be applicable to the cleanup action include the following:

- **CERCLA.** Cleanup of the Site is being performed under the MTCA regulations with Ecology oversight. This FS has also been prepared in such a manner as to be consistent with the NCP. The final rule (EPA 1990) explains that a private party cleanup is consistent with the NCP if, when evaluated as a whole, it achieved “substantial compliance” with potentially applicable NCP requirements and resulted in a “CERCLA-quality cleanup.” A CERCLA-quality cleanup is defined as one that protects human health and the environment, utilizes permanent solutions and alternative technologies to the maximum extent practicable, and is cost effective. These are also requirements under MTCA.
- **Washington Water Pollution Control Act (Chapter 90.48 Revised Code of Washington [RCW]) and its implementing regulations: Water Quality Standards for Surface Waters of the State of Washington (Chapter 173-201A WAC).** These regulations establish water quality standards for surface waters of the State of Washington consistent with public health and public enjoyment of the waters and the propagation and protection of fish, shellfish, and wildlife, pursuant to the provisions of chapter 90.48 RCW. The regulations provide numeric criteria for ecological and human health, designated uses, and an antidegradation policy for surface waters of the state. The development of CULs for the remediation of contaminated groundwater with the potential to discharge to marine surface waters must take into consideration the protection of surface water beneficial uses. Because the Hylebos and Blair Waterways are non-potable, marine water bodies, potentially applicable cleanup criteria for protection of human health are based on consumption of organisms only.
- **National Toxics Rule (NTR; 40 Code of Federal Regulations [CFR] 131).** These regulations establish the requirements and procedures for developing, reviewing, revising, and approving

[43] CULs are based on protection of groundwater for drinking water use, using the procedures described in WAC 173-340-747(4).

water quality standards by the States as authorized by section 303(c) of the Clean Water Act. Section 131.45 specifically promulgates human health criteria for priority toxic pollutants in surface waters in Washington, *including the approval or superseding of certain numeric criteria established under WAC 173-201A*. However, as of April 16, 2020, EPA withdrew the human health criteria for all but a few constituents, thereby approving all other human health criteria values promulgated under WAC 173-201A.

- **Washington Hazardous Waste Management Act (Chapter 70.105 RCW) and its implementing regulations: Dangerous Waste Regulations (Chapter 173-303 WAC).** These regulations establish a comprehensive statewide framework for the planning, regulation, control, and management of dangerous waste. The regulations designate those solid wastes that are dangerous or extremely hazardous to human health and the environment. The management of excavated contaminated soil from the Site would be conducted in accordance with these regulations to the extent that any dangerous wastes are discovered or generated during the cleanup action.
- **Washington Solid Waste Management Act (Chapter 70.95 RCW) and its implementing regulation: Criteria for Municipal Solid Waste Landfills (Chapter 173-351 WAC).** These regulations establish a comprehensive statewide program for solid waste management including proper handling and disposal. The management of any contaminated soil removed from the Site would be conducted in accordance with these regulations to the extent that this soil could be managed as solid waste instead of dangerous waste.
- **Hazardous Waste Operations (Chapter 296-843 WAC).** Establishes safety requirements for workers conducting investigation and cleanup operations at sites containing hazardous materials. These requirements would be applicable to onsite cleanup activities and would be addressed in a site health and safety plan prepared specifically for these activities.
- **Clean Water Act, Section 404—Dredge or Fill Requirements Regulations, 33 United States Code (USC) 1344(a)–(d); 33 CFR Parts 320–330; 40 CFR Part 230.** These requirements are applicable to cleanup action alternatives in or near navigable waters and establish requirements that limit the discharge of dredged or fill material to these waters. EPA guidelines for discharge of dredged or fill materials in 40 CFR 230 specify consideration of alternatives that have less adverse impacts; prohibit discharges that would result in exceedance of surface water quality standards, exceedance of toxic effluent standards, and jeopardy of threatened or endangered species; and provide for evaluation and testing of fill materials before placement.
- **Clean Water Act National Pollutant Discharge Elimination System (NPDES) Permit and State Construction Stormwater General Permit.** Construction activities that disturb one or more acres of land typically need to obtain an NPDES Construction Stormwater General Permit from Ecology. A substantive requirement would be to prepare a stormwater pollution prevention plan (SWPPP) prior to the earthwork activities. The SWPPP would document planned procedures designed to prevent stormwater pollution by controlling erosion of exposed soil and by containing soil stockpiles and other materials that could contribute pollutants to stormwater.
- **Clean Water Act, Section 401, Water Quality Certification, 33 USC 1340; WAC 173-225-010.** Section 401 of the Federal Water Pollution Control Act provides that applicants for a license or permit from the federal government relating to any activity that may result in any discharge into the navigable waters shall obtain a certification from the state that the water quality

standards will be met. Ecology would review any Nationwide Permit issued by the USACE. Ecology would also review any associated draft and final design of the chosen cleanup action alternative to document substantive compliance with the Washington State Water Pollution Control Act requirements.

- **Washington Hydraulics Project Approval (RCW 75.20.100; Chapter 220-110 WAC).** This regulation requires Washington Department of Fish & Wildlife (WDFW) approval for projects that will use, divert, obstruct, or change the natural flow or bed of waters of the state, such as the Hylebos or Blair Waterways. WDFW typically issues in-stream work windows under the authority of this program.
- **State Environmental Policy Act (SEPA), RCW 43.21.036, WAC 197-11-250 through 268.** Under the SEPA rules, MTCA and SEPA processes are to be combined to reduce duplication and improve public participation (WAC 97-11-250). Ecology is the lead agency for implementing the substantive requirements of SEPA as described in WAC 197-11-253. Ecology is likely to determine that it will act as the lead agency for implementing the requirements of SEPA for cleanup actions at the Site. A SEPA checklist will be completed and attached to the dCAP. It is expected that a determination of non-significance will be issued, as the alternatives evaluated in this FS are unlikely to have a significant adverse environmental impact.
- **Washington Minimum Standards for Construction and Decommissioning Wells (WAC 173-160-381).** Under WAC 173-160-381, Ecology or its delegated authority establishes requirements for the construction and decommissioning of monitoring wells.
- **Underground Injection Control Program (UIC; WAC 173-218).** Under WAC 173-160, UIC registration is required for the injection of any materials bgs for the purposes of groundwater cleanup. This would include injection of reducing agents such as electron donor substrates for bioremediation, zero valent iron, oxidants for chemical oxidation, or other chemical activation agents or catalysts; or reinjection of treated groundwater.
- **Puget Sound Clean Air Agency (PSCAA; Reg. I, Section 6.05[b][94]).** A Notice of Construction application and Order of Approval from PSCAA are not required for soil and groundwater remediation projects that emit "<15 pounds per year of benzene or VC, <500 pounds per year of perchloroethylene, and <1,000 pounds per year of toxic air contaminants," provided that "sufficient records are kept to document the exemption." It is not anticipated that any of these thresholds will be exceeded under any of the remedial alternatives being considered for the Site.
- **Local Permits (City of Tacoma/Pierce County).** Depending on the final remedy selected, local permits—such as construction, grading, electrical, mechanical, or waste disposal—may be required (or if exempted, per WAC 173-340-710[9], the substantive requirements thereof must be adhered to).

## 3.5 Other Regulatory Requirements

For cleanup actions that use containment for some or all of the remedy, such that soil or groundwater CULs will not be met at the standard POC within a reasonable restoration time frame, institutional controls must be put in place that prohibit or limit activities that could interfere with the long-term integrity of the containment system or the remedy. Therefore, institutional controls will be a required element of several of the remedial alternatives evaluated in this FS report. Associated compliance monitoring and periodic reviews to ensure the long-term integrity of the containment system will also be required**.**

## 3.6 Remediation Levels

In addition to the CULs identified above, the use of RLs is also proposed for decision making related to remedial actions and activities at the Site. Per WAC 173-340-355(1), RLs are used to identify the concentrations (or other methods of identification) of hazardous substances at which different cleanup action components will be used or terminated.

Depending on the remedial alternative, RLs may be used for different areas of the Site as follows:

- The area east of the Hylebos peninsula groundwater divide (see Section 2.1) where elevated soil and groundwater contaminant concentrations and traces of LNAPL appear to be acting as a source of groundwater contamination discharging to the Hylebos Waterway—"Hylebos Hot Spot."
- The area west of the Hylebos peninsula groundwater divide where measurable LNAPL is located and elevated soil and groundwater contaminant concentrations appear to be acting as a source of groundwater contamination migrating toward the Blair Waterway – "Blair Hot Spot." Note that, depending on the specific location and potential seasonal variability of the groundwater divide, contaminated groundwater from the Blair Hot Spot may also migrate toward the Hylebos Waterway.
- The Blair Hot Spot includes areas beneath Alexander Avenue; however, under excavation-based cleanup scenarios/alternatives, this area would have its own RLs. Because of the unique nature of this area being located beneath a major roadway that services the Port, it cannot be accessed for excavation activities.
- Site-wide, benzene concentrations in groundwater exceed the VI SL. Because of the potential for future occupied buildings to be constructed nearly anywhere on the Site, an RL equivalent to the VI SL will also be applied to Site-wide groundwater for many of the remedial alternatives.

The areas listed above are used in the RL evaluation in Appendix D. The RLs and specific areas that they apply to, associated with the different remedial alternatives, are described in more detail in Section 5 and are summarized in Table 3-2. Additional information regarding how hot spots were delineated is included in Section 2.3 and in Appendix C.

# 4.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Per WAC 173-340-350(8)(b), an initial screening of remedial technologies and alternatives may be performed to reduce the number of alternatives for the final detailed evaluation or remedial alternatives.

With agreement from Ecology, the initial screening of remedial technologies and alternatives for the Site was performed under separate cover in the Final Feasibility Study Technology Screening document (technology screening document; LAI 2018a). In the technical screening document, potential general response actions and remedial technologies were identified based on the known Site conditions, media impacted, contaminant types, and best professional judgment. A wide range of potential remedial technologies were considered under the general response actions for applicability to the Site. Remedial technologies that were determined to be inapplicable to the Site were screened out of additional consideration in this FS report. Potential remedial technologies were grouped into the following general response actions:

- Institutional Controls: Institutional controls involve land and groundwater use restrictions and site administrative procedures to limit or mitigate potential exposure risks and pathways. Institutional controls retained in the technology screening document for possible inclusion in remedial alternatives included land use restrictions, groundwater use restrictions, and site administrative procedures (e.g., site security or health and safety protocols).
- Engineering Controls: Engineering controls involve creating a physical barrier or employing an engineered system to limit or mitigate potential exposure risks and pathways. Engineering controls retained in the technology screening document for possible inclusion in remedial alternatives included media capping, a permeable reactive barrier (PRB) near the Hylebos Waterway shoreline, and vapor barrier or subslab depressurization.
- *Ex Situ* Treatment or Disposal: *Ex situ* treatment or disposal involves the removal and treatment or disposal of contaminated media (e.g., groundwater or soil) to mitigate or eliminate potential exposure risks and pathways. *Ex situ* treatment or disposal technologies retained in the technology screening document for possible inclusion in remedial alternatives included excavation and off-site disposal of soil, as well as groundwater extraction and treatment.
- *In Situ* Treatment: *In situ* treatment involves the treatment of contaminated media (e.g., groundwater) in place to mitigate or eliminate potential exposure risks and pathways. *In situ* treatment technologies retained in the technology screening document for possible inclusion in remedial alternatives included enhanced bioremediation through substrate injection and bioventing for petroleum hot spot/smear zone/LNAPL areas, and a bioremediation-based PRB/treatment zone near the Hylebos Waterway shoreline.
- Monitored Natural Attenuation: Monitored natural attenuation (MNA) involves monitoring the degradation of contaminants in impacted media due to naturally occurring attenuation processes. MNA was retained in the technology screening document for possible inclusion in the remedial alternatives.

Remedial technologies retained in the technology screening document were assembled into seven cleanup action alternatives. Alternative 1 in the technology screening document included no action at the Site except for long-term monitoring of Site COCs. Alternative 2 included Site-wide MNA with bioremediation near the Hylebos Waterway shoreline. Alternative 3 included elements of Alternative 2, but also bioremediation in hot spot areas (Alternative 3a) or an expanded version of this area (Alternative 3b). Alternative 4 included elements of Alternative 2, but also remedial excavation in hot spot areas (Alternative 4a) or an expanded version of this area (Alternative 4b). Alternative 5 included extensive remedial excavation of contaminated soil over the majority of the Site.

With Ecology's concurrence, previous Alternatives 3b and 4b, which included remedial actions within an expanded area (beyond the statistically defined "hot spots" used for Alternatives 3a and 4a) that had no statistical or regulatory significance, were removed from consideration in the agency review draft FS report. Accordingly, the five remaining remedial alternatives were further evaluated in the agency review draft of the FS report. Based on subsequent discussions with Ecology after review of the agency review draft, a new Alternative 4 was added, that is similar to Alternative 3, but includes enhanced bioremediation in both the Blair and Hylebos Hot Spot areas (instead of shoreline bioremediation) and the previous Alternatives 4 and 5 (hot spot excavation and extended excavation, respectively) were renumbered to Alternatives 5 and 6 (but remain largely unchanged). For the purposes of this FS report (and for Alternatives 3, 4, and 5), hot spot areas are defined as areas with TPH concentrations in soil greater than 19,000 mg/kg or benzene concentrations in soil greater than 19 mg/kg, as discussed in Section 2.3.

# 5.0 REMEDIAL ACTION ALTERNATIVES

The following sections identify the objectives that each remedial action alternative must be in compliance with MTCA and provide a summary of each of the remedial action alternatives developed for evaluation under this FS.

## 5.1 Remedial Action Objectives

Remedial action objectives (RAOs) define the goals of the cleanup that must be achieved to adequately protect human health and the environment. As discussed above, the current conditions at the Site do not present a risk to Site users because contaminated soil is mostly capped by the existing asphalt pavement, and groundwater at the Site is not used for drinking water or other activities. However, migration of contaminated groundwater from the Site to the Hylebos and Blair Waterways represents a potential risk to surface water beneficial uses. For cleanup of the Site, the RAOs must address all affected media, and each remedial alternative must achieve all RAOs to be considered a viable cleanup action. RAOs can be either action-specific or media-specific. Action-specific RAOs are based on actions required for environmental protection that are not intended to achieve specific chemical criteria. Media-specific RAOs incorporate the CULs developed in Section 3. Based on the characterization of Site conditions presented in Section 2 and the CULs, the action-specific and media-specific RAOs identified for the Site consist of:

- RAO-1: Prevent COCs in groundwater from discharging into surface water at concentrations that impact surface water beneficial uses.
- RAO-2: Protect Site workers from exposure to contaminants in surface soil and protect excavation or utility workers from exposure to soil or shallow groundwater containing COCs at concentrations above worker exposure CULs.
- RAO-3: Prevent (or mitigate, as necessary) intrusion of soil vapor to indoor air of potential future occupied buildings, as needed for protection of indoor air. This RAO is potentially applicable at Site locations where volatile COCs may be present in vadose zone soil and shallow groundwater at concentrations above CULs protective of indoor air.
- RAO-4: Mitigate intrusion of COCs in groundwater and/or vapor into sewer or storm drain lines at concentrations above worker exposure CULs.

RAO-1 can be achieved through containment, treatment, and/or removal of the contaminated media (soil and groundwater cleanup action). RAO-2 can be achieved by preventing exposure to the contaminated soil and groundwater through soil and groundwater cleanup actions, monitoring, and institutional controls. RAO-3 may be addressed through soil and groundwater cleanup actions and/or engineered controls for future occupied buildings. RAO-4 can be achieved through containment, groundwater cleanup actions, and/or institutional controls.

Remedial Alternatives 2 through 6, described in Sections 5.3 through 5.8, achieve these four RAOs and meet all of the MTCA threshold requirements (described in Section 6.1.1); therefore, each of these alternatives is a viable cleanup alternative for the Site under MTCA. Remedial Alternative 1 is the No

Action alternative. The "No Action" General Response Action is included as required for consistency with the NCP. As such, although "No Action" would not meet the RAOs and, therefore, does not meet MTCA minimum requirements, a "No Action" remedial alternative is included for evaluation in the FS.

The degree to which each cleanup action alternative meets the threshold requirements and other requirements listed in WAC 173-340-360(2) will be determined by applying the specific evaluation criteria identified in MTCA (Sections 6.1 and 6.2).

## 5.2 Summary of Remedial Alternatives

Six alternatives are evaluated in this FS to address contaminated media at the Site. Alternatives 2 through 6 discussed below were developed to be protective of human health and the environment, meet the RAOs, and be consistent with the MTCA regulations. As indicated above, Alternative 1 is included to satisfy NCP requirements. Alternatives 2 through 6 incorporate the most viable cleanup action technologies within the general response action categories of containment, source removal (i.e., excavation), treatment, and institutional controls. The six alternatives are:

- Alternative 1: No Action (Monitoring Only).
- Alternative 2: Shoreline Enhanced *In Situ* Bioremediation (EISB), Site-Wide MNA, and Institutional and Engineering Controls (I&ECs).
- Alternative 3: Blair Hot Spot EISB and Bioventing, Hylebos Hot Spot Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs.
- Alternative 4: Hot Spot EISB and Bioventing, Site-Wide MNA, and I&ECs.
- Alternative 5: Hot Spot Excavation, Alexander Avenue EISB and Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs.
- Alternative 6: Extended Remedial Excavation, Alexander Avenue EISB and Bioventing, and MNA for Deep Groundwater.

A detailed description of each alternative is presented below, including discussion of proposed POCs and estimated restoration time frames[44] to meet pCULs and RLs (where applicable). As discussed in Sections 2.1, 2.5.3, and 2.6, it is recognized that there may be intrusion of contaminated groundwater and/or soil vapor into the sanitary sewer within the Site boundaries. Although not discussed specifically in any of the remedial alternative descriptions below, regardless of which is selected as the final remedy, this potential migration pathway will be addressed during cleanup (specific action to be determined during engineering design, in consultation with city of Tacoma Public Works Department). All six alternatives also assume modified hydraulic conditions at the Site resulting from the implementation of the anticipated remedy of the Occidental Site. Implementation of the Occidental Site remedy is considered an existing condition as summarized in Section 2.5. While the Occidental Site remedy will provide some Site containment and will likely provide enhanced flushing

[44] Restoration time frames are generally discussed as time from initial remedy implementation (assumed to be 2021).

and beneficial attenuation of Site contaminants such as cVOCs and TPH, it is not being relied upon for remediation of Site contaminants.

EISB is proposed as a remedial action component of most of the alternatives (all except Alternative 1). EISB has been shown to be effective at enhancing attenuation rates of TPH and benzene in groundwater at other locations with similar contaminant conditions to the Site. Enhanced attenuation of TPH and benzene following EISB treatment is well-documented in the literature (Anderson et al. 2020, Campbell et al. 2009, Cunningham et al. 2001, Houston et al. 2011, Wiedemeier et al. 1999) and has been performed at two separate marine shoreline sites in the Puget Sound region, as summarized by LAI (2018b). Based on the results from these sites and best engineering judgement, the conservative estimated increase in attenuation rates compared with natural attenuation rates (e.g., EISB is estimated to accelerate attenuation by three times in the Blair Hot Spot LNAPL area and six times in the Hylebos Hot Spot dissolved plume area—see Section 5.5.2.1) is used in this FS for estimated treatment durations, restoration time frames, and associated cost estimates.

A summary of RLs associated with each remedial alternative is presented in Table 3-2. Cost estimates for each remedial alternative are included in Tables 5-1 through 5-6. A summary of estimated restoration time frames for each remedial alternative is included in Table 5-7.

Note that during evaluation of restoration time frames, benzene trends, overall, did much better in the statistical significance testing than TPH trends (i.e., TPH-G and TPH-D/O trends) and greater confidence can be given to restoration time frame estimates calculated from benzene attenuation rates. Therefore, throughout the following evaluation of alternatives, the restoration time frames indicated and used for cost estimates are based on benzene attenuation. While the TPH data available is insufficient to perform a restoration time frame analysis, the restoration time frames for these constituents are anticipated to be similar to benzene based on evaluation of data sets from two other similar sites (LAI 2018b). Although TPH restoration time frames are unlikely to be identical to benzene, the results would not be anticipated to be significantly different enough to impact the selection of a final remedy.

## 5.3 Alternative 1: No Action (Monitoring Only)

Alternative 1 consists of no active remedial action, with only groundwater compliance monitoring at existing Site monitoring wells. MTCA does not require a no action alternative; however, as discussed in Sections 1.0, 3.4, and 5.2; a no action alternative is included to be consistent with NCP requirements. Figure 5-1 presents a conceptual representation of this Alternative. Compliance monitoring is a requirement under MTCA to confirm the long-term effectiveness once cleanup standards have been achieved and would be used to verify no unacceptable human or ecological exposures to hazardous substances at the Site. Site soil to 15 ft bgs and groundwater monitoring wells throughout the Site are standard POCs under this Alternative. No RLs are proposed for this Alternative.

### 5.3.1 Point of Compliance

The standard POC for soil (from ground surface to 15 ft bgs) and groundwater (monitoring wells throughout the Site) are proposed under this Alternative.

### 5.3.2 No Action

This alternative is considered a "No Action" General Response Action that is consistent with the NCP requirement, per CERCLA 40 CFR 300.430(e)(6), that a no-action alternative be developed. The EPA indicates that it may be determined that no action is warranted under the following circumstances (EPA 1991):

- "When the site or a specific problem or area of the site (i.e., an operable unit) poses no current or potential threat to human health or the environment;" or, in other words, "Where the baseline risk assessment concluded that conditions at the site pose no unacceptable risks to human health and the environment"; or
- "When a previous response eliminated the need for further remedial response" or, in other words, "Where a previous removal action eliminated existing and potential risks to human health and the environment such that no further action is necessary."

If it could be demonstrated at the Site, through a risk assessment, that the conditions at the Site pose no unacceptable risks to human health and the environment, then a no action alternative could be selected for the Site if it were being cleaned up under CERCLA. However, this alternative does not meet the requirements of MTCA to protect human health and the environment in a reasonable restoration time frame.

### 5.3.3 Compliance Monitoring

EPA guidance (EPA 1991) indicates that a "no action" alternative may include monitoring only "to verify that no unacceptable exposures to potential hazards posed by conditions at the site…occur in the future."

Alternative 1 includes Site compliance monitoring as follows:

- Protection monitoring will be provided for groundwater monitoring personnel as provided in a Site-specific health and safety plan.
- Long-term groundwater performance monitoring will be conducted until such time as soil and groundwater contaminant concentrations at the Site are below the soil, groundwater, and surface water pCULs across the Site. A minimum of four quarters of confirmational groundwater monitoring will be performed after completion of performance monitoring.

Based on an evaluation of natural attenuation at well 721-MW2-15 (conservatively chosen because it is anticipated to be the final well at the Site to reach CULs), 152 years may be required for benzene to reach CULs Site-wide that are protective of surface water (Appendix F). For the purposes of this FS, it is assumed that performance monitoring for groundwater would be performed annually for 5 years, then biennially (every 2 years) for a total of approximately 29 years until concentrations in groundwater are anticipated to meet pCULs at the CPOC (based on natural attenuation at well MW-104-15). Thereafter, groundwater performance sampling would be performed at selected Site monitoring wells every 5 years, for a total duration of approximately 152 years. This 152-year estimate is the maximum restoration time frame for pCULs to be met throughout the Site with no implementation of active remedial actions. The groundwater screening level for benzene that is protective for the vapor pathway would be met in approximately 85 years. These time frames are estimated through an evaluation of Site historical groundwater quality conditions; calculations for determining the estimated restoration time frame are included in Appendix F.[45] These estimates are considered conservative as they do not take into consideration the impact of the Occidental Site remedy on the restoration time frames for the Site. The Site monitoring wells that will be used for performance sampling will be selected during the remedial design from the wells shown on Figure 5-1.

During this 152-year restoration time frame for groundwater, natural attenuation processes in smear zone and vadose zone soils are also expected to degrade contamination in soil to below pCULs. Once groundwater has been demonstrated to meet pCULs, soil sampling would be also conducted to confirm compliance with soil pCULs.

### 5.3.4 Cost Estimate

The specific items anticipated to be included in Alternative 1 are listed in Table 5-1 along with their estimated costs. The total estimated present-worth cost of Alternative 1 is approximately $540,000. This is an FS-level estimate and the actual costs may be as much as 30 percent less or 50 percent greater than the estimate.

## 5.4 Alternative 2: Site-Wide MNA, Shoreline EISB, and I&ECs

Alternative 2 includes shoreline bioremediation and Site-wide MNA, as well as the common remedial components: I&ECs and compliance/performance monitoring. Figure 5-2 presents a conceptual representation of Alternative 2. The standard POC for soil will be used for this alternative. The point or points where groundwater discharges to surface water will be the groundwater CPOC under this alternative. Note that the same CPOC and location for demonstration of compliance with pCULs, as described below, are proposed for Alternatives 2 through 5. RLs are proposed to guide treatment operations of the proposed bioremediation system and to transition from Site-wide MNA to 5-year reviews (general groundwater quality performance monitoring).

[45] The restoration time frame estimate is based on predictions from observed rates of natural attenuation of benzene at groundwater monitoring well 721-MW2-15. Benzene concentrations at the well are estimated to meet the target concentration, 1.6 µg/L, in 152 years. Well 721-MW2-15 was chosen to estimate restoration time frame because it is anticipated to be the final well at the Site to reach groundwater concentrations protective of surface water (based on current concentration and contaminant decay rate).

### 5.4.1 Point of Compliance

The standard POC for soil (from ground surface to 15 ft bgs) is proposed for this alternative. A CPOC for groundwater is proposed at the point or points at which groundwater flows into surface water. Because it is not practical to measure groundwater at the point of discharge to surface water, new monitoring wells that will be installed near the waterways are the proposed monitoring points to demonstrate compliance with the CULs at the CPOC for groundwater under Alternative 2.

As described in Section 3.2.2, compliance with pCULs at the CPOC would be demonstrated using upland monitoring wells, consisting of angled shoreline wells near the Hylebos Waterway and angled or vertical wells on the Blair Waterway side of the Site. The contaminant concentrations that will determine compliance with the pCULs at the CPOC will be determined based on estimated attenuation over distance relationships near each of the shorelines at the Site, derived from the investigation results.[46] Specifically, the wells to be used to demonstrate compliance on the Hylebos Waterway side of the Site will be angled monitoring wells to be installed within the 15-ft and 25-ft depth zones and within approximately 15–20 ft upgradient from where groundwater flows to the Hylebos Waterway.[47] Similar angled wells – or vertical wells located further upland – will be installed within the 15-ft and 25-ft depth zones on the Blair Waterway side of the Site.

For the purposes of this FS report, all the wells proposed to be used to demonstrate compliance with pCULs at the CPOC are referred to simply as 'angled wells.' The quantity and location of the angled wells will be determined during the pre-remedial design investigation. Sampling from the proposed angled wells, coupled with an assessment of nearshore attenuation in the groundwater-surface water transition zone, would demonstrate that shoreline bioremediation and Site-wide MNA are effectively mitigating discharge of contaminated groundwater to the waterways. The proposed angled wells are upgradient of where groundwater flows to the Hylebos and Blair Waterways, and as close as practicable to the contaminant source(s)—i.e., the former industrial areas where the COCs were likely used and released, areas of measurable LNAPL, and areas of residual soil contamination that may still act as an ongoing source of groundwater contamination.

### 5.4.2 Shoreline EISB

Alternative 2 includes a shoreline bioremediation area that would be located along the Hylebos Waterway.[48] The area of shoreline bioremediation would extend south of the sheet pile wall anticipated for the Occidental Site remedy, for containment through EISB of contaminated

[46] Consistent with WAC 173-340-720(8)(e).

[47] RI data indicate that low-level contaminants that have reached the 50-ft zone do not discharge to surface water; therefore, CPOC monitoring points for the 50-ft zone are not necessary.

[48] Because groundwater quality appears to already meet groundwater pCULs near the Blair Waterway, shoreline treatment along the Blair Waterway is not likely to be needed based on naturally occurring plume attenuation and is, therefore, not included as a remedy component. However, if it is discovered during pre-remedial design investigation work, which will include installation of CPOC monitoring point wells in the 15- and 25-ft zones along the Blair Waterway, that contaminated groundwater is discharging to surface water, the need for shoreline remediation will be re-evaluated.

groundwater not otherwise contained by the Occidental Site remedy. This alternative assumes that anaerobic bioremediation in the groundwater-surface water transition zone would be stimulated through injection of nitrate and/or sulfate (or similar—to be determined during remedial design) electron acceptors. Implementation of EISB is anticipated to increase attenuation by a factor of 3 to 6 relative to natural attenuation (Appendix F). It is anticipated that active treatment measures along the shoreline would achieve pCULs at the CPOC, as demonstrated at the proposed angled wells, within 5 years from commencing active treatment (estimated to commence in 2021). However, contaminated groundwater from the upgradient Hylebos Hot Spot would continue to migrate toward the shoreline. As further described below, it is estimated that, within 21 years, MNA across the rest of the Site (and specifically at the Hylebos Hot Spot area) would result in conditions along the shoreline protective of surface water beneficial uses that would allow discontinuation of the shoreline treatment measures. The calculations of estimated restoration time frames for Alternative 2 are included in Appendix F.

For cost-estimating purposes, it is assumed that 1 row of approximately 60 injection wells (30 pairs of 15-ft deep and 30-ft deep wells spaced on approximately 15-ft centers for approximately 400–450 ft of shoreline south of the anticipated Occidental Site sheet pile wall) will be installed parallel to and around 100 ft upgradient of the Hylebos Waterway. Injections of sulfate and/or nitrate (or similar—to be determined during remedial design) solution would be performed on a periodic basis to stimulate anaerobic biodegradation of the dissolved-phase petroleum to below groundwater RLs identified below. For cost-estimating purposes, it is assumed that up to 16 injection events will be performed over 21 years, and that quarterly groundwater monitoring will be performed at 10 new angled monitoring wells over this period. Implementation of bioremediation treatment at the Hylebos shoreline is included in remedial Alternatives 2, 3, and 5.

#### 5.4.2.1 Remediation Levels—Hylebos Hot Spot

RLs for the Hylebos Hot Spot are proposed to manage the treatment operations and injection frequency of the shoreline bioremediation system, and to determine when shoreline bioremediation and associated monitoring can be discontinued.

It is assumed that bioremediation injections for shoreline treatment can be discontinued once groundwater concentrations in the upgradient Hylebos Hot Spot fall below an appropriate RL; the Hylebos Hot Spot is the assumed source of petroleum contamination at the Hylebos shoreline monitoring wells and seeps.

Based on an evaluation of natural attenuation of benzene and TPH at Hylebos Hot Spot groundwater monitoring wells MW-109-15, 721-MW6-15, 721-MW11-15, and MW-104-15, as summarized in Appendix D, the proposed RLs for the Hylebos Hot Spot that will allow for discontinuing shoreline bioremediation are as follows:

- **Benzene:** 86 µg/L (for groundwater protection of surface water CUL of 1.6 µg/L)

- **TPH-D/O without SGC:** 2,600 µg/L (for groundwater protection of surface water CUL of 500 µg/L)
- TPH-G**:** 85,000 µg/L (for groundwater protection of surface water CUL of 800 µg/L)
  - Note: The TPH-G RL is already being met at the Hylebos Hot Spot; therefore, a TPH-G RL is not likely to be needed for the Hylebos Hot Spot.

Based on current benzene concentrations at the Site, it is estimated that the Hylebos Hot Spot groundwater RL can be achieved in approximately 21 years (see Appendix F).[49] Meeting the Hylebos Hot Spot RL will achieve the groundwater pCULs at the CPOC.

Once the Hylebos Hot Spot RLs are achieved and bioinjections are discontinued, 2 years of quarterly compliance monitoring at the angled wells will be performed to confirm no rebound above the pCUL for groundwater protective of surface water. If rebound occurs, additional injection events for shoreline treatment may be needed.

### 5.4.3 Site-Wide MNA

Alternative 2 includes MNA to reduce benzene concentrations in groundwater to the Site-wide RLs protective of potential VI into potential future Site buildings. MNA involves regular monitoring of select wells for natural attenuation parameters, as well as contaminant concentrations and trend evaluation.

The conclusions of the natural attenuation evaluation established that natural attenuation of petroleum hydrocarbons is ongoing and that biodegradation is a significant component of the observed natural attenuation at the Site (Port 2017). This is based on multiple lines of evidence: the majority of wells analyzed are showing decreasing trends of benzene and TPH concentrations over time, and electron acceptors—such as dissolved oxygen (DO), nitrate ($NO_{3^-}$), and sulfate($SO_4^{2-}$)—appear to be fully utilized in areas of petroleum impact, while metabolic by-products—such as methane and alkalinity[50]—appear to be elevated. As expected, attenuation rates are lower where LNAPL is present, and higher in downgradient areas of the plume. Based on these findings, MNA would be utilized as the primary cleanup action for most of the Site for Alternative 2.

Note that, while MNA is primarily being discussed as a remedy for petroleum-contaminated groundwater, it is also recognized that enhanced and co-beneficial attenuation of Site cVOCs and TPH is anticipated to be occurring at the Site. Naturally occurring, biologically mediated degradation of TPH and cVOCs is and will occur where cVOCs are present in the northeast portion of the Site and on the OCC property to the north. Micro-organisms require both electron acceptors for respiration and electron donors as food for metabolism. Bioremediation of Site IHS involves microbial metabolism of TPH (electron donor) and cVOCs (electron acceptor), resulting in enhanced bioremediation of both

[49] Restoration time frame includes 2-year groundwater transport time from the hot spot to the Hylebos Waterway—allowing time to see the effects of hot spot attenuation to be observed at the receiving surface water body.
[50] Resulting from carbon dioxide ($CO_2$) production.

contaminants. Additionally, the change in groundwater flow resulting from the anticipated enhanced groundwater extraction, containment, and treatment system for the Occidental Site is expected to result in additional mixing of TPH and cVOCs and further enhance current attenuation rates.

MNA would include periodic monitoring of Site groundwater conditions in the shallow and intermediate groundwater zones (15- and 25-ft zones), including contaminant concentrations and natural attenuation parameters (geochemical indicators), that may include DO, nitrate, sulfate, soluble manganese ($Mn^{2+}$), ferrous iron ($Fe^{2+}$), and methane ($CH_4$) at selected monitoring wells across the Site. MNA monitoring results would be evaluated to demonstrate compliance with the MTCA criteria for use of MNA (e.g., stable or shrinking plume, chemical/biological degradation [which is a substantial mechanism of natural attenuation at the Site], and reasonable rates of restoration). Because benzene in the deep (50-ft) groundwater zone is already below the MNA RL (see Section 5.4.3.1), only contaminant concentrations will be monitored to observe for data trends, which are expected to decrease proportionally to the concentrations in the shallower zones.

For cost-estimating purposes, it is assumed that the MNA monitoring schedule would be similar to Ecology guidance (Ecology 2005) and would include quarterly groundwater sampling from a select representative subset (to be determined) of the monitoring wells shown on Figure 5-2 for the first year, annual sampling for 5 years, and biennially (every 2 years) for the next 10 years. Thereafter, it is assumed that groundwater monitoring and sampling would be conducted every 2.5 years until the MNA RL proposed in Section 5.4.3.1 is met, or if requested by the Port and approved by Ecology to further reduce the sampling frequency.

Another form of naturally occurring attenuation known as natural source zone depletion (NSZD) is anticipated to result in cleanup of smear zone and vadose zone soils at the Site. NSZD depletes LNAPL and residual petroleum mass and reduces LNAPL saturation and mobility through the combined action of natural processes including volatilization, dissolution, and biodegradation (ITRC 2018). Under this alternative, the effect of NSZD will be observable through LNAPL monitoring during MNA monitoring and empirically based on the results of groundwater monitoring; however, confirmation soil sampling will not be performed until after groundwater pCULs are met.[51]

#### 5.4.3.1 Remediation Level—MNA (Vapor Intrusion Screening Level)

A benzene RL was developed to identify a point at which MNA monitoring can be discontinued followed by general compliance monitoring as required by the institutional controls and the 5-year review process. The proposed RL for discontinuing MNA monitoring and eliminating the requirement

[51] Soil performance sampling is not required because groundwater concentrations will serve as the method for evaluating compliance with the soil leaching to groundwater pathway and because direct contact exposure with potentially contaminated soil will be protected through institutional controls. In addition, the RI identified no TPH concentrations above the pCULs within 5 ft of ground surface making it unlikely for human direct contact to occur, especially with the implementation of appropriate institutional controls.

for engineering controls on future buildings will be equivalent to the VI groundwater SL as follows for Site-wide monitoring wells:

- **Benzene**—concentrations Site-wide below the VI groundwater SL of 24 µg/L[52]
- **PCE**—concentrations Site-wide below the VI groundwater SL of 100 µg/L
- **TCE**—concentrations Site-wide below the VI groundwater SL of 8.4 µg/L
- **VC**—concentrations Site-wide below the VI groundwater SL of 3.5 µg/L.

Recent guidance from Ecology (Implementation Memorandum No. 18; Ecology 2018c) rescinded previously published groundwater SLs for VPH in groundwater. Several justifications were cited, one of which is that attenuation of benzene in the vadose zone is slower than for other hydrocarbons, making the benzene SLs inherently more conservative and a good proxy for assessing overall VI risk.

Based on current benzene concentrations at the Site, it is estimated that the MNA groundwater RL for benzene related to VI can be achieved in groundwater across the Site in approximately 85 years (or 64 years after shoreline treatment is completed) and that the benzene groundwater CUL may be achieved Site-wide (standard POC) in 152 years (or 67 years after the VI RL is met; see Appendix F).

### 5.4.4 Compliance Monitoring

Alternative 2 includes compliance monitoring as follows:

- Protection monitoring will be provided for groundwater monitoring personnel as provided in a Site-specific health and safety plan.
- Performance monitoring will be conducted upgradient and downgradient of the shoreline EISB treatment zone, in the Hylebos Hot Spot, and for Site-wide MNA as indicated above.

After the Hylebos Hot Spot RL is met (estimated 21 years; Appendix F) and the MNA RL is met (estimated 85 years; Appendix F), compliance sampling and monitoring will be performed for COCs only as required by the institutional controls and the 5-year review process until the upland groundwater CULs are achieved at the standard POC (estimated 152 years[53] total from initial implementation; Appendix F). A minimum of four quarters of confirmational groundwater monitoring will be performed after completion of performance monitoring.

[52] It is recognized that reaching the MNA remediation level (vapor intrusion screening level) for groundwater does not guarantee that soil gas SLs will also be met (i.e., benzene concentration in soil gas below 107 micrograms per cubic meter [µg/m$^3$] across the Site). In the event future occupied buildings are planned, performance soil gas sampling will be required to determine whether soil gas contaminant concentrations, originating from residual soil contamination, are in exceedance of soil gas SLs and whether engineering controls will be needed.

[53] Restoration time frame estimates are based on natural attenuation of benzene at Blair Hot Spot groundwater monitoring well 721-MW2-15. Benzene concentrations at the well are estimated to meet the RL for VI (24 µg/L) in 85 years, and the pCUL at the standard POC (1.6 µg/L) in 152 years. 721-MW2-15 was chosen to estimate restoration time frames because it is anticipated to be the final well to reach the RL and pCUL (based on current concentration and contaminant decay rate).

The time estimates to reach the RLs and the CULs at the standard POC are considered conservative, as they do not take into consideration the beneficial impact of the Occidental Site remedy on the restoration time frames for the Site. Based on the Buscheck and Alcantar (1995) analytical solution for biodegradation,[54] the anticipated effect of the Occidental Site remedy of roughly doubling hydraulic gradient, should halve the restoration time frames presented in this FS report, which reflect current Site hydrology. Additionally, the change in groundwater flow will enhance comingling of TPH and cVOCs and pull in electron acceptors naturally present in groundwater outside the petroleum plume, both of which are expected to further enhance contaminant attenuation rates at the Site and reduce restoration time frames.

As indicated in Section 5.4.3, the effects of NSZD on smear zone and vadose zone soil will be observable based on LNAPL monitoring and groundwater quality monitoring; however, NSZD performance monitoring in soil will not be conducted. During the 152-year restoration time frame for groundwater, NSZD processes in soil are also expected to degrade contamination in soil to below pCULs. Once groundwater has been demonstrated to meet pCULs, soil sampling would be also conducted to confirm compliance with soil pCULs.

### 5.4.5 Institutional and Engineering Controls

Per WAC 173-340-440(4)(e), institutional controls are required for this remedial alternative because of the use of a CPOC as the basis for measuring compliance at the Site. Engineering controls may be necessary in conjunction with the institutional controls.

Institutional controls would be established for as long as necessary until CULs are met at the standard POC (estimated 152 years; see Appendix F). Institutional controls for this alternative would be implemented (in accordance with WAC 173-340-440) to achieve the following:

- Prohibit the use of groundwater at the Site as a potable water supply (groundwater at the Site has been determined to not be a source of potable water; Aspect 2016).
- Restrict intrusive activities with an environmental covenant attached to tenant leases at the Site that would put workers or the public in contact with contaminated soil or groundwater without Ecology's written consent.
- Require that proper safety measures and soil management practices be implemented as part of any project involving disturbance of soils at depths that may encounter contaminated soil or groundwater.

[54] The Buscheck and Alcantar approach is the basis of the biodegradation rate calculation in Module 5 of Ecology's Natural Attenuation Analysis Tool Package for Petroleum-Contaminated Groundwater Data Analysis Tool Package.

$\lambda = \frac{v_c}{4\alpha_x} \times \left\{ \left[ 1 + 2\alpha_x \left( \frac{k}{v_{gw}} \right) \right]^2 - 1 \right\}$; where λ = biodegradation rate, $v_c$ = contaminant velocity, α = dispersity, k = bulk attenuation rate, $v_{gw}$ = groundwater velocity.

- Require any design for new construction of occupied facilities to include the evaluation and, if necessary, implementation of engineering controls to mitigate potential VI while groundwater and/or soil gas concentrations are above levels protective of VI.

