Quendall Terminals Superfund Site, Operable Unit 1 Proposed Plan

Renton, Washington **September 2019**

U.S. Environmental Protection Agency, Region 10

Proposed Plan for Public Comment

1. Introduction

The U.S. Environmental Protection Agency (EPA) is proposing a plan for the cleanup of the Quendall Terminals Superfund Site (Quendall Site or Site) and is inviting the public to review and comment on the Proposed Plan. The Site is a former creosote-manufacturing facility located on Lake Washington near Renton, Washington (**Figure 1-1**[1]). Facility operations, including transport of raw materials in, and finished creosote product out of the Site, have resulted in contamination of soil, groundwater, and sediment at the Site.

This Proposed Plan provides background information on the Site and the cleanup process for Operable Unit 1 (OU1), describes the cleanup alternatives that were evaluated, identifies EPA's Preferred Alternative, and explains the reasons for this preference. The topics covered by this Proposed Plan are shown in the inset box below.

Inside this Proposed Plan:

1. **Introduction** 1
2. **Site Background** 3
3. **Site Characteristics** 4
4. **Scope and Role of Operable Unit 1** 5
5. **Summary of Site Risks** 6
6. **Remedial Action Objectives and Preliminary Remediation Goals** 7
7. **Remedial Alternatives** 8
8. **Comparative Analysis of Alternatives** 15
9. **Preferred Alternative** 17
10. **References** 19

Abbreviations and Acronyms 19
Glossary of Terms 20

Tables
Figures
Appendixes

Public Comment Period: Now through October 9, 2019

Where to review the Proposed Plan:

The Administrative Record, which contains the Proposed Plan and other documents that support the basis for the Preferred Alternative, is available for public review at the following locations:

- **Renton Public Library**
  100 Mill Avenue South
  Renton, WA 98057
  425-430-6610 (call for hours)
- **EPA Superfund Records Center**
  1200 Sixth Avenue
  Seattle, WA 98101
  800-424-4372, extension 4494 (call for appointment)
- **Online:** https://www.epa.gov/superfund/quendall-terminal

How to Comment on the Proposed Plan:

Written comments may be submitted at any time during the public comment period (now through October 9, 2019) by U.S. mail or email to one of the following recipients:

- **U.S. Mail:** Kathryn Cerise, EPA Region 10,
  1200 Sixth Avenue, Suite 155, ECL Mail Code 122,
  Seattle WA 98101
- **Email:** quendallcomments@epa.gov

Public Meeting, Tuesday, September 24, 2019:

EPA will hold a public meeting to present the information provided in this Proposed Plan, take comments from the public, and provide the public the opportunity to ask EPA questions. EPA will accept oral and written comments at the public meeting.

Tuesday, September 24, 2019
4:00 to 6:30 p.m.—Open House
6:30 p.m.—Presentation and Public Comment
Stan Head Cultural Center
Aegis Gardens Newcastle
13056 SE 76th Street
Newcastle, WA 98056

Additional meeting information will be published in the *Renton Reporter* and *Bellevue Reporter*, as well as on EPA's website.[2]

---

[1] Tables and figures are located at the end of this document.

[2] https://www.epa.gov/superfund/quendall-terminal

The Site is located on the southeast shore of Lake Washington, near the northernmost limits of the City of Renton, Washington (**Figure 1-1**). The Site includes two OUs: OU1 comprises the upland portion of the Site, and OU2 comprises the portion of the Site extending into the adjacent lakebed and sediments of Lake Washington. This Proposed Plan identifies EPA's Preferred Alternative for OU1 to address contamination in soil and groundwater in the uplands portion of the Site. The Proposed Plan for EPA's Preferred Alternative for OU2 will be provided in a separate document.

A Proposed Plan is a document that EPA is required to issue under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund, and the regulations that implement CERCLA, known as the National Contingency Plan (NCP). By issuing the Proposed Plan, EPA fulfills the statutory and regulatory requirements of CERCLA § 117(a) and the NCP § 300.430(f)(2).

The Quendall Site is unique in that it occupies the last large undeveloped portion of shoreline along Lake Washington and is situated immediately adjacent to residential and commercial properties, and a public walking trail. Therefore, another important aspect in developing remedial alternatives considered "using an innovative technology when such technology offers the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse impacts than other available approaches, or lower costs for similar levels of performance than demonstrated technologies" (NCP § 300.430(a)(1)(iii)(A-F)).

EPA is the lead agency at the Quendall Site, and the Washington State Department of Ecology (Ecology) is the supporting agency. EPA, in consultation with Ecology, may modify the Preferred Alternative or select another response action presented in this Proposed Plan based on new information or public comment. The Muckleshoot Tribe has been invited to consult.

This Proposed Plan highlights key information from the remedial investigation (RI) and feasibility study (FS) reports. The reader should consult the RI/FS reports and documents in the administrative record for more information regarding the proposed remedial action.