The institutional controls for the Site would be conveyed as a restrictive covenant, in adherence with WAC 173-340-440, and recorded on the deeds registered with Pierce County and/or the City. This covenant would be binding on the owner's successors and assignees. Documented administrative procedures would need to be established to ensure that development and construction activities on the Site are coordinated carefully to prevent unacceptable exposure of subsurface contamination to construction contractors.

Note that the southern and western portions of the Site (portions of the 1001 property and the 500 property), which are the actively used portions of the Site, are fully paved, which will minimize the potential for inadvertent human contact with Site soil. The northern portion (the 709 property) is primarily unpaved, with the exception of a gravel roadway and small asphalt pad. Although capping is often utilized in combination with institutional controls as a protective engineering control for human health direct contact with shallow soil and groundwater contamination, the Port and Mariana are electing not to use capping as an engineering control at the Site. The rationale for this decision is as follows: 1) it is not deemed necessary as the Site is securely fenced, there are strict access controls for entry on to the Site, and administrative/institutional controls will readily prevent unauthorized intrusive activities that could put workers into contact with contaminated media at the Site; and 2) capping is counter-productive to natural attenuation/NSZD processes for petroleum products (i.e., limiting natural soil respiration inhibits biological and oxidative reactions that degrade petroleum and degradation byproducts). Parts of the Site are already paved, but no additional paving will be added to the Site as part of this remedy.

The current lease for the actively used portions of the 1001 property precludes the possibility of construction of any occupied facilities on those properties until at least 2040 (when the current lease ends). If benzene concentrations in groundwater are still above concentrations protective of indoor air at such future time that an occupied building is planned for this portion of the Site,[55] engineering controls will be implemented as part of building design and construction. The use of vapor barriers or subslab depressurization may be implemented, as needed, for protection of indoor air at future occupied buildings; this may be needed at Site locations where volatile COCs are present in vadose zone soil and/or shallow groundwater at concentrations above CULs protective of indoor air. The requirement for VI controls under these conditions will be conveyed in the institutional controls.

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[55] Note that the historical 721 portion of the 1001 property is the primary area of the Site where benzene concentrations exceed VI SLs. The Alexander Avenue ROW will not support occupied facilities, benzene has not been measured at concentrations exceeding the VI SL on the 709 property, and the benzene levels at the 500 property (which has no occupied buildings within the Site boundaries and is not anticipated to change usage in the near future) are not anticipated to exceed the VI SL for an extended period after final cleanup is initiated.

### 5.4.6 Cost Estimate

The specific items anticipated to be included in Alternative 2 are listed in Table 5-2 along with their estimated costs. The total estimated present-worth cost of Alternative 2 is approximately $3,100,000. This is an FS-level estimate and the actual costs may be as much as 30 percent less or 50 percent greater than the estimate.

## 5.5 Alternative 3: Blair Hot Spot EISB and Bioventing, Hylebos Hot Spot Bioventing, Shoreline EISB, and MNA

Alternative 3 includes hot spot bioremediation (EISB and bioventing at the Blair Hot Spot, bioventing only at the Hylebos Hot Spot) in addition to the remedial components of Alternative 2, which are shoreline bioremediation, MNA, I&ECs, and compliance/performance monitoring. Figure 5-3 presents a conceptual representation of Alternative 3, including the proposed hot spot bioremediation areas.

Hotspot EISB and bioventing will be applied to the shallow (15-ft) groundwater zone only to address the primary sources of groundwater and soil contamination. The results of these actions are anticipated to result in more rapid reductions in groundwater contamination in the deeper (25- and 50-ft) groundwater zones.

Angled wells near the Site shorelines are proposed to demonstrate compliance with the pCULs at the CPOC for groundwater under this Alternative (same CPOC proposed for Alternatives 2 through 5, which is the point or points where groundwater flows into surface water). RLs are proposed to guide operations of the proposed bioremediation systems at the shoreline and in the hot spots. It is anticipated that when RLs are met at the hotspots, nearshore site groundwater would be protective of surface water, bioremediation injections would cease, and long term monitoring for MNA would begin. The following sections provide additional descriptions of each element of Alternative 3.

### 5.5.1 Point of Compliance

The same POCs as Alternative 2 (see Section 5.4.1) are proposed for Alternative 3: standard POC for soil from ground surface to 15 ft bgs; CPOC for groundwater at the point at which groundwater discharges to surface water. Compliance with pCULs at the CPOC will be demonstrated at new angled groundwater monitoring wells installed within the 15-ft and 25-ft depth zones and located near Site shorelines (or at alternative locations determined during the pre-remedial design investigation).

### 5.5.2 Hot Spot Bioremediation

Hot spot remediation (bioventing or EISB or both) will be performed in the areas of the Site where TPH concentrations in soil are greater than 19,000 mg/kg or benzene concentrations in soil are greater than 19 mg/kg. These hot spots appear to be acting as ongoing sources of groundwater contamination in other downgradient areas of the Site, as well as in deeper groundwater. The hot spot areas include the Blair Hot Spot (LNAPL area beneath and east of Alexander Avenue) and the

Hylebos Hot Spot (hot spot analysis is described in Section 2.3 and the LNAPL area is described in Section 2.2).

Alternative 3 bioremediation includes a combination of bioventing and EISB at the Blair Hot Spot to address LNAPL and bioventing only at the Hylebos Hot Spot to address elevated levels of petroleum contamination. The following sections provide additional details on this approach.

#### 5.5.2.1 Bioventing—Blair and Hylebos Hot Spots

Bioventing will be initiated across both Site hot spots at the start of the final cleanup action. Bioventing will be performed to enhance NSZD that is naturally occurring in the hot spots. As discussed in Section 5.4.3, NSZD depletes LNAPL mass and reduces LNAPL saturation and mobility through the combined action of natural processes (volatilization, dissolution, and biodegradation).[56] Bioventing would use active or passive systems to deliver air to the subsurface. This enhances NSZD through aerobic biological degradation of the petroleum hydrocarbons in the saturated and unsaturated zone and by conversion and venting of the methane and carbon dioxide ($CO_2$) resulting from biological degradation of the petroleum hydrocarbons under methanogenic conditions.[57] The intent of focusing bioventing in the hot spot areas is to target free petroleum mass that could act as an ongoing source of dissolved-phase groundwater contamination and reduce restoration time frames for meeting overall Site remediation goals.[58]

For hot spot bioventing cost-estimating purposes, it is assumed that four air pumps (e.g., wind turbines) and approximately 2,200 lineal ft of 4-inch perforated pipe would be required for adequate bioventing of hot spot areas. It is assumed that bioventing implementation would include quarterly groundwater sampling in the treatment areas for the first year, semiannual sampling for years two and three, and then annually until the RL is met. The bioventing system would also require an operation and maintenance (O&M) program. It is assumed that the bioventing system will be operated for approximately 9 years at the Hylebos Hot Spot until the groundwater RL is met (see Section 5.5.2.2) and approximately 9 years (in conjunction with EISB) at the Blair Hot Spot (see Appendix F) until the LNAPL thickness RL is met (see Section 5.5.2.4). Once the hot spot RLs have been met, the bioventing system will continue to be operated while monitoring data indicates that it is

[56] The recent advances in understanding NSZD have resulted in a shift toward a fuller appreciation of the importance of methanogenesis, direct biodegradation of LNAPL, and vadose zone transport of biogenic gases. It has also become evident that the rate of LNAPL depletion had historically been greatly underestimated. To date, most measurements have provided NSZD rates in a relatively narrow range. An analysis of rate information from 25 sites revealed the middle 50 percent of sites exhibited NSZD rates falling between 700 and 2,800 gallons/acre/year, with a median of approximately 1,700 gallons/acre/year (ITRC 2018).

[57] Accumulation of the methane and $CO_2$ byproducts of petroleum degradation in the vadose zone can slow the rate of NSZD. Bioventing results in optimal oxidation of methane to $CO_2$, venting of both byproducts, and optimal NSZD rates.

[58] It is assumed that bioventing technology will accelerate decay by 1.5 times in the Blair Hot Spot and 3 times in the Hylebos Hot Spot (slower rate anticipated in the Blair Hot Spot due to greater concentration of TPH mass and decay rate observations in the natural attenuation analysis; Port 2017). EISB would accelerate decay by 3 times in the Blair Hot Spot and 6 times Hylebos Hot Spot in the downgradient dissolved plume. Rates are based on degradation rate increases observed at other bioremediation sites (LAI 2018b; see Appendix F).

effectively enhancing degradation of subsurface petroleum contamination (and contingent upon its components not resulting in unacceptable restrictions or limitations on Site use or development).[59]

#### 5.5.2.2 Remediation Levels—Hylebos Hot Spot Bioventing

The proposed groundwater RLs for bioventing in the Hylebos Hot Spot are based on protection of marine surface water beneficial uses. The Hylebos Hot Spot appears to be the primary upgradient source of groundwater impacts at the shoreline of the Hylebos Waterway. Water quality data collected in May and August 2016 were used to model the attenuation of TPH and benzene that occurs between the Hylebos Hot Spot and the shoreline (shoreline wells). The attenuation factors calculated by the model were then used to determine RL concentrations in the Hylebos Hot Spot (see Section 5.4.2.1) that, when achieved, are expected to result in meeting pCULs at the CPOC.

The primary COCs at the Site shorelines are benzene, TPH-D/O, and TPH-G; thus, attenuation models were developed for those constituents. Model calculations, results, and a description of the methodology are presented in Appendix D. Based on modeled attenuation rates for these contaminants, the proposed RLs are as follows for monitoring wells in the Hylebos Hot Spot area:

- **Benzene:** 86 µg/L (for groundwater protection of surface water CUL of 1.6 µg/L).
- **TPH-D/O without SGC:** 2,600 µg/L (for groundwater protection of surface water CUL of 500 µg/L).
- TPH-G: 85,000 µg/L (for groundwater protection of surface water CUL of 800 µg/L).
    - Note: The TPH-G RL is already being met at the Hylebos Hot Spot; therefore, a TPH-G RL is not likely to be needed for the Hylebos Hot Spot.

If bioventing accelerates the benzene decay rate by a factor of 3,[60] the Hylebos Hot Spot RL may be expected to be met and result in reaching the pCULs for benzene at the shoreline CPOC in 9 years (see Appendix F).[61]

#### 5.5.2.3 EISB—Blair Hot Spot

Injection of nitrate and/or sulfate as electron acceptors would be performed in the Blair Hot Spot area to stimulate EISB where a LNAPL thickness greater than 0.1 ft was identified in monitoring wells during the RI (see Figure 1-4). An area of LNAPL greater than 0.1-ft thick was identified in the Blair Hot

[59] The Port may elect to continue operating the bioventing for as long as it is determined by the Port to be cost-effective in relation to substantive reductions in the overall Site restoration time frame.

[60] Compared to the current condition with minimal vadose zone air movement because of pavement over much of the Site.

[61] MW-109-15 was chosen to estimate the restoration time frame because it anticipated to be the final well on the Hylebos-side of the groundwater divide to reach the surface water protection concentration (based on current concentration and contaminant decay rate). The estimated 9 years to reach pCUL for benzene at the CPOC is based on an anticipated 7 years to reach the Hylebos Hot Spot RL with an additional 2 years to account for groundwater travel times between the hot spot on the waterway.

Spot but not within the Hylebos Hot Spot. EISB injections would be initiated at the same time as bioventing is initiated.

The extent and specific location of the EISB injection well network will be based on conditions at the Site identified during a pre-remedial design investigation conducted in conjunction with the engineering design phase of the cleanup. This adaptive management approach will help to optimize EISB injections and most efficiently meet the remedial objectives and RLs for the Blair Hot Spot area. However, for cost-estimating purposes for this FS, it is assumed that the injection system will consist of up to 42 injection wells (oriented in rows perpendicular to the direction of groundwater flow spaced on approximately 10-ft centers) plus three horizontal injection wells installed in the portion of the LNAPL area beneath the Alexander Avenue ROW. Nitrate and/or sulfate solutions (or equivalent—to be determined during design) would be periodically injected to groundwater via the injection wells to stimulate anaerobic biodegradation of the petroleum LNAPL. It is assumed that enhanced bioremediation would include quarterly groundwater sampling in the treatment areas for the first year of implementation, semiannual sampling for years two and three, and then annually until the RL is met. For FS costing, up to 20 injection events over the course of approximately 9 years may be necessary to degrade the mobile LNAPL and reach RLs in the Blair Hot Spot treatment area.

#### 5.5.2.4 Remediation Levels—Blair Hot Spot Bioremediation

Bioremediation through the combination of bioventing and EISB will be used to meet the RLs in the Blair Hot Spot. Site data indicate that the Blair Hot Spot may not be resulting in a complete exposure pathway to the surface water body (the Blair Waterway)—i.e., benzene and TPH concentrations are not in exceedance of shoreline preliminary groundwater RLs (see discussion at end of this section) at the 25’ Blair shoreline monitoring well. However, shallow water quality (in the 15-ft groundwater zone) near the Blair shoreline has not been evaluated. This area has been identified by Ecology as a data gap to be resolved through monitoring well installation during remedial design. In addition to impacts to Blair Waterway, the Alexander Avenue sanitary sewer line runs through the Blair Hot Spot and contaminated groundwater can infiltrate into the line. Bioventing and EISB are proposed for implementation in the Blair Hot Spot to target LNAPL that could act as an ongoing source of dissolved-phase petroleum contamination in upland groundwater areas.

The proposed RL for bioventing and EISB injections in the Blair Hot Spot is based on treating groundwater to concentrations that are protective of human health direct contact and achieving reduction of LNAPL (source control) to the extent practicable as required for later transition of the remedy to MNA. Accordingly, the RL is a mass reduction target based on achieving the lower of the TPH pCUL for soil (17,000 mg/kg) and the residual saturation concentration for weathered gasoline and middle distillate in the fine-to-medium sand occurring at the Site. MTCA Table 747-5 provides residual saturation limits for weathered gasoline (1,000 mg/kg) and middle distillates (diesel-range hydrocarbons; 2,000 mg/kg) in coarse sand and gravelly soils. However, residual saturation will be higher in the fine-to-medium sands at the Site. Because the extent of observed LNAPL aligns closely with the extent of TPH in soil greater than the hot spot value of 19,000 mg/kg determined by Ecology (see Section 2-3 and Figures 1-4 and 2-3), the 19,000 mg/kg TPH value appears to be an empirically based, close approximation of the residual saturation limit for the Site.[62] Therefore, the RL and the goal for the Blair Hot Spot remediation is as follows:

- **TPH**—Reduction of soil concentrations to below the residual saturation level RL and the direct contact pCUL for soil of 17,000 mg/kg.

Because obtaining consistent and accurate soil concentrations over time is difficult due to soil and contaminant heterogeneities, a visual/measured LNAPL standard will be used in the Blair Hot Spot area as a proxy for ongoing evaluation of the progress of bioventing and EISB injections in achieving the RL. The following will be used as an approximate guide for evaluating successful degradation of LNAPL and achieving the TPH RL at the Blair Hot Spot:

- In the area with LNAPL thickness greater than 0.1 ft, EISB injections will generally be continued until LNAPL thickness is reduced to less than 0.1 ft for four consecutive quarters of monitoring (measured in existing monitoring wells).
- In the area with measurable LNAPL (thickness greater than 0.01 ft; inclusive of area in bullet above), bioventing will continue at least until EISB injections are completed (i.e., until LNAPL thickness greater than 0.1 ft in the Blair Hot Spot is reduced to less than 0.1 ft—see bullet above).

Once the above LNAPL targets are met and EISB has been discontinued. Bioventing in this area could also be discontinued; however, the bioventing systems may continue to operate if monitoring data indicates they are effectively enhancing degradation of petroleum, or until Site development or other requirements necessitate their removal. To demonstrate that residual saturation levels have been achieved, performance soil testing may be conducted to demonstrate achievement of the soil RL for the Blair Hot Spot. If soil sampling identifies some remaining areas above the RL, active bioventing will continue in those areas until the residual saturation (LNAPL thickness target) RL is achieved.[63]

If monitoring wells to be installed in the 15-ft zone near the Blair Waterway during remedial design indicate that surface water may be impacted, preliminary RLs have been estimated at the Blair Hot Spot for protection of surface water in the Blair Waterway. Model calculations, results, and a description of the methodology are presented in Appendix D. Based on modeled attenuation rates for these contaminants, the preliminary RLs are as follows for monitoring wells in the Blair Hot Spot area (however, may be revised based on the results of pre-remedial investigation of the 15-ft zone):

- **Benzene:** 2,600 µg/L (for groundwater protection of surface water CUL of 1.6 µg/L).

[62] This value is also consistent with documented data for empirical relationships between LNAPL type, soil type, and residual saturation that has been compiled in multiple academic and regulatory agency documents (Mercer and Cohen 1990, Brost and DeVaull 2000, Adamski, et al. 2003).

[63] For the purposes of this FS, active bioventing is assumed to be terminated when LNAPL thickness is reduced to less than 0.1 ft (estimated to be 9 years).

- Note: The benzene RL is already being met at the Blair Hot Spot and CULs currently appear to be met in groundwater near the Blair Waterway shoreline; therefore, a benzene RL is not likely to be needed for the Blair Hot Spot.

- **TPH-D/O without SGC:** 7,300 µg/L (for groundwater protection of surface water CUL of 500 µg/L).
- **TPH-G**: 4,600 µg/L (for groundwater protection of surface water CUL of 800 µg/L).

Note that based on the following assumptions, it is estimated that the Blair Hot Spot concentrations will be reduced to the soil direct contact CUL (17,000 mg/kg) in 13 years with EISB and bioventing for the first 9 years, and bioventing only for the following 4 years (see Appendix F):

- Bioventing would enhance the NSZD rate[64] to the median published value of 1,700 gallons/acre/year (ITRC 2018);[65]
- Combination of bioventing and EISB injections would enhance the NSZD rate to the typical upper end published value of 2,800 gallons/acre/year (ITRC 2018).

### 5.5.3 Shoreline EISB

Shoreline EISB would be incorporated into Alternative 3 in the same manner and with the same RLs as discussed in Alternative 2 (see Section 5.4.2). As shown for Alternative 2, shoreline EISB is expected to reduce shoreline concentrations to be protective of surface waters in 5 years. However, because of active treatment at the upgradient Hylebos Hot Spot, the total number of injection events and the duration of shoreline treatment are assumed to be lower for Alternative 3. It is estimated that the Hylebos Hot Spot RL (benzene = 86 µg/L; TPH-D/O = 2,600 µg/L, as described in Section 5.5.2.2) for groundwater protective of surface water will be achieved within 7 years after implementation of the bioventing system. Based on a groundwater travel time between the Hylebos Hot Spot and the shoreline (estimated at 2 years), it is assumed for cost-estimating purposes that the shoreline remediation system will consist of up to 10 injection events over 5 years (see Appendix F) with quarterly groundwater sampling. If rebound occurs following this period of shoreline treatment, additional injection events may be necessary. Prior to termination of shoreline treatment, groundwater CULs protective of surface water at the new angled wells (CPOC) will be confirmed via groundwater sampling.

### 5.5.4 MNA

While natural attenuation will be continually occurring in areas of the Site not undergoing active remediation, formal MNA would not begin until completion of hot spot and shoreline bioremediation. MNA would include analysis of contaminant concentrations and natural attenuation parameters (geochemical indicators) as described under Alternative 2, Section 5.4.3. MNA monitoring would be

[64] NSZD rates stated are from the ITRC guidance for the middle 50 percent of the 25 NSZD study sites evaluated.

[65] Estimated volume of TPH in the Blair Hot Spot is 95,000 gallons. The estimated volume remaining after reaching residual saturation is 64,000 gallons. See Appendix D.

discontinued upon meeting the MNA RL described in Section 5.4.3.1 (24 µg/L benzene), after which COC sampling would be performed until pCULs are met Site-wide.

For cost-estimating purposes, it is assumed that MNA implementation would include quarterly groundwater sampling from a select representative subset of monitoring wells shown on Figure 5-2 for the first year after completion of other active remedial actions (assumed to be year 10), annually for 4 years, and biennially for the next 5 years. After the first 10 years of MNA, MNA sampling would be conducted every 2.5 years until the MNA RL is met, or if requested by the Port and approved by Ecology to further reduce the sampling frequency. Because overall Site restoration would be more rapid due to bioremediation of the hot spot  areas, it is estimated that the MNA RL would be met in approximately 29 years from initial remedy implementation (see Appendix F), after which performance sampling and analysis would be conducted (every 5 years) for COCs only until CULs are achieved at the standard POC (estimated 94 years total from initial implementation; see Appendix F).

### 5.5.5 Compliance Monitoring

Alternative 3 includes compliance monitoring as follows:

- Protection monitoring will be provided for groundwater remediation, O&M, and monitoring personnel as provided in a Site-specific health and safety plan.
- Performance monitoring will be conducted upgradient and downgradient of the shoreline EISB treatment zone, in the Hylebos and Blair Hot Spots, and for Site-wide MNA as indicated above. Additional performance sampling and monitoring will be performed for COCs as required by the institutional controls and the 5-year review process until the upland groundwater CULs are achieved at the standard POC (estimated 94 years; Appendix F) [66]. A minimum of four quarters of confirmational groundwater monitoring will be performed after completion of performance monitoring.

As indicated for Alternative 2, the effects of NSZD on smear zone and vadose zone soil will be observable based on LNAPL monitoring and groundwater quality monitoring; however, NSZD performance monitoring in soil will not be conducted. Also, as indicated above, bioventing will significantly enhance the effects of NSZD. During the 94-year restoration time frame for groundwater, bioventing and NSZD processes in soil are also expected to degrade contamination in soil to below pCULs. Once groundwater has been demonstrated to meet pCULs, soil sampling would be also conducted to confirm compliance with soil pCULs.

### 5.5.6 Institutional and Engineering Controls

I&ECs would be incorporated into Alternative 3 in the same manner as Alternative 2 (Section 5.4.5).

[66] 721-MW2-15 was chosen to estimate restoration time frames because it is anticipated to be the final well to reach the RL and pCUL (based on current concentration and contaminant decay rate).

### 5.5.7 Cost Estimate

The specific items anticipated to be included in Alternative 3 are listed in Table 5-3 along with their estimated costs. The total estimated present-worth cost of Alternative 3 is approximately $4,700,000. This is an FS-level estimate and the actual costs may be as much as 30 percent less or 50 percent greater than the estimate.

## 5.6 Alternative 4: Hot Spot EISB and Bioventing and MNA

Alternative 4 includes hot spot bioremediation (EISB and bioventing at both Blair and Hylebos Hot Spots) in addition to MNA, I&ECs, and compliance/performance monitoring. Figure 5-4 presents a conceptual representation of Alternative 4, including the proposed hot spot bioremediation areas. The CPOC for groundwater under this Alternative is the point or points at which groundwater flows into surface water (same CPOCs proposed for Alternatives 2 through 5). RLs are proposed to guide operations of the proposed bioremediation systems in the hot spots, and to transition from MNA (to meet the VI screening levels) to 5-year reviews (performance monitoring). The following sections provide additional descriptions of each element of Alternative 4.

### 5.6.1 Point of Compliance

The same POCs as Alternative 2 (see Section 5.4.1) are proposed for Alternative 4: standard POC for soil from ground surface to 15 ft bgs and CPOC for groundwater at the point or points at which groundwater flows into surface water. Compliance with pCULs at the CPOC would be demonstrated using angled monitoring wells to be installed within the 15-ft and 25-ft depth zones and within approximately 15–20 ft upgradient from where groundwater discharges to surface water (or at alternative locations determined during the pre-remedial design investigation).

### 5.6.2 Hot Spot Bioremediation

Hot spot remediation (bioventing and EISB) will be performed in the areas of the Site where TPH concentrations in soil are greater than 19,000 mg/kg or benzene concentrations in soil are greater than 19 mg/kg. These hot spots appear to be acting as ongoing sources of groundwater contamination in other downgradient areas of the Site, as well as in deeper groundwater. The hot spot areas include the Blair Hot Spot (including the LNAPL area beneath and east of Alexander Avenue) and the Hylebos Hot Spot (hot spot analysis is described in Section 2.3 and the LNAPL area is described in Section 2.2).

Alternative 4 bioremediation includes a combination of bioventing and EISB at both the Blair and Hylebos Hot Spots. The following sections provide additional details on this approach.

#### 5.6.2.1 Bioventing—Blair and Hylebos Hot Spots

Bioventing will be initiated across both Site hot spots at the start of the final cleanup action. Bioventing will be performed to enhance NSZD in the same manner as described for Alternative 3 (see

Section 5.5.2.1). The same assumptions are also made for hot spot bioventing cost-estimating purposes as in Alternative 3.

It is assumed that the bioventing system will be operated throughout the period estimated to reach groundwater benzene VI SL, approximately 29 years at the Blair Hot Spot and 5 years at the Hylebos Hot Spot (see Appendix F).

#### 5.6.2.2 Remediation Levels—Blair and Hylebos Hot Spots Bioventing

The proposed groundwater RLs for discontinuing bioventing in the Blair and Hylebos Hot Spots will be equivalent to the VI groundwater SL:

- **Benzene**—concentrations below the VI groundwater SL of 24 µg/L.

The bioventing RL is expected to be met within 29 years of remedy implementation at the Blair Hot Spot and within 7 years at the Hylebos Hot Spot (Appendix F).

#### 5.6.2.3 EISB—Blair and Hylebos Hot Spots

EISB in the form of injection of nitrate and/or sulfate (or equivalent—to be determined during engineering design) as electron acceptors would be performed in both hot spot areas to stimulate petroleum biodegradation. EISB injections would be initiated at the same time bioventing is initiated.

The extent and specific location of the EISB injection well network will be based on conditions at the Site identified during a pre-remedial design investigation conducted in conjunction with the engineering design phase of the cleanup. This adaptive management approach will help to optimize EISB injections and most efficiently meet the remedial objectives and RLs for the Blair and Hylebos Hot Spot areas. However, for cost-estimating purposes for this FS, it is assumed that the injection system will consist of up to 115 injection wells (oriented in rows perpendicular to the direction of groundwater flow spaced on approximately 10-ft centers) plus three horizontal injection wells installed in the portion of the LNAPL area beneath the Alexander Avenue ROW. Nitrate and/or sulfate solutions (or equivalent—to be determined during design) would be periodically injected to groundwater via the injection wells to stimulate anaerobic biodegradation of the petroleum LNAPL and dissolved phase petroleum. It is assumed that implementation of EISB would include quarterly groundwater sampling in the treatment areas for the first year of implementation, semiannual sampling for years two and three, and then annually until the RL is met. For FS costing, it is assumed that up to 20 injection events over the course of approximately 9 years at the Blair Hot Spot and up to 10 injection events over the course of approximately 5 years at the Hylebos Hot Spot may be necessary to degrade the mobile LNAPL and reach RLs in the hot spot treatment areas.

#### 5.6.2.4 Remediation Levels—Blair and Hylebos Hot Spots EISB

Bioremediation through the combination of bioventing and EISB will be used to meet the RLs in the Blair and Hylebos Hot Spots. The TPH RL and LNAPL thickness target values for the Blair Hot Spot are the same for Alternative 4 as for Alternative 3 (see Section 5.5.2.4).

Once the above LNAPL targets are met, EISB will be discontinued and performance soil testing may be conducted to demonstrate achievement of the soil RL for the Blair Hot Spot. If soil sampling identifies some remaining areas above the RL, bioventing will continue in those areas until the RL is achieved. The same as for Alternative 3, it is estimated that the Blair Hot Spot concentrations will be reduced to the RL (17,000 mg/kg) in 13 years with implementation of bioventing and EISB in conjunction (see Appendix F).

The RLs for discontinuation of EISB for the Hylebos Hot Spot are the same as for bioventing under Alternative 3 (see Section 5.5.2.2). When achieved, these concentrations are expected to result in meeting shoreline pCULs at the CPOC.

- **Benzene:** 86 µg/L (for groundwater protection of surface water CUL of 1.6 µg/L).
- **TPH-D/O without SGC:** 2,600 µg/L (for groundwater protection of surface water CUL of 500 µg/L).
- **TPH-G:** 85,000 µg/L (for groundwater protection of surface water CUL of 800 µg/L).
    - Note: The TPH-G RL is already being met at the Hylebos Hot Spot; therefore, a TPH-G RL is not likely to be needed for the Hylebos Hot Spot.

EISB will be discontinued when benzene and TPH concentrations in the Hylebos Hot Spot are below the RLs, which is predicted to be in 5 years.

### 5.6.3 MNA

MNA would begin following completion of hot spot area bioremediation and would include analysis of contaminant concentrations and natural attenuation parameters (geochemical indicators), as described under Alternative 2, Section 5.4.3. MNA monitoring would be discontinued upon meeting the MNA RLs described in Section 5.4.3.1 (estimated time frame approximately 29 years [20 years after bioremediation]), after which COC sampling would be performed until benzene pCULs are met Site-wide (estimated to be 94 years from remedy implementation; Appendix F).

For cost-estimating purposes, it is assumed that the MNA implementation would commence following hot spot EISB and would include quarterly groundwater sampling for the first year, annual sampling for 4 years, biennial sampling for the following 5-year period, and then every 2.5 years thereafter until the MNA RL is met, [67] or if requested by the Port and approved by Ecology to further reduce the

[67] Proposed MNA sampling frequency are similar and not inconsistent with Ecology Guidance on Remediation of Petroleum-Contaminated Ground Water By Natural Attenuation. Publication No. 05-09-091, July 2005, which suggests a progression of

sampling frequency. When the MNA RL is met, groundwater sampling would transition to COC sampling to be conducted every 5 years in conjunction with a periodic review until pCULs are met Site-wide.

### 5.6.4 Compliance Monitoring

Alternative 4 includes compliance monitoring as follows:

- Protection monitoring will be provided for groundwater remediation, O&M, and monitoring personnel as provided in a Site-specific health and safety plan.
- Performance monitoring will be conducted in the Hylebos and Blair Hot Spots, and for Site-wide MNA as indicated above. Additional performance sampling and monitoring will be performed for COCs as required by the institutional controls and the 5-year review process until the upland groundwater CULs are achieved at the standard POC (estimated 94 years; Appendix F).[68] A minimum of four quarters of confirmational groundwater monitoring will be performed after completion of performance monitoring.

As indicated for Alternatives 2 and 3, the effects of bioventing and NSZD on smear zone and vadose zone soil will be observable based on LNAPL monitoring and groundwater quality monitoring; however, NSZD performance monitoring in soil will not be conducted. During the 94-year restoration time frame for groundwater, bioventing and NSZD processes in soil are also expected to degrade contamination in soil to below pCULs. Once groundwater has been demonstrated to meet pCULs, soil sampling would be also conducted to confirm compliance with soil pCULs.

### 5.6.5 Institutional and Engineering Controls

I&ECs would be incorporated into Alternative 4 in the same manner as Alternatives 2 and 3.

### 5.6.6 Cost Estimate

The specific items anticipated to be included in Alternative 4 are listed in Table 5-4 along with their estimated costs. The total estimated present-worth cost of Alternative 4 is approximately $4,500,000. This is an FS-level estimate and the actual costs may be as much as 30 percent less or 50 percent greater than the estimate.

## 5.7 Alternative 5: Hot Spot Excavation, Alexander Avenue Bioremediation, Shoreline EISB, and MNA

Alternative 5 includes the excavation of the accessible areas of Site hot spots, bioremediation of the hot spot under Alexander Avenue, in addition to the remedial components of Alternative 2, which are shoreline bioremediation, MNA, I&ECs, and compliance monitoring. Figure 5-5 presents the

declining frequencies of quarterly for the first year, semi-annually for the second and third years, and annually, **or less frequently** (emphasis added), for subsequent years.

[68] 721-MW2-15 was chosen to estimate restoration time frames because it is anticipated to be the final well to reach the RL and pCUL (based on current concentration and contaminant decay rate).

Alternative 5 Remedial Action components, including a delineation of the hot spot areas of the Site that would be targeted for excavation. New angled shoreline monitoring wells are proposed to demonstrate compliance with the pCULs at the CPOC for groundwater under Alternative 5 (same POCs proposed in Alternatives 2 through 4). RLs are proposed to guide operations of the proposed bioremediation system at the shoreline and in the soil hot spots. The following sections provide additional descriptions of each element of Alternative 5.

### 5.7.1 Point of Compliance

The same POCs are proposed for Alternatives 2 through 5 (see Section 5.4.1). This consists of the standard POC for soil (from ground surface to 15 ft bgs) and a CPOC for groundwater at the point or points where groundwater flows into surface water. Compliance with pCULs at the CPOC would be evaluated using new angled groundwater monitoring wells installed within the 15-ft and 25-ft depth zones and located near Site shorelines (or at alternative locations determined during the pre-remedial design investigation).

### 5.7.2 Hot Spot Excavation

Remedial excavations would be performed in the hot spot areas of the Site (Blair and Hylebos Hot Spots) where TPH concentrations in soil are greater than 19,000 mg/kg or benzene concentrations in soil are greater than 19 mg/kg (hot spot analysis is described in Section 2.3). Excavation would include removal of impacted soil in the vadose zone and smear zone soil above and beneath the static groundwater table, and removal of floating product where encountered in the excavation. This excavation area includes most of the area of measurable LNAPL (LNAPL source area described in Section 2.2). To remove the entire smear zone, dewatering would likely be required. The groundwater table at the Site is at approximately 7–9 ft bgs and the smear zone extends approximately 2–3 ft below the seasonally low groundwater table, bringing the projected depth of the excavation to approximately 12 ft bgs.

For cost-estimating purposes, it is assumed that the hot spot areas accessible to excavation (i.e., not under Alexander Avenue) extend over approximately 51,000 square ft of the Site and would be excavated to a depth of approximately 12 ft bgs (total estimated contaminated soil volume of approximately 16,000 $yd^3$). Excavated contaminated soil would be removed from the Site and disposed of at a Subtitle D landfill (likely the Pierce County/LRI landfill), while clean overburden soil will be segregated for possible reuse as excavation fill. It is also assumed that the water generated by dewatering operations during the remedial excavation would require treatment and disposal.

The intent of hot spot excavation is to remove LNAPL that could act as an ongoing source of dissolved-phase groundwater. Removal of LNAPL will reduce restoration time frames for meeting overall Site remediation goals.

The initial limits of the remedial excavation for the two hot spot areas—the Hylebos Hot Spot and the Blair Hot Spot—are defined by previously collected RI data. The excavation extent may be refined through potential additional soil sampling during the remedial design phase to better refine the extent of contamination, and sidewall confirmation sampling collected during the course of the remedial excavation. The actual excavation will be extended laterally, as practicable, until the hot spot RLs (see Section 5.7.2.1) are met. The excavation will also be extended vertically, as practicable, to remove the smear zone soils, but will not extend greater than 3 ft below the static groundwater table elevation or as otherwise achievable with general excavation pit dewatering.

The western portion of the Blair Hot Spot extends beneath the Alexander Avenue ROW and would not be excavated; petroleum mass beneath the roadway would be treated with bioremediation as described in Section 5.7.3. If the presence of other Site infrastructure (e.g., buildings, major underground utilities) in the proposed hot spot excavation areas limits the ability to perform remedial excavation work, these will be addressed on a case-by-case basis.

#### 5.7.2.1 Remediation Levels—Remedial Excavation

The proposed RLs for excavation of the Blair and Hylebos Hot Spots are based on Ecology's hot spot analysis (see Section 2.3). Because these hot spots appear to be the primary upgradient source of groundwater impacts at or near the shorelines of the Blair and Hylebos Waterways, it is anticipated that completion of remedial excavations in these areas will eventually result in improvement in groundwater quality and meeting the shoreline RLs (shoreline RLs are discussed in Section 5.4.2.1) and surface water pCULs.

The proposed remedial excavation RLs for the hot spot excavations are as follows:

- **Benzene**—concentrations in soil greater than 19 mg/kg
- **TPH**—concentrations in soil greater than 19,000 mg/kg.

It is assumed that the remedial excavation would take less than 1 year to complete and these RLs would be reached upon completion (except beneath the Alexander Avenue ROW). It is expected that Site soil CULs (with the exception of the Blair Hot Spot beneath Alexander Avenue) would largely be achieved at the completion of the remedial excavation and fully achieved shortly thereafter through NSZD/MNA. Based on current benzene concentrations downgradient of the Hylebos Hot Spot, it is estimated that shoreline groundwater RLs can be achieved in approximately 5 years; this is based on a 2-year groundwater travel time from the Hylebos Hot Spot to the shoreline (see Section 5.7.4). Shoreline bioremediation treatment is planned to occur during this 5-year interval, as described in Section 5.7.4. Prior to termination of shoreline treatment, compliance with groundwater pCULs at the CPOC will be confirmed via sampling at the new angled shoreline wells.

### 5.7.3 Alexander Avenue Bioremediation

Monitoring well data (e.g., HC-N11-6) and RI boring data (e.g., borings B-120 and B-121) indicate that LNAPL in the Blair Hot Spot area extends beneath and a small distance west of Alexander Avenue (Aspect 2016). The Alexander Avenue ROW is functionally inaccessible to excavation because it is a heavily used arterial truck route and rail lines for port-related activities; therefore, it is considered infeasible to excavate this portion of the Blair Hot Spot. The hot spot area beneath and west of Alexander Avenue would be treated with bioremediation. For cost-estimating purposes, it is assumed that bioventing and EISB injections would be performed using three horizontal injection wells bored beneath Alexander Avenue.

#### 5.7.3.1 Remediation Levels—Alexander Avenue

The proposed RL for bioventing and EISB injections under Alexander Avenue is based on the same criteria and approach as the RL for the Blair Hot Spot (see Section 5.5.2.4), treating to concentrations that are protective of human health direct contact and achieving treatment of mobile LNAPL. Accordingly, the RL is a mass reduction target based on achieving the lower of the TPH pCUL for soil (17,000 mg/kg) and the residual saturation concentration (estimated as 19,000 mg/kg TPH). The RL for the Alexander Avenue is as follows:

- **TPH**—Reduction of soil concentrations to below the residual saturation level RL and the direct contact pCUL for soil of 17,000 mg/kg.

Because obtaining consistent and accurate soil concentrations over time is difficult due to soil and contaminant heterogeneities, especially with the access limitations beneath Alexander Avenue, a visual/measured LNAPL standard may also be used for the Alexander Avenue area as a proxy for ongoing evaluation of the progress of bioventing and EISB injections in achieving the RL. The following will be used as an approximate guide for evaluating successful degradation of LNAPL and achieving the TPH RL at Alexander Ave:

- Reduction of LNAPL thickness to less than 0.1 ft for four consecutive quarters (if appropriate monitoring well locations can be established in Alexander Avenue).

It is assumed that the combination of EISB and passive bioventing will accelerate the NSZD rate to the typical upper end published value of 2,800 gallons/acre/year (ITRC 2018). Based on this rate, it is estimated that the residual saturation RL (LNAPL target thickness) will be met in 9 years and the TPH direct contact pCUL will be met in 13 years (see Appendix F). For cost-estimating purposes, it is assumed that 20 injection events would be required over approximately 13 years, in conjunction with bioventing, to degrade the remaining mobile LNAPL in the Alexander Avenue treatment area.

### 5.7.4 Shoreline Bioremediation

Shoreline bioremediation injections will be incorporated into Alternative 5 in the same manner as discussed in Alternatives 2 (see Section 5.4.2) and 3. However, the total number of injection events are assumed to be lower. Assuming the shoreline treatment system is installed by 2021 and benzene degradation is accelerated by a factor of 6, the shoreline CPOC pCUL will be reached within approximately 5 years of implementation (based on reaching a concentration of 39 µg/L benzene in the shoreline well MW-104-15; See Appendix D). In this alternative, it is estimated that mass removal in the Hylebos Hot Spot will reduce groundwater benzene levels in the Hylebos Hot Spot to a concentration protective of surface water (86 µg/L) within 1–3 years of excavation, and groundwater travel time between the Hylebos Hot Spot and the shoreline is estimated at 2 years. Thus, for cost-estimating purposes, it is assumed that the shoreline remediation system will consist of up to 8 injection events over the course of approximately 5 years (see Appendix F). Prior to termination of shoreline treatment, compliance with groundwater pCULs at the CPOC will be confirmed via sampling at the new angled shoreline wells.

Once the shoreline bioremediation RL is achieved and bioinjections are discontinued, 2 years of quarterly compliance monitoring will determine whether additional future injection events are needed to maintain groundwater compliance at the shoreline angled wells.

### 5.7.5 MNA

MNA would begin following completion of hot spot area excavations and Alexander Avenue bioremediation and would include analysis of contaminant concentrations and natural attenuation parameters (geochemical indicators), as described under Alternative 2, Section 5.4.3. MNA monitoring would be discontinued upon meeting the MNA RLs described in Section 5.4.3.1 (groundwater VI screening level – 24 µg/L of benzene), after which COC performance sampling would be performed until pCULs are met Site-wide.

For cost-estimating purposes, it is assumed that the MNA implementation would commence everywhere except Alexander Avenue following hot spot excavation and 5 years of shoreline bioremediation, and would include quarterly groundwater sampling for 1 year, semiannual sampling for the following 2 years, then annual sampling thereafter until the MNA RL is met. Because overall Site restoration would be more rapid due to excavation of the hot spot areas and bioremediation beneath Alexander Avenue, it is estimated that the MNA RL would be met in approximately 11 years from initial cleanup implementation (see Appendix F). After the MNA RL is met, COC sampling (performance monitoring) would be conducted (every 5 years in conjunction with a periodic review) until pCULs are met Site-wide (estimated 22 years).

### 5.7.6 Compliance Monitoring

Alternative 5 includes compliance monitoring as follows:

- Protection monitoring will be provided for remedial excavation activities, groundwater remediation actions, O&M, and monitoring personnel as provided in a Site-specific health and safety plan.
- Performance monitoring will be conducted during remedial excavation, upgradient and downgradient of the shoreline EISB treatment zone, in the Alexander Avenue treatment zone,

and for Site-wide MNA as indicated above. Performance sampling and monitoring would be performed for COCs as required by the institutional controls and the 5-year review process until the upland groundwater CULs are achieved at the standard POC (estimated 22 years; Appendix F). [69] A minimum of four quarters of confirmational groundwater monitoring will be performed after completion of performance monitoring.