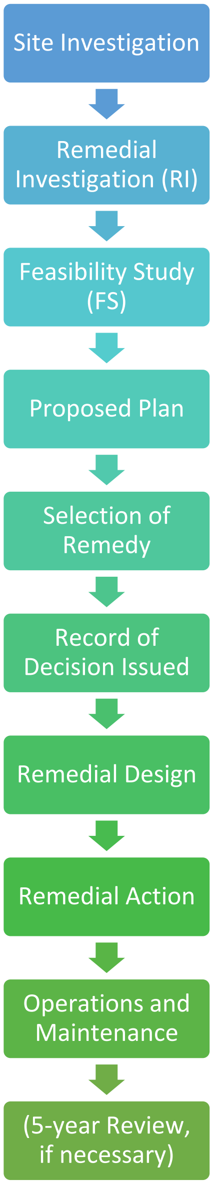
EPA is inviting input and new information from the public on all alternatives and on the rationale for the Preferred Alternative. Public comments are important and can help shape the cleanup plan. EPA wants to hear from you and will consider public comments before making a final cleanup decision for the Site. EPA will accept comments through October 9, 2019.

EPA will consider comments received and present the selected remedial actions in a Record of Decision (ROD). EPA's response to public comments will be provided in a Responsiveness Summary, which will be part of the ROD. Information on how to provide comments or questions to EPA is presented in the inset on page 1.

The Superfund Process

The Superfund process, as established by CERCLA and the NCP, is structured to guide the cleanup of contaminated sites. The process includes defined steps, illustrated at right, leading from discovery of a site, through investigation, remedy selection, and implementation of a remedy. The NCP includes procedures, expectations, and program management principles to guide the process. EPA has developed technical guidance and policy on a range of issues so that decisions are based on sound science and to ensure that cleanup actions will ultimately be protective of human health and the environment.

Steps in the Superfund Cleanup Process



Summary of Preferred Alternative

EPA proposes to use a phased approach to clean up soils containing dense nonaqueous phase liquid (DNAPL) at the Site that includes the application of *in situ* (in place) self-sustaining smoldering combustion and/or *in situ* solidification. The smoldering combustion process (similar to charcoal burning in a grill), is a thermal treatment that destroys certain types of oily contaminants like creosote and coal tar where they exist underground. The combustion process basically converts these chemicals into carbon dioxide, carbon monoxide, and water, which are then captured and treated as part of the process. *In situ* solidification is a treatment process that immobilizes site contaminants in soil by mixing in amendments to the soil and solidifying the soil into a stabilized mass (similar to a concrete block). Potential amendments include bentonite and cement.

Amendments can be mixed with soil in place using large-diameter augers.

Based on the results of a smoldering combustion field pilot study conducted at Quendall during summer 2018, smoldering combustion is expected to permanently destroy the significant sources of DNAPL contamination in the upland areas. As part of the implementation strategy, the actual areas for combustion will be refined with additional pre-treatment characterization during remedial design (Phase 1). If determined necessary to further reduce source strength following combustion, solidification will treat the lesser contaminated areas that are not amenable to combustion (Phase 2). The need for additional source treatment following combustion will be determined based on passive flux monitoring results and soil core characterization data.

In addition to treatment of DNAPL, a 3-foot permeable cap would be placed over parts of OU1 where lower-level soil concentrations remain above risk-based concentrations. Groundwater would be monitored to verify that the remedy is performing as intended (that is, concentrations of contaminants of concern [COCs] are decreasing over time). These proposed remedial actions are estimated to cost approximately $66.1 million using a present value 7 percent discount rate.

2. Site Background

This section summarizes the Site history and associated releases of contamination, emphasizing Site features and characteristics that informed EPA’s selection of the Preferred Alternative presented in this Proposed Plan.

Site History

The Quendall Site (**Figure 2-1**) is located on Lake Washington in the northernmost limits of the City of Renton, within a former industrial area that now includes residential and commercial uses. The physical address is 4503 Lake Washington Boulevard North. In addition to the portion of the Site owned by Quendall Terminals (referred to as the Quendall property), the Site also includes the Burlington Northern Railroad right-of-way to the east (referred to as the Railroad property) and state-owned aquatic lands to the west.

The upland portion of the Site encompasses approximately 22 acres, is relatively flat, and occupies the middle portion of a roughly 70-acre alluvial plain that has been modified over the last 90 years by filling and grading. Shortly after the lowering of Lake Washington in 1916 to construct the Lake Washington Ship Canal, the Site, including newly exposed portions of the former May Creek delta, was developed into a creosote-manufacturing facility. May Creek originally ran through the Site to Lake Washington until it was diverted to the south of the property prior to 1936. From 1969 to approximately 1983, some of the aboveground storage tanks at the Site were used intermittently for storage of crude oil, waste oil, and diesel fuel. From 1975 to 2009, the Site was used primarily for log sorting and storage. The Site is currently vacant and fenced.