As indicated for Alternatives 2 and 3, the effects of bioventing and NSZD on smear zone and vadose zone soil will be observable based on LNAPL monitoring and groundwater quality monitoring; however, NSZD performance monitoring in soil will not be conducted. During the 22-year restoration time frame for groundwater, bioventing and NSZD processes in soil are also expected to degrade residual contamination in soil remaining after excavation to below pCULs. Once groundwater has been demonstrated to meet pCULs, soil sampling would be also conducted to confirm compliance with soil pCULs.

### 5.7.7 Institutional and Engineering Controls

I&ECs would be incorporated into Alternative 5 in the same manner as Alternatives 2 through 4.

### 5.7.8 Cost Estimate

The specific items anticipated to be included in Alternative 5 are listed in Table 5-5 along with their estimated costs. The total estimated present-worth cost of Alternative 5 is approximately $8,500,000. This is an FS-level estimate and the actual costs may be as much as 30 percent less or 50 percent greater than the estimate.

## 5.8 Alternative 6: Extended Remedial Excavation, Alexander Avenue Bioremediation, and MNA for Deep Groundwater

Alternative 6 includes extended remedial soil excavation with bioremediation under Alexander Avenue, MNA, and compliance monitoring. Shoreline bioremediation is not included in this alternative. Figure 5-6 presents the Alternative 6 Remedial Action components, including a conceptual depiction of the remedial excavation area. Groundwater monitoring wells throughout the Site is the standard POC under this Alternative. No RLs are proposed for this Alternative. The following sections provide additional descriptions of each element of Alternative 6.

### 5.8.1 Point of Compliance

The standard POC for soil (from ground surface to 15 ft bgs) and groundwater (monitoring wells throughout the Site) are proposed under this Alternative.

[69] 721-MW12-15 was chosen to estimate restoration time frames because it is anticipated to be the final well outside of the hot spots to reach the RL and pCUL (based on current concentration and contaminant decay rate).

### 5.8.2 Extended Remedial Excavation

Alternative 6 includes performing a remedial excavation in areas of the Site where TPH concentrations in soil exceed 2,000 mg/kg or benzene concentrations in soil exceed 0.03 mg/kg (area with concentrations exceeding Method A CULs for unrestricted land use).[70] Excavation of the extended remedial excavation area, where feasible, would include removal of vadose zone soils and smear zone soils beneath the static groundwater table. To remove the entire smear zone, dewatering would likely be required. The groundwater table at the Site is at approximately 7–9 ft bgs and the smear zone extends approximately 2–3 ft below the seasonally low groundwater table, bringing the projected depth of the excavation to approximately 12 ft bgs.

As part of the extended remedial excavation, the Hylebos Waterway bulkhead along the Site shoreline would be removed and replaced following completion of excavation. To protect the Hylebos Waterway from excessive impacts caused by soil erosion and sedimentation during excavation and bulkhead removal and replacement, a temporary cofferdam would be installed within the waterway.

For cost-estimating purposes, it is assumed that an approximately 353,000-square-ft area of the Site would be excavated to a depth of approximately 12 ft bgs (total estimated soil volume of 157,000 $yd^3$). An estimated 98,000 $yd^3$ of contaminated soil (approximately 7 ft of smear zone and additional contaminated soil in vadose zone) would be removed from the Site and disposed of at a Subtitle D landfill (likely the Pierce County/LRI landfill); clean soil would be stockpiled at the Site and re-used as excavation fill material. It is also assumed that the water produced by dewatering operations would require treatment and disposal.

### 5.8.3 Alexander Avenue Bioremediation

As stated in Section 5.7.3, RI data indicates that LNAPL extends beneath Alexander Avenue (Aspect 2016); however, this area is functionally inaccessible because of its use as an arterial truck route and rail transportation, and it is considered infeasible to excavate this portion of the Site. Therefore, contaminated media beneath Alexander Avenue would be treated with bioventing and bioremediation injections using three horizontal injection wells.

It is assumed that the combination of bioinjections and passive bioventing will accelerate the NSZD rate to approximately 2,800 gallons/acre/year; and it is estimated that the Ecology-requested soil TPH CUL for this Alternative (total TPH = 2,000 mg/kg) will be met in 28 years (see Appendix F). For cost-estimating purposes, it is assumed that up to 20 injection events would be required over this period to degrade the LNAPL beneath Alexander Avenue and reach groundwater RLs (see Appendix F).

[70] Note that these CULs are lower than the pCULs identified in this FS and this alternative. Using these lower CUL values was included at Ecology's request.

### 5.8.4 MNA for Deep Groundwater

The remedial excavation and Alexander Avenue bioremediation actions described above are anticipated to result in cleanup of groundwater in the 15-ft zone, as well as removal of the source of contamination for the deeper groundwater zones. However, some benzene and TPH-G concentrations in the 25-ft zone (and benzene in the 50-ft zone) exceed the pCULs, and MNA may be necessary to achieve cleanup in these zones. MNA would include analysis of contaminant concentrations and natural attenuation parameters (geochemical indicators), as described under Alternative 2, Section 5.4.2. MNA monitoring would begin following completion of excavation and groundwater restoration to the VI SL (benzene = 24 µg/L) in shallow groundwater, and will be conducted at a select representative subset of the wells from the deeper groundwater zones, in a similar manner (e.g., same analytes, evaluation methodology) as Alternative 2. Assuming MNA monitoring will be discontinued when pCULs are met Site-wide, the estimated restoration time frame for MNA is approximately 22 years from original remedy implementation (see Appendix F).

For cost-estimating purposes, it is assumed that the MNA implementation would include quarterly groundwater sampling in the deep zone for the first year, annual groundwater sampling for the next 4 years, biennial sampling (every 2 years) for the following 5-year period (and if necessary, every 5 years thereafter), until pCULs are met in deep groundwater Site-wide (estimated 22 years total from initial implementation; see Appendix F).

### 5.8.5 Compliance Monitoring

Compliance monitoring is a requirement under MTCA to confirm the long-term effectiveness of a remedy. Because it is anticipated that the groundwater pCULs will be achieved at the standard POC in an estimated 22 years (Appendix F),[71] the only performance sampling and monitoring anticipated for this Alternative (beyond deep groundwater MNA monitoring discussed above) is EISB monitoring for the Alexander Avenue bioremediation, which may extend as long as 29 years (Appendix F). A minimum of four quarters of confirmational groundwater monitoring will be performed after completion of performance monitoring.

The effects of EISB, bioventing, and NSZD on smear zone and vadose zone soil under Alexander Avenue will be observable based on LNAPL monitoring and groundwater quality monitoring; however, NSZD performance monitoring in soil will not be conducted. During the 22-year restoration time frame for groundwater, EISB, bioventing and NSZD processes in soil are also expected to degrade residual contamination in soil remaining under Alexander Avenue to below pCULs. Once groundwater has been demonstrated to meet pCULs, soil sampling would be also conducted to confirm compliance with soil pCULs.

[71] 721-MW12-15 was chosen to estimate restoration time frames because it is anticipated to be the final well outside of the hot spots to reach the RL and pCUL (based on current concentration and contaminant decay rate).

### 5.8.6 Cost Estimate

The specific items anticipated to be included in Alternative 6 are listed in Table 5-6 along with their estimated costs. The total estimated present-worth cost of the extended excavation alternative is approximately $34,800,000. This is an FS-level estimate and the actual costs may be as much as 30 percent less or 50 percent greater than the estimate.

# 6.0 DETAILED EVALUATION OF REMEDIAL ACTION ALTERNATIVES

The six remedial alternatives for cleanup of the Site are evaluated in this section, using applicable MTCA evaluation criteria. A preferred alternative is selected based on the evaluation and comparison of the alternatives.

## 6.1 Evaluation Criteria

MTCA requires that cleanup alternatives meet certain minimum (threshold and other) requirements and be compared to a number of criteria to evaluate the adequacy of each alternative in achieving the intent of the regulations, and as a basis for comparing the relative merits of each of the cleanup action alternatives. Consistent with MTCA, the alternatives were evaluated with respect to compliance with threshold requirements, using permanent solutions to the maximum extent practicable, restoration time frame, and consideration of public concerns. The following sections briefly summarize the MTCA threshold and other requirements that the remedial alternatives under consideration must meet.

### 6.1.1 MTCA Threshold Requirements

As specified in WAC 173-340-360(2), all cleanup actions are required to meet the following threshold requirements:

- Protect human health and the environment.
- Comply with cleanup standards.
- Comply with applicable state and federal laws.
- Provide for compliance monitoring.

Remedial Alternatives 2 through 6 described in Section 5 achieve the four RAOs (Section 5.1) and meet all of the MTCA threshold requirements; therefore, each of these alternatives is a viable cleanup alternative for the Site under MTCA. The degree to which each cleanup action alternative meets the threshold requirements and other requirements listed in WAC 173-340-360(2) were determined by applying the specific evaluation criteria identified in MTCA (Sections 6.1 and 6.2).

As previously indicated, Remedial Alternative 1 is the No Action alternative. The “No Action” General Response Action is included as required for consistency with NCP. Alternative 1 does not meet MTCA minimum requirements (and cannot be selected as the preferred remedial action); however, for completeness, Alternative 1 is evaluated consistent with evaluation of the other five alternatives.

### 6.1.2 MTCA Additional Requirements

Under WAC 173-340-360(2)(b), when selecting from alternatives that meet the threshold requirements, the selection action must also address the following three criteria: use permanent solutions to the maximum extent practicable, provide a reasonable restoration time frame, and consider public concerns.

#### 6.1.2.1 Permanent Solution to the Maximum Extent Practicable

WAC 173-340-200 defines a permanent solution as one in which cleanup standards can be met without further action being required at the Site or any other site involved with the cleanup action, other than the approved disposal site of any residue from the treatment of hazardous substances. Ecology recognizes that permanent solutions may not be practicable for all sites and provides a procedure referred to as a disproportionate cost analysis (DCA; WAC 173-340-360[3][e]) to determine whether a cleanup action is permanent to the maximum extent practicable.

The purpose of the DCA is to determine if the incremental increase in costs of a cleanup alternative over that of a lower cost alternative is justified by providing a corresponding incremental increase in human health and environmental benefits. The DCA evaluates the relative benefits of a cleanup alternative based on a series of evaluation criteria. These criteria include:

- Protectiveness: Overall protectiveness of human health and the environment, including the degree to which site risks are reduced, time required to reduce risk at the facility and attain cleanup standards, risks during implementation, and improvement of overall environmental quality.
- Permanence: The degree of reduction in toxicity, mobility, and volume of hazardous substances, including the reduction or elimination of hazardous substance releases and sources of releases.
- Cost: Cost to implement the remedy including capital costs and operation and maintenance costs.
- Effectiveness over the long-term: Long-term effectiveness, including the degree of certainty that the alternative will be successful, long-term reliability, the magnitude of residual risk, and the effectiveness of controls required to manage treatment residues and remaining waste. The following types of cleanup action components are preferred in descending order, when assessing the relative degree of long-term effectiveness: Reuse or recycling; destruction or detoxification; immobilization or solidification; onsite or offsite disposal in an engineered, lined, and monitored facility; onsite isolation or containment with attendant engineering controls; and institutional controls and monitoring.
- Management of short-term risks: The risk to human health and the environment during construction and implementation, and the effectiveness of measures to manage the risk.
- Technical and administrative implementability: Implementability, including consideration of whether the alternative is technically possible; the availability of necessary offsite facilities, services, and materials; administrative and regulatory requirements; scheduling, size, and complexity of construction; monitoring requirements; access for construction, operations, and monitoring; and integration with existing facility operations.
- Consideration of public concerns: Whether the community has concerns and the extent to which those concerns are addressed.

If the incremental increase in cost is determined to be disproportionate to the incremental benefits, the more expensive alternative is considered impracticable and the lower cost alternative is determined to be permanent to the maximum extent practicable. This process provides a mechanism for balancing the permanence of the cleanup action with its costs, while ensuring that human health and the environment are adequately protected. Evaluation of the remedial alternatives through the DCA process is provided in Section 6.2.

#### 6.1.2.2 Reasonable Restoration Time Frame

WAC 173-340-360(4)(b) specifies that the following factors be considered when determining whether a cleanup action provides for a reasonable restoration time frame:

- Potential risks to human health and the environment.
- Practicability of achieving a shorter restoration time frame.
- Current use of the site, surrounding areas, and associated resources that are, or may be, affected by releases from the site.
- Availability of alternative water supplies.
- Likely effectiveness and reliability of institutional controls.
- Ability to control and monitor migration of hazardous substances from the site.
- Toxicity of the hazardous substances at the site.
- Natural processes that reduce concentrations of hazardous substances and have been documented to occur at the site or under similar site conditions.

Evaluation of restoration time frames for the remedial alternatives is provided in Section 6.2.4.

#### 6.1.2.3 Consideration of Public Concerns

Consideration of public concerns is an inherent part of the cleanup process under MTCA (see WAC 173-340-600). Prior to implementation of a cleanup action, Ecology will issue a CAP for public comment as specified in WAC 173-340-380. Under this process, the RI and FS reports, and the CAP will be available for public review as part of the 30-day comment period for the agreed order under the Ecology formal program.

## 6.2 Evaluation and Comparison of Alternatives

This section evaluates and compares the adequacy of each alternative relative to the criteria discussed in Section 6.1. As previously discussed, each of the cleanup action alternatives described in Section 5.0 (except Alternative 1) achieves the four RAOs presented in Section 5.1 and meets all of the MTCA threshold requirements; each alternative (except for Alternative 1) is, therefore, a viable and appropriate cleanup alternative under MTCA. The comparative analysis of the alternatives is organized by criteria and is presented in the following sections.

### 6.2.1 Threshold Requirements

For an alternative to achieve the threshold requirements, it must adequately protect human health and the environment, comply with cleanup standards, comply with state and federal laws, and provide for compliance monitoring. The remedial alternatives do or do not achieve the threshold requirements as identified in Table 6-1 and as summarized below:

- Protection of human health and the environment: Remedial Alternatives 2, 3, 4, 5, and 6 would be protective of human health and the environment by meeting the RAOs, reducing Site risks, addressing exposure pathways, protecting human and ecological receptors, and improving overall environmental quality. Alternative 1 does not adequately meet the RAOs, reduce Site risks, address exposure pathways, protect human and ecological receptors, or improve overall environmental quality.
- Compliance with cleanup standards: Remedial Alternatives 2, 3, 4, 5, and 6 comply with the cleanup standards. Alternatives 2 through 5 would comply with applicable soil cleanup standards through application of institutional and engineering controls (per WAC 173-340-440) to protect human health, comply with groundwater standards protective of surface water at a CPOC. Alternative 6 would comply with cleanup standards by meeting soil, groundwater, and surface water pCULs at the standard POCs. Alternative 1 would not comply with cleanup standards as it would not provide mechanisms for protection of human receptors (no institutional or engineering controls) and would not be protective of surface water beneficial uses (would not prevent discharge of contaminated groundwater to surface water).
- Compliance with applicable state and federal laws: Remedial Alternatives 2, 3, 4, 5, and 6 will comply with applicable state and federal laws as described in Section 3.4 or as otherwise applicable through proper development of pCULs (Section 3.0) and pursuit of achieving those CULs through active remedial measures. While CULs would still be developed under Alternative 1, it does not actively address protection of surface water beneficial uses; therefore, would not comply with the Clean Water Act or Washington Water Quality Standards.
- Provisions for compliance monitoring: Alternatives 1 through 6 include compliance monitoring (protection monitoring, performance monitoring, and confirmational monitoring as required under WAC 173-340-410 and compliance monitoring required by the cleanup standards (WAC 173-340-720 through -760).

### 6.2.2 Restoration Time Frame

This section evaluates and compares the restoration time frame associated with each of the remedial alternatives. The restoration time frame is defined in MTCA as "the period of time needed to achieve the required CULs at the points of compliance established for the site" (WAC 173-340-200). Per WAC 173-340-360(4)(b), the selected alternative must meet the CULs within a reasonable time frame based on the eight factors for consideration identified in Section 6.1.2.2 to determine if the alternatives provide for a reasonable restoration time frame. A summary of the total estimated restoration time frames for each remedial alternative to reach pCULs and how each of the associated factors relates to "reasonableness" is summarized in Table 6-1.

Supporting information for the estimated restoration time frames (estimation methods, calculations, and results) are included in Appendix F. The restoration time frames from the start of the final remedy (assumed to be 2021) are estimated for each alternative and are summarized in Table 5-7).

The groundwater restoration time frame for Alternative 1 (estimated 152 years) is not considered reasonable because the remedy does not include engineering or institutional controls for protection of human and ecological exposure pathways.

As indicated, Alternatives 2, 3, 4, and 5 would achieve groundwater pCULs protective of surface water at the CPOC (to be evaluated using angled wells at the shorelines with the application of an attenuation factor (see Section 3.2.2) in approximately 5 years. Based on the minimal risk to receptors once the groundwater protective of surface water pCULs are met where groundwater flows into surface water, longer restoration time frames for site-wide groundwater could be considered reasonable; however, the extended durations of approximately 22 to 152 years that it would take for these alternatives to achieve groundwater pCULs at the standard POC may not be considered reasonable. Until the groundwater SLs for VI are met (85 years for Alternative 2; 29 years for Alternatives 3 and 4; 11 years for Alternative 5), construction of any occupied building on the Site shall include appropriate engineering controls in the design and construction to protect the VI pathway. The restoration time frame estimates for meeting pCULs at the standard POC is based on projected trends at the Blair Hot Spot. The Blair Hot Spot has a large concentration of TPH mass and slow natural attenuation rates; it is projected to be the last part of the Site to reach restoration time frames. Figure 6-1 compares the effect of the Alternatives on restoration time frames in the Blair Hot Spot.

Site-wide excavation for Alternative 6 is anticipated to nearly immediately achieve the soil CULs at the standard POC. And while the complete restoration of groundwater Site-wide under this alternative is considerably longer (estimated 22 years), it may be considered reasonable because of the extensive removal of soil and smear-zone contamination, and associated reduction of direct contact and VI risks and protectiveness of surface water beneficial uses. The estimated time for groundwater SLs for VI to be met is 11 years for Alternative 6; construction of any occupied building on the Site during this time shall include appropriate engineering controls in the design and construction to protect the VI pathway. However, as detailed in Section 6.2.4, implementation of Alternative 6 is disproportionately costly, therefore, it is not practicable to achieve the groundwater pCULs at the standard POC.

### 6.2.3 Requirement for Consideration of Public Concerns

As previously indicated, consideration of public concerns is an inherent part of the cleanup process under MTCA (see WAC 173-340-600). Prior to implementation of a cleanup action, Ecology will issue a CAP for public comment as specified in WAC 173-340-380. Under this process, the RI and FS reports and the CAP will be available for public review as part of the 30-day comment period for the agreed order under the Ecology formal program.

### 6.2.4 Permanent Solutions to the Maximum Extent Practicable (i.e., Disproportionate Cost Analysis)

As described in Section 6.1.1.1, a DCA is performed to determine whether a cleanup alternative is permanent to the maximum extent practicable. The purpose of the DCA is to determine if the costs of a cleanup alternative are disproportionate to the human health and environmental benefits achieved by the cleanup action, thus, rendering the alternative impracticable. Each of the remedial alternatives are evaluated, using the DCA criteria found in MTCA (WAC 173-340-360[3][e]). Alternative 6 is considered the most permanent solution and, as such, is the baseline cleanup action alternative against which the other cleanup action alternatives are compared.

The results of the DCA for the six alternatives identified in Section 5 are provided as figure and table attachments to this FS report. Table 6-2 provides an evaluation and comparison of each of the DCA criteria for each of the six remedial alternatives which serve as the justifications for the corresponding benefits scores. Table 6-3 provides a summary of the complete DCA evaluation with comparisons of the benefit scores to the associated cost estimates related to each alternative, including the relative benefit-to-cost ratio used for comparing each alternative and identifying which alternative is considered permanent to the maximum extent practicable. Figure 6-2 provides a visual representation of the results provided in the tables. Tables 5-1 through 5-6 include the detailed cost estimates for Alternatives 1 through Alternative 6.

The following provides a brief summary of the rankings for each alternative for each qualitative DCA criteria:

- Protectiveness: Alternative 6 received the highest benefit ranking for the protectiveness criteria because it reduces potential current and future risks more rapidly than any other alternative and achieves cleanup standards in shallow soil and groundwater significantly faster than any of the other alternatives. Each of the other alternatives is ranked accordingly with lower protectiveness scores.
- Permanence: Alternative 4 received the highest benefit ranking for the permanence criteria because it will destroy and detoxify contaminants in soil and groundwater *in situ,* via implementation of EISB, bioventing, and natural attenuation (compared to Alternatives 5 and 6 that rely primarily on offsite disposal in an engineered landfill). Each of the other alternatives is ranked accordingly with lower permanence scores.
- Effectiveness over the long-term: Alternative 6 received the highest benefit ranking for the long-term effectiveness criteria because it has the highest degree of certainty that it will be successful in achieving Site cleanup and be reliable while contaminant concentrations are above pCULs. However, because Alternative 6 (and Alternative 5) relies primarily on offsite disposal in an engineered landfill, per the MTCA criteria, the *in situ* destruction and detoxification of contaminants that occur in Alternatives 3 and 4 are considered preferable, even though given slightly lower scores. Each of the other alternatives is ranked accordingly with lower long-term effectiveness scores.
- Management of short-term risks: Alternative 1 received the highest benefit ranking for the management of short-term risks criteria because it includes no additional drilling (unless

required by Ecology for additional monitoring purposes), soil excavation and hauling, or construction activities that could pose a risk to Site workers or the general public. However, Alternative 1 was determined to not meet minimum threshold requirements. Alternative 2 received the highest ranking of the remaining viable alternatives because it requires the least amount of drilling and bioinjection work (and no excavation). Each of the other alternatives is ranked accordingly with lower management of short-term risk scores.

- Technical and administrative implementability: Alternative 1 received the highest benefit ranking for technical and administrative implementability criteria because it includes no additional construction or implementation and no permitting or other administrative challenges. However, Alternative 1 was determined to not meet minimum threshold requirements. Alternative 2 received the highest ranking of the remaining viable alternatives because it requires the least amount of construction and implementation, and administrative challenges are limited to UIC permitting and filing of institutional controls with the City/Pierce County. Each of the other alternatives is ranked accordingly with lower implementability scores.
- Consideration of public concerns: Alternative 4 received the highest benefit ranking for the consideration of public concerns criteria. The “no action” Alternative 1 would not adequately address public concerns related to actively cleaning up the Site and addressing protection of adjacent waterways. The extensive excavation (including along the shoreline) and waste hauling required for Alternatives 5 and 6 would likely be of significant public concern. Each of these alternatives is protective of human health and the environment. Public concerns related to all the alternatives will be considered and addressed in the same manner by responding to comments received during the required public comment period for the RI/FS (and possibly the CAP), as part of the cleanup process under MTCA.

Based on these benefit rankings for each criteria and the assigned weighting factors, the overall weighted benefit score for each alternative is as follows (from highest to lowest):

- Alternative 4: 8.2
- Alternative 5: 7.3
- Alternative 6: 7.1
- Alternative 3: 6.7
- Alternative 2: 4.4
- Alternative 1: 2.8.

The final DCA criterion to be evaluated is the cost of each alternative:

- Cost: Alternative 1 is the least expensive alternative and Alternative 6 is the most expensive as summarized below (a breakdown of these costs is presented in Tables 5-1 through 5-6) and summarized below (from highest to lowest):
  - Alternative 6: $34.8 million
  - Alternative 5: $8.5 million
  - Alternative 3: $4.7 million

- Alternative 4: $4.5 million
- Alternative 2: $3.1 million
- Alternative 1: $0.54 million.

To aid in determining whether the cost of each alternative is disproportionate to its benefits and to provide a quantitative approach for direct comparison of each alternative (WAC 173-340-360[3][e][ii][C]), the benefit-to-cost ratio was determined for each alternative by dividing the calculated overall weighted benefit score by the cost of the alternative.[72] This benefit-to-cost ratio provides a metric to evaluate whether the cost of each alternative is commensurate with its benefits. The alternative with the next higher relative benefit-to-cost ratio than the most permanent alternative being evaluated is considered “permanent to the maximum extent practicable,” so long as its benefits are also not disproportionate to its costs compared to other alternatives with still higher benefit-to-cost ratios.

Using this methodology, the benefit-to-cost ratios for each alternative are as follows (from highest to lowest):

- Alternative 1: 5.2 (however, Alternative 1 does not meet threshold requirements).
- Alternative 4: 1.8
- Alternative 2: 1.4
- Alternative 3: 1.4
- Alternative 5: 0.9
- Alternative 6: 0.2.

### 6.2.5 Conclusion of Disproportionate Cost Analysis

A complete DCA analysis summary is presented in Table 6-3 and the rankings and associated rationale for the various rankings are presented in Table 6-2. A relative cost and relative benefit analysis was also performed as part of the DCA.

Based on the weighted benefit scores, Alternative 4 has the highest overall benefit score and is considered the most permanent alternative being evaluated. However, a DCA analysis must be performed to determine whether the most permanent alternative is permanent to the maximum extent practicable. Under the DCA, costs are considered disproportionate to benefits if the incremental costs of the more permanent alternative exceed the incremental degree of benefits achieved by the other lower cost alternatives (WAC 173-340-360[e][i]).

The overall weighted benefit score, estimated cost, and calculated relative benefit-to-cost ratio identified by the DCA for each Alternative are as follows:

[72] This value is also then multiplied by 1,000,000 to normalize and scale the data to fit on the chart.

| Remedial Alternative | Overall Weighted Benefit Score | Estimated Remedy Cost ($millions) | Relative Benefit-to-Cost Ratio |
|---|---|---|---|
| Alternative 1* | 2.8 | $0.54 | 5.2 |
| **Alternative 2** | 4.4 | $3.1 | 1.4 |
| **Alternative 3** | 6.7 | $4.7 | 1.4 |
| **Alternative 4** | 8.2 | $4.5 | 1.8 |
| **Alternative 5** | 7.7 | $8.5 | 0.9 |
| **Alternative 6** | 7.1 | $34.8 | 0.2 |

*Does not meet MTCA threshold criteria

A graph of the DCA results for the Site showing the relative benefit and cost for each alternative is presented on Figure 6-2. Relative benefit scores for each alternative are shown by benefit (green) bars. Alternatives costs are shown by cost (red) bars. The figure also displays the relative benefit-to-cost ratios with an overlying (blue) line graph; the alternative with highest benefit-to-cost ratio has the highest benefit-to-cost score on this line. The following provides a summary comparison of the benefit to costs for each of the alternatives and provides the rational for determining which alternative is permanent to the maximum extent practicable:

- Alternative 4 has the highest overall benefit score against which to compare the remaining alternatives.
- Alternatives 3, 5, and 6 are all more expensive and have lower benefit scores compared to Alternative 4; therefore, Alternatives 3, 5, and 6 are considered disproportionate to their benefits and, therefore, are eliminated from further consideration.
- The estimated cost for Alternative 2 is significantly lower than those of Alternative 4 (around $1.7 million less). The overall benefits of Alternative 2 are also much lower than Alternative 4 (4.4 compared to 8.2), indicating that the lower cost of Alternative 2 would not result in it being designated as permanent to the maximum extent practicable.
- As previously indicated, Alternative 1 does not meet MTCA minimum threshold requirements and is, therefore, not a viable cleanup alternative and is eliminated from further consideration.

Therefore, based on the MTCA DCA evaluation, **Alternative 4**, which includes hot spot bioremediation, Site-wide MNA, and I&ECs, is **permanent to the maximum extent practicable** and is the preferred remedial alternative for the Site.

# 7.0 PREFERRED CLEANUP ACTION

Based on this FS, including the DCA presented in Section 6.2.3, the preferred remedial action alternative for the Site is Alternative 4. Alternative 4 consists of:

- Bioremediation (bioventing and EISB bioinjections) at the Blair and Hylebos Hot Spots to clean up groundwater to be protective of surface water beneficial uses at the waterways;
- Site-wide MNA to address residual groundwater contamination impacted by TPH and benzene;
- I&ECs to prevent human exposure to shallow contaminated soil and groundwater.

Cleanup under this alternative will be further enhanced by the existing condition of the anticipated Occidental Site remedy's groundwater containment, extraction, and treatment system.

Selection of Alternative 4 over the other alternatives is primarily based on the following:

- Alternative 4 achieves each of the four RAOs and each of the threshold requirements.
- Alternative 4 uses permanent solutions to the maximum extent practicable as described in Section 6.2.5.
- Alternative 4 provides for a reasonable restoration time frame as described in Section 6.2.2. EISB bioinjections and bioventing in the Hylebos Hot Spot will provide relatively rapid compliance with surface water pCULs protective of surface water beneficial uses at the CPOC without additional active remediation. EISB bioinjections and bioventing in the Blair Hot Spot will minimize the presence of mobile LNAPL and stimulate biodegradation on the Blair side of the Hylebos peninsula groundwater divide.
- Data evaluation for Alternative 4 indicates that groundwater concentrations are naturally attenuating at a reasonable rate and that after completion of bioremediation activities at the hot spots, Site-wide groundwater MNA RLs (protective of VI) will be achieved across the Site in a reasonably short time frame (estimated 29 years). MNA will eventually achieve CULs that are protective of surface water beneficial uses (estimated 94 years). This can be considered to be a reasonable duration in consideration of current and potential future industrial land uses, and that the primary pathway of protecting surface water will be controlled in a much shorter time frame.
- Institutional controls will be used minimize risks of human/worker exposure to shallow contaminated soil and groundwater. Additionally, groundwater at the Site is non-potable, so there is no risk of groundwater being used as a drinking water source.
- Engineering controls, as necessary, will be used to protect indoor air if future occupied buildings are constructed at the Site before groundwater is cleaned up to the VI SL.
- Engineering solutions will be employed to minimize intrusion of contaminated groundwater or VI into the sewer system at the Site.

Based on the results of this FS, Alternative 4 is permanent to the maximum extent practicable and is the preferred remedial alternative for the Site.

# 8.0 USE OF THIS REPORT

This feasibility study has been prepared for the exclusive use of the Port of Tacoma and Washington State Department of Ecology for specific application to the Alexander Avenue Petroleum Tank Facilities Site. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of LAI. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by LAI, shall be at the user's sole risk. LAI warrants that within the limitations of scope, schedule, and budget, our services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. We make no other warranty, either express or implied.

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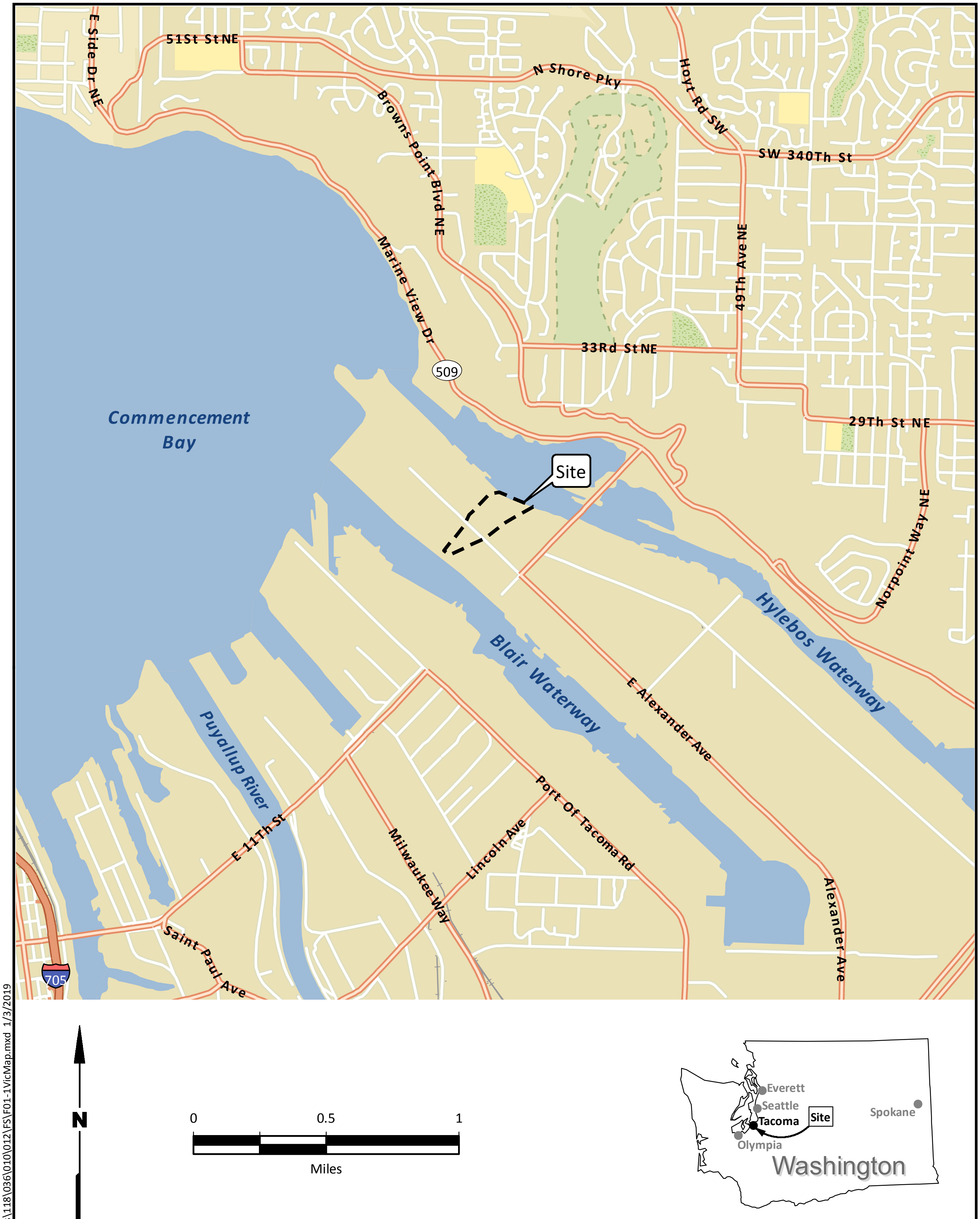


Data Source: Esri 2012

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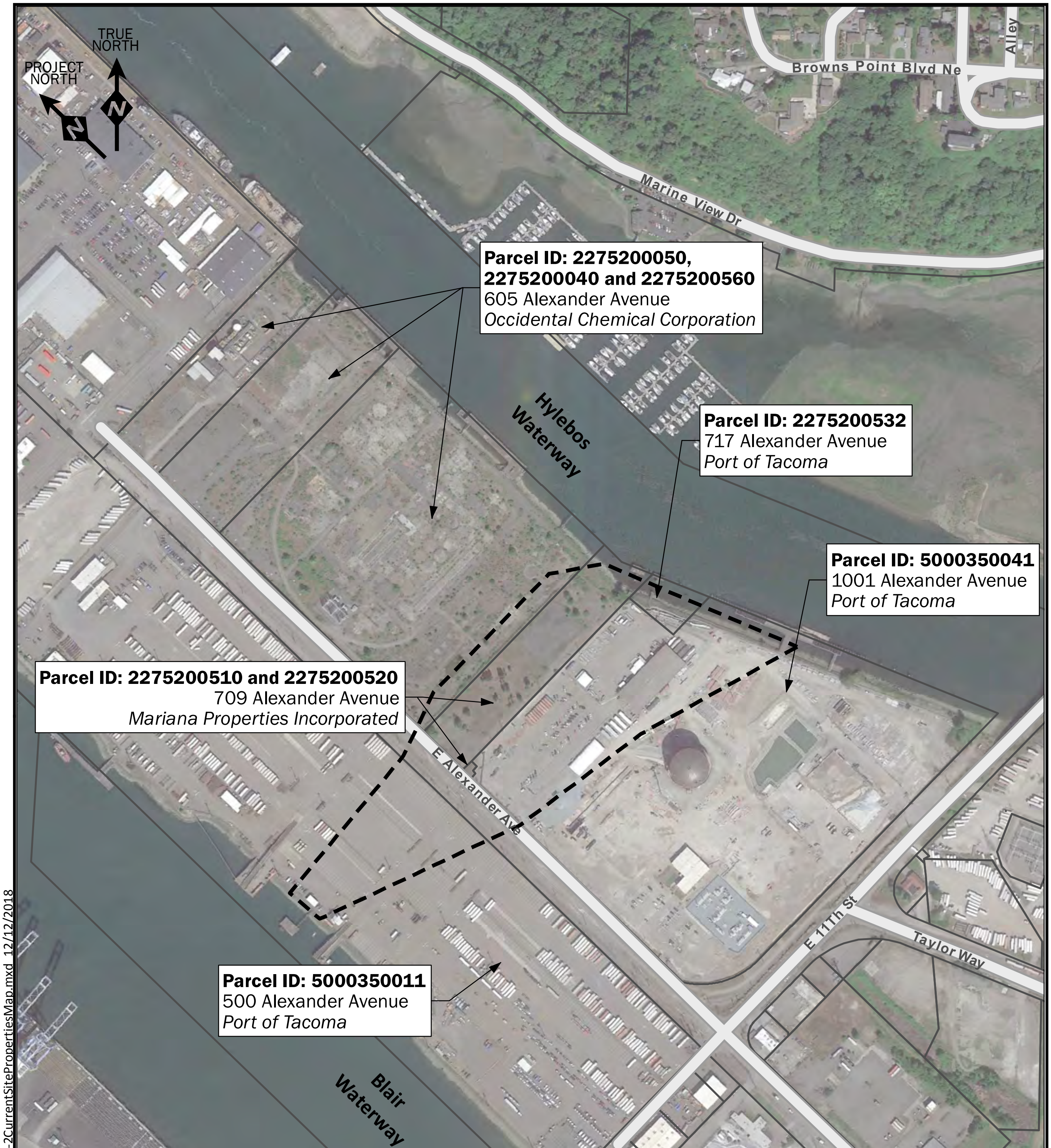
| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | Vicinity Map | Figure 1-1 |
|---|---|---|




Parcel ID → **Parcel ID: 5000350041**
Parcel Address and Information → 1001 Alexander Avenue
Owner → *Port of Tacoma*

Approximate Site Boundary

Tax Parcel Boundary

**Note**

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

0 500 1,000

Scale in Feet

Sources: Pierce County GIS; Google Earth Pro.

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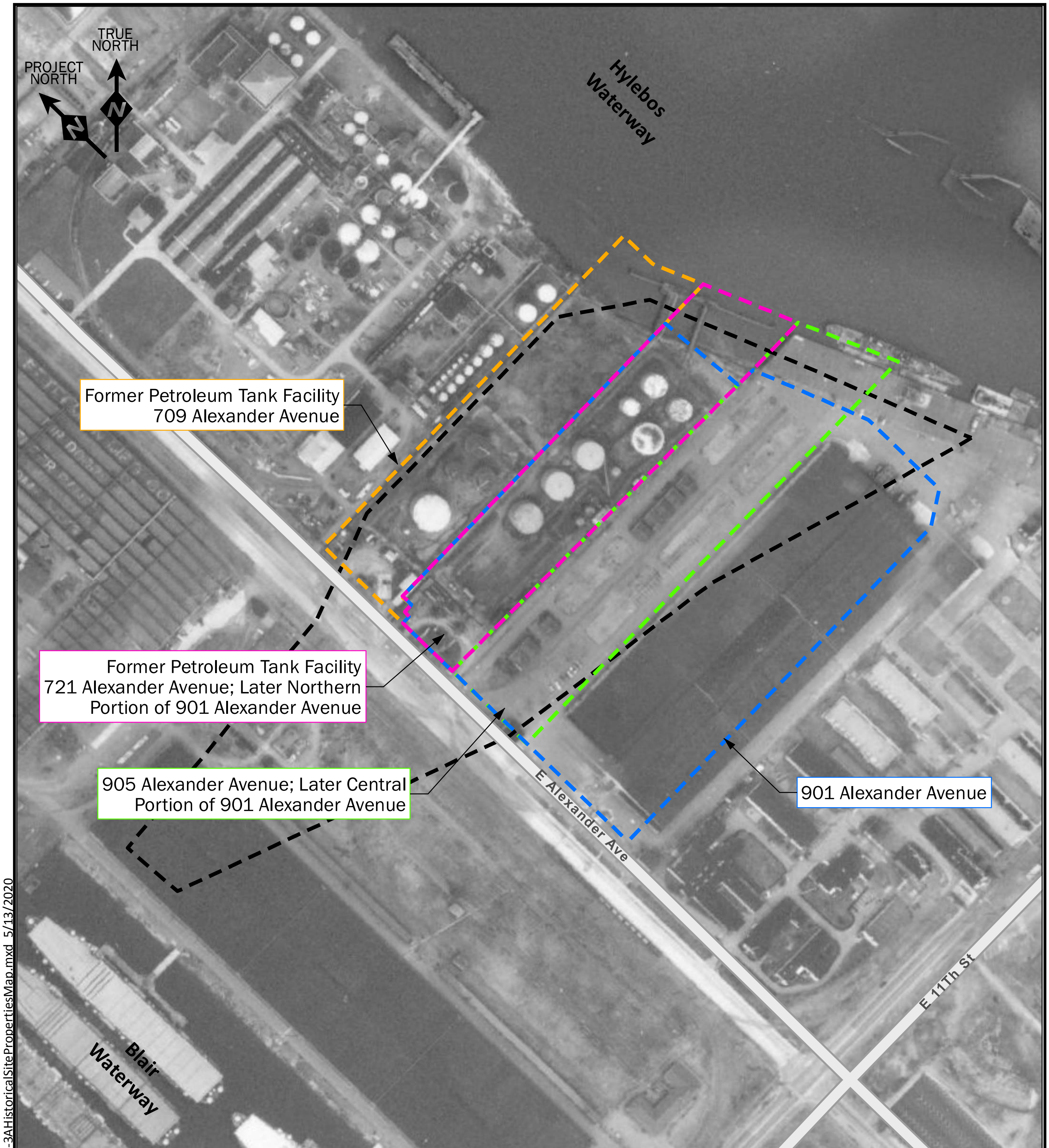
| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | **Site Map (Current Parcel Boundaries)** | Figure 1-2 |
|---|---|---|




Parcel Address: 901 Alexander Avenue

Approximate Site Boundary

Approximate Historical Property Boundaries

0 300 600

Scale in Feet

**Note**

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Data Source: Pierce County GIS. Aerial Photo Source: City of Tacoma IT-GIS. Photo Date: 1950.

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Landau Associates

Alexander Avenue Petroleum Tank Facility Site Feasibility Study

**Site Map (Historical Property Boundaries)**

Figure 1-3A

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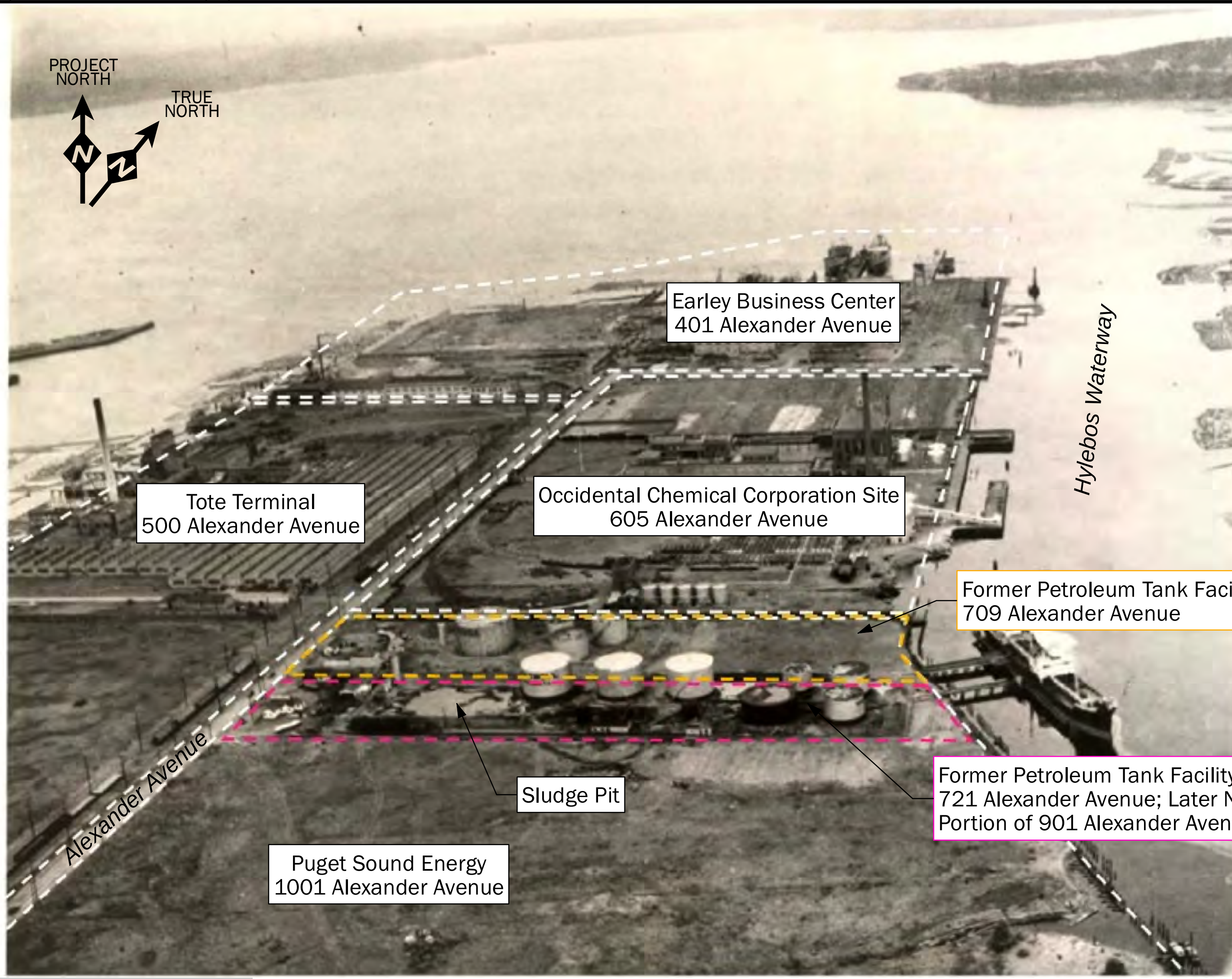


Legend
- Approximate Current Property Boundaries
- Approximate Historical Property Boundaries

Data Source: Occidental Chemical Corporation.

Note
1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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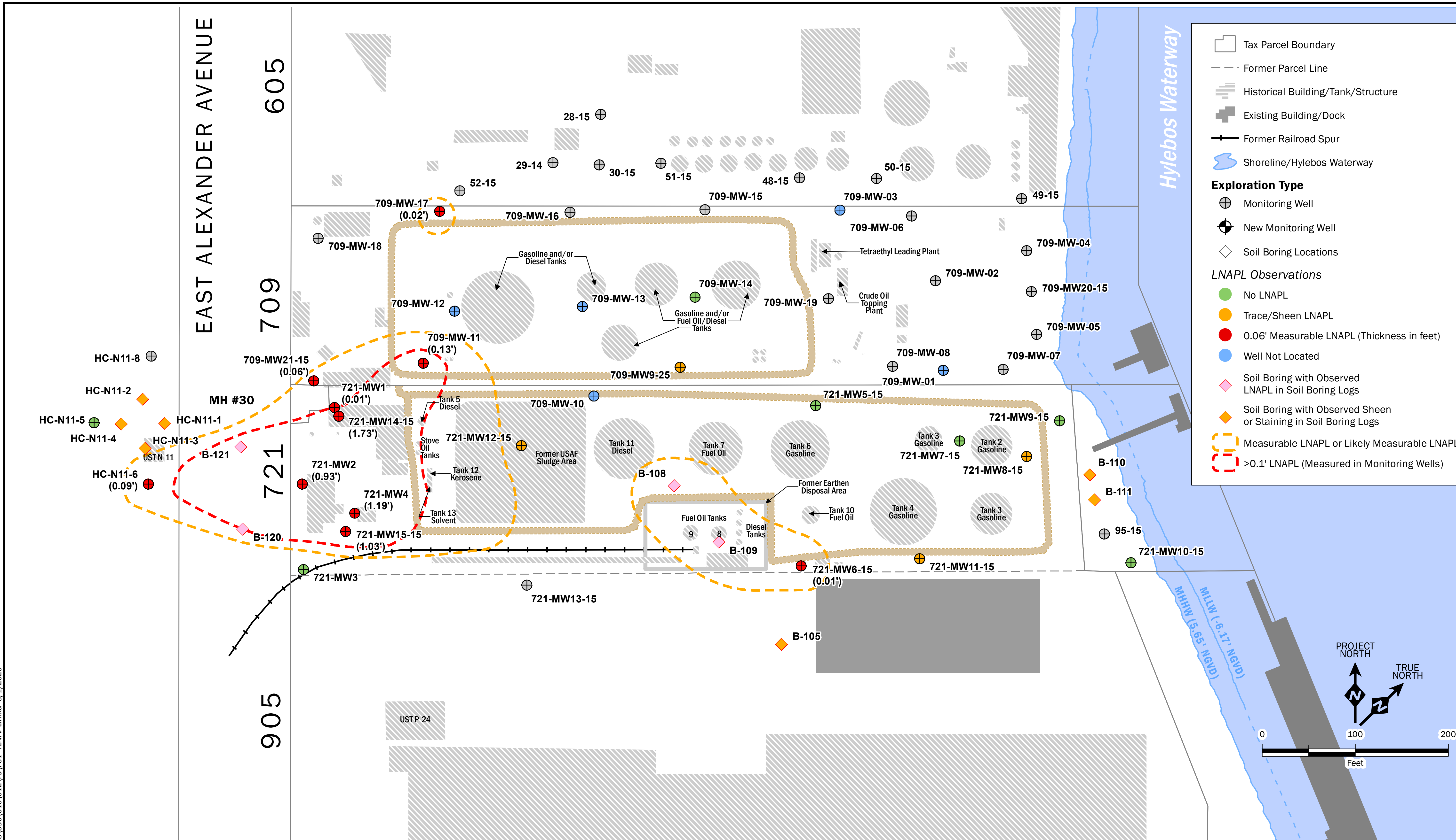
| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | **Historical Photo (Date 1936-1946)** | Figure 1-3B |
|---|---|---|




Note
1. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products or other chemicals throughout their lifespan.

Source: Port of Tacoma, 2017; Aspect Consulting, 2016; GHD, 2017b

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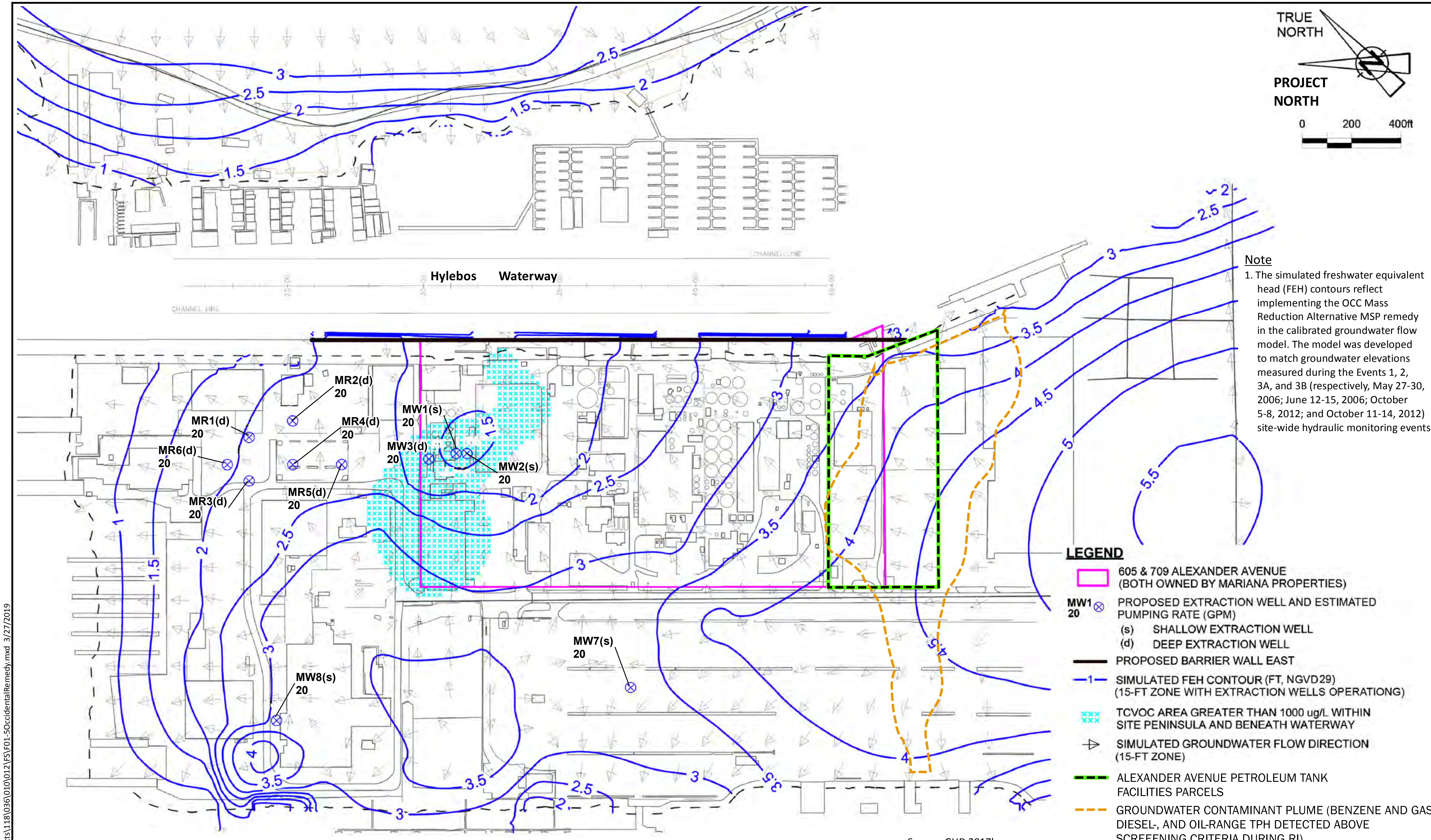
| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | Maximum LNAPL Occurrences (2014-2015) | Figure 1-4 |
|---|---|---|




Source: GHD 2017b

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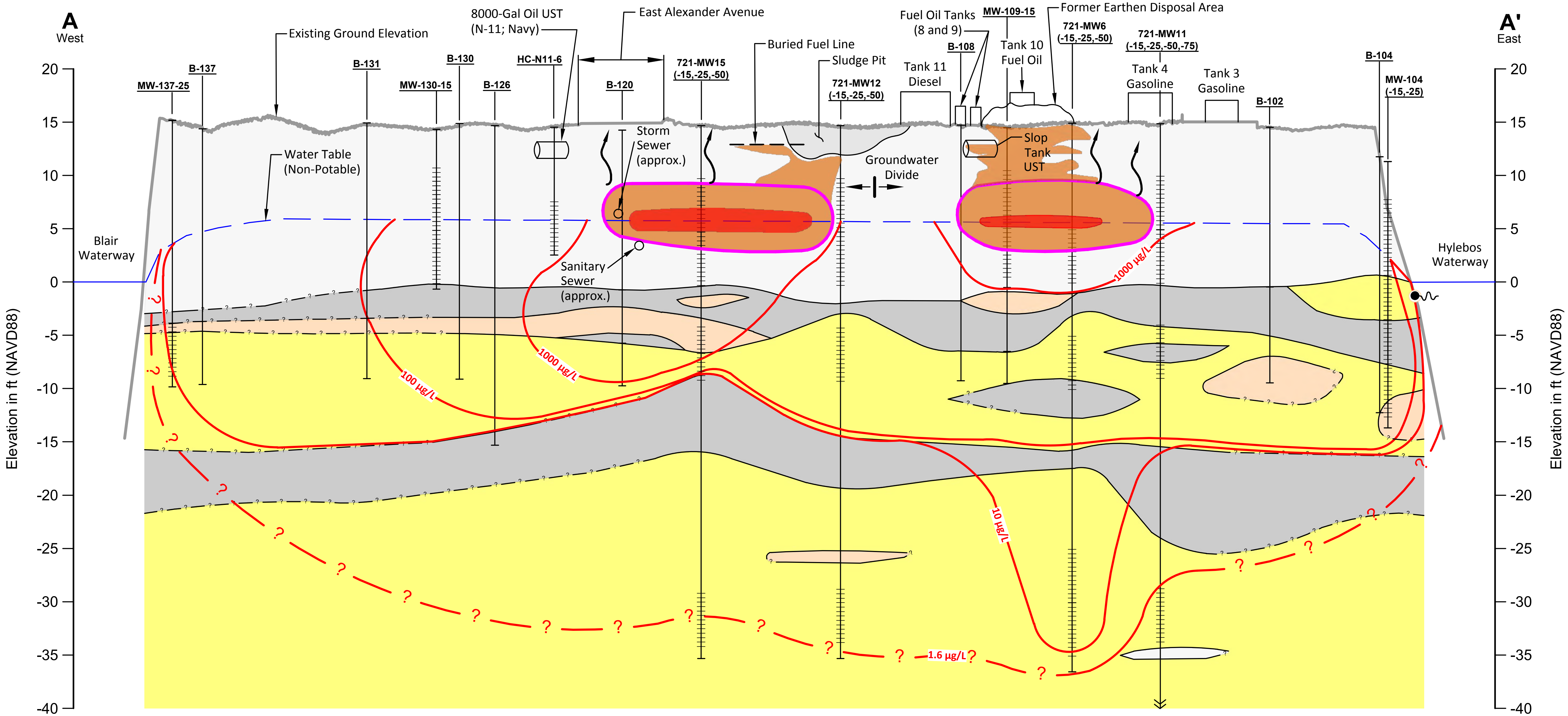
Landau Associates

| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | Occidental Remedy Groundwater Elevation Contours (15-ft Zone) | Figure 1-5 |
|---|---|---|




Legend

- Top of Exploration
- Inferred Geologic Contact
- Well Screen Interval (If Installed)
- Bottom of Exploration
- Seep Location
- Disolve Phase Benzene Plume Isoconcentration Contours (See Notes 3 and 4)
- Benzene > pCUL (1.6 µg/L)
- LNAPL
- Residual LNAPL
- Hot Spot
- Vapor Migration

Soil Legend

- Fill
- Sands and Gravels
- Silty Sands and Sandy Silts
- Silts and Clays

## Cross Section A-A'

Horizontal Scale in Feet: 1"=150'
Vertical Scale in Feet: 1"=10'

Notes

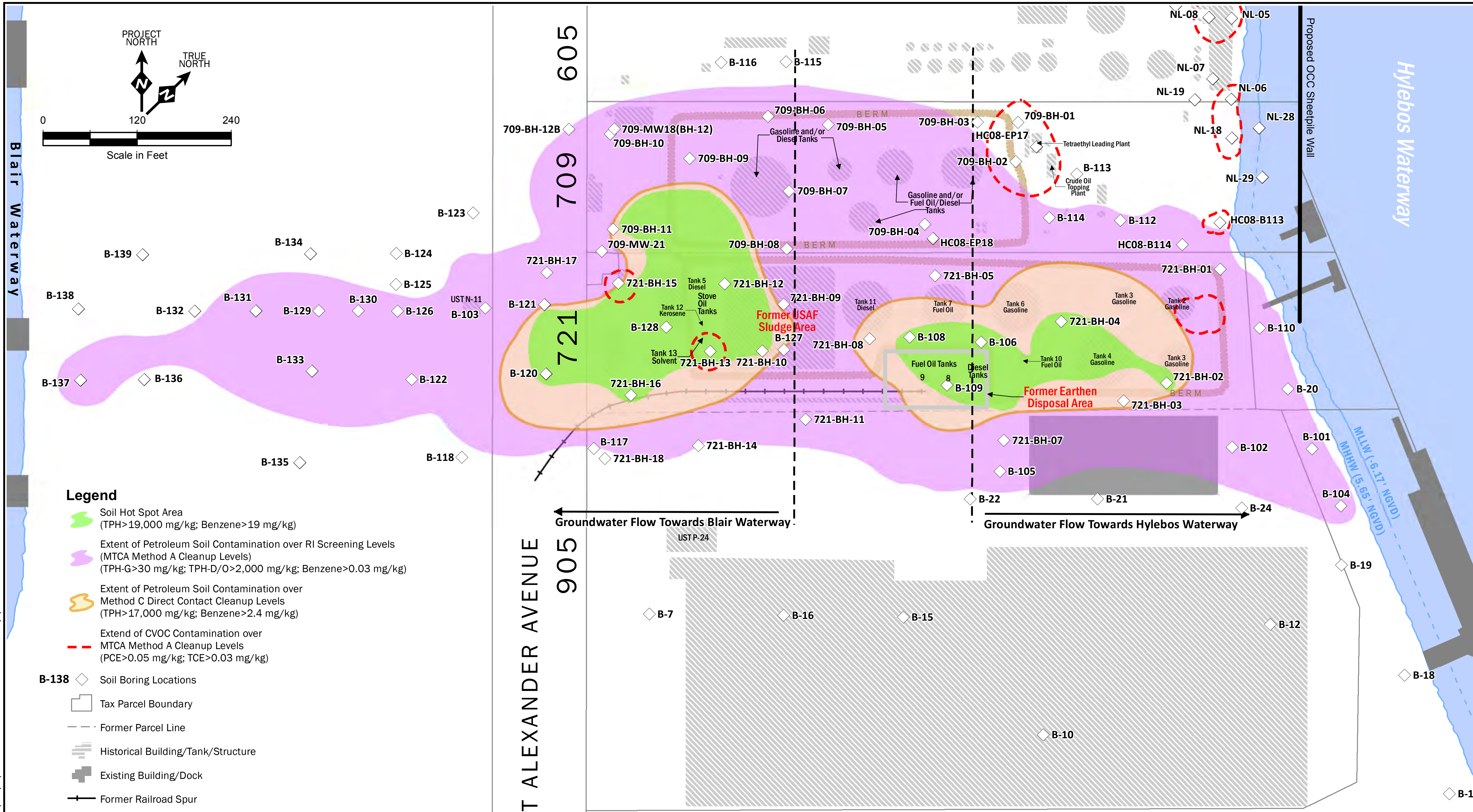
1. Soil descriptions are generalized, based on interpretation of field and laboratory data. Stratigraphic contacts are interpolated between borings and based on topographic features; actual conditions may vary.
2. For cross-section location, see Figure 2-3.
3. Site also impacted by TPH (gas, diesel, and oil) from onsite releases and CVOCs from OCC site adjacent to the north.
4. Benzene concentration in groundwater at the site also exceed the vapor intrusion to screening level (24 µg/L). However, no occupied buildings are currently present.
5. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

0 150 300
Horizontal Scale in Feet

Source: Port of Tacoma, 2019

| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | Conceptual Site Model | Figure 2-1 |
|---|---|---|

Landau Associates

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Notes
1. RI soil screening levels are 0.02 mg/kg benzene, 30 mg/kg gasoline, and 2000 mg/kg diesel + oil.
2. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
3. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Aspect Consulting, 2016; Ecology, 2018.

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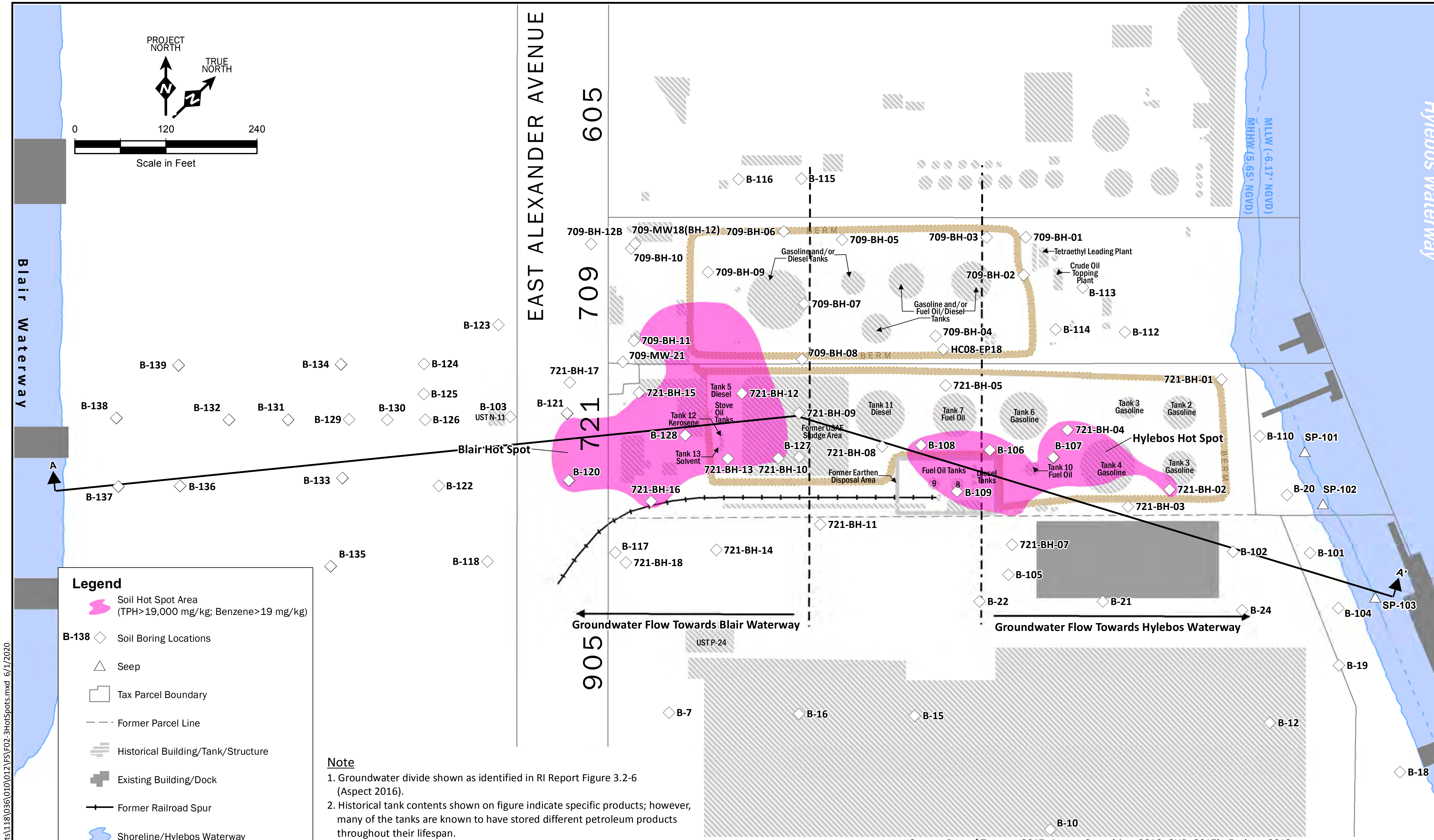
| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | **Extent of Soil Contamination (Petroleum Hydrocarbons and CVOCs)** | Figure 2-2 |
|---|---|---|




**Note**

1. Groundwater divide shown as identified in RI Report Figure 3.2-6 (Aspect 2016).
2. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
3. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Port of Tacoma, 2017; Aspect Consulting, 2016; GHD, 2017b; Ecology, 2019.

| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | Soil Contamination - Total Petroleum Hydrocarbon "Hot Spot" Areas | Figure 2-3 |
|---|---|---|

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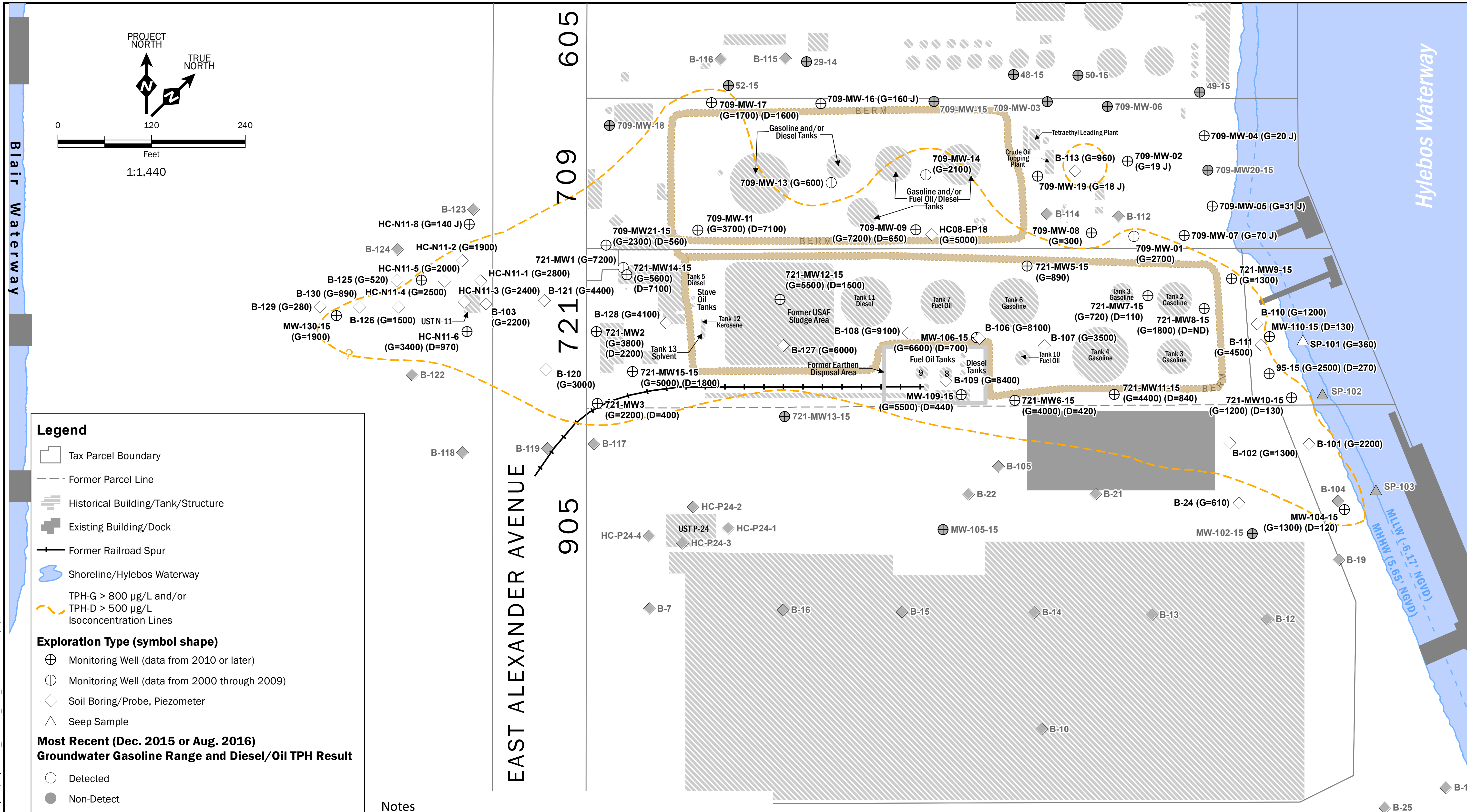


## Notes

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.
2. Concentration values are the TPH-G and TPH-D/O values reported in the RI (Aspect 2016) or for post-RI sampling reported in the natural attenuation memo (Port 2017).
3. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.

Source: Aspect Consulting, 2016/2017; Ecology, 2018.

Alexander Avenue Petroleum Tank Facility Site Feasibility Study

**Extent of TPH-G & TPH-D/O in Groundwater (with Silica Gel Cleanup) 15-foot Zone**

Figure 2-4A

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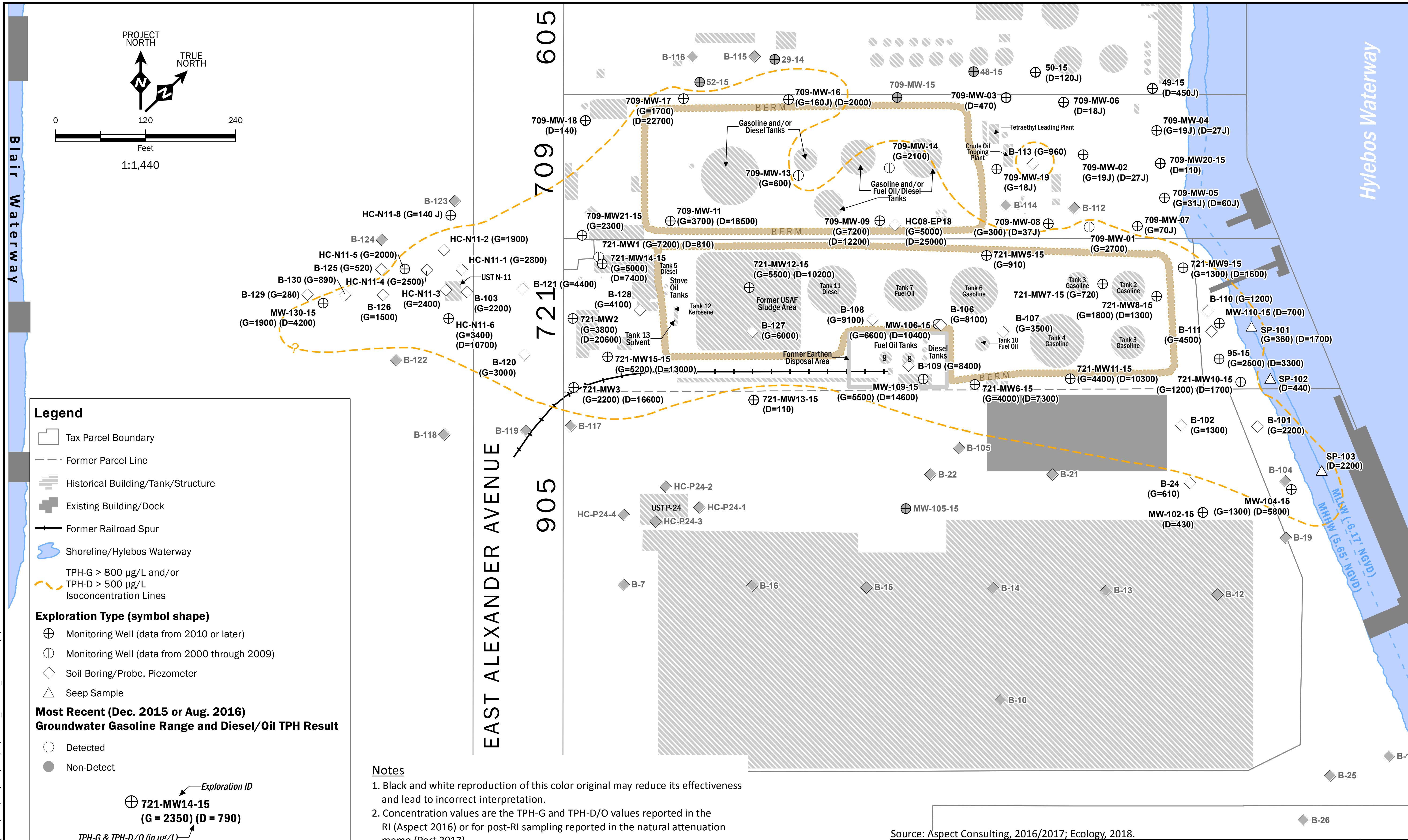


## Notes

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.
2. Concentration values are the TPH-G and TPH-D/O values reported in the RI (Aspect 2016) or for post-RI sampling reported in the natural attenuation memo (Port 2017).
3. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.

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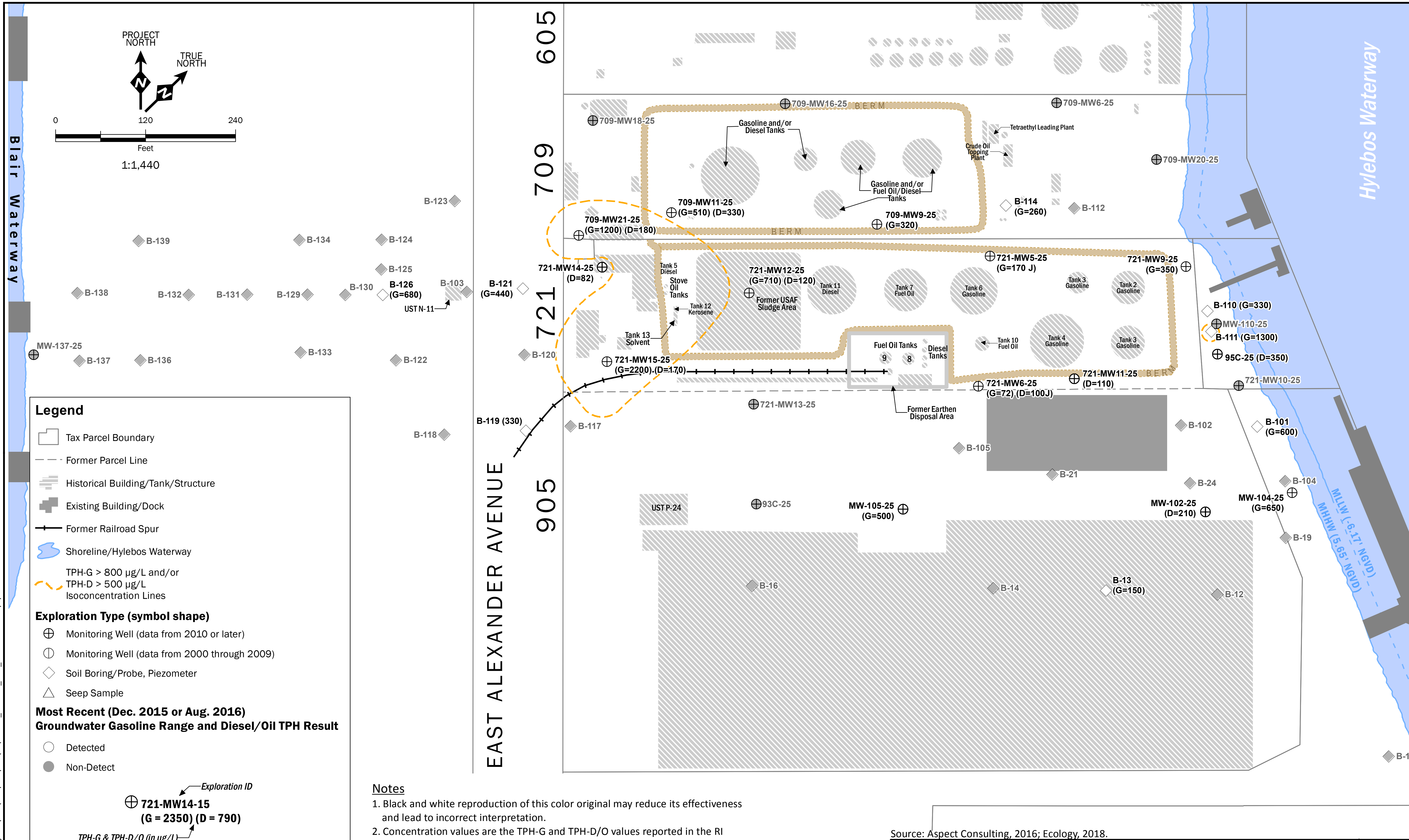
Alexander Avenue Petroleum Tank Facility Site Feasibility Study

**Extent of TPH-G & TPH-D/O (without Silica Gel Cleanup) in Groundwater 15-foot Zone**

Figure 2-4B

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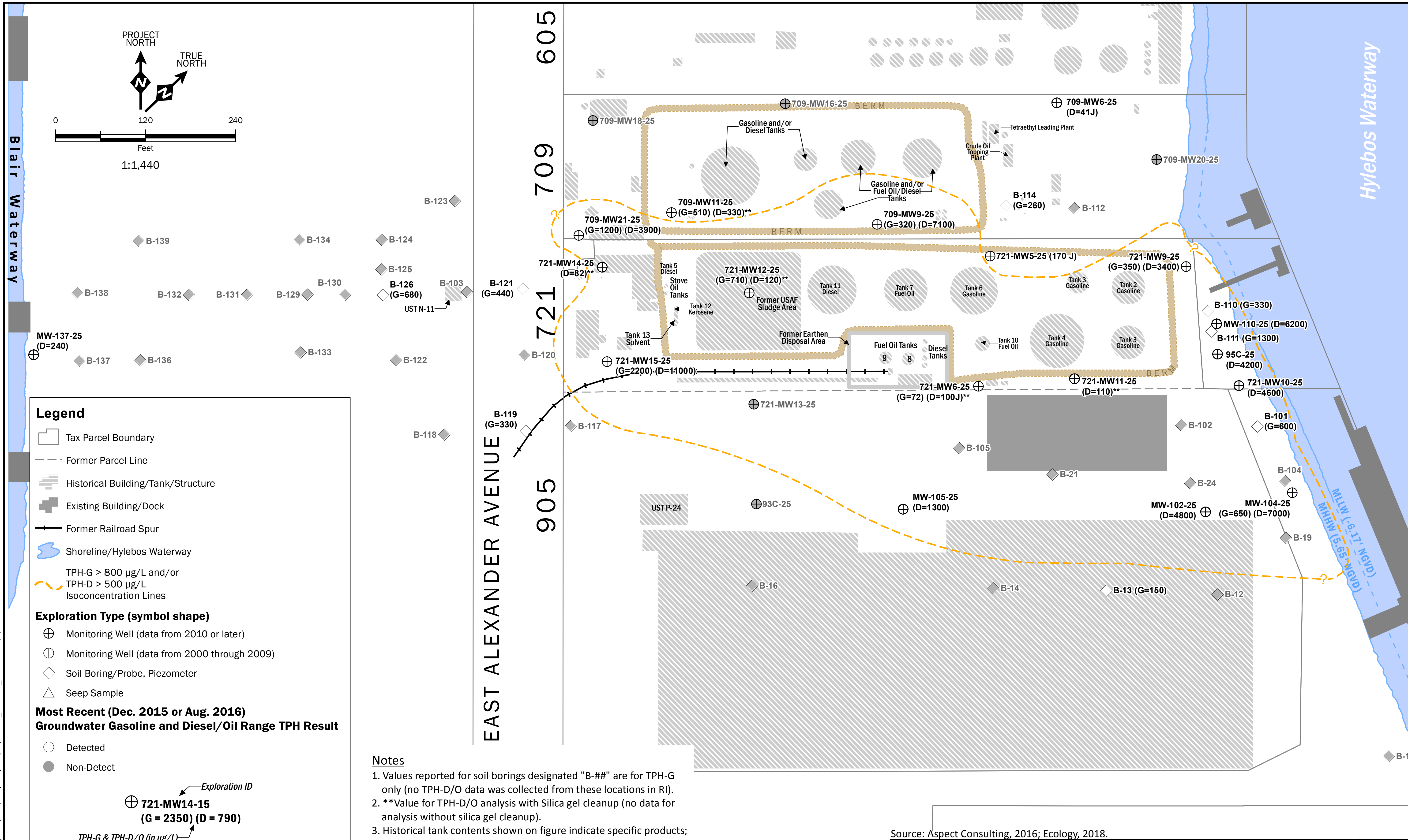
Notes
1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.
2. Concentration values are the TPH-G and TPH-D/O values reported in the RI (Aspect 2016).
3. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.

Source: Aspect Consulting, 2016; Ecology, 2018.

| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | Extent of TPH-G & TPH-D/O in Groundwater (with Silica Gel Cleanup) 25-foot Zone | Figure 2-4C |
|---|---|---|

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Notes

1. Values reported for soil borings designated "B-##" are for TPH-G only (no TPH-D/O data was collected from these locations in RI).
2. **Value for TPH-D/O analysis with Silica gel cleanup (no data for analysis without silica gel cleanup).
3. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
4. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Aspect Consulting, 2016; Ecology, 2018.

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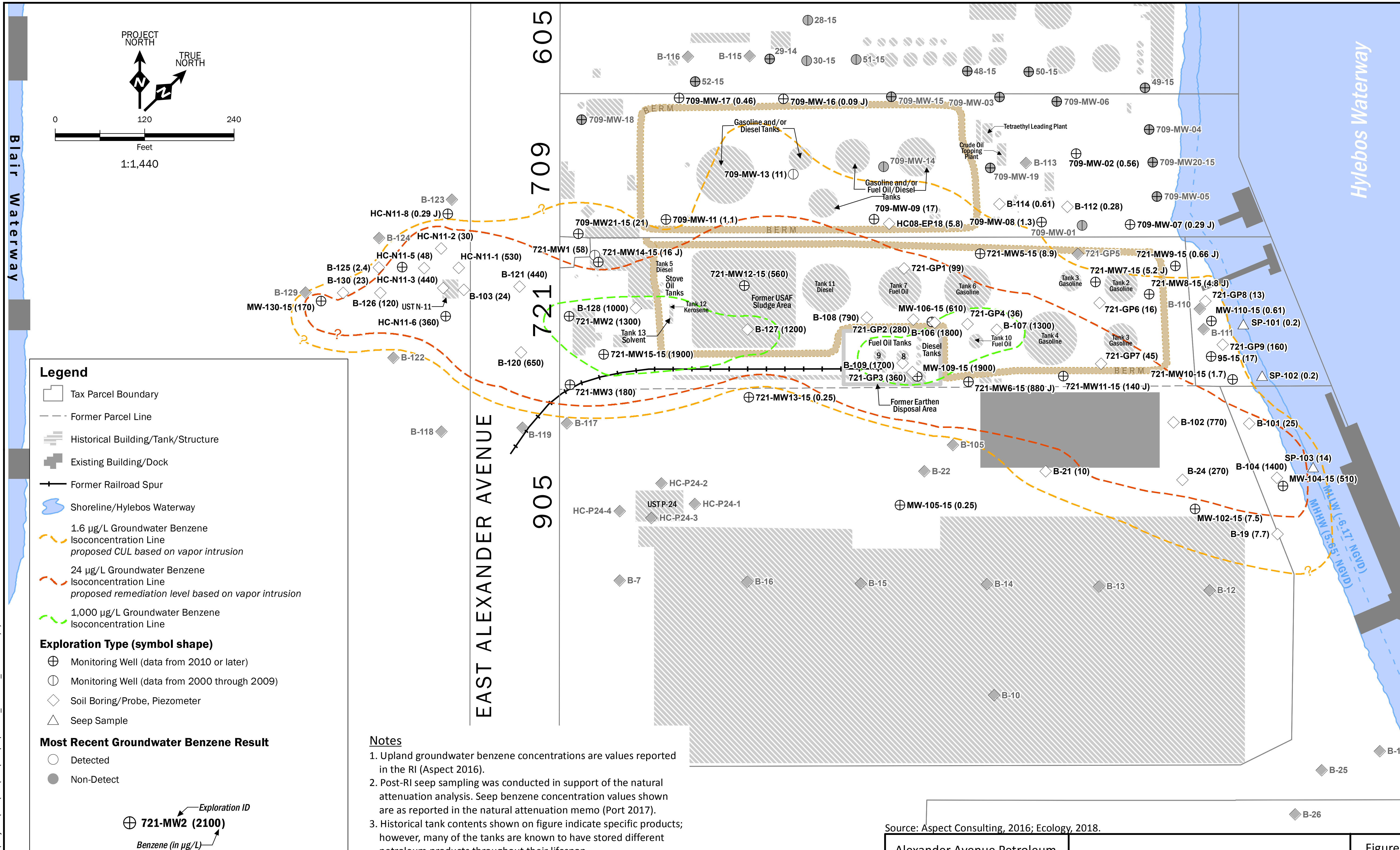
| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | **Extent of TPH-G & TPH-D/O (without Silica Gel Cleanup) in Groundwater 25-foot Zone** | Figure 2-4D |
|---|---|---|

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Notes
1. Upland groundwater benzene concentrations are values reported in the RI (Aspect 2016).
2. Post-RI seep sampling was conducted in support of the natural attenuation analysis. Seep benzene concentration values shown are as reported in the natural attenuation memo (Port 2017).
3. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
4. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Aspect Consulting, 2016; Ecology, 2018.

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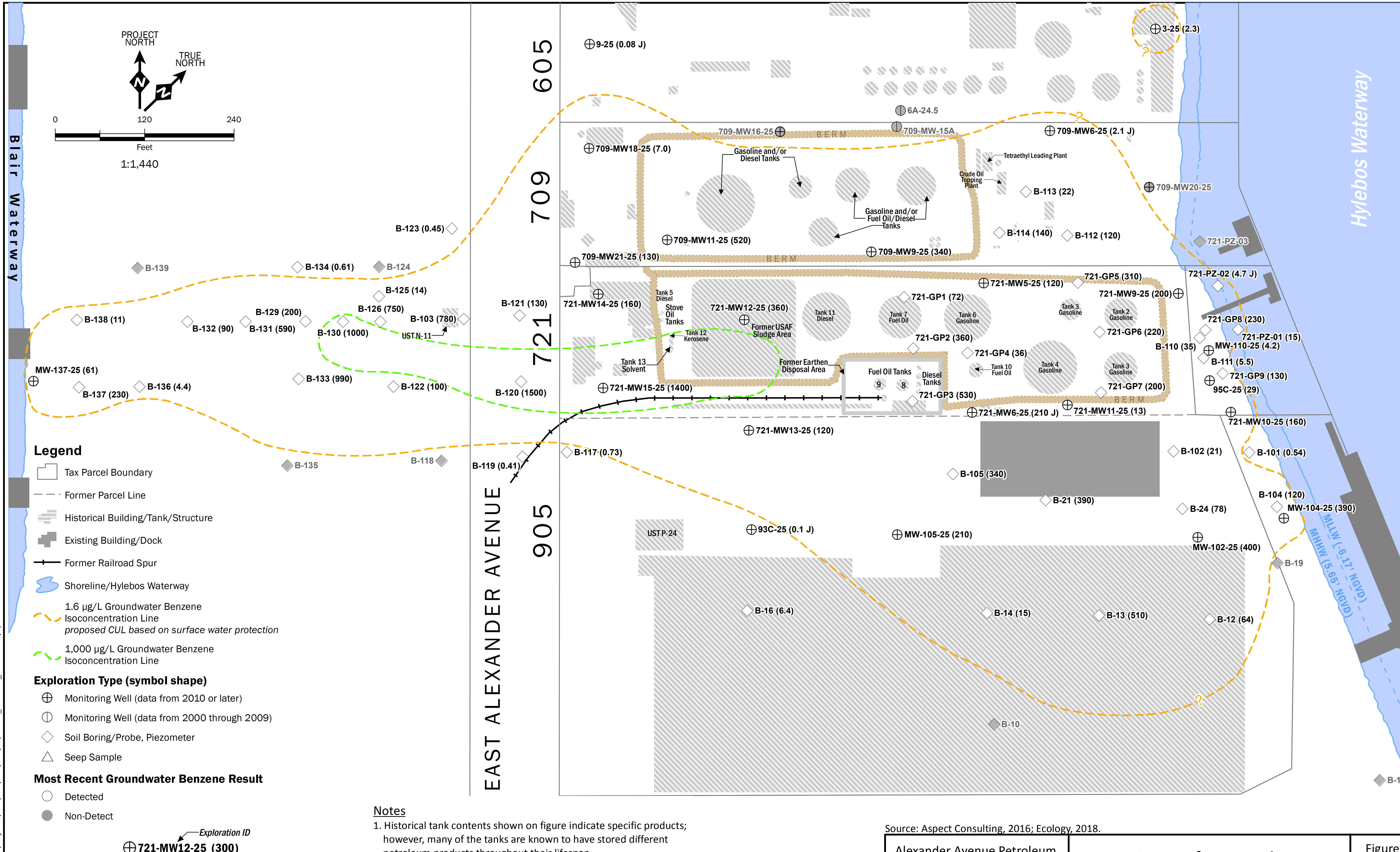
Alexander Avenue Petroleum Tank Facility Site Feasibility Study

**Extent of Benzene in Groundwater 15-foot Zone**

Figure 2-4E

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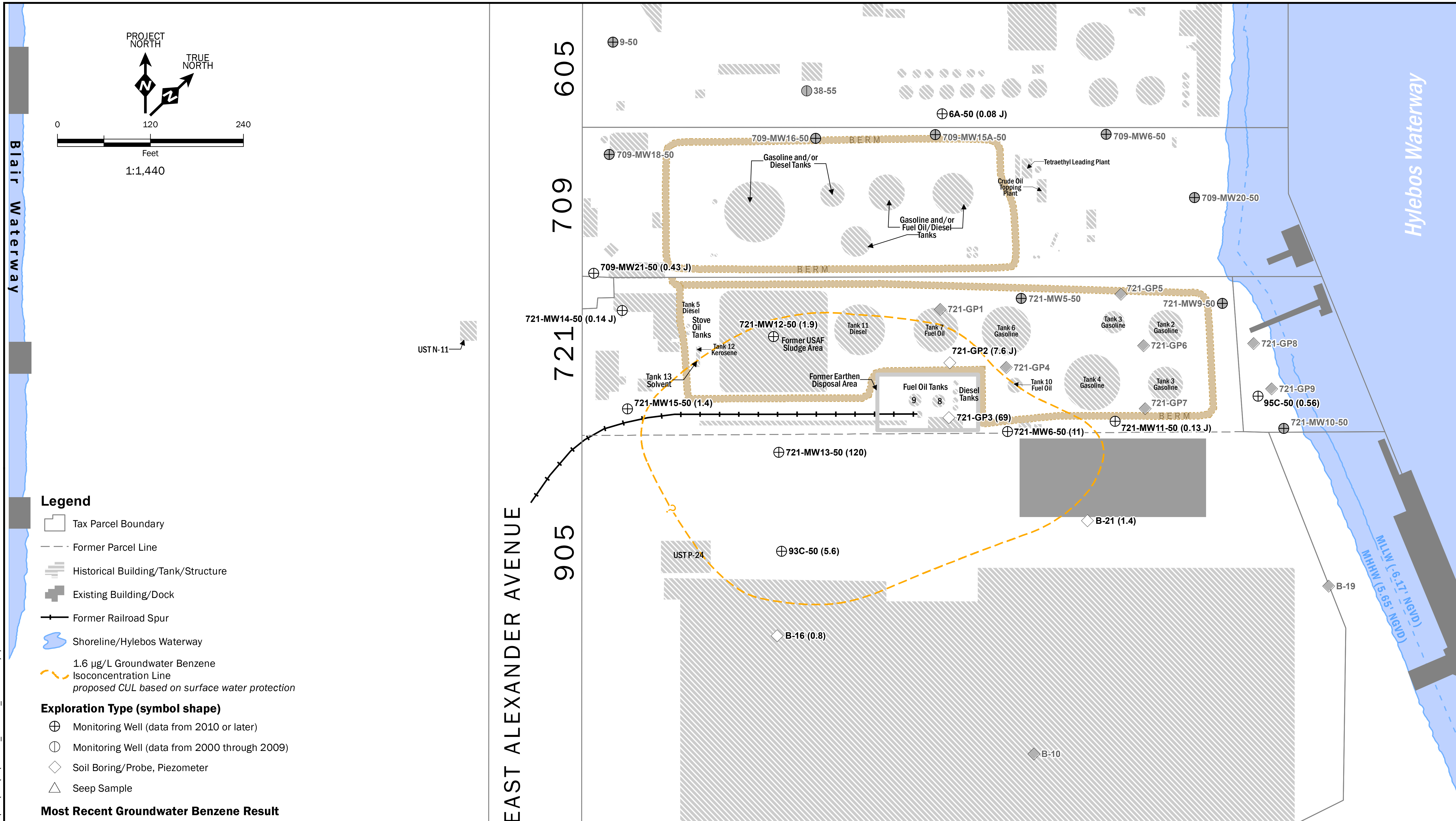
**Notes**

1. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Aspect Consulting, 2016; Ecology, 2018.

| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | **Extent of Benzene in Groundwater 25-foot Zone** | Figure 2-4F |
|---|---|---|




Exploration ID

721-MW12-25 (300)

Benzene (in µg/L)

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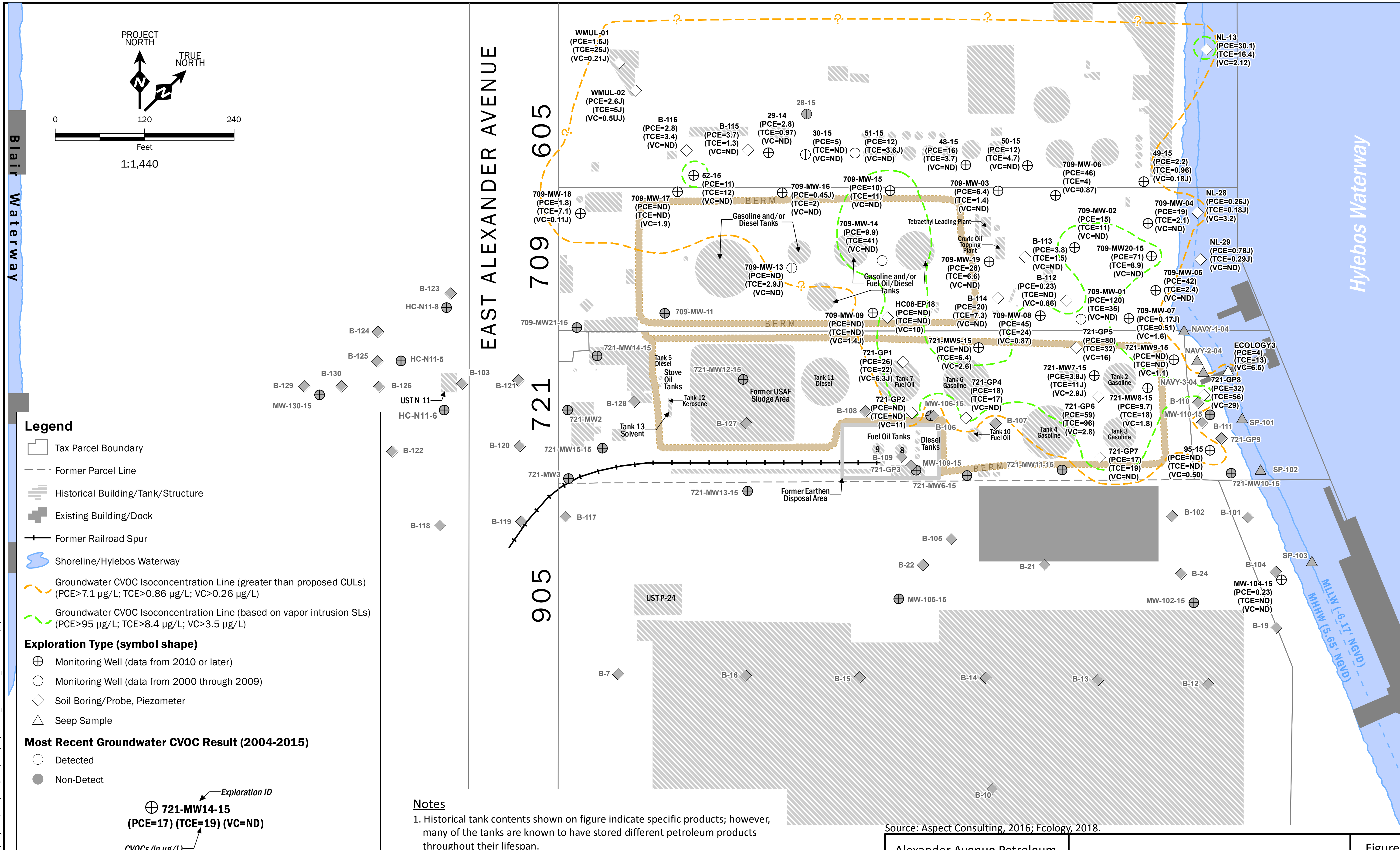
LANDAU ASSOCIATES

Notes

1. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Aspect Consulting, 2016; Ecology, 2018.

| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | **Extent of Benzene in Groundwater 50-foot Zone** | Figure 2-4G |
|---|---|---|




Notes

1. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | Extent of CVOCs in Groundwater 15-foot Zone | Figure 2-5A |
|---|---|---|

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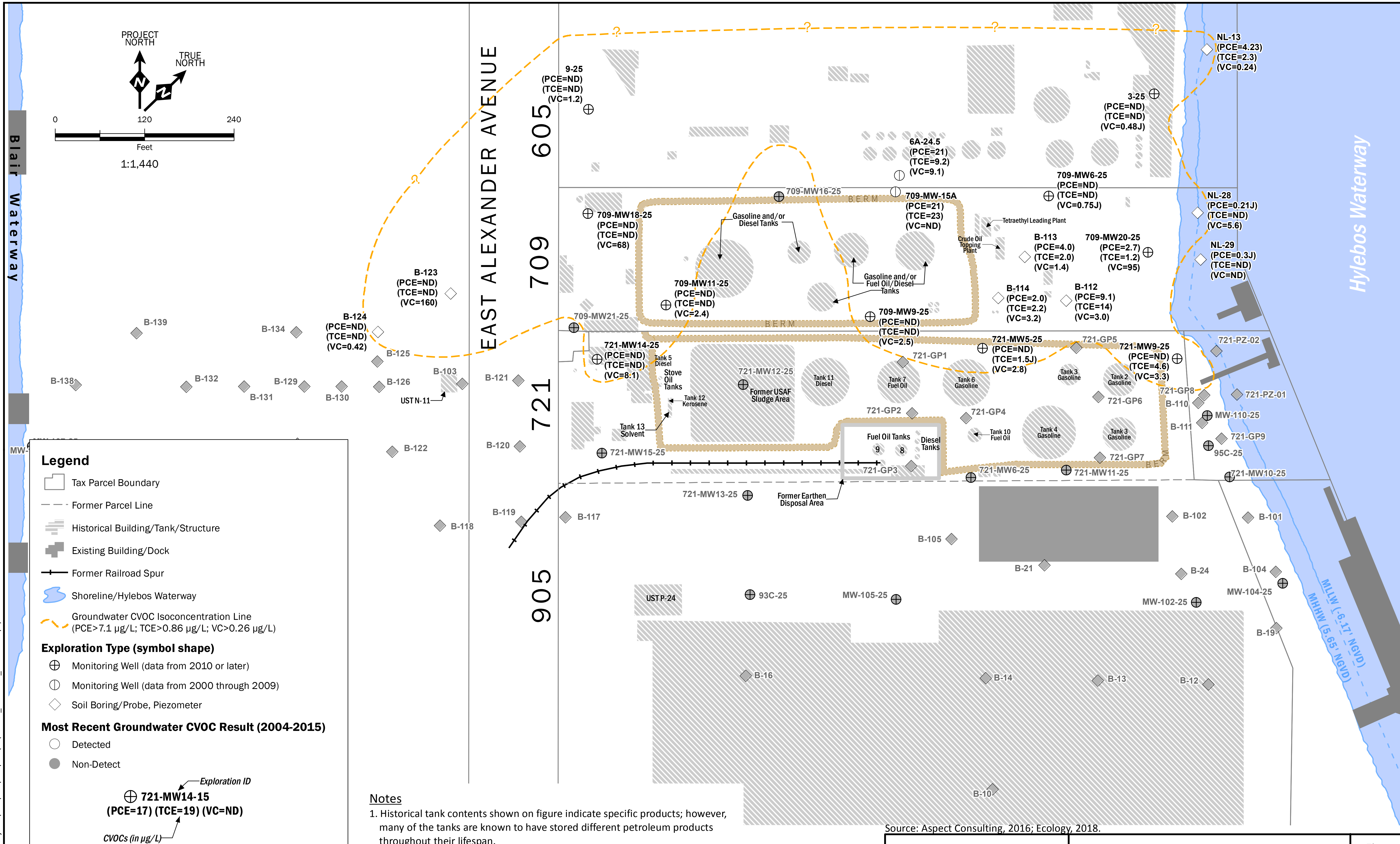


G:\Projects\118\036\010\012\FS\F02-5B_CVOCGW_25ft.mxd 6/1/2020

## Notes

1. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Aspect Consulting, 2016; Ecology, 2018.

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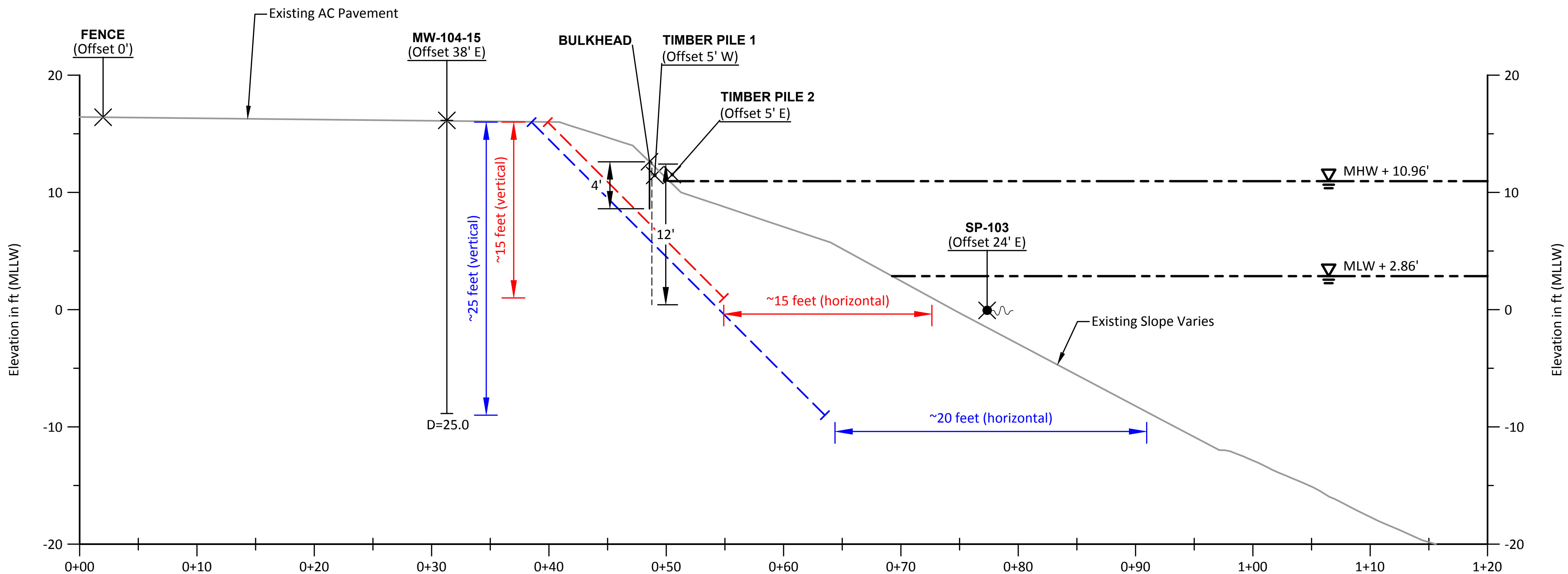
| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | **Extent of CVOCs in Groundwater 25-foot Zone** | Figure 2-5B |
|---|---|---|




Geologic Profile Alignment 1

Horizontal Scale in Feet: 1"=10'
Vertical Scale in Feet: 1"=10'
Vertical Datum: MLLW

Legend

Water Level

Note

1. Water levels based on NOAA bench marks (https://tidesandcurrents.noaa.gov/benchmarks.html?id=9446545&type=superseded)

Source: USACE

0 10 20
Scale in Feet

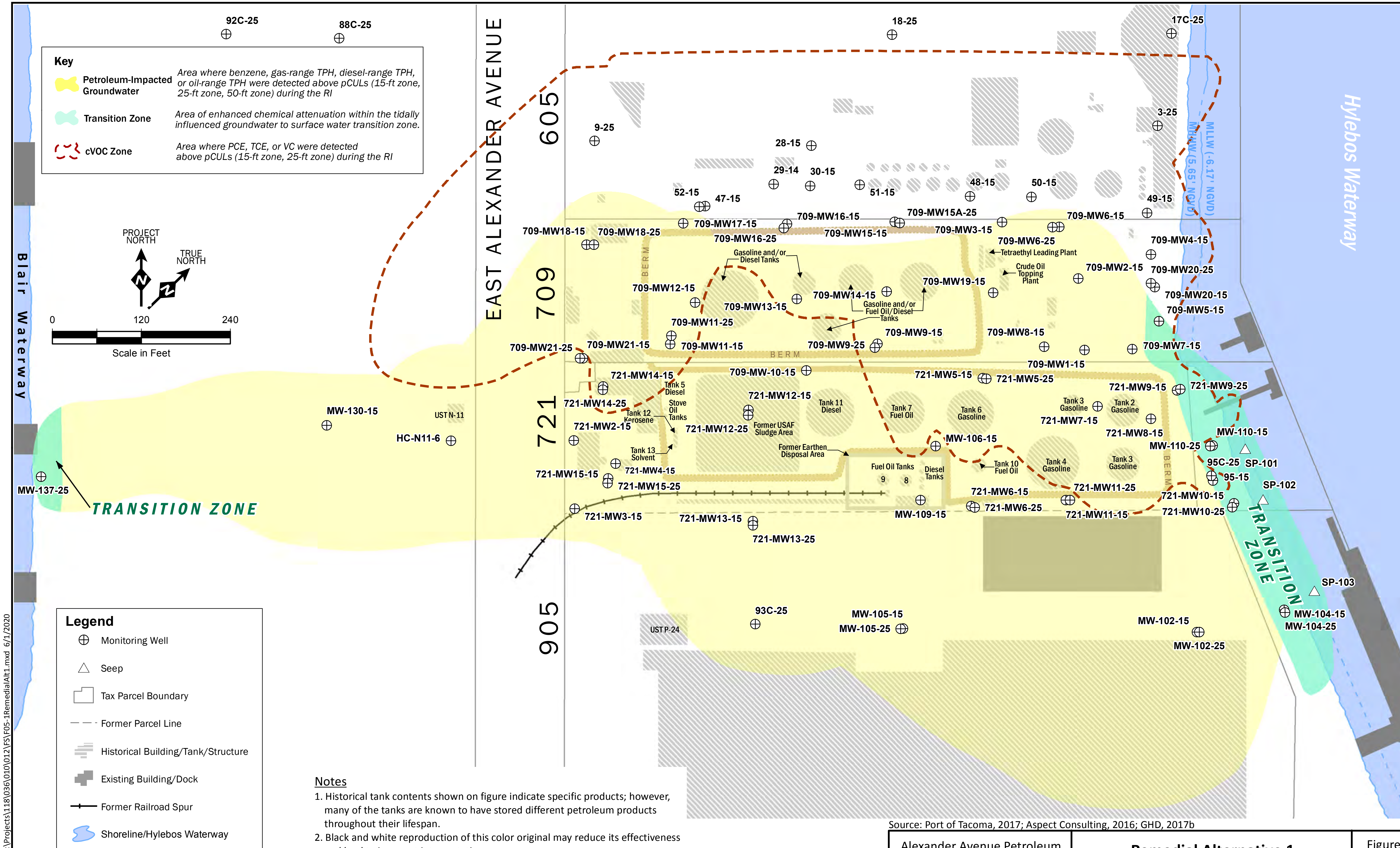
Landau Associates

Alexander Avenue Petroleum Tank Faclity Site Feasibility Study

**Conceptual Angled Well Configuration**

Figure 3-1

Landau Associates | G:\Projects\118\036\010\012\FS\F03-1 Well Profile.dwg | 3/31/2020 12:25 PM | ezick

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Notes
1. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Port of Tacoma, 2017; Aspect Consulting, 2016; GHD, 2017b

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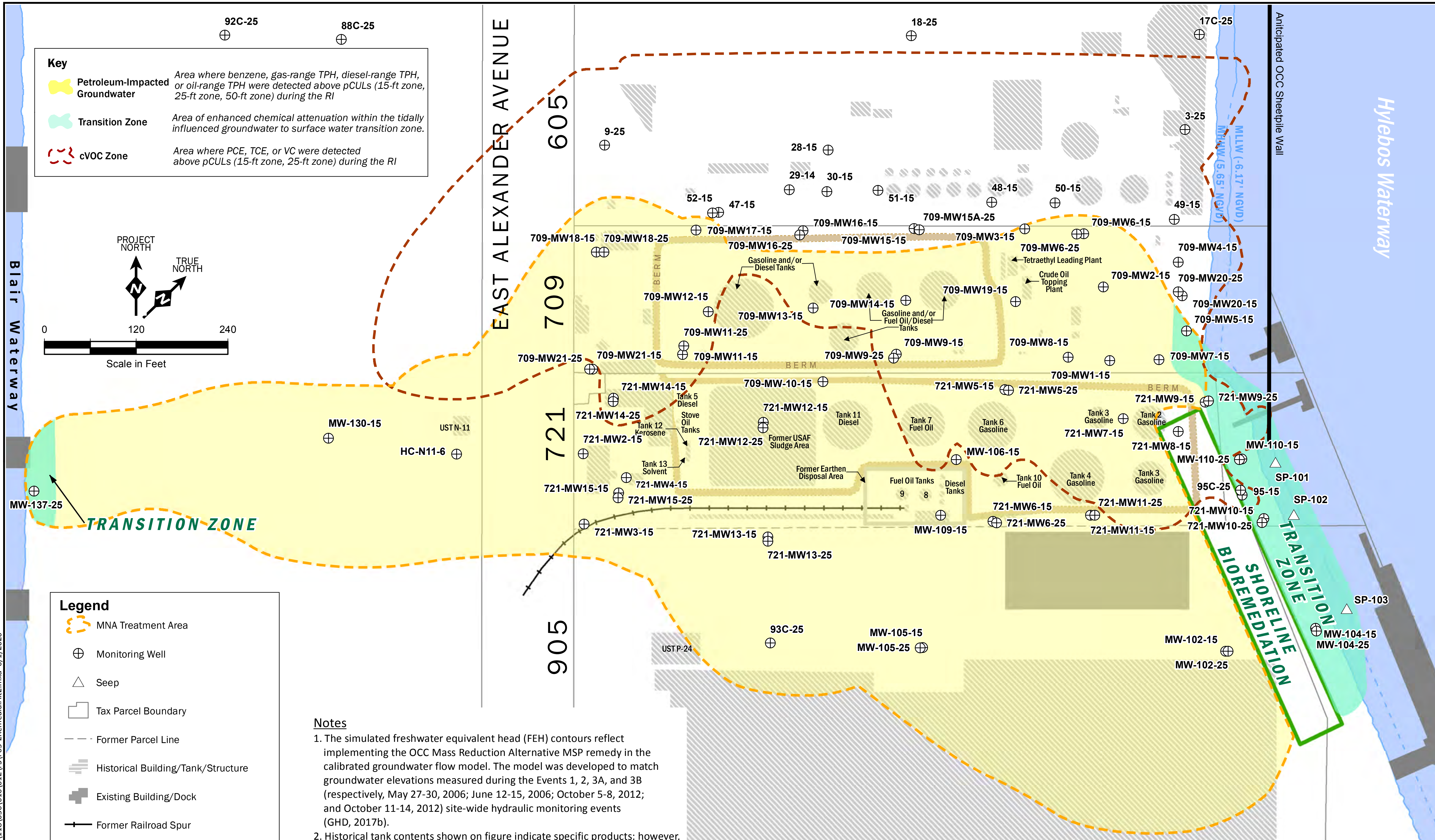
| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | Remedial Alternative 1 No Action (Monitoring Only) | Figure 5-1 |
|---|---|---|




## Notes

1. The simulated freshwater equivalent head (FEH) contours reflect implementing the OCC Mass Reduction Alternative MSP remedy in the calibrated groundwater flow model. The model was developed to match groundwater elevations measured during the Events 1, 2, 3A, and 3B (respectively, May 27-30, 2006; June 12-15, 2006; October 5-8, 2012; and October 11-14, 2012) site-wide hydraulic monitoring events (GHD, 2017b).
2. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
3. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Port of Tacoma, 2017; Aspect Consulting, 2016; GHD, 2017b

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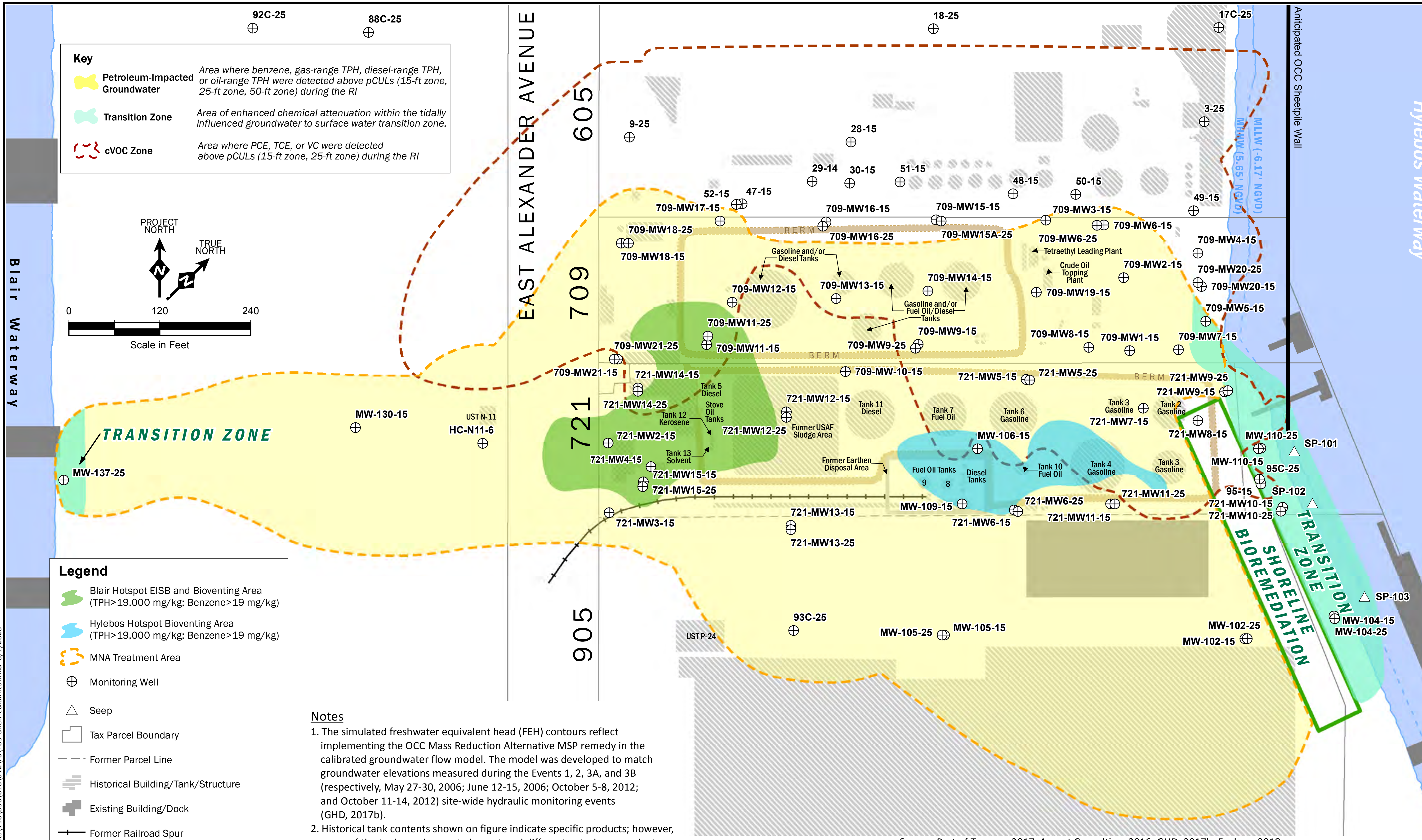
Alexander Avenue Petroleum Tank Facility Site Feasibility Study

**Remedial Alternative 2**
**MNA and Shoreline EISB**

Figure 5-2




Source: Port of Tacoma, 2017; Aspect Consulting, 2016; GHD, 2017b; Ecology, 2018.

Notes

1. The simulated freshwater equivalent head (FEH) contours reflect implementing the OCC Mass Reduction Alternative MSP remedy in the calibrated groundwater flow model. The model was developed to match groundwater elevations measured during the Events 1, 2, 3A, and 3B (respectively, May 27-30, 2006; June 12-15, 2006; October 5-8, 2012; and October 11-14, 2012) site-wide hydraulic monitoring events (GHD, 2017b).
2. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
3. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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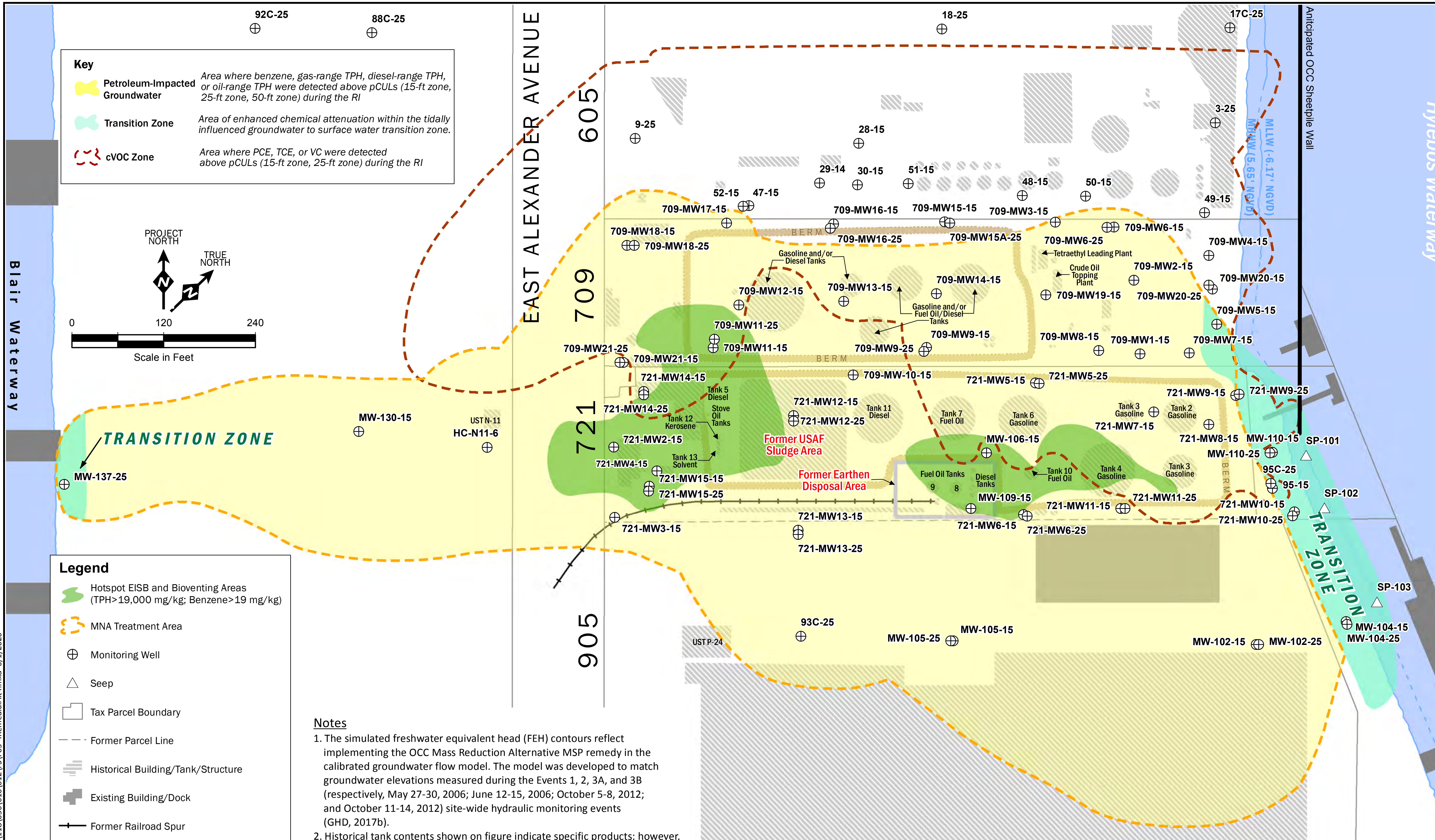
| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | **Remedial Alternative 3 - Shoreline EISB, Blair Hotspot EISB and Bioventing, Hylebos Hotspot Bioventing, and MNA** | Figure 5-3 |
|---|---|---|




Notes
1. The simulated freshwater equivalent head (FEH) contours reflect implementing the OCC Mass Reduction Alternative MSP remedy in the calibrated groundwater flow model. The model was developed to match groundwater elevations measured during the Events 1, 2, 3A, and 3B (respectively, May 27-30, 2006; June 12-15, 2006; October 5-8, 2012; and October 11-14, 2012) site-wide hydraulic monitoring events (GHD, 2017b).
2. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Port of Tacoma, 2017; Aspect Consulting, 2016; GHD, 2017b; Ecology, 2018.

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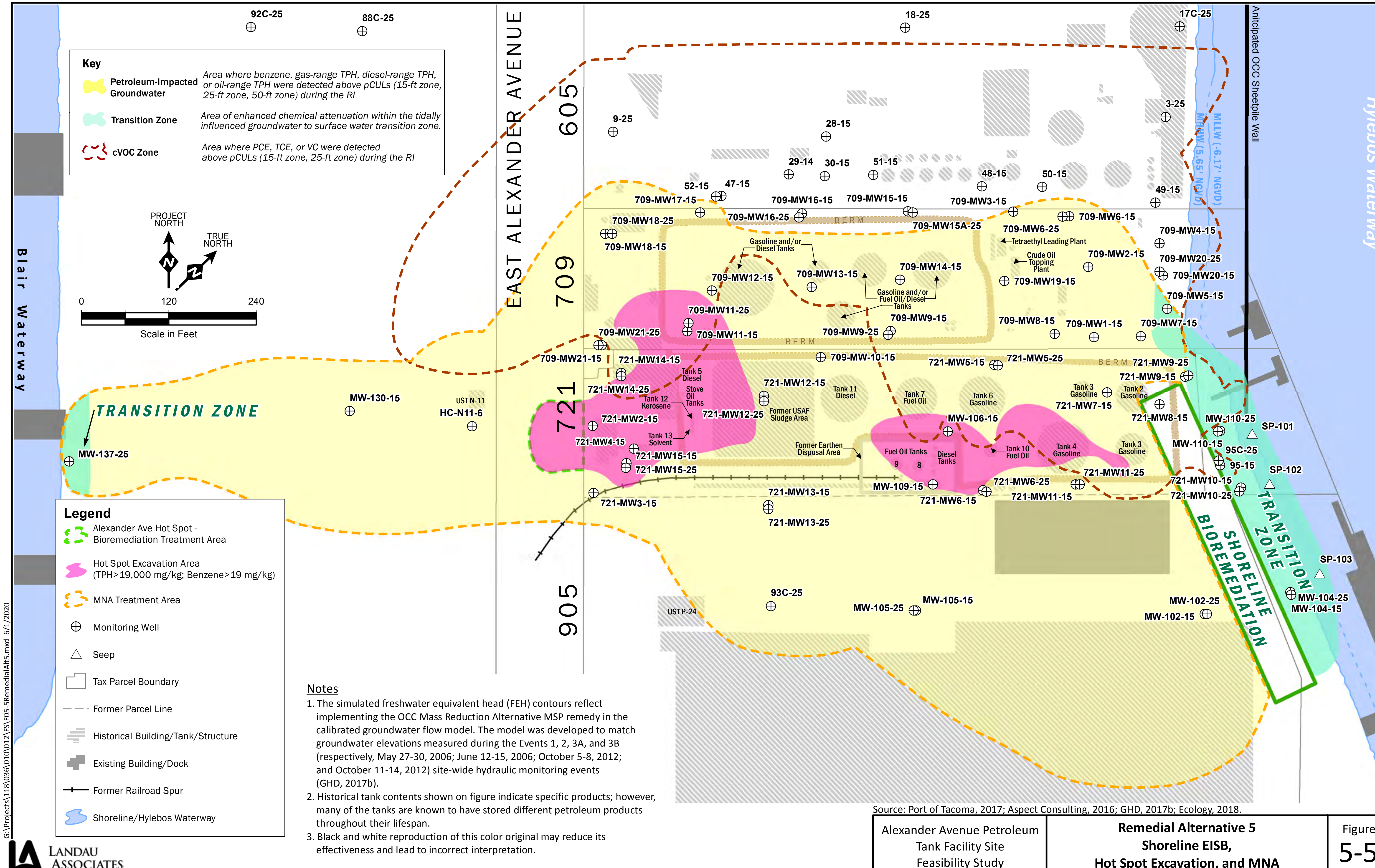
Alexander Avenue Petroleum Tank Facility Site Feasibility Study

**Remedial Alternative 4**
**Hotspot EISB and Bioventing, and MNA**

Figure 5-4

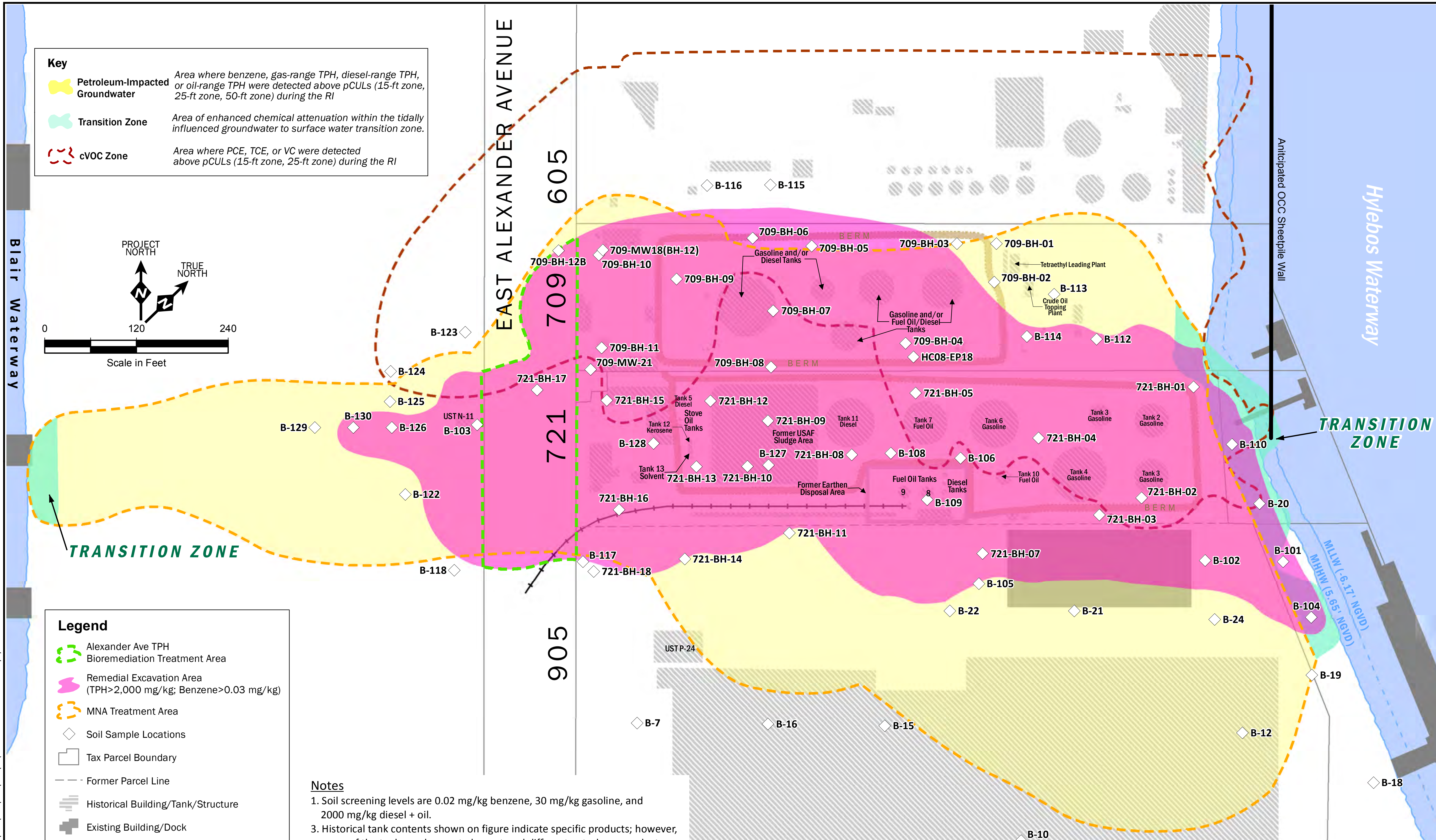



Notes

1. The simulated freshwater equivalent head (FEH) contours reflect implementing the OCC Mass Reduction Alternative MSP remedy in the calibrated groundwater flow model. The model was developed to match groundwater elevations measured during the Events 1, 2, 3A, and 3B (respectively, May 27-30, 2006; June 12-15, 2006; October 5-8, 2012; and October 11-14, 2012) site-wide hydraulic monitoring events (GHD, 2017b).
2. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
3. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Port of Tacoma, 2017; Aspect Consulting, 2016; GHD, 2017b; Ecology, 2018.

| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | **Remedial Alternative 5 Shoreline EISB, Hot Spot Excavation, and MNA** | Figure 5-5 |
|---|---|---|




Notes
1. Soil screening levels are 0.02 mg/kg benzene, 30 mg/kg gasoline, and 2000 mg/kg diesel + oil.
3. Historical tank contents shown on figure indicate specific products; however, many of the tanks are known to have stored different petroleum products throughout their lifespan.
3. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: Aspect Consulting, 2016; Ecology, 2018.

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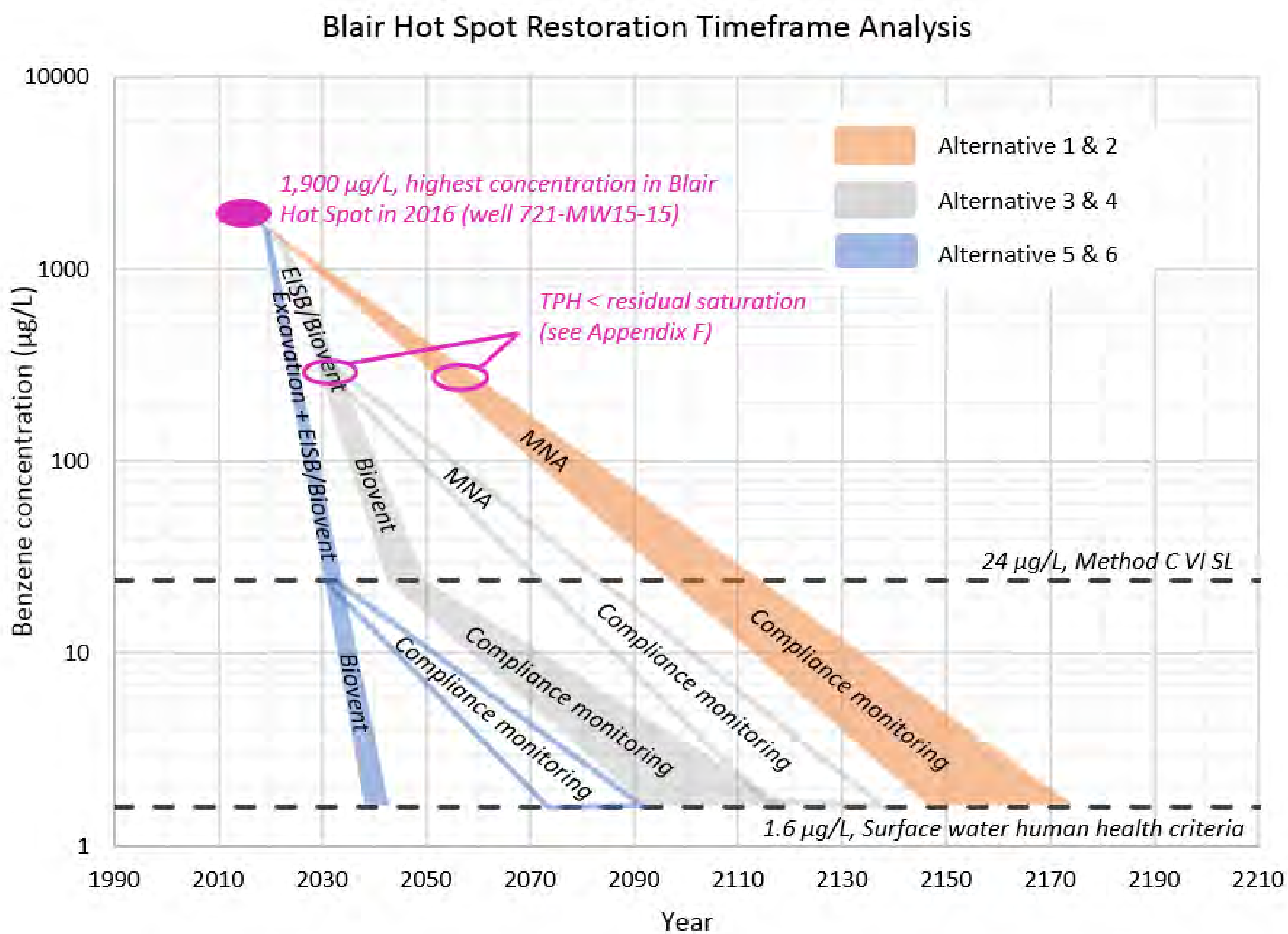
LANDAU ASSOCIATES

| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | Remedial Alternative 6 Remedial Excavation and MNA | Figure 5-6 |
|---|---|---|




Notes:

- Under Alternatives 3 and 5 there is the option to terminate bioventing when respective RLs are met (TPH < residual saturation, and benzene < VI SL). These options are projected in gray and blue outline, it is assumed that due to the low cost of bioventing those system will continue to operate. Restoration timeframes presented in Table 5-7 reflect that assumption.
- Projected restoration time frames are extracted from Appendix F. Width of projections represents uncertainty and is based off the difference between the well decay rate and the average attenuation rate.

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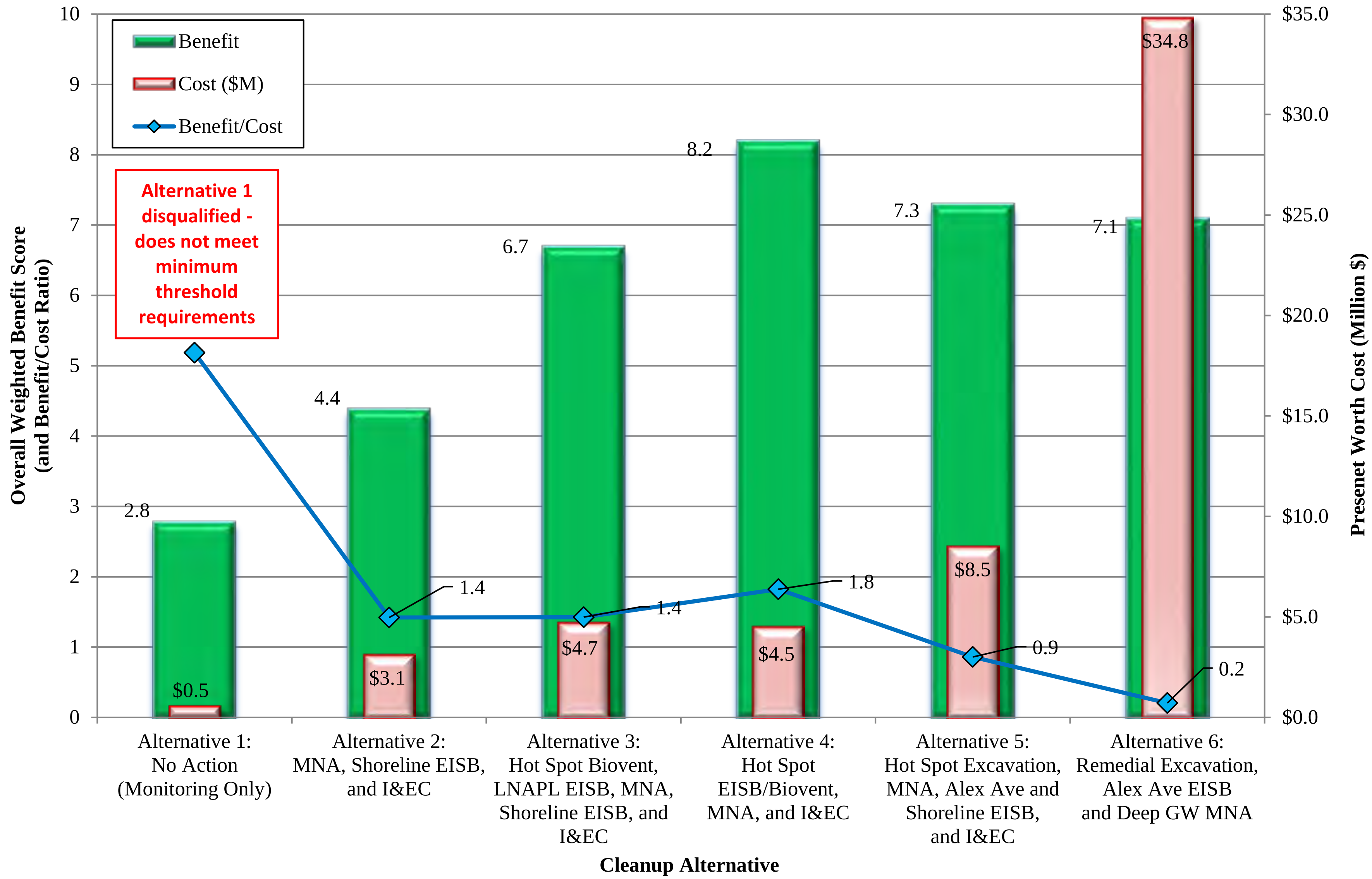
| Alexander Avenue Petroleum Tank Facility Site Feasibility Study | **Blair Hot Spot Restoration Time Frame Analysis** | Figure 6-1 |
|---|---|---|

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Alexander Avenue Petroleum Tank Facility Site Feasibility Study

**Remedial Alternatives Disproportionate Cost Analysis**

Figure 6-2

# Table 3-1
# Proposed Cleanup Levels
# Alexander Avenue Cleanup Site
# Tacoma, Washington

| Analyte | Proposed Cleanup Level - by Media | | | |
|---|---|---|---|---|
| | Groundwater pCUL at CPOC (Point of Flow to Surface Water) (µg/L) | Groundwater Concentrations at Angled Well for Demonstrating Compliance at Hylebos Waterway CPOC (µg/L) | Groundwater Concentrations at Angled Well for Demonstrating Compliance at Blair Waterway CPOC (µg/L) | Soil pCULs (mg/kg) |
| | Protection of Marine Surface Water (a) | Protection of Marine Surface Water (b) | Protection of Marine Surface Water (b) | Direct Contact Method C (0–15 ft) |
| **Benzene** | 1.6 | 4.0 | TBD | 2400 |
| **Total Petroleum Hydrocarbons (TPH)** | NA | NA | NA | 17,000 (c) |
| **Gasoline-Range Organics (TPH-G)** | 800 | 2,200 | TBD | NA |
| **Diesel-Range Organics (TPH-D/O)** | 500 | 680 | TBD | NA |
| **Tetrachloroethene (PCE)** | 7.1 (d) | 7.1 (d) | 7.1 (d) | NA |
| **Trichloroethene (TCE)** | 0.86 (d) | 0.86 (d) | 0.86 (d) | NA |
| **Vinyl Chloride (VC)** | 0.26 (d) | 0.26 (d) | 0.26 (d) | NA |

**Abbreviations and Acronyms:**

µg/L = micrograms per liter
COC = constituent of concern
CPOC = conditional point of compliance
Ecology = Washington State Department of Ecology
EPA = US Environmental Protection Agency
ft = feet
mg/kg = milligrams per kilogram
NA = not applicable
NTR = National Toxics Rule
pCUL = proposed cleanup level
RI = remedial investigation
TBD = to be determined (see Note a)
WAC = Washington Administrative Code

**Notes:**

(a) Groundwater pCUL protective of surface water at point or points where groundwater flows to surface water; this pCUL will not be demonstrated through direct sampling at this location; instead it will be demonstrated through compliance with attenuation-based compliance values at upland angled wells, as allowable under WAC 173-340-720(8)(e); (see columns to right and Note b).

(b) Preliminary concentrations for demonstrating compliance for benzene, TPH-G, and TPH-D/O at the Hylebos shoreline (15-ft zone) CPOC based on attenuation rate data from existing shoreline wells and seeps interpolated to projected location of proposed angled wells to be used for demonstrating compliance at the CPOC (see Appendix D). Insufficient data is available for similar evaluation for the 25-ft zone and the Blair shoreline. Final values for both Hylebos and Blair shorelines (15-ft and 25-ft zones) to be based on calculated attenuation rates between upland groundwater monitoring wells (angled wells) to be used for demonstrating compliance and existing or other upland monitoring wells; final values to be determined after installation and sampling of angled wells and calculation of actual attenuation between existing wells (vertical) and new angled wells. Groundwater data from the RI indicates that Site COCs in the 50-ft zone do not discharge to surface water above pCULs.

(c) Based on Method C direct contact value as calculated by Equation 745-3; assumes that the entire petroleum fraction is associated with the Aromatic 10-12 carbon range fraction and soil ingestion rate of 100 milligrams per day (outdoor worker).

(d) August 1, 2016 rulemaking for WAC 173-201A - new human health criteria were established under part 240 (became effective September 1, 2016), but during the EPA approval process, the state water quality criteria were revised for some COCs by the EPA's November 15, 2016 response and codified under NTR (40 Code of Federal Regulations 131.45) on November 28, 2016. However, as of April 16, 2020, the EPA has withdrawn most of the human health criteria for Washington found in the NTR. The rule withdrawal has resulted in final approval of the WAC 173-201A values. However, Ecology has since filed suit against EPA for withdrawing the NTR human health criteria values and has issued Interim Policy 720 (January 2021) encouraging potentially liable parties to take into account the withdrawn NTR criteria (PCE = 2.9 µg/L; TCE = 0.7 µg/L; VC = 0.18 µg/L) .

(e) Attenuation rates for chlorinated solvents have not been calculated for developing preliminary cleanup levels for chlorinated solvents at proposed upland angled wells to be used for demonstration of compliance at the CPOC due to insufficient availability of data; attenuation rates will be developed in the future, as necessary, if needed to demonstrate compliance at the CPOC; values shown are equal to the surface water quality standards.

**Table 3-2**
**Remediation Levels**
**Alexander Avenue Cleanup Site**
**Tacoma, Washington**

| | Groundwater (a) | | | | Soil/LNAPL Thickness | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Shoreline Angled Wells RL Concentration (CPOC Compliance) (µg/L) | Hylebos Hot Spot RL (EISB, Natural Attenuation, Bioventing) (µg/L) | Blair Hot Spot Preliminary RL (CPOC compliance) (µg/L) | Site-Wide GW MNA/VI RL (All Remedial Alternatives) (µg/L) | Blair Hot Spot RL - LNAPL Area (>0.1 ft) (EISB and Bioventing) (ft LNAPL)/(mg/kg) | Blair Hot Spot RL - LNAPL Area (>0.01 ft) (Bioventing) (ft LNAPL)/(mg/kg) | Alexander Avenue RL (EISB and Bioventing) (mg/kg) | Blair and Hylebos Hot Spots (Excavation) (mg/kg) | Site-Wide Soil (Excavation) (mg/kg) |
| **Applicable Alternatives** | **2,3,5** | **2, 3, 4** | **2, 3** | **2, 3, 4, 5** | **3, 4** | **3, 4** | **3, 4, 5, 6** | **5** | **6** |
| **Analytes** | | | | | | | | | |
| **Benzene** | 4 | 86 (Alt. 2, 3)<br>24 (Alt. 4 bioventing) | 2,600 | 24 | -- | -- | -- | 19 | 0.03 |
| **Total TPH (w/SGC)** | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **Total TPH (w/out SGC)** | -- | -- | -- | -- | 17000 (b) | 17000 (b) | 17,000 (Alt. 3, 4, 5)<br>2,000 (Alt. 6) | 19,000 | 2,000 |
| **TPH-D/O (w/out SGC)** | 680 | 2,600 | 7,300 | -- | -- | -- | -- | -- | -- |
| **TPH-G** | 2,200 | NA (85,000) | 4,600 | -- | -- | -- | -- | -- | -- |
| **LNAPL Thickness** | -- | -- | -- | -- | <0.1 ft LNAPL (b) | <0.1 ft LNAPL (b) | <0.1 ft LNAPL (b) | -- | -- |
| **CVOCs** | -- | -- | -- | PCE = 100<br>TCE = 8.4<br>VC = 3.5 | -- | -- | -- | -- | -- |
| **Remediation Level Purpose** | Meet surface water CULs in Hylebos Waterway as a result of shoreline treatment | Meet surface water CULs in Hylebos Waterway as a result of Hylebos Hot Spot treatment | Meet surface water CULs in Blair Waterway as a result of Blair Hot Spot treatment | Meet VI SLs for potential future buildings | Meet direct contact CUL for TPH; eliminate formation of free LNAPL | Meet direct contact CUL; eliminate formation of free LNAPL | Meet direct contact CUL; eliminate formation of free LNAPL | Meet direct contact CUL; eliminate formation of free LNAPL | Meet unrestricted soil CUL for TPH |
| **Remedial Alternative** | **Action Upon Reaching Remediation Level** | | | | | | | | |
| **Alt 1: No Action** | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **Alt 2: Site-Wide MNA, Shoreline EISB, and I&ECs** | Stop shoreline treatment, provided Hylebos Hot Spot RLs are also met, begin Site-wide MNA | Stop shoreline treatment, provided compliance concentrations are also met at shoreline angled wells, begin MNA monitoring | Confirm groundwater concentrations protective of Blair Waterway | Stop MNA groundwater monitoring, begin compliance monitoring | -- | -- | -- | -- | -- |
| **Alt 3: Blair Hot Spot EISB and Bioventing, Hylebos Hot Spot Bioventing, Shoreline EISB, and MNA** | Stop shoreline treatment, provided Hylebos Hot Spot RLs are also met | Stop shoreline treatment and bioventing at Hylebos Hot Spot, provided compliance concentrations are met at angled wells, begin MNA monitoring | Confirm groundwater concentrations protective of Blair Waterway | Stop MNA groundwater monitoring, begin compliance monitoring | Stop EISB, bioventing continues | Stop bioventing, confirm compliance with soil CULs with sampling, begin MNA groundwater monitoring | -- | -- | -- |

**Table 3-2**
**Remediation Levels**
**Alexander Avenue Cleanup Site**
**Tacoma, Washington**

| | Groundwater (a) | | | | Soil/LNAPL Thickness | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Shoreline Angled Wells RL Concentration (CPOC Compliance) (µg/L)** | **Hylebos Hot Spot RL (EISB, Natural Attenuation, Bioventing) (µg/L)** | **Blair Hot Spot Preliminary RL (CPOC compliance) (µg/L)** | **Site-Wide GW MNA/VI RL (All Remedial Alternatives) (µg/L)** | **Blair Hot Spot RL - LNAPL Area (>0.1 ft) (EISB and Bioventing) (ft LNAPL)/(mg/kg)** | **Blair Hot Spot RL - LNAPL Area (>0.01 ft) (Bioventing) (ft LNAPL)/(mg/kg)** | **Alexander Avenue RL (EISB and Bioventing) (mg/kg)** | **Blair and Hylebos Hot Spots (Excavation) (mg/kg)** | **Site-Wide Soil (Excavation) (mg/kg)** |
| **Applicable Alternatives** | **2,3,5** | **2, 3, 4** | **2, 3** | **2, 3, 4, 5** | **3, 4** | **3, 4** | **3, 4, 5, 6** | **5** | **6** |
| **Alt 4: Hot Spot EISB and Bioventing and MNA** | -- | Stop EISB at Hylebos Hot Spot, provided CULs are also met at shoreline angled wells, continue bioventing | Confirm groundwater concentrations protective of Blair Waterway | Stop bioventing at Hylebos Hot Spot and MNA groundwater monitoring, begin compliance monitoring | Stop EISB, bioventing continues | -- | -- | -- | -- |
| **Alt 5: Hot Spot Excavation, Alexander Avenue Bioremediation, Shoreline EISB, and MNA** | Stop shoreline treatment, provided Hylebos Hot Spot RLs are also met, begin Site-wide MNA | Stop shoreline treatment, provided CULs are also met at shoreline angled wells, begin MNA monitoring | Confirm groundwater concentrations protective of Blair Waterway | Stop MNA groundwater monitoring, begin compliance monitoring | -- | -- | Stop EISB and bioventing, confirm compliance with soil CULs with sampling, begin MNA monitoring | Stop excavation, begin MNA monitoring | -- |
| **Alt 6: Extended Remedial Excavation, Alexander Avenue Bioremediation, and MNA for Deep Groundwater** | -- | -- | -- | Stop MNA groundwater monitoring, begin compliance monitoring | -- | -- | Stop EISB and bioventing, confirm compliance with soil CULs with sampling | -- | Stop excavation, begin MNA groundwater monitoring |

**Abbreviations and Acronyms:**

-- = not applicable
µg/L = micrograms per liter
Alt = Alternative
CUL = cleanup level
EISB = enhanced *in situ* bioremediation
ft = feet
I&ECs = institutional and engineering controls
LNAPL = light non-aqueous phase liquid
mg/kg = milligrams per kilogram
MNA = monitored natural attenuation
NA = not applicable
pCUL = proposed cleanup level
RL = remediation level
RS = residual saturation concentration
SGC = silica gel cleanup
SL = screening level
TPH = total petroleum hydrocarbons
TPH-D = diesel-range total petroleum hydrocarbons
TPH-G = gasoline-range total petroleum hydrocarbons
TPH-O = oil-range total petroleum hydrocarbons
VI = vapor intrusion

**Notes:**

(a) Preliminary remediation levels for benzene, TPH-G, and TPH-O at the Hylebos shoreline and hot spot based on attenuation rate data from existing hot spot wells, shoreline wells, and seeps. Insufficient data available for similar evaluation for Blair shoreline. Final values for both Hylebos and Blair hot spots and shorelines to be based on calculated attenuation rates between conditional point of compliance groundwater monitoring wells (angled wells) near shoreline; final values to be determined after installation and sampling of angled wells and calculation of actual attenuation between existing shoreline wells (vertical) and point of compliance wells.

(b) Goal of Blair Hotspot (including Alexander Ave hotspot) remediation is to reach lower of residual saturation concentration (estimated 19,000 mg/kg) and direct contact CUL of 17,000 mg/kg; LNAPL thickness RL is provided as a surrogate for the residual saturation concentration

**Table 5-1**
**Remedial Alternative 1 - Feasibility Study Cost Estimate**
**Alexander Avenue Cleanup Site**
**Port of Tacoma**
**Tacoma, Washington**

**Alternative 1: No Action (Site Monitoring Only)**
Assumptions: Seep monitoring for 29 years, groundwater monitoring for 152 years

| ITEM | QUANTITY | UNIT | UNIT COST | TOTAL | Comments |
|---|---|---|---|---|---|
| **1 Work Plans/Design/Reporting/Other** | | | | | |
| Risk Assessment | 1 | LS | $ 50,000 | $ 20,000 | to demonstrate no risk to human health and the environment |
| Site Monitoring Plan | 1 | LS | $ 15,000 | $ 20,000 | |
| Remediation Completion Report | 1 | LS | $ 15,000 | $ 15,000 | upon completion |
| Engineering Design | 12% | pct | $ - | $ - | assume 12% of capital costs; engineering designs and specifications; per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Construction Management/Oversight | 8% | pct | $ - | $ - | assume 8% of capital costs; per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Project Management | 6% | pct | $ 439,300 | $ 26,358 | assume 6% of total costs (Items 2, 3, & 4); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Ecology Oversight | 5% | pct | $ 439,300 | $ 21,965 | assume 5% of total costs (Items 2, 3 & 4) |
| *Task Subtotal* | | | | *$ 103,323* | |
| **2 Pre-Monitoring Submittals and Tasks** | | | | | |
| Health and Safety Plan | 1 | LS | $ 2,000 | $ 2,000 | |
| Schedule | 1 | LS | $ 500 | $ 500 | |
| *Task Subtotal* | | | | *$ 2,500* | |
| **3 Site Monitoring** | | | | | |
| | | Discount Rate | 2.5% | | Per Port of Tacoma finance department direction |
| Annual/Biennial Surface water Monitoring | 29 | years | $ 2,500 | *$ 16,000* | Sampling/monitoring annually for 5 year and every 2 years for 24 years (3 seeps/event, TPH, BTEX) |
| Annual/Biennial Groundwater Monitoring and Reporting | 29 | years | $ 28,000 | *$ 247,000* | Sampling/monitoring annually for 5 years and every 2 years for 24 years (55 wells/event, TPH, BTEX) |
| 5-year Groundwater Monitoring and Reporting | 85 | years | $ 28,000 | *$ 101,000* | Sampling/monitoring every 5 years from year 30 through 152 (55 wells/event, TPH, BTEX) |
| **4 Monitoring Contingency** | 20% | pct | $ 364,000 | $ 72,800 | Assume 20% of monitoring costs for occasional monitoring well repairs, additional monitoring/sampling |
| *Task Subtotal* | | | | *$ 436,800* | |
| | | | **Total** | **$ 543,000** | |
| Estimated Cost Range (-30% to +50%) | | | $ 380,000 to | $ 810,000 | |

Notes:
1) Discount Rate is 2.5% per Port of Tacoma finance department direction

# Table 5-2
## Remedial Alternative 2 - Feasibility Study Cost Estimate
## Alexander Avenue Cleanup Site
## Port of Tacoma
## Tacoma, Washington

**Alternative 2: Site-Wide MNA, Shoreline EISB, and I&Ecs**
Assumptions: Shoreline Bioinjections for 21 years, MNA for 85 Years, 5-Year Monitoring for 67 years (152 years total)

| ITEM | QUANTITY | UNIT | UNIT COST | TOTAL | Comments |
|---|---|---|---|---|---|
| **1 Work Plans/Design/Reporting/Other** | | | | | |
| UIC Permit | 1 | LS | $ 5,000 | $ 5,000 | |
| Shoreline PRB Pilot Study Work plan | 1 | LS | $ 20,000 | $ 20,000 | Pilot test work plan (includes work plan for angled wells to define CPOC CULs) |
| Shoreline PRB Pilot Study | 1 | LS | $ 90,000 | $ 90,000 | Four 15 ft and 30 ft injection wells installed (install costs below) and injected with sulfate; 1 year qtly monitoring at existing wells. Five each 15 ft and 25 ft zone angled CPOC monitoring wells installed; 4 quarters of monitoring to determine CPOC CULs |
| Bid Package/Procurement | 1 | LS | $ 20,000 | $ 20,000 | Port and/or Port's consultant cost |
| Construction Report | 1 | LS | $ 20,000 | $ 20,000 | Upon completion |
| Engineering Design | 8% | pct | $ 684,432 | $ 54,755 | Assume 8% of capital costs (Items 3, 4, 5 & 6); engineering designs and specifications; per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Construction Management/Oversight | 6% | pct | $ 684,432 | $ 41,066 | Assume 6% of capital costs (Items 3, 4, 5 & 6); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Project Management | 5% | pct | $ 2,595,232 | $ 129,762 | Assume 5% of total costs (Items 2 through 8); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Ecology Oversight | 5% | pct | $ 2,595,232 | $ 129,762 | Assume 5% of total costs (Items 2 through 8) |
| *Task Subtotal* | | | | *$ 510,344* | |
| **2 Preconstruction Submittals and Tasks** | | | | | |
| Health and Safety Plan | 1 | LS | $ 2,000 | $ 2,000 | |
| Schedule | 1 | LS | $ 500 | $ 500 | |
| Other submittals | 1 | LS | $ 1,000 | $ 1,000 | Equipment/materials list, manuals, instructions, certificates, etc. |
| Mobilization | 1 | LS | $ 10,000 | $ 10,000 | Mobilize equipment and materials to site |
| *Task Subtotal* | | | | *$ 13,500* | |
| **3 Shoreline Bioinjection Permeable Reactive Barrier** | Discount Rate | | 2.5% | | Per Port of Tacoma finance department direction (for multi-year injection and monitoring events) |
| 3.1 **Injection System Construction** | | | | | |
| 2" Injection Wells (~15' deep) | 30 | EA | $ 3,100 | $ 93,000 | 2" sch. 40 PVC wells 15 ft deep, w/5 ft screens (all drilling related costs) (includes 4 pilot test IW) |
| 2" Injection Wells (~30' deep) | 30 | EA | $ 4,600 | $ 138,000 | 2" sch. 40 PVC wells, 30 ft deep, w/5-10 ft screens (all drilling related costs) (includes 4 pilot test IW) |
| IDW management/ disposal | 100 | drums | $ 60 | $ 6,000 | Drill cuttings and purge water, assume disposal as non-haz solid waste |
| Injection manifold and equipment | 1 | LS | $ 50,000 | $ 50,000 | |
| Baseline groundwater sampling at injection wells | 30 | sample | $ 350 | $ 10,500 | TPH-Dx/Gx/benzene sampling at each vertical injection well; includes labor |
| 3.2 **Injections** | | | | | Assume up to 16 injection events conducted over 21 years |
| Materials | 16 | Event | $ 12,000 | $ 154,000 | Assume each injection event consists of 60 injection wells injected w/nitrate and/or sulfate solution w/added nutrients. Costs assume liquid ammonium nitrate or magnesium sulfate for shoreline injections. |
| Labor and expenses | 16 | Event | $ 32,000 | $ 418,000 | |
| 3.3 **Quarterly EISB groundwater monitoring & annual reporting** | 21 | years | $ 45,000 | $ 546,000 | Quarterly for up to 21 years, $475/sample for TPH-Dx/Gx/benzene and MNA parameters; assume 10 wells and 3 seeps/event. |
| *Task Subtotal* | | | | *$ 1,415,500* | |
| **4 Construction Contingency** | 25% | pct | $ 441,000 | *$ 110,250* | Assume 25% bid and scope contingency - low end of scope contingency for groundwater treatment (15%) plus low end of bid contingency (10%); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| **5 Contractor bond fee, overhead, and profit** | 20% | pct | $ 441,000 | *$ 88,200* | Assume 20% of construction costs (Item 3.1) |
| **6 Sales Tax (commercial equipment/services)** | 10.2% | pct | $ 441,000 | *$ 44,982* | WSST |
| **7 Monitored Natural Attenuation/Institutional Controls** | | | | | |
| | Discount Rate | | 2.5% | | Per Port of Tacoma finance department direction |
| Quarterly MNA groundwater monitoring and annual reporting | 4 | event | $ 37,500 | $ 150,000 | Quarterly for Yr 1, $475/sample for TPH-Dx/Gx/benzene and MNA parameters; 55 wells/event |
| Annual MNA groundwater monitoring and reporting | 4 | event | $ 45,000 | $ 165,000 | Annually for Yrs 2 - 5 |
| Biannual MNA groundwater monitoring and reporting | 5 | event | $ 45,000 | $ 172,000 | Every 2 years (Yrs 6 - 15) |
| 5 year MNA reviews (until MNA/VI RL met) | 8 | event | $ 45,000 | $ 220,000 | Every 5 years from Yrs 16 - 85 |
| 5 year performance monitoring reviews (until pCULs met Site-wide) | 13 | event | $ 30,000 | $ 25,000 | Every 5 years from Yrs 86 - 152; $175/sample for TPH-Dx/Gx/benzene; 55 wells/event |
| I&EC Monitoring | 100 | yrs | $ 1,000 | $ 37,000 | Annual monitoring of site facilities for institutional controls |
| **8 MNA/5Yr Review Contingency** | 20% | pct | $ 769,000 | $ 153,800 | Assume 20% of monitoring and MNA costs for occasional facility repairs related to ICs, additional MNA monitoring/sampling |
| *Task Subtotal* | | | | *$ 922,800* | |
| | | | **Total** | **$ 3,106,000** | |
| Estimated Cost Range (-30% to +50%) | | | $ 2,174,000 to | $ 4,660,000 | |

Notes:
1) Discount Rate is 2.5% per Port of Tacoma finance department direction

**Table 5-3**
**Remedial Alternative 3 - Feasibility Study Cost Estimate**
**Alexander Avenue Cleanup Site**
**Port of Tacoma**
**Tacoma, Washington**

**Alternative 3: Hot Spot EISB and Bioventing, Shoreline EISB Site-Wide MNA, and I&ECs**
Assumptions: Shoreline Bioinjections for 5 years, Bioventing hot spots (TPH > 19,000 µg/kg) for 9 years (Blair Hot Spot) and 5 years (Hylebos Hot Spot), and EISB in NAPL >0.1' for 9 years, MNA for 11 years after hot spot RLs met

| ITEM | QUANTITY | UNIT | UNIT COST | TOTAL | Comments |
|---|---|---|---|---|---|
| **1 Work Plans/Design/Reporting/Other** | | | | | |
| UIC Permit | 1 | LS | $ 5,000 | $ 5,000 | |
| Shoreline PRB Pilot Study and Pre-Remedial Design Work Pla | 1 | LS | $ 20,000 | $ 20,000 | Pilot test work plan; high resolution site characterization and installation of angled shoreline wells to define hot spots and CPOC CULs |
| Shoreline PRB Pilot Study and Pre-Remedial Design Investiga | 1 | LS | $ 130,000 | $ 130,000 | Five each 15 ft and 30 ft injection wells installed (install costs below) and injected with sulfate; 1 year qtly monitoring at existing wells; and high resolution site characterization. Five each 15 ft and 25 ft zone angled CPOC monitoring wells installed; 4 quarters of monitoring to determine CPOC CULs. |
| Bid Package/Procurement | 1 | LS | $ 25,000 | $ 25,000 | Port and/or Port's consultant cost |
| Construction Report | 1 | LS | $ 15,000 | $ 15,000 | Upon completion |
| Engineering Design | 8% | pct | $ 1,192,671 | $ 95,414 | Assume 8% of capital costs (Items 3.1, 3.4, 4, 5 & 6); engineering designs and specifications; per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Construction Management/Oversight | 6% | pct | $ 1,192,671 | $ 71,560 | Assume 6% of capital costs (Items 3.1, 3,4, 4, 5 & 6); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Project Management | 5% | pct | $ 3,958,371 | $ 197,919 | Assume 5% of total costs (Items 2 - 7); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Ecology Oversight | 5% | pct | $ 3,958,371 | $ 197,919 | Assume 5% of total costs (Items 2 - 7) |
| *Task Subtotal* | | | | *$ 757,811* | |
| **2 Preconstruction Submittals and Tasks** | | | | | |
| Health and Safety Plan | 1 | LS | $ 2,000 | $ 2,000 | |
| Schedule | 1 | LS | $ 500 | $ 500 | |
| Other submittals | 1 | LS | $ 1,000 | $ 1,000 | Equipment/materials list, manuals, instructions, certificates, etc. |
| Mobilization | 1 | LS | $ 20,000 | $ 20,000 | Mobilize equipment and materials to site |
| *Task Subtotal* | | | | *$ 23,500* | |
| **3 Hot Spot Bioremediation/Source Zone Depletion/ Shoreline Permeable Reactive Barrier Bioinjections** | | Discount Rate | 2.5% | | Per Port of Tacoma finance department direction (for multi-year injection, monitoring and O&M events) |
| **3.1 Injection System Construction** | | | | | |
| 2" Injection Wells (~15' deep) | 72 | EA | $ 3,100 | $ 223,200 | 2" sch. 40 PVC wells 15 ft deep, w/5 ft screens (all drilling related costs); 30 shoreline, 42 source area wells (and 3 horizontal below Alexander Ave - see line item below) |
| 2" Injection Wells (~30' deep) | 30 | EA | $ 4,600 | $ 138,000 | 2" sch. 40 PVC wells, 30 ft deep, w/5-10 ft screens (all drilling related costs); shoreline wells |
| 3" Horizontal Wells (~12' deep) | 3 | EA | $ 30,200 | $ 90,600 | 3" PVC or HDPE (all drilling related costs): horizontal wells beneath Alexander Avenue |
| Injection manifold and equipment | 1 | LS | $ 50,000 | $ 50,000 | |
| **3.2 Injections - Blair Hot Spot (LNAPL Area)** | | | | | Assume 20 LNAPL area injection events over 13 years |
| Materials | 20 | event | $ 36,000 | $ 569,000 | Each injection event consists of equivalent of 42 vertical injection wells and 3 horizontal injection wells injected with nitrate and/or sulfate solution with added nutrients. Costs assume liquid ammonium nitrate (10x dose) for LNAPL area wells. |
| Labor and expenses | 20 | event | $ 40,000 | $ 632,000 | |
| EISB groundwater monitoring | 10 | years | $ 7,500 | $ 118,000 | Sampling for up to 13 years (quarterly for 1st year, biennially for 2nd & 3rd year, annually thereafter), $475/sample for TPH-Dx/Gx/benzene and MNA parameters; assume 10 wells/event. |
| **3.3 Injections - Shoreline** | | | | | Assume 10 shoreline injection events over 5 years |
| Materials | 10 | event | $ 12,000 | $ 111,000 | Assume each injection event consists of 60 injection wells injected w/nitrate and/or sulfate solution w/added nutrients. Costs assume liquid ammonium nitrate or magnesium sulfate for shoreline injections. |
| Labor and expenses | 10 | event | $ 32,000 | $ 297,000 | |
| EISB groundwater monitoring | 7 | years | $ 35,000 | $ 222,000 | Quarterly for up to 7 years (5 yrs active injections, 2 years post injection monitoring), $475/sample for TPH-Dx/Gx/benzene and MNA parameters; assume 10 wells and 3 seeps/event. |
| **3.4 Bioventing System Construction** | | | | | |
| Install Bioventing Infrastructure - windmill/turbines | 4 | EA | $ 25,000 | $ 100,000 | Assume combination of installing 4 active 15 CFM wind turbines and subgrade perforated vent piping in TPH hotspot areas and passive bioventing zones opened up in pavement in vadose zone hotspots |
| Bioventing - trenching, stockpiling, backfill, compact | 1467 | CY | $ 15 | $ 22,000 | Assume approx. 2200 LF of trenching, 3 ft wide, 6 ft deep |
| Bioventing - bedding material, place compact | 489 | CY | $ 35 | $ 17,111 | Assume approx. 2200 LF of trenching, 3 ft wide, 2 ft deep pipe bedding (gravel) |
| Bioventing - piping | 2200 | LF | $ 12 | $ 26,400 | Assume approx. 2200 LF of 4" perf pipe and header piping, installed cost |
| Bioventing - disposal of trenching spoils | 782 | TN | $ 48 | $ 37,547 | Assume 2 ft thick layer in bottom of 3 ft wide trench is in smear zone and requires disposal (1.6 ton/cy) |
| Repaving trench | 733 | SY | $ 42 | $ 30,800 | Assume repaving over length of trench; 4" HMA Asphalt |

# Table 5-3
## Remedial Alternative 3 - Feasibility Study Cost Estimate
## Alexander Avenue Cleanup Site
## Port of Tacoma
## Tacoma, Washington

**Alternative 3: Hot Spot EISB and Bioventing, Shoreline EISB Site-Wide MNA, and I&ECs**
Assumptions: Shoreline Bioinjections for 5 years, Bioventing hot spots (TPH > 19,000 µg/kg) for 9 years (Blair Hot Spot) and 5 years (Hylebos Hot Spot), and EISB in NAPL >0.1' for 9 years, MNA for 11 years after hot spot RLs met

| ITEM | QUANTITY | UNIT | UNIT COST | TOTAL | Comments |
|---|---|---|---|---|---|
| 3.5 **Bioventing Operations, Maintenance, and Monitoring** | 18 | event | $ 9,000 | $ 142,000 | Assume 13 years of minor O&M for active bioventing (equip maint, annual vapor sampling). Assume gw and vapor sampling for up to 13 years (quarterly 1st year, biennially 2nd & 3rd years, and annually thereafter), $175/gw sample for TPH-Dx/Gx/benzene; $150/vapor sample for TPH-G/benzene; assume 10 wells and 4 turbine vents/event. |
| 3.6 **EISB/Bioventing annual reporting** | 9 | years | $ 10,000 | $ 80,000 | Assume $10K/yr for annual reporting during active injections and bioventing (9 years). |
| *Task Subtotal* | | | | *$ 2,906,658* | |
| 4 **Construction Contingency** | 30% | pct | $ 759,158 | *$ 227,747* | Assume 30% scope and bid contingency (Items 2, 3.1 & 3.4) - Low end of scope contingency for groundwater treatment - multiple (15%) plus mid range of bid contingency (15%); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| 5 **Contractor bond fee, overhead, and profit** | 20% | pct | $ 759,158 | *$ 151,832* | Assume 20% of construction costs (Items 2, 3.1 & 3.4) |
| 6 **Sales Tax (commercial equipment/services)** | 10.2% | pct | $ 759,158 | *$ 77,434* | WSST |
| 7 **Monitored Natural Attenuation/Institutional Controls** | | | | | Assume MNA monitoring occurs after 13 years of active EISB |
| | | Discount Rate | 2.5% | | Per Port of Tacoma finance department direction |
| Quarterly MNA groundwater monitoring and annual reporting | 4 | event | $ 32,500 | *$ 102,000* | Quarterly for Yr 10, $475/sample for TPH-Dx/Gx/benzene and MNA parameters; 55 wells/event |
| Annual MNA groundwater monitoring and reporting | 5 | event | $ 40,000 | *$ 145,000* | Annually for Yrs 11 - 15 |
| Biannual MNA groundwater monitoring and reporting | 5 | event | $ 40,000 | *$ 77,000* | Every 2 years (Yrs 16 - 20) |
| 5 year MNA reviews (until MNA/VI RL met) | 2 | event | $ 45,000 | $ 46,000 | Every 5 years from Yrs 20-29 |
| 5 year reviews (until pCULs met) | 13 | event | $ 24,000 | *$ 70,000* | Every 5 years from Yrs 30-94, $175/sample for TPH-Dx/Gx/benzene; 55 wells/event |
| I&EC Monitoring | 94 | yrs | $ 1,000 | $ 36,000 | Annual monitoring of site facilities for institutional controls |
| 8 **MNA/5Yr Review Contingency** | 20% | pct | $ 476,000 | $ 95,200 | Assume 20% of MNA costs for occasional facility repairs related to ICs, additional MNA monitoring/sampling |
| *Task Subtotal* | | | | *$ 571,200* | |
| | | | **Total** | **$ 4,716,000** | |
| Estimated Cost Range (-30% to +50%) | | | $ 3,301,000 to | $ 7,070,000 | |

Notes:
1) Discount Rate is 2.5% per Port of Tacoma finance department direction

**Table 5-4**
**Remedial Alternative 4 - Feasibility Study Cost Estimate**
**Alexander Avenue Cleanup Site**
**Port of Tacoma**
**Tacoma, Washington**

**Alternative 4: Hot Spot EISB and Bioventing, Site-Wide MNA, and I&ECs**
Assumptions: Bioinjections in Blair Hot Spot NAPL >0.1' (9 years/20 events), Bioinjections in Hylebos Hot Spot > 86 µg/L, Bioventing both hot spots TPH > 19,000 µg/kg, hot spot bioventing and MNA afterward through Year 49

| ITEM | QUANTITY | UNIT | UNIT COST | TOTAL | Comments |
|---|---|---|---|---|---|
| **1 Work Plans/Design/Reporting/Other** | | | | | |
| UIC Permit | 1 | LS | $ 5,000 | $ 5,000 | |
| Pre-Remedial Design Investigation Work Plan | 1 | LS | $ 20,000 | $ 20,000 | Work plan for angled wells and high resolution site characterization to define hot spots and CPOC CULs |
| Pre-Remedial Design Investigation | 1 | LS | $ 150,000 | $ 150,000 | Five each 15 ft and 25 ft zone angled CPOC monitoring wells installed; 4 quarters of monitoring to determine CPOC CULs; high resolution site characterization to define both hot spots |
| Bid Package/Procurement | 1 | LS | $ 25,000 | $ 25,000 | Port and/or Port's consultant cost |
| Construction Report | 1 | LS | $ 15,000 | $ 15,000 | Upon completion |
| Engineering Design | 8% | pct | $ 1,058,669 | $ 84,694 | Assume 8% of capital costs (Items 3.1, 3.4, 4, 5 & 6); engineering designs and specifications; per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Construction Management/Oversight | 6% | pct | $ 1,058,669 | $ 63,520 | Assume 6% of capital costs (Items 3.1, 3,4, 4, 5 & 6); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Project Management | 5% | pct | $ 3,779,969 | $ 188,998 | Assume 5% of total costs (Items 2 - 8); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Ecology Oversight | 5% | pct | $ 3,779,969 | $ 188,998 | Assume 5% of total costs (Items 2 - 8) |
| *Task Subtotal* | | | | *$ 736,211* | |
| **2 Preconstruction Submittals and Tasks** | | | | | |
| Health and Safety Plan | 1 | LS | $ 2,000 | $ 2,000 | |
| Schedule | 1 | LS | $ 500 | $ 500 | |
| Other submittals | 1 | LS | $ 1,000 | $ 1,000 | Equipment/materials list, manuals, instructions, certificates, etc. |
| Mobilization | 1 | LS | $ 20,000 | $ 20,000 | Mobilize equipment and materials to site |
| *Task Subtotal* | | | | *$ 23,500* | |
| **3 Hot Spot EISB and Bioventing/Source Zone Depletion** | Discount Rate | | 2.5% | | Per Port of Tacoma finance department direction (for multi-year injection, monitoring and O&M events) |
| 3.1 **Injection System Construction** | | | | | |
| 2" Injection Wells (~15' deep) | 85 | EA | $ 3,100 | $ 263,500 | 2" sch. 40 PVC wells 15 ft deep, w/5 ft screens (all drilling related costs); 43 Hylebos Hot Spot wells; 42 Blair Hot Spot wells (and 3 horizontal below Alexander Ave - see line item below) |
| 3" Horizontal Wells (~12' deep) | 3 | EA | $ 30,200 | $ 90,600 | 3" PVC or HDPE (all drilling related costs): horizontal wells beneath Alexander Avenue |
| Injection manifold and equipment | 1 | LS | $ 50,000 | $ 50,000 | |
| 3.2 **Injections - Blair Hot Spot (LNAPL Area)** | | | | | Assume 20 LNAPL area injection events over 13 years |
| Materials | 20 | event | $ 36,000 | $ 569,000 | Each injection event consists of equivalent of 42 vertical injection wells and 3 horizontal injection wells injected with nitrate and/or sulfate solution with added nutrients. Costs assume liquid ammonium nitrate (10x dose) for Blair Hot Spot area wells. |
| Labor and expenses | 20 | event | $ 40,000 | $ 632,000 | |
| EISB groundwater monitoring | 13 | years | $ 7,500 | $ 118,000 | Sampling for up to 13 years (quarterly for 1st year, biennially for 2nd & 3rd year, annually thereafter), $475/sample for TPH-Dx/Gx/benzene and MNA parameters; assume 10 wells/event. |
| 3.3 **Injections - Hylebos Hot Spot** | | | | | Assume 10 shoreline injection events over 5 years |
| Materials | 10 | event | $ 25,000 | $ 232,000 | Each injection event consists of equivalent of 43 vertical injection wells injected with nitrate and/or sulfate solution with added nutrients. Costs assume liquid ammonium nitrate (10x dose) for Hylebos Hot Spot wells. |
| Labor and expenses | 10 | event | $ 30,000 | $ 279,000 | |
| EISB groundwater monitoring | 5 | years | $ 8,800 | $ 83,000 | Sampling for up to 5 years (quarterly for 1st year, biennially for 2nd & 3rd year, annually thereafter), $475/sample for TPH-Dx/Gx/benzene and MNA parameters; assume 10 wells and 3 seeps/event. |
| 3.4 **Bioventing System Construction** | | | | | |
| Install Bioventing Infrastructure - windmill/turbines | 4 | EA | $ 25,000 | $ 100,000 | Assume combination of installing 4 active 15 CFM wind turbines and subgrade perforated vent piping in TPH hot spot areas and passive bioventing zones opened up in pavement in vadose zone hot spots |
| Bioventing - trenching, stockpiling, backfill, compact | 1667 | CY | $ 15 | $ 25,000 | Assume approx. 2500 LF of trenching, 3 ft wide, 6 ft deep |
| Bioventing - bedding material, place compact | 556 | CY | $ 35 | $ 19,444 | Assume approx. 2500 LF of trenching, 3 ft wide, 2 ft deep pipe bedding (gravel) |
| Bioventing - piping | 2500 | LF | $ 12 | $ 30,000 | Assume approx. 2500 LF of 4" perf pipe and header piping, installed cost |
| Bioventing - disposal of trenching spoils | 889 | TN | $ 48 | $ 42,667 | Assume 2 ft thick layer in bottom of 3 ft wide trench is in smear zone and requires disposal (1.6 ton/cy) |
| Repaving trench | 733 | SY | $ 42 | $ 30,800 | Assume repaving over length of trench; 4" HMA Asphalt |

**Table 5-4**
**Remedial Alternative 4 - Feasibility Study Cost Estimate**
**Alexander Avenue Cleanup Site**
**Port of Tacoma**
**Tacoma, Washington**

**Alternative 4: Hot Spot EISB and Bioventing, Site-Wide MNA, and I&ECs**
Assumptions: Bioinjections in Blair Hot Spot NAPL >0.1' (9 years/20 events), Bioinjections in Hylebos Hot Spot > 86 µg/L, Bioventing both hot spots TPH > 19,000 µg/kg, hot spot bioventing and MNA afterward through Year 49

| ITEM | QUANTITY | UNIT | UNIT COST | TOTAL | Comments |
|---|---|---|---|---|---|
| 3.5 **Bioventing Operations, Maintenance, and Monitoring** | 34 | event | $ 4,200 | $ 106,000 | Assume 29 years of minor O&M for active bioventing (equip maint, annual vapor sampling). Assume vapor sampling for up to 29 years (quarterly 1st year, biennially 2nd & 3rd years, and annually thereafter), $150/vapor sample for TPH-G/benzene; assume 4 turbine vents/event. |
| 3.6 **EISB/Bioventing annual reporting** | 29 | years | $ 10,000 | $ 146,000 | Assume $10K/yr for annual reporting during active injections and bioventing (10 years); and $5k/yr after for bioventing reporting only. |
| *Task Subtotal* | | | | *$ 2,817,011* | |
| 4 **Construction Contingency** | 30% | pct | $ 675,511 | *$ 202,653* | Assume 30% scope and bid contingency (Items 2, 3.1 & 3.4) - Low end of scope contingency for groundwater treatment - multiple (15%) plus mid range of bid contingency (15%); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| 5 **Contractor bond fee, overhead, and profit** | 20% | pct | $ 675,511 | *$ 135,102* | Assume 20% of construction costs (Items 2, 3.1 & 3.4) |
| 6 **Sales Tax (commercial equipment/services)** | 10.2% | pct | $ 675,511 | *$ 68,902* | WSST |
| 7 **Monitored Natural Attenuation/Institutional Controls** | | | | | Assume MNA monitoring occurs after 13 years of active EISB |
| | | Discount Rate | 2.5% | | Per Port of Tacoma finance department direction |
| Quarterly Groundwater monitoring and annual reporting | 4 | event | $ 32,500 | *$ 92,000* | Quarterly for Yr 14, $475/sample for TPH-Dx/Gx/benzene and MNA parameters; 55 wells/event |
| Annual Groundwater monitoring and reporting | 4 | event | $ 40,000 | *$ 106,000* | Annually for Yrs 15 - 18 |
| Biannual Groundwater monitoring and reporting | 7 | event | $ 40,000 | *$ 133,000* | Every 2 years (Yrs 19 - 29) throughout active bioventing |
| 5 year reviews (until pCULs met) | 7 | event | $ 24,000 | *$ 77,000* | Every 5 years from Yrs 30 - 94, $175/sample for TPH-Dx/Gx/benzene; 55 wells/event |
| I&EC Monitoring | 94 | yrs | $ 1,000 | $ 36,000 | Annual monitoring of site facilities for institutional controls |
| 8 **MNA/5Yr Review Contingency** | 20% | pct | $ 444,000 | $ 88,800 | Assume 20% of MNA/5yr review costs for occasional facility repairs related to ICs, additional MNA monitoring/sampling |
| *Task Subtotal* | | | | *$ 532,800* | |
| | | | **Total** | **$ 4,516,000** | |
| Estimated Cost Range (-30% to +50%) | | | $ 3,161,000 to | $ 6,770,000 | |

Notes:
1) Discount Rate is 2.5% per Port of Tacoma finance department direction

# Table 5-5
## Remedial Alternative 5 - Feasibility Study Cost Estimate
## Alexander Avenue Cleanup Site
## Port of Tacoma
## Tacoma, Washington

**Alternative 5: Hot Spot Excavation, Alexander Avenue EISB and Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs**
Assumptions: Excavate Hot Spot Areas (TPH>19,000 mg/kg), Shoreline Bioinjections for 5 years, Bioinjections/bioventing Hot Spot Under Alexander Avenue Inaccessible for Excavation for 11 years, MNA for 11 years afterward

| ITEM | QUANTITY | UNIT | UNIT COST | TOTAL | Comments |
|---|---|---|---|---|---|
| **1 Work Plans/Design/Reporting/Other** | | | | | |
| UIC Permit | 1 | LS | $ 5,000 | $ 5,000 | |
| Shoreline PRB Pilot Study Work plan | 1 | LS | $ 20,000 | $ 20,000 | Pilot test work plan |
| Shoreline PRB Pilot Study | 1 | LS | $ 60,000 | $ 60,000 | One 25 ft and one 15 ft injection well installed and tested for injection rates |
| Bid Package/Procurement | 1 | LS | $ 25,000 | $ 25,000 | Port and/or Port's consultant cost |
| Construction Report | 1 | LS | $ 15,000 | $ 15,000 | Upon completion |
| Engineering Design | 8% | pct | $ 5,312,265 | $ 424,981 | Assume 6% of capital costs (Items 3.1, 4, 5, 6, 7 & 8); engineering designs and specifications; per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Construction Management/Oversight | 6% | pct | $ 5,312,265 | $ 318,736 | Assume 6% of capital costs (Items 3.1, 4, 5, 6, 7 & 8); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Project Management | 5% | pct | $ 6,918,665 | $ 345,933 | Assume 5% of total costs (Items 2 through 10); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Ecology Oversight | 5% | pct | $ 6,918,665 | $ 345,933 | Assume 5% of total costs (Items 2 through 10) |
| *Task Subtotal* | | | | *$ 1,560,584* | |
| **2 Preconstruction Submittals and Tasks** | | | | | |
| Health and Safety Plan | 1 | LS | $ 2,000 | $ 2,000 | |
| Schedule | 1 | LS | $ 500 | $ 500 | |
| Other submittals | 1 | LS | $ 1,000 | $ 1,000 | Equipment/materials list, manuals, instructions, certificates, etc. |
| TESC Plan | 1 | LS | $ 5,000 | $ 5,000 | Plan for sediment control for excavation work TESC and restoration |
| Permit Applications | 1 | LS | $ 3,000 | $ 3,000 | Grading permit, public works permit, etc., as applicable. |
| Mobilization | 1 | LS | $ 30,000 | $ 30,000 | Mobilize equipment and materials to site |
| *Task Subtotal* | | | | *$ 41,500* | |
| **Hot Spot Bioremediation and Shoreline Bioinjection** | | | | | |
| **3 Permeable Reactive Barrier** | Discount Rate | | 2.5% | | Per Port of Tacoma finance department direction (multi-year injection and monitoring events) |
| **3.1 Alexander Ave Bioventing/Injection System Construction** | | | | | |
| 2" Injection Wells (~15' deep) | 30 | EA | $ 3,200 | $ 96,000 | 2" sch. 40 PVC wells 15 ft deep, w/5 ft screens (all drilling related costs); 30 shoreline wells |
| 2" Injection Wells (~30' deep) | 30 | EA | $ 4,200 | $ 126,000 | 2" sch. 40 PVC wells, 30 ft deep, w/5-10 ft screens (all drilling related costs); shoreline wells |
| 3" Horizontal Wells (~12' deep) | 3 | EA | $ 30,200 | $ 90,600 | 3" PVC or HDPE (all drilling related costs): wells beneath Alexander Avenue |
| Baseline groundwater sampling at injection wells | 60 | sample | $ 350 | $ 21,000 | TPH-Dx/Gx/benzene sampling at each vertical injection well; includes labor |
| Injection manifold and equipment | 1 | LS | $ 50,000 | $ 50,000 | |
| Install Bioventing Infrastructure - windmill/turbines | 1 | EA | $ 35,000 | $ 35,000 | Assume installing 1 active 15 CFM wind turbine to attach to horizontal injection wells beneath Alexander Avenue plus manifold, parts and fittings |
| **3.2 Injections - Alexander Ave only** | | | | | Assume 20 LNAPL area injection events over 13 years |
| Materials | 20 | event | $ 7,500 | $ 133,000 | Each injection event consists of 3 horizontal injection wells injected with nitrate and/or sulfate solution with added nutrients. Costs assume liquid ammonium nitrate (4x dose) |
| Labor and expenses | 20 | event | $ 18,000 | $ 319,200 | |
| **3.3 Injections - Shoreline** | | event | | | Assume 8 shoreline events over 5 years |
| Materials | 6 | event | $ 12,000 | $ 90,000 | Each injection event consists of 60 injection wells injected with nitrate and/or sulfate solution with added nutrients. Costs assume liquid ammonium nitrate (4x dose) |
| Labor and expenses | 6 | event | $ 32,000 | $ 240,100 | |
| **3.4 Bioventing Operations, Maintenance, and Monitoring** | 16 | event | $ 1,500 | $ 24,000 | Assume 13 years of minor O&M for active bioventing (equip maint, annual vapor sampling) at Alexander Ave. Assume vapor sampling for up to 13 years (quarterly 1st year, biennially 2nd & 3rd years, and annually thereafter), $150/vapor sample for TPH-G/benzene; assume 1 turbine vent/event. |
| **3.5 EISB groundwater monitoring and annual reporting** | 16 | event | $ 13,500 | $ 323,000 | Quarterly for 1st year, biennially for next two years, and annually thereafter for up to 13 years total, $475/sample for TPH-Dx/Gx/benzene and MNA parameters; assume 20 shoreline and Alexander Ave wells/event. Total cost includes $10K reporting for each year of injection events. |
| *Task Subtotal* | | | | *$ 1,547,900* | |
| **4 Hot Spot Area Remedial Excavation** | | | | | Assume all areas w/TPH>19,000 mg/kg and benzene >19 mg/kg excavated |
| Site Preparation | 1 | LS | $ 15,000 | $ 15,000 | Set up temp soil dewatering/stockpile, erosion and sediment control, utility locates. |
| Asphalt Paving Demo/Disposal | 51000 | SF | $ 1 | $ 51,000 | Per ECY area calculations for TPH >19,000 mg/kg, excluding area beneath Alexander Ave |
| Dewatering and Water Treatment | 3 | mo | $ 50,000 | $ 150,000 | Treatment system rental and operation |
| Water disposal | 12960000 | gal | $ 0.009 | $ 116,640 | Assume 100 gpm discharge to City of Tacoma sanitary sewer, assume Category 1 discharge rate of $8.69/1000-gal |
| Clean Overburden Soil Excavation/Stockpiling | 6611 | CY | $ 12 | $ 79,333 | Assume 5' overburden excavation with 70% of hot spot areas are contaminated to surface |
| Contaminated Soil Excavation | 16056 | CY | $ 14 | $ 224,778 | Assume 12' deep excavation (total), soil contam. w/TPH from 5' to 12' |
| Contaminated Soil Stockpiling/Loading | 20872 | CY | $ 5 | $ 104,361 | Temporary stockpile, load to truck. Assumed 30% soil fluff factor |
| Contaminated Soil Hauling | 25689 | TN | $ 13 | $ 333,956 | Assume 1.6 TN/CY; $130/hr x 3 hr load round trip/30 tons/load (to LRI) |
| Contaminated Soil Disposal | 25689 | TN | $ 32 | $ 822,044 | Assume all soil must be disposed; Subtitle D Landfill Disposal (LRI landfill) |
| Confirmation Sampling | 50 | Sample | $ 190 | $ 9,500 | TPH-Dx/Gx/benzene analysis on 50 ft grid on base and every 50 ft around excavation sidewalls |
| Furnish clean fill | 25689 | TN | $ 20 | *$ 513,778* | Assume 1.6 TN/CY; imported clean fill from local source |
| Place fill | 22667 | CY | $ 4 | *$ 90,667* | Pit Run and Road Base; Place, compact, grade fill material |
| Repaving | 5667 | SY | $ 42 | $ 238,000 | 4" HMA Asphalt |
| *Task Subtotal* | | | | *$ 2,749,057* | |

# Table 5-5
## Remedial Alternative 5 - Feasibility Study Cost Estimate
## Alexander Avenue Cleanup Site
## Port of Tacoma
## Tacoma, Washington

**Alternative 5: Hot Spot Excavation, Alexander Avenue EISB and Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs**
Assumptions: Excavate Hot Spot Areas (TPH>19,000 mg/kg), Shoreline Bioinjections for 5 years, Bioinjections/bioventing Hot Spot Under Alexander Avenue Inaccessible for Excavation for 11 years, MNA for 11 years afterward

| ITEM | QUANTITY | UNIT | UNIT COST | TOTAL | Comments |
|---|---|---|---|---|---|
| **5 Decommissioned and Replacement Monitoring Wells** | | | | | |
| Well Decommissioning - Driller | 10 | EA | $ 1,000 | $ 10,000 | |
| 2" Monitoring Wells (~25' deep) | 10 | EA | $ 3,800 | $ 38,000 | 2" PVC casing and screen (all drilling related costs); assume all monitoring wells removed during excavation must be replaced. |
| *Task Subtotal* | | | | *$ 48,000* | |
| **6 Construction Contingency** | 35% | pct | $ 3,215,657 | *$ 1,125,479.83* | Assume 35% scope and bid contingency (Items 3.1, 4 & 5) - low end of scope contingency for soil excavation & offsite disposal (20%) plus mid range of bid contingency (15%); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| **7 Contractor bond fee, overhead, and profit** | 20% | pct | $ 3,215,657 | $ 643,131.33 | Assume 20% of construction costs (Items 3.1, 4 &5) |
| **8 Sales Tax (commercial equipment/services)** | 10.2% | pct | $ 3,215,657 | *$ 327,997* | WSST |
| **9 Monitored Natural Attenuation/Institutional Controls** | | | | | Assume MNA monitoring occurs everywhere except Alexander Avenue after remedial excavation and 5 years shoreline EISB |
| | | Discount Rate | 2.5% | | Per Port of Tacoma finance department direction |
| Quarterly Groundwater MNA monitoring and annual reporting | 11 | event | $ 35,000 | *$ 319,000* | Quarterly for Yr 6, semiannual for Yrs 7 & 8, annual for Yrs 9 - 11, $475/sample for TPH-Dx/Gx/benzene and MNA parameters; 45 wells/event |
| 5 year groundwater sampling (until pCULs met) | 2 | event | $ 22,000 | *$ 27,000* | Every 5 years for Yrs 16 - 22; $175/sample for TPH-Dx/Gx/benzene; 45 wells/event |
| I&EC Monitoring | 22 | yrs | $ 1,000 | $ 17,000 | Annual monitoring of site facilities for institutional controls for 22 years |
| **10 MNA/5Yr Review Contingency** | 20% | pct | $ 363,000 | $ 72,600 | Assume 20% of MNA costs for occasional facility repairs related to ICs, additional MNA monitoring/sampling |
| *Task Subtotal* | | | | *$ 435,600* | |
| | | | **Total** | **$ 8,479,000** | |
| Estimated Cost Range (-30% to +50%) | | | $ 5,935,000 to | $ 12,720,000 | |

Notes:
1) Discount Rate is 2.5% per Port of Tacoma finance department direction

**Table 5-6**
**Remedial Alternative 6 - Feasibility Study Cost Estimate**
**Alexander Avenue Cleanup Site**
**Port of Tacoma**
**Tacoma, Washington**

**Alternative 6: Extended Remedial Excavation, Alexander Avenue EISB and Bioventing, and MNA for Deep Groundwater**
Assumptions: Excavate soil w/TPH>2,000 mg/kg), EISB and bioventing beneath Alexander Ave (for 28 years), MNA for deep groundwater for 11 years after VI SLs met in shallow groundwater

| ITEM | QUANTITY | UNIT | UNIT COST | TOTAL | Comments |
|---|---|---|---|---|---|
| **1 Work Plans/Design/Reporting/Other** | | | | | |
| Shoreline Work Permitting | 1 | LS | $ 80,000 | $ 80,000 | JARPA, HPA, Biological Assessment, Shoreline Permit, SEPA, Cultural Assessment |
| Bid Package/Procurement | 1 | LS | $ 25,000 | $ 25,000 | Port and/or Port's consultant cost |
| Construction Report | 1 | LS | $ 15,000 | $ 15,000 | Upon completion |
| Engineering Design | 5% | pct | $ 28,125,002 | $ 1,406,250 | Assume 5% of capital costs (Items 3.1, 4, 5, 6, 7 & 8); engineering designs and specifications; per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Construction Management/Oversight | 6% | pct | $ 28,125,002 | $ 1,687,500 | Assume 6% of capital costs (Items 3.1, 4, 5, 6, 7 & 8); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Project Management | 5% | pct | $ 29,259,902 | $ 1,462,995 | Assume 5% of total costs (Items 2 - 10); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| Ecology Oversight | 3% | pct | $ 29,259,902 | $ 877,797 | Assume 3% of total costs (Items 2 - 10) |
| *Task Subtotal* | | | | *$ 5,554,542* | |
| **2 Preconstruction Submittals and Tasks** | | | | | |
| Health and Safety Plan | 1 | LS | $ 2,000 | $ 2,000 | |
| Schedule | 1 | LS | $ 500 | $ 500 | |
| Other submittals | 1 | LS | $ 1,000 | $ 1,000 | Equipment/materials list, manuals, instructions, certificates, etc. |
| TESC Plan | 1 | LS | $ 5,000 | $ 5,000 | Plan for sediment control for excavation work TESC and restoration |
| Permit Applications | 1 | LS | $ 3,000 | $ 3,000 | Grading permit, public works permit, etc., as applicable. |
| Mobilization | 1 | LS | $ 50,000 | $ 50,000 | Mobilize equipment and materials to site |
| *Task Subtotal* | | | | *$ 61,500* | |
| **3 Alexander Avenue Bioremediation** | | Discount Rate | 2.5% | | Per Port of Tacoma finance department direction (for multi-year injection and monitoring events) |
| 3.1 **Injection System Construction** | | | | | |
| 3" Horizontal Wells (~12' deep) | 3 | EA | $ 32,000 | $ 96,000 | 3" PVC or HDPE (all drilling related costs): wells beneath Alexander Avenue |
| Injection manifold and equipment | 1 | LS | $ 50,000 | $ 50,000 | |
| 3.2 **Injections - Alexander Ave only** | | | | | Assume 20 source area events over 29 years |
| Materials | 20 | event | $ 12,000 | $ 196,400 | Each injection event consists of 3 horizontal injection wells injected with nitrate and/or sulfate solution with added nutrients. Assumes liquid ammonium nitrate for Alexander Ave injections (10x dose). |
| Labor and expenses | 20 | event | $ 18,000 | $ 294,700 | |
| 3.3 **EISB groundwater monitoring and reporting** | 17 | event | $ 7,500 | $ 425,000 | Quarterly for 1st year after excavation (year 4), biennially for next two years, and annually thereafter for up year 28, $475/sample for TPH-Dx/Gx/benzene and MNA parameters; assume 10 wells/event. Total cost includes $8K reporting for each year of injection events. |
| *Task Subtotal* | | | | *$ 1,062,100* | |
| **4 Remedial Excavation** | | | | | Assume all areas w/TPH>2,000 mg/kg |
| Site Preparation | 1 | LS | $ 20,000 | $ 20,000 | Set up temp soil dewatering/stockpile, erosion and sediment control, utility locates. |
| Coffer Dam | 1 | LS | $ 450,000 | $ 450,000 | Place on water side of project to protect Hylebos. |
| Asphalt Paving Demo/Disposal | 353000 | SF | $ 1 | $ 353,000 | Per ECY area calculations for TPH>2,000 mg/kg, excluding area beneath Alexander Ave |
| Remove Existing Hylebos Bulkhead | 350 | LF | $ 133 | $ 46,666 | Assume removal along 350 ft of shoreline to accommodate soil removal |
| Reinstall Hylebos Bulkhead and Armoring | 6125 | SF | $ 70 | $ 428,750 | Assume 350 ft of shoreline with 17.5 ft tall bulkhead (5 ft above mudline, 12.5 ft embedded+riprap armoring |
| Dewatering and Water Treatment | 6 | mo | $ 50,000 | $ 300,000 | Treatment system rental and operation |
| Water disposal | 25920000 | gal | $ 0.009 | $ 233,280 | Assume 100 gpm discharge to City of Tacoma sanitary sewer, assume Category 1 discharge rate of $8.69/1000-gal |
| Clean Overburden Soil Excavation/Stockpiling | 58759 | CY | $ 12 | $ 705,111 | Assume 5' overburden excavation with 70% of hot spot areas area contaminated to surface |
| Contaminated Soil Excavation | 98130 | CY | $ 14 | $ 1,373,815 | Assume 12' deep excavation, soil contam. w/TPH from 5' to 12', plus 70% of hot spot area contaminated to surface |
| Contaminated Soil Stockpiling/Loading | 127569 | CY | $ 5 | $ 637,843 | Temporary stockpile, load to truck. Assumed 30% soil fluff factor |
| Contaminated Soil Hauling | 157007 | TN | $ 13 | $ 2,041,096 | Assume 1.6 TN/CY; $130/hr x 3 hr load round trip/30 tons/load (to LRI) |
| Contaminated Soil Disposal | 157007 | TN | $ 30 | $ 4,710,222 | Assume all soil must be disposed; Subtitle D Landfill Disposal (LRI landfill) |
| Confirmation Sampling | 200 | Sample | $ 190 | $ 38,000 | TPH-Dx/Gx/benzene analysis on 50 ft grid on base and every 50 ft around excavation sidewalls |
| Furnish clean fill | 157007 | TN | $ 20 | *$ 3,140,148* | Assume 1.6 TN/CY; imported clean fill from local source |
| Place fill | 156889 | CY | $ 4 | *$ 627,556* | Pit Run and Road Base; Place, compact, grade fill material |
| Repaving | 39222 | SY | $ 42 | $ 1,647,333 | 4" HMA Asphalt |
| *Task Subtotal* | | | | *$ 16,752,820* | |

**Table 5-6**
**Remedial Alternative 6 - Feasibility Study Cost Estimate**
**Alexander Avenue Cleanup Site**
**Port of Tacoma**
**Tacoma, Washington**

**Alternative 6: Extended Remedial Excavation, Alexander Avenue EISB and Bioventing, and MNA for Deep Groundwater**
Assumptions: Excavate soil w/TPH>2,000 mg/kg), EISB and bioventing beneath Alexander Ave (for 28 years), MNA for deep groundwater for 11 years after VI SLs met in shallow groundwater

| ITEM | QUANTITY | UNIT | UNIT COST | TOTAL | Comments |
|---|---|---|---|---|---|
| **5 Decommissioned and Replacement Monitoring Wells** | | | | | |
| Well Decommissioning - Driller | 50 | EA | $ 1,000 | $ 50,000 | |
| 2" Monitoring Wells (~25' deep) | 20 | EA | $ 3,800 | $ 76,000 | 2" PVC casing and screen (all drilling related costs); assume 20 monitoring wells removed during excavation must be replaced. |
| *Task Subtotal* | | | | *$ 126,000* | |
| **6 Construction Contingency** | 35% | pct | $ 17,024,820 | *$ 5,958,687* | Assume 35% scope and bid contingency (Items 3.1, 4 & 5) - low end of scope contingency for soil excavation & offsite disposal (20%) plus mid range of bid contingency (15%); per EPA Guide to FS Cost Estimates (EPA 540-R-00-002, July 2000) |
| **7 Contractor bond fee, overhead, and profit** | 20% | pct | $ 17,024,820 | $ 3,404,964 | Assume 20% of construction costs (Items 3.1, 4 &5) |
| **8 Sales Tax (commercial equipment/services)** | 10.2% | pct | $ 17,024,820 | *$ 1,736,532* | WSST |
| **9 Monitored Natural Attenuation (Deep Groundwater)** | | | | | Deep groundwater only, begin after benzene VI SL met in shallow groundwater |
| | | Discount Rate | 2.5% | | Per Port of Tacoma finance department direction |
| Quarterly deep groundwater MNA monitoring and annual reporting | 4 | event | $ 15,000 | *$ 45,000* | Quarterly for Yr 12, $475/sample for TPH-Dx/Gx/benzene and MNA parameters; 20 wells/event; $10K/yr rpt |
| Annual deep groundwater MNA monitoring and reporting | 2 | event | $ 23,500 | *$ 66,000* | Annually for Yrs 13 -16; $10K/yr rpt |
| Biennial deep groundwater monitoring and reporting (until pCULs n | 7 | event | $ 17,500 | *$ 32,000* | Every 2 years from Yrs 17 - 22, $175/sample for TPH-Dx/Gx/benzene; 20 wells/event; $10K/yr rpt |
| **10 MNA Contingency** | 10% | pct | $ 143,000 | $ 14,300 | Assume 10% of MNA costs for occasional well maintenance or additional sampling. |
| *Task Subtotal* | | | | *$ 157,300* | |
| | | | **Total** | **$ 34,814,000** | |
| Estimated Cost Range (-30% to +50%) | | | $ 24,370,000 to | $ 52,220,000 | |

Notes:
1) Discount Rate is 0.6% per Office of Management and Budget, Circular A-94 Appendix C, Revised Feb. 2018

# Table 5-7
## Summary of Restoration Time Frame Estimates
## Alexander Avenue Cleanup Site
## Tacoma, Washington

| Alternative | Restoration Time Frame to Reach RLs at Applicable Area of Site (Years) | | | | | Restoration Time Frame to Reach CULs at Applicable Point of Compliance (Years) (c) | |
|---|---|---|---|---|---|---|---|
| | Hylebos Hot Spot RL (Wells within Hot Spot, 86 µg/L benzene) | Blair Hot Spot/ Alexander Ave RL (Wells within Hot Spot, LNAPL thickness < 0.1 ft) | Soil Excavation RLs (Limits of Excavation) (a) | Blair Hot Spot/ Alexander Ave Soil pCUL (Monitoring point TBD) (b) | MNA RL (VI SL) (Site-Wide, 24 µg/L benzene) | Groundwater pCULs at Conditional POC (1.6 µg/L benzene) (d) | Groundwater pCULs at Standard POC (Site-Wide, 1.6 µg/L benzene) |
| 1 | -- | -- | -- | -- | 85 | 29 | 152 |
| 2 | 21 | -- | -- | -- | 85 | 5 | 152 |
| 3 | 7 (e) | 9 | -- | 13 | 29 | 5 | 94 |
| 4 | 3 (e) | 9 | -- | 13 | 29 | 5 | 94 |
| 5 | 1 - 3 | 9 | 1 - 2 | 13 | 11 | 5 | 22 |
| 6 | -- | -- | 2 - 3 | 28 | 11 | 9 | 22 |

**Abbreviations and Acronyms:**

-- = not applicable
µg/L = micrograms per liter
CPOC = conditional point of compliance
CUL = cleanup level
Ecology = Washington State Department of Ecology
ft = feet
LNAPL = light non-aqueous phase liquid
mg/kg = milligrams per kilogram
MNA = monitored natural attenuation
MTCA = Model Toxics Control Act
pCUL = proposed cleanup level
POC = point of compliance
RL = remediation level
SL = screening level
TBD = to be determined
TPH = total petroleum hydrocarbon
VI = vapor intrusion

**Notes:**

a) Soil excavation RLs for Alternative 5 are 19,000 mg/kg TPH and 19 mg/kg benzene for Blair and Hylebos hot spots; Ecology-requested RL for Alternative 6 site-wide is 2,000 mg/kg TPH (equivalent to MTCA Method A soil CULs)
b) Alexander Avenue RL for Alternative 5 is 17,000 mg/kg TPH; RL for Alternative 6 is 2,000 mg/kg TPH
c) Demonstration of compliance with surface water CULs are not required for any remedial alternatives because compliance will be measured at groundwater CPOC
d) Compliance with groundwater pCULs at CPOC (point where groundwater flows to surface water) will be demonstrated through measurement at angled wells for Alternatives 2-5 using a compliance value (benzene = 4 µg/L) and site-wide for Alternatives 1 and 6 (no CPOC, restoration values shown for informational purposes only)
e) Estimated groundwater travel time is 2 years; add 2 years to restoration time frame for Hylebos hot spot to identify time to reach shoreline pCULs without shoreline treatment

# Table 6-1
## Summary of Remedial Alternatives Compliance with MTCA Threshold Requirements
## Alexander Avenue Cleanup Site
## Tacoma, Washington

| Alternative Number: | Alternative 1 | Alternative 2 | Alternative 3 | Alternative 4 | Alternative 5 | Alternative 6 |
|---|---|---|---|---|---|---|
| Description: | **No Action (Monitoring Only)** | **Site-Wide MNA, Shoreline EISB, and I&ECs** | **Blair Hot Spot EISB and Bioventing, Hylebos Hot Spot Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs** | **Hot Spot EISB and Bioventing, Site-Wide MNA, and I&ECs** | **Hot Spot Excavation, Alexander Avenue EISB and Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs** | **Extended Remedial Excavation, Alexander Avenue EISB and Bioventing, and Deep Groundwater MNA** |
| **Compliance with MTCA Threshold Criteria (WAC 173-340-360[2][a])** | | | | | | |
| **- Protect human health and the environment** | **No** - Alternative will not eliminate discharge of contaminated groundwater to surface water, is not protective of direct contact pathway, and is not protective of soil/groundwater to indoor air pathway for future occupied buildings. | **Yes** - Alternative will protect human health and the environment through treatment and natural attenuation of contaminated groundwater, and containment of contaminated soil, and I&ECs | **Yes** - Alternative will protect human health and the environment through treatment of soil/smear zone "hot spots" and NAPL, bioremediation and natural attenuation of contaminated groundwater, and containment of contaminated soil, and I&ECs | **Yes** - Alternative will protect human health and the environment through treatment of soil/smear zone "hot spots" and NAPL, bioremediation and natural attenuation of contaminated groundwater, and containment of contaminated soil, and I&ECs | **Yes** - Alternative will protect human health and the environment through excavation (and treatment beneath Alexander Avenue) of soil/smear zone "hot spots" and NAPL, treatment and natural attenuation of contaminated groundwater, and containment of contaminated soil, and I&ECs | **Yes** - Alternative will protect human health and the environment through excavation (and treatment beneath Alexander Avenue) of smear zone and NAPL impacted soil, and treatment and natural attenuation of contaminated groundwater |
| **- Comply with cleanup standards (WAC 173-360-700 through 760)** | **No** - Will not achieve cleanup standards in soil or groundwater at standard or conditional POC | **Yes** - Containment and ICs will be used for soil not complying with cleanup standards, groundwater will comply with cleanup standards at CPOC, engineering controls used as needed for compliance with vapor intrusion/air cleanup standards | **Yes** - Containment and ICs will be used for soil not complying with cleanup standards, groundwater will comply with cleanup standards at CPOC, engineering controls used as needed for compliance with vapor intrusion/air cleanup standards | **Yes** - Containment and ICs will be used for soil not complying with cleanup standards, groundwater will comply with cleanup standards at CPOC, engineering controls used as needed for compliance with vapor intrusion/air cleanup standards | **Yes** - Containment and ICs will be used for soil not complying with cleanup standards, groundwater will comply with cleanup standards at CPOC, engineering controls used as needed for compliance with vapor intrusion/air cleanup standards | **Yes** - Containment and ICs will be used, if necessary, for remaining soil not complying with cleanup standards, groundwater will comply with cleanup standards at standard POC |
| **- Comply w/applicable state/federal laws (WAC 173-360-710)** | **No** - Alternative necessary for NCP compliance, but does not comply with WAC | **Yes** - Alternative complies with applicable, relevant, and appropriate requirements and laws | **Yes** - Alternative complies with applicable, relevant, and appropriate requirements and laws | **Yes** - Alternative complies with applicable laws (see report Section 3.0) | **Yes** - Alternative complies with applicable, relevant, and appropriate requirements and laws | **Yes** - Alternative complies with applicable, relevant, and appropriate requirements and laws |
| **- Provide for compliance monitoring (WAC 173-360-410)** | **Yes** - Alternative includes provisions for compliance monitoring (health and safety during groundwater sampling, and long-term groundwater performance and confirmation monitoring | **Yes** - Alternative includes provisions for compliance monitoring (health and safety monitoring during construction/O&M, site monitoring for ICs, long-term groundwater MNA and confirmation monitoring) | **Yes** - Alternative includes provisions for compliance monitoring (health and safety monitoring during construction/O&M, site monitoring for ICs, long-term groundwater MNA and confirmation monitoring) | **Yes** - Alternative includes provisions for compliance monitoring (health and safety monitoring during construction/O&M, soil cap monitoring for ICs, long-term groundwater MNA and confirmation monitoring) | **Yes** - Alternative includes provisions for compliance monitoring (health and safety monitoring during construction/O&M, site monitoring for ICs, long-term groundwater MNA and confirmation monitoring) | **Yes** - Alternative includes provisions for compliance monitoring (health and safety monitoring during construction/O&M, site monitoring for ICs, long-term groundwater MNA and confirmation monitoring) |
| **Compliance with other requirements (WAC 173-340-360[2][b])** | | | | | | |
| **Permanent Solutions to the Maximum Extent Practicable (WAC 173-340-360[3])** | | | | | | |
| **- Permanent to the Maximum Extent Practicable** | **No** - See Disproportionate Cost Analysis (Table 6-2) | **No** - See Disproportionate Cost Analysis (Table 6-2) | **Yes** - See Disproportionate Cost Analysis (Table 6-2) | **Yes** - See Disproportionate Cost Analysis (Table 6-2) | **No** - See Disproportionate Cost Analysis (Table 6-2) | **No** - See Disproportionate Cost Analysis (Table 6-2) |
| **Reasonable Restoration Time Frame (WAC 173-340-360[4][b])** | | | | | | |
| **- Provide for a reasonable restoration time frame** | No - Estimated restoration time frame is **152 years** for natural attenuation to achieve CULs at the standard POC. Because alternative allows for continued discharge of contaminated groundwater to surface water, is not protective of direct contact pathway, and is not protective of soil/groundwater to indoor air pathway for future occupied buildings, 100+yr restoration time frame is not considered reasonable. See factors below. | **Yes (at CPOC)** - Estimated restoration time frame is **5 years** to achieve CULs at the CPOC, treatment will need to continue for 21 years for upgradient groundwater to be protective without shoreline treatment. ICs and long-term monitoring of groundwater needed to ensure compliance. See factors below. ***No (at Standard POC) -*** *Estimated restoration time frame is* ***152 years*** *to reach groundwater CUL standard POC.* | **Yes (at CPOC)** - Estimated restoration time frame is **5 years** for construction, implementation, and demonstration that groundwater CULs are being met at CPOC; treatment will need to continue for 9 years for upgradient groundwater to be protective without shoreline treatment. ICs and long-term monitoring of groundwater needed to ensure compliance. See factors below. ***No (at Standard POC) -*** *Estimated restoration time frame is* ***94 years*** *to reach groundwater CUL standard POC.* | **Yes (at CPOC)** - Estimated restoration time frame is **5 years** for design, construction, implementation, and demonstration that groundwater CULs are being met at CPOC. ICs and long-term monitoring of groundwater and cap needed to ensure compliance. See factors below. ***No (at Standard POC) -*** *Estimated restoration time frame is* ***94 years*** *to reach groundwater CUL standard POC.* | **Yes (at CPOC)** - Estimated restoration time frame is **5 years** for construction, implementation, and demonstration that groundwater CULs are being met at CPOC. ICs and long-term monitoring of groundwater needed to ensure compliance. See factors below. ***No (at Standard POC) -*** *Estimated restoration time frame is* ***22 years*** *to reach groundwater CUL standard POC.* | Yes - Estimated restoration time frame is **9 years** for construction, implementation, and demonstration that shallow groundwater CULs are being met at standard POC; however, estimated restoration time frame is **22 years** for deep groundwater to meet CULs at the standard POC. Long-term monitoring of groundwater needed to ensure compliance. See factors below. |
| **- Potential risk to human health and environment [a]** | High - Alternative will not eliminate discharge of contaminated groundwater to surface water is not protective of direct contact pathway, and is not protective of soil/groundwater to indoor air pathway for future occupied buildings, or workers who may come into contact with soil contamination or vapor in sewer. | Low - Treatment of contaminated groundwater to minimize migration to the Hylebos and Blair waterways, and engineering controls as needed to prevent vapor intrusion protects human health and the environment. Engineering solution will minimize risk of vapor/contaminated groundwater intrusion into sewer. ICs will minimize risk for workers who may come into contact with soil contamination. | Low - Treatment of hot spots/NAPL-impacted soils, treatment of contaminated groundwater to minimize migration to the Hylebos and Blair waterways, and engineering controls as needed to prevent vapor intrusion protects human health and the environment. Engineering solution will minimize risk of vapor/contaminated groundwater intrusion into sewer. ICs will minimize risk for workers who may come into contact with soil contamination. | Low - Treatment of hot spots/NAPL-impacted soils, treatment of contaminated groundwater to minimize migration to the Hylebos and Blair waterways, and engineering controls as needed to prevent vapor intrusion protects human health and the environment. Engineering solution will minimize risk of vapor/contaminated groundwater intrusion into sewer. ICs will minimize risk for workers who may come into contact with soil contamination. | Low - Excavation of hot spots/NAPL-impacted soils, treatment of contaminated groundwater to minimize migration to the Hylebos and Blair waterways, and engineering controls as needed to prevent vapor intrusion protects human health and the environment. Engineering solution will minimize risk of vapor/contaminated groundwater intrusion into sewer. ICs will minimize risk for workers who may come into contact with soil contamination. | Low - Excavation of smear zone/NAPL and petroleum-impacted soil, treatment of contaminated groundwater to minimize migration to the Hylebos, and engineering controls as needed to prevent vapor intrusion protects human health and the environment. Engineering solution will minimize risk of vapor/contaminated groundwater intrusion into sewer. ICs will minimize risk for workers who may come into contact with soil contamination. |
| **- Practicability of achieving shorter restoration time** | Yes - Shorter restoration time frames can be practicably achieved. See Disproportionate Cost Analysis (Table 6-2) | Yes - Shorter restoration time frames can be practicably achieved. See Disproportionate Cost Analysis (Table 6-2) | No - See Disproportionate Cost Analysis (Table 6-2) | No - See Disproportionate Cost Analysis (Table 6-2) | No - See Disproportionate Cost Analysis (Table 6-2) | No - See Disproportionate Cost Analysis (Table 6-2) |
| **- Current use of site, surrounding area, and associated resources that are, or may be affected by releases from the site.** | Onsite: Industrial<br>Surrounding areas: Industrial, Hylebos/Blair Waterways<br>Resources: Surface water beneficial uses | Onsite: Industrial<br>Surrounding areas: Industrial, Hylebos/Blair Waterways<br>Resources: Surface water beneficial uses | Onsite: Industrial<br>Surrounding areas: Industrial, Hylebos/Blair Waterways<br>Resources: Surface water beneficial uses | Onsite: Industrial<br>Surrounding areas: Industrial, Hylebos/Blair Waterways<br>Resources: Surface water beneficial uses | Onsite: Industrial<br>Surrounding areas: Industrial, Hylebos/Blair Waterways<br>Resources: Surface water beneficial uses | Onsite: Industrial<br>Surrounding areas: Industrial, Hylebos/Blair Waterways<br>Resources: Surface water beneficial uses |
| **- Potential future use of site, surrounding area, and resources that are, or may be affected by releases from the site.** | Onsite: Industrial<br>Surrounding areas: Industrial, Hylebos/Blair Waterways<br>Resources: Surface water beneficial uses | Onsite: Industrial<br>Surrounding areas: Industrial, Hylebos/Blair Waterways<br>Resources: Surface water beneficial uses | Onsite: Industrial<br>Surrounding areas: Industrial, Hylebos/Blair Waterways<br>Resources: Surface water beneficial uses | Onsite: Industrial<br>Surrounding areas: Industrial, Hylebos/Blair Waterways<br>Resources: Surface water beneficial uses | Onsite: Industrial<br>Surrounding areas: Industrial, Hylebos/Blair Waterways<br>Resources: Surface water beneficial uses | Onsite: Industrial<br>Surrounding areas: Industrial, Hylebos/Blair Waterways<br>Resources: Surface water beneficial uses |
| **- Availability of alternative water supplies** | Yes. The Site is located within the Tacoma city limits, which is supplied by a municipal water supply. | Yes. The Site is located within the Tacoma city limits, which is supplied by a municipal water supply. | Yes. The Site is located within the Tacoma city limits, which is supplied by a municipal water supply. | Yes. The Site is located within the Tacoma city limits, which is supplied by a municipal water supply. | Yes. The Site is located within the Tacoma city limits, which is supplied by a municipal water supply. | Yes. The Site is located within the Tacoma city limits, which is supplied by a municipal water supply. |
| **- Likely effectiveness/reliability of institutional controls [a]** | N/A. Alternative does not include ICs. | High. Site is fenced; access controlled industrial site; administrative controls and environmental covenants specifying requirements for disturbance of subsurface soils and VI engineering controls for future occupied buildings attached to tenant leases. | High. Site is fenced; access controlled industrial site; administrative controls and environmental covenants specifying requirements for disturbance of subsurface soils and VI engineering controls for future occupied buildings attached to tenant leases. | High. Site is fenced; access controlled industrial site; administrative controls and environmental covenants specifying requirements for disturbance of subsurface soils and VI engineering controls for future occupied buildings attached to tenant leases. | High. Site is fenced; access controlled industrial site; administrative controls and environmental covenants specifying requirements for disturbance of subsurface soils and VI engineering controls for future occupied buildings attached to tenant leases. | High. Not needed if CULs met at standard POC. Site is fenced; access controlled industrial site; administrative controls specifying requirements VI engineering controls for future occupied buildings can be attached to tenant leases. |

# Table 6-1
## Summary of Remedial Alternatives Compliance with MTCA Threshold Requirements
## Alexander Avenue Cleanup Site
## Tacoma, Washington

| Alternative Number: | Alternative 1 | Alternative 2 | Alternative 3 | Alternative 4 | Alternative 5 | Alternative 6 |
|---|---|---|---|---|---|---|
| Description: | **No Action (Monitoring Only)** | **Site-Wide MNA, Shoreline EISB, and I&ECs** | **Blair Hot Spot EISB and Bioventing, Hylebos Hot Spot Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs** | **Hot Spot EISB and Bioventing, Site-Wide MNA, and I&ECs** | **Hot Spot Excavation, Alexander Avenue EISB and Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs** | **Extended Remedial Excavation, Alexander Avenue EISB and Bioventing, and Deep Groundwater MNA** |
| **- Ability to control and monitor migration of hazardous substances [a]** | Low. Appropriate groundwater monitoring network present and will be supplemented as necessary to adequately monitor groundwater; however, alternative does not provide ability to control migration of contaminants. | Moderate. Appropriate groundwater monitoring network present and will be supplemented as necessary to adequately monitor groundwater after implementation. Shoreline treatment will control migration to surface water. | Moderate. Appropriate groundwater monitoring network present and will be supplemented as necessary to adequately monitor groundwater after implementation. Performance soil/groundwater sampling will be conducted during and after hot spot/NAPL treatment. Hot spot and shoreline treatment will control migration within the Site and to surface water. | Moderate. Appropriate groundwater monitoring network present and will be supplemented as necessary to adequately monitor groundwater after implementation. Performance soil/groundwater sampling will be conducted during and after hot spot/NAPL treatment. Hot spot treatment will control migration within the Site and to surface water. | High. Appropriate groundwater monitoring network present and will be supplemented as necessary to adequately monitor groundwater after implementation. Performance soil/groundwater sampling will be conducted after hot spot/NAPL excavation. Hot spot excavation and shoreline treatment will control migration within the Site and to surface water. | High. Appropriate groundwater monitoring network present and will be supplemented as necessary to adequately monitor groundwater after implementation. Performance soil/groundwater sampling will be conducted after remedial excavation . Remedial excavation and hot spot treatment will control migration within the Site and to surface water. |
| **- Toxicity of hazardous substances at the site [a]** | Contaminant and media dependent -<br>Soil (dermal contact): low<br>Water (surface water beneficial uses): low to moderately high. | Contaminant and media dependent -<br>Soil (dermal contact): low<br>Water (surface water beneficial uses): low to moderately high. | Contaminant and media dependent -<br>Soil (dermal contact): low<br>Water (surface water beneficial uses): low to moderately high. | Contaminant and media dependent -<br>Soil (dermal contact): low<br>Water (surface water beneficial uses): low to moderately high. | Contaminant and media dependent -<br>Soil (dermal contact): low<br>Water (surface water beneficial uses): low to moderately high. | Contaminant and media dependent -<br>Soil (dermal contact): low<br>Water (surface water beneficial uses): low to moderately high. |
| **- Natural processes that reduce concentrations of hazardous substances and have been documented to occur at the site or under similar conditions.** | High - TPH is highly susceptible to natural degradation and natural attenuation has been documented as a prevalent degradation pathway at the Site. Co-mingled petroleum and CVOCs provide mutually beneficial degradation effects. | High - TPH is highly susceptible to natural degradation and natural attenuation has been documented as a prevalent degradation pathway at the Site. Co-mingled petroleum and CVOCs provide mutually beneficial degradation effects. | High - TPH is highly susceptible to natural degradation and natural attenuation has been documented as a prevalent degradation pathway at the Site. Co-mingled petroleum and CVOCs provide mutually beneficial degradation effects. | High - TPH is highly susceptible to natural degradation and natural attenuation has been documented as a prevalent degradation pathway at the Site. Co-mingled petroleum and CVOCs provide mutually beneficial degradation effects. | High - TPH is highly susceptible to natural degradation and natural attenuation has been documented as a prevalent degradation pathway at the Site. Co-mingled petroleum and CVOCs provide mutually beneficial degradation effects. | High - TPH is highly susceptible to natural degradation and natural attenuation has been documented as a prevalent degradation pathway at the Site. Co-mingled petroleum and CVOCs provide mutually beneficial degradation effects. |
| **Consider Public Concerns (WAC 173-340-600[13])** | | | | | | |
| **- Consider public concerns** | **No** - While public notice and public comment period will be provided for review of the RI/FS (possibly combined with CAP) it is anticipated that performing no active cleanup activities to protect adjacent surface water will not be looked upon favorably by the public. | **Yes** - Public notice and public comment period will be provided for review of the RI/FS (possibly combined with CAP). No comments from public with concerns about site cleanup alternatives have been received. | **Yes** - Public notice and public comment period will be provided for review of the RI/FS (possibly combined with CAP). No comments from public with concerns about site cleanup alternatives have been received. | **Yes** - Public notice and public comment period will be provided for review of the RI/FS (possibly combined with CAP). No comments from public with concerns about site cleanup alternatives have been received. | **Yes** - Public notice and public comment period will be provided for review of the RI/FS (possibly combined with CAP). No comments from public with concerns about site cleanup alternatives have been received. | **Yes** - Public notice and public comment period will be provided for review of the RI/FS (possibly combined with CAP). No comments from public with concerns about site cleanup alternatives have been received. |

**Notes:**

[a] Ratings used: Low, Moderate, or High.

**Abbreviations and Acronyms:**

CAP = cleanup action plan
CPOC = conditional point of compliance
CUL = cleanup level
CVOC = chlorinated volatile organic compound
EISB = enhanced *in situ* bioremediation
FS = feasibility study
I&ECs = institutional and engineering controls
ICs = institutional controls
MNA = monitored natural attenuation
MTCA = Model Toxics Control Act
NAPL = non-aqueous phase liquid
NCP = National Contingency Plan
O&M = operations and maintenance
POC = point of compliance
RI = remedial investigation
TPH = total petroleum hydrocarbon
WAC = Washington Administrative Code
yr = year

# Table 6-2
## Disproportionate Cost Analysis Relative Benefits Ranking Considerations
## Alexander Avenue Cleanup Site
## Tacoma, Washington

| Alternative Number: | | | Alternative 1 | | Alternative 2 | | Alternative 3 | | Alternative 4 | | Alternative 5 | | Alternative 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alternative Name: | | | No Action (Monitoring Only) | | Site-Wide MNA, Shoreline EISB, and I&ECs | | Blair Hot Spot EISB and Bioventing, Hylebos Hot Spot Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs | | Hot Spot EISB and Bioventing, Site-Wide MNA, and I&ECs | | Hot Spot Excavation, Alexander Avenue EISB and Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs | | Extended Remedial Excavation, Alexander Avenue EISB and Bioventing, and Deep Groundwater MNA |
| Relative Benefits Ranking for DCA | | | | | | | | | | | | | |
| Evaluation Criteria: WAC 173-340-360(3)(f) | Weighting Factor | Benefit Score | Ranking Considerations [a] | Benefit Score | Ranking Considerations [a] | Benefit Score | Ranking Considerations [a] | Benefit Score | Ranking Considerations [a] | Benefit Score | Ranking Considerations [a] | Benefit Score | Ranking Considerations [a] |
| -Protectiveness | 30% | 1 | **Poor**<br>• Risk of direct contact with contaminated media not mitigated<br>• No protective measures implemented to prevent migration of contaminated groundwater to surface water and attain groundwater cleanup standards at CPOC (long time to reduce Site risks; long time frame to achieve cleanup standards)<br>• No controls in place to mitigate vapor intrusion to potential future occupied buildings<br>•Improvement to overall environmental quality only through long-term natural attenuation (very long term restoration time frame)<br>•Does not directly address LNAPL or soil contamination | 3 | **Fair**<br>• Institutional controls to mitigate risk of direct contact with contaminated media<br>• Shoreline treatment of groundwater and prevent migration of contaminated groundwater to surface water and attain groundwater cleanup standards at CPOC (rapid reduction of Site risks; rapid time frame to achieve cleanup standards)<br>• Engineering controls to mitigate vapor intrusion to potential future occupied buildings<br>•Improvement to overall environmental quality through shoreline treatment and monitored natural attenuation (long-term restoration time frame)<br>•Does not directly address LNAPL or soil contamination | 7 | **Excellent**<br>• Bioremediation of hot spots/NAPL areas (injections for NAPL >0.1 ft; bioventing for all hot spot/NAPL areas)<br>• Institutional controls to mitigate risk of direct contact with contaminated media<br>• Shoreline treatment of groundwater and prevent migration of contaminated groundwater to surface water and attain groundwater cleanup standards at CPOC (rapid reduction of Site risks; rapid time frame to achieve cleanup standards)<br>• Engineering controls to mitigate vapor intrusion to potential future occupied buildings<br>•Improvement to overall environmental quality through shoreline treatment and monitored natural attenuation (moderate restoration time frame) | 9 | **Superior**<br>• EISB and bioventing at hot spots/NAPL areas to treat contaminated groundwater source areas and attain groundwater cleanup standards at CPOC (rapid reduction of Site risks; rapid time frame to achieve cleanup standards)<br>• Institutional controls to mitigate risk of direct contact with contaminated media<br>• Engineering controls to mitigate vapor intrusion to potential future occupied buildings<br>•Improvement to overall environmental quality through hotspot treatment and monitored natural attenuation (moderate restoration time frame) | 9 | **Superior**<br>• Excavation of hot spots/NAPL area (bioremediation beneath Alexander Avenue)<br>• Institutional controls to mitigate risk of direct contact with contaminated media<br>• Shoreline treatment of groundwater and prevent migration of contaminated groundwater to surface water and attain groundwater cleanup standards at CPOC (rapid reduction of Site risks; rapid time frame to achieve cleanup standards)<br>• Engineering controls to mitigate vapor intrusion to potential future occupied buildings<br>•Improvement to overall environmental quality through shoreline treatment, OCC remedy, and monitored natural attenuation (moderate restoration time frame) | 10 | **Superior**<br>• Provides high level of protection through near complete removal of NAPL and contaminated smear zone soil (bioremediation beneath Alexander Avenue) to meet soil cleanup standards at standard POC<br>• Bioremediation of residual groundwater contamination, prevent migration of contaminated groundwater to surface water, and attain groundwater standards at standard POC (rapid reduction of Site risks; moderate time frame to achieve cleanup standards)<br>• Complete restoration Site and overall environmental quality (moderate restoration time frame)<br>• Some risk of contaminated sediment release during excavation adjacent to waterways. |
| -Permanence | 20% | 1 | **Poor**<br>• Contaminated soil left in place Site-wide<br>• NAPL source area/smear zone not removed<br>• Existing capped areas not maintained, no institutional controls to maintain containment<br>• Restoration of groundwater through long-term and unmonitored natural attenuation | 3 | **Fair**<br>• Natural attenuation provides primary mechanism for reduction of toxicity, mobility, and volume of groundwater contamination<br>• Contaminated soil left in place Site-wide, long restoration period for smear zone and NAPL natural source zone depletion to occur<br>• Long restoration period for remediation of hot spot and smear zone/NAPL areas<br>• Permanence of containment maintained through institutional controls<br>• Shoreline groundwater treatment continued until risk to surface water no longer present<br>• Treatment is irreversible | 7 | **Excellent**<br>• Enhanced bioremediation through biostimulation, bioventing, natural source zone depletion, and natural attenuation all used to reduction toxicity, mobility, and volume of both soil and groundwater contamination<br>• Permanence of containment maintained through institutional controls<br>• Shoreline groundwater treatment continued until risk to surface water no longer present<br>• Treatment is irreversible | 8 | **Excellent**<br>• Enhanced bioremediation through biostimulation, bioventing, natural source zone depletion, and natural attenuation all used to reduction toxicity, mobility, and volume of both soil and groundwater contamination<br>• Permanence of containment maintained through institutional controls<br>• Hotspot groundwater treatment continued until risk to surface water no longer present<br>• Treatment is irreversible | 6 | **Good**<br>• Hot spot and smears zone/NAPL areas excavated (treated with bioremediation beneath Alexander Avenue) for reduction in onsite volume of contaminated soil and groundwater<br>• Volume of contaminated soil transferred to engineered landfill to limit mobility (volume not changed, not permanently destroyed)<br>• Final groundwater restoration through natural attenuation<br>• Permanence of containment maintained through institutional controls<br>• Shoreline groundwater treatment continued until risk to surface water no longer present | 6 | **Good**<br>• Provides high level of permanence through near complete removal of contaminated soil and NAPL (treatment beneath Alexander Avenue) for reduction in onsite volume of contaminated soil and groundwater<br>• Volume of contaminated soil transferred to engineered landfill to limit mobility<br>• Bioremediation and natural attenuation addresses residual groundwater contamination<br>• Large volume of contaminated soil transferred to engineered landfill to limit mobility (volume not changed, not permanently destroyed) |
| -Long-Term Effectiveness | 20% | 1 | **Poor**<br>• Certainty of alternative success very minimal<br>• Long-term effectiveness relies on monitoring only | 4 | **Fair**<br>• Primarily involves *in situ* destruction of contaminants<br>• Long-term effectiveness of MNA is expected to be successful<br>• Shoreline PRB treatment is expected to be effective at protecting impacts to surface water beneficial uses<br>• Direct contact exposure and risk is mitigated by cap<br>• Vapor intrusion exposure and risk is mitigated by engineering controls<br>• Long-term effectiveness relies on monitoring and institutional controls | 5 | **Good**<br>• Primarily involves *in situ* destruction of contaminants<br>• Treatment of NAPL with bioremediation expected to be successful over time and reduce overall site restoration time frame<br>• Long-term effectiveness of MNA is expected to be successful<br>• Shoreline PRB treatment is expected to be effective at protecting impacts to surface water beneficial uses<br>• Direct contact exposure and risk is mitigated by cap<br>• Vapor intrusion exposure and risk is mitigated by engineering controls<br>• Long-term effectiveness partially relies on monitoring and institutional controls | 8 | Excellent<br>• Primarily involves in situ destruction of contaminants<br>• Treatment of NAPL with bioremediation (EISB and bioventing) expected to be successful protecting impacts to surface water beneficial uses, groundwater treatment over time, and reducing overall site restoration time frame<br>• Long-term effectiveness of MNA is expected to be successful<br>• Direct contact exposure and risk is mitigated by cap<br>• Vapor intrusion exposure and risk is mitigated by engineering controls<br>• Long-term effectiveness partially relies on monitoring and institutional controls | 8 | Excellent<br>• Involves combination of offsite disposal in engineered landfill and *in situ* destruction of contaminants<br>• Excavation of hot spots/NAPL will be immediately effective and reduce overall site restoration time frame<br>• Treatment of hot spots/NAPL beneath Alexander Avenue with bioremediation expected to be successful over time and further reduce restoration time frame<br>• Long-term effectiveness of MNA is expected to be successful<br>• Shoreline PRB treatment is expected to be effective at protecting impacts to surface water beneficial uses<br>• Direct contact exposure and risk is mitigated by cap<br>• Vapor intrusion exposure and risk is mitigated by engineering controls<br>• Long-term effectiveness partially relies on monitoring and institutional controls<br>• Some contaminated soil moved to engineered landfill | 9 | **Superior**<br>• Primarily involves offsite disposal in engineered landfill<br>• Provides high long-term effectiveness through removal (treatment beneath Alexander Avenue) of NAPL and contaminated soil Site-wide<br>• Bioremediation of residual contamination is expected to be successful<br>• Large quantities of contaminated soil moved to engineered landfill |

**Table 6-2**
**Disproportionate Cost Analysis Relative Benefits Ranking Considerations**
**Alexander Avenue Cleanup Site**
**Tacoma, Washington**

| Alternative Number: | | | Alternative 1 | | Alternative 2 | | Alternative 3 | | Alternative 4 | | Alternative 5 | | Alternative 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alternative Name: | | | No Action (Monitoring Only) | | Site-Wide MNA, Shoreline EISB, and I&ECs | | Blair Hot Spot EISB and Bioventing, Hylebos Hot Spot Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs | | Hot Spot EISB and Bioventing, Site-Wide MNA, and I&ECs | | Hot Spot Excavation, Alexander Avenue EISB and Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs | | Extended Remedial Excavation, Alexander Avenue EISB and Bioventing, and Deep Groundwater MNA |
| -Management of Short-Term Risk | 10% | 10 | **Superior**<br>• Minimal worker health and safety risk from contact with contaminated media during monitoring activities | 9 | **Superior**<br>• Minimal worker health and safety risk during MNA sampling<br>• Minimal worker safety risk during shoreline injection well drilling; will be completed by HAZWOPER-certified drillers<br>• Minimal worker health risk during shoreline bioinjections (injectant stable and non-toxic); will be completed by HAZWOPER-certified personnel | 8 | **Excellent**<br>• Minimal worker health and safety risk during MNA sampling<br>• Minimal worker safety risk during shoreline and hot spot/NAPL area injection well drilling; will be completed by HAZWOPER-certified drillers<br>• Minimal worker health risk during shoreline bioinjections (injectant stable and non-toxic); will be completed by HAZWOPER-certified personnel | 8 | **Excellent**<br>• Minimal worker health and safety risk during MNA sampling<br>• Minimal worker safety risk during hot spot/NAPL area injection well drilling; will be completed by HAZWOPER-certified drillers<br>• Minimal worker health risk during bioinjections (injectant stable and non-toxic); will be completed by HAZWOPER-certified personnel | 6 | **Good**<br>• Minimal worker health and safety risk during MNA sampling<br>• Minimal worker safety risk during shoreline and Alexander Avenue injection well drilling; will be completed by HAZWOPER-certified drillers<br>• Minimal worker health risk during shoreline/Alexander Avenue bioinjections (injectant stable and non-toxic); will be completed by HAZWOPER-certified personnel<br>• Moderate worker safety risk during source area NAPL dewatering, excavation, stockpiling, loading, hauling to offsite disposal; moderate health risk for workers to come into contact with contaminated media during remedial excavation activities; will be completed by HAZWOPER-certified contractors | 4 | **Fair**<br>• Moderate to High worker safety risk during coffer dam installation and Site-wide dewatering, excavation, stockpiling, loading, hauling to offsite disposal; moderate health risk for workers to come into contact with contaminated media during remedial excavation activities; will be completed by HAZWOPER-certified contractors<br>• Moderate risk to environment from excavation along shoreline-risk of contaminated water/sediment discharge to surface water<br>• Minimal worker safety risk during Alexander Avenue and deep groundwater injection well drilling; will be completed by HAZWOPER-certified drillers<br>• Minimal worker health risk during Alexander Avenue and deep groundwater bioinjections (injectant stable and non-toxic); will be completed by HAZWOPER-certified personnel |
| -Implementability | 10% | 10 | **Superior**<br>• Technical implementation of monitoring program uncomplicated<br>• Administration implementation challenges negligible | 8 | **Excellent**<br>• Technical implementation relatively uncomplicated; installation of shoreline injection wells and implementation and monitoring of bioinjections provide limited technical challenges; MNA monitoring program uncomplicated; engineering controls on potential future occupied buildings (as needed) relatively uncomplicated<br>• Administration implementation challenges include permitting for injections (UIC permit), filing institutional controls with City/County, and design of engineering controls as needed | 7 | **Excellent**<br>• Technical implementation relatively uncomplicated; installation of shoreline and NAPL area injection wells and implementation and monitoring of bioinjections provide limited technical challenges; impacts of OCC remedy on groundwater flow will be necessary; MNA monitoring program uncomplicated; engineering controls on potential future occupied buildings (as needed) relatively uncomplicated<br>• Administration implementation challenges include permitting for injections (UIC permit), filing institutional controls with City/County, and design of engineering controls as needed | 7 | **Excellent**<br>• Technical implementation relatively uncomplicated; installation of shoreline and NAPL area injection wells and implementation and monitoring of bioinjections provide limited technical challenges; impacts of OCC remedy on groundwater flow will be necessary; MNA monitoring program uncomplicated; engineering controls on potential future occupied buildings (as needed) relatively uncomplicated<br>• Administration implementation challenges include permitting for injections (UIC permit), filing institutional controls with City/County, and design of engineering controls as needed | 6 | **Good**<br>• Technical implementation presents some technical challenges; installation of shoreline and NAPL area injection wells and implementation and monitoring of bioinjections relative uncomplicated; dewatering, shoring, management of utilities, stockpiling/loading/hauling, importing fill and backfilling/compaction during NAPL source area excavation present challenges; MNA monitoring program uncomplicated; engineering controls on potential future occupied buildings (as needed) relatively uncomplicated<br>• Administration implementation challenges include permitting for injections (UIC permit) and for excavation (grading permit; SWPPP permit/plan may be necessary); and filing institutional controls with City/County, and design of engineering controls as needed. | 2 | **Poor**<br>• Technical implementation presents significant technical challenges; dewatering and shoring for large excavation below groundwater and around utilities and infrastructure, soil removal and TESC for shoreline soil removal, management of utilities, stockpiling/loading/hauling, importing fill and backfilling/compaction during remedial excavation present significant challenges; installation of injection wells and implementation and monitoring of bioinjections relative uncomplicated<br>• Administration implementation challenges include permitting for discharge of treated dewatering water (industrial waste discharge permit), grading permit, SWPPP permit/plan; and permitting for in-water work (JARPA/USACE/WDFW permit) |
| -Consideration of Public Concerns | 10% | 1 | **Poor**<br>• While public notice and public comment period will be provided for review of the RI/FS (possibly combined with CAP) it is anticipated that performing no active cleanup activities to protect adjacent surface water will not be looked upon favorably by the public. | 4 | **Fair**<br>• Protective of human health and the environment<br>• Provides at least the minimum level of protection under MTCA<br>• Public comments/concerns will be addressed during RI/FS/CAP public comment period(s) | 7 | **Excellent**<br>• Protective of human health and the environment<br>• Provides at least the minimum level of protection under MTCA<br>• Public comments/concerns will be addressed during RI/FS/CAP public comment period(s) | 8 | **Excellent**<br>• Protective of human health and the environment<br>• Provides at least the minimum level of protection under MTCA<br>• Public comments/concerns will be addressed during RI/FS/CAP public comment period(s) | 6 | **Good**<br>• Protective of human health and the environment<br>• Provides at least the minimum level of protection under MTCA<br>• Public comments/concerns will be addressed during RI/FS/CAP public comment period(s) | 5 | **Good**<br>• Protective of human health and the environment<br>• Provides at least the minimum level of protection under MTCA<br>• Public comments/concerns will be addressed during RI/FS/CAP public comment period(s)<br>• Extent of excavation work, waste hauling and disposal, and shoreline work likely to raise public concerns |
| Estimated Cost ($) | | | $540,000 | | $3,100,000 | | $4,700,000 | | $4,500,000 | | $8,500,000 | | $34,800,000 |
| Overall Weighted Benefit Score [a] | | 2.8 | Poor/Fair | 4.4 | Fair | 6.7 | Good/Excellent | 8.2 | Excellent/Superior | 7.3 | Excellent | 7.1 | Excellent |

**Notes:**

[a] Ratings used: Poor (1-2), Fair (3-4), Good (5-6), Excellent (7-8), and Superior (9-10).

**Abbreviations and Acronyms:**

CAP = cleanup action plan
CPOC = conditional point of compliance
EISB = enhanced in situ bioremediation
FS = feasibility study
ft = feet
I&ECs = institutional and engineering controls
JARPA = Joint Aquatic Resources Permit Application
MNA = monitored natural attenuation
MTCA = Model Toxics Control Act
NAPL = non-aqueous phase liquid
OCC = Occidental Chemical Corporation
POC = point of compliance
PRB = permeable reactive barrier
RI = remedial investigation
SWPPP = stormwater pollution prevention plan
TESC = temporary erosion and sediment control
UIC = underground injection control
USACE = US Army Corps of Engineers
WAC = Washington Administrative Code
WDFW = Washington Department of Fish & Wildlife

# Table 6-3
## Summary of MTCA Alternatives Relative Benefits Ranking
## Alexander Avenue Cleanup Site
## Tacoma, Washington

**Relative Benefits Ranking for DCA**
[WAC 173-340-360(2)(b)(i) and
WAC 173-340-36093)(f)]

| Alternative Number and Name | Alternative 1: No Action (Monitoring Only) | | | | Alternative 2: Site-Wide MNA, Shoreline EISB, and I&ECs | | | | Alternative 3: Blair Hot Spot EISB and Bioventing, Hylebos Hot Spot Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Comparative Overall Benefit* [a] | | Score | Weighting Factor | Weighted Score | | Score | Weighting Factor | Weighted Score | | Score | Weighting Factor | Weighted Score |
| - Protectiveness | Poor | 1 | 0.3 | 0.3 | Fair | 3 | 0.3 | 0.9 | Excellent | 7 | 0.3 | 2.1 |
| - Permanence | Poor | 1 | 0.2 | 0.2 | Fair | 3 | 0.2 | 0.6 | Excellent | 7 | 0.2 | 1.4 |
| - Long-Term Effectiveness | Poor | 1 | 0.2 | 0.2 | Fair | 4 | 0.2 | 0.8 | Good | 5 | 0.2 | 1 |
| - Management of Short-Term Risk | Superior | 10 | 0.1 | 1 | Superior | 9 | 0.1 | 0.9 | Excellent | 8 | 0.1 | 0.8 |
| - Implementability | Superior | 10 | 0.1 | 1 | Excellent | 8 | 0.1 | 0.8 | Excellent | 7 | 0.1 | 0.7 |
| - Consideration of Public Concerns | Poor | 1 | 0.1 | 0.1 | Fair | 4 | 0.1 | 0.4 | Excellent | 7 | 0.1 | 0.7 |
| ***Overall Weighted Benefit Score*** | | | | **2.8** | | | | **4.4** | | | | **6.7** |

| Alternative Number and Name | Alternative 4: Hot Spot EISB and Bioventing, Site-Wide MNA, and I&ECs | | | | Alternative 5: Hot Spot Excavation, Alexander Avenue EISB and Bioventing, Shoreline EISB, Site-Wide MNA, and I&ECs | | | | Alternative 6: Extended Remedial Excavation, Alexander Avenue EISB and Bioventing, and Deep Groundwater MNA | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Comparative Overall Benefit* [a] | | Score | Weighting Factor | Weighted Score | | Score | Weighting Factor | Weighted Score | | Score | Weighting Factor | Weighted Score |
| - Protectiveness | Superior | 9 | 0.3 | 2.7 | Superior | 9 | 0.3 | 2.7 | Superior | 10 | 0.3 | 3 |
| - Permanence | Excellent | 8 | 0.2 | 1.6 | Good | 6 | 0.2 | 1.2 | Good | 6 | 0.2 | 1.2 |
| - Long-Term Effectiveness | Excellent | 8 | 0.2 | 1.6 | Excellent | 8 | 0.2 | 1.6 | Superior | 9 | 0.2 | 1.8 |
| - Management of Short-Term Risk | Excellent | 8 | 0.1 | 0.8 | Good | 6 | 0.1 | 0.6 | Fair | 4 | 0.1 | 0.4 |
| - Implementability | Excellent | 7 | 0.1 | 0.7 | Good | 6 | 0.1 | 0.6 | Poor | 2 | 0.1 | 0.2 |
| - Consideration of Public Concerns | Excellent | 8 | 0.1 | 0.8 | Good | 6 | 0.1 | 0.6 | Good | 5 | 0.1 | 0.5 |
| ***Overall Weighted Benefit Score*** | | | | **8.2** | | | | **7.3** | | | | **7.1** |

**Disproportionate Cost Analysis - Quantitative Evaluation**

| | Alternative 1 | Alternative 2 | Alternative 3 | Alternative 4 | Alternative 5 | Alternative 6 |
|---|---|---|---|---|---|---|
| Overall Weighted Benefit Score | 2.8 | 4.4 | 6.7 | 8.2 | 7.3 | 7.1 |
| Estimated Remedy Cost | $540,000 | $3,100,000 | $4,700,000 | $4,500,000 | $8,500,000 | $34,800,000 |
| Relative Benefit/Cost Ratio [b] | 5.2 | 1.4 | 1.4 | 1.8 | 0.9 | 0.2 |
| Most Permanent Solution | No | No | No | No | No | **Yes** |
| Lowest Cost Alternative | No | **Yes** | No | No | No | No |
| Costs Disproportionate to Incremental Benefits | No | Yes | Yes | No | Yes | Yes |
| ***Remedy Permanent to the Maximum Extent Practicable?*** | No | No | No | **Yes** | No | No |
| **Preferred Alternative** | **No** | **No** | **No** | **Yes** | **No** | **No** |

**Notes:**

[a] Ratings used: Poor (1-2), Fair (3-4), Good (5-6), Excellent (7-8), and Superior (9-10).

[b] Benefit/Cost Ratio scaled (multiplied) by 1,000,000 in order to compare ranges similar in scale to comparative overall benefit, as presented on Figure 6-1.

**Abbreviations and Acronyms:**

DCA = Disproportionate Cost Analysis
EISB = enhanced *in situ* bioremediation
I&ECs = institutional and engineering controls
MNA = monitored natural attenuation
MTCA = Model Toxics Control Act
WAC = Washington Administrative Code