Historical Releases of Contaminants

Contaminant releases at the Site are primarily related to historical creosote-manufacturing processes and associated activities. Creosote manufacturing was conducted at the Site from 1916 through 1969. Coal and oil-gas tar residues (collectively referred to as coal tars) were distilled into three fractions that were shipped offsite for a variety of uses or transported to the neighboring J.H. Baxter & Co. site for use in wood-treating operations. The light distillate fraction was typically used as a feedstock in chemical manufacturing. The middle distillate fraction was used in the wood-preserving industry. The bottom fraction, or “pitch,” was used for applications such as roofing tar (Hart Crowser, 1994 as referenced in Aspect and Arcadis, 2016). At Site locations where product transport, production, storage, and/or disposal were performed, coal tars and distillate products were released to the environment. **Figure 2-2** shows the locations of historical Site features, and **Figure 2-3** presents a timeline of Site operations.

Releases of coal tars and distillate products occurred in five upland areas as follows (see **Figure 2-2** for site features referenced below):

- Coal tar was distilled, and creosote and light distillates were transferred to surrounding tanks via piping near the former Still House. A pipeline was present between the tanks west of the former Still House and the property to the north of the Site (formerly occupied by J.H. Baxter & Company, which operated a wood-treatment plant at that location from 1955 until 1982). This pipeline was used to transport creosote for wood-treatment processes. Reported releases include product spills and leaks directly onto the earthen floor of the Still House (CH2M, 1983 and Ecology, 1989 as referenced in Aspect and Arcadis, 2016).
- Apparent historical spills occurred at the former railroad tank car loading area east of the Still House. The loading area was situated on a trestle built over May Creek. A solid material-loading platform was located further north along the tracks.
- Wastes from historical operations were released into the former May Creek Channel, located south of the

former Still House and storage tanks. Wastes from nearby tanks were reportedly placed in the eastern portion of the former channel, and the western portion of the channel reportedly received creosote wastes discharged from the former Still House sewer outfall. Waste from the former May Creek Channel area has migrated into adjacent Lake Washington.

- The former Still House cooling lines released influent into the north and south sumps; this effluent sometimes contained creosote and tars. Shortly after the plant shut down, approximately 50 truckloads of material were excavated from the north sump and disposed of at the Coal Creek Landfill. The south sump was reportedly filled in before 1950 (Hart Crowser, 1994, as referenced in Aspect and Arcadis, 2016). There were no reports of any materials being removed from the south sump before it was filled in.
- Quendall Pond, located near the shoreline, was constructed in 1972 as an area where tank bottoms from nearby storage tanks were placed. This area also received wastes from north sump overflows. Waste from the Quendall Pond area has migrated into adjacent Lake Washington through the subsurface and possibly by overland surface water flow.

Some solid wastes were also disposed of at the Site. Heavy tar produced by the distillation process was cooled and solidified in pitch bays located north of the Still House. The waste pitch, also called Saturday coke, was chiseled out and reportedly placed near the Site shoreline (CH2M, 1983 as referenced in Aspect and Arcadis, 2016). Solid tar products have also been observed in shallow soils around the northern railroad loading area, where solid products were loaded onto railcars.

After the creosote plant was closed in 1969, all structures, except for six aboveground storage tanks and the office, were demolished. Petroleum was stored at the Quendall Site using the remaining tanks for approximately 13 years—from 1969 to 1982. While spills of petroleum product were reported around the aboveground storage tanks, light nonaqueous phase liquid has not been detected the Site.

3. Site Characteristics

This section describes the physical setting, current and potential future uses, natural habitat functions, and volume and type of contamination at the Site.

Physical Setting

The Site is located within the Puget Sound Lowland. Much of what is now the upland portion of the Site was formerly the lakebed of Lake Washington before the lake was lowered 9 feet in 1916, which exposed the alluvial delta of May Creek.

Two aquifers are recognized at the Site:

- **Shallow Aquifer** occurs to depths of approximately 30 to 50 feet below ground surface (bgs). The groundwater table is typically encountered at 6 to 8 feet bgs.
- **Deep Aquifer** occurs to a depth of approximately 140 feet bgs.

Groundwater generally flows horizontally across the Site from east to west, ultimately discharging to Lake Washington.

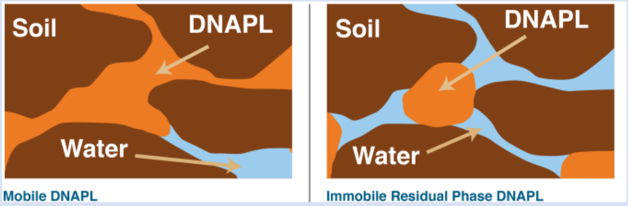
Current and Future Site Uses

Currently, the Site is vacant and unused, and has been fenced and access restricted. Land use surrounding the site is commercial and residential.

Groundwater beneath the Site and Lake Washington is designated as potable water; however, neither is currently used as a source of drinking water. City of Renton and Coal Creek Utility District serve Site facilities and all surrounding properties.

What are NAPLs?

Nonaqueous phase liquids (NAPLs) are contaminants like oil, gasoline, and petroleum products that do not dissolve in or easily mix with water. Dense NAPLs (DNAPLs) are liquids more dense than water and will sink in water or groundwater.



Mobile DNAPL

Immobile Residual Phase DNAPL

NAPLs can be found in two different forms: mobile, or free phase, which is a continuous mass of NAPL that can migrate through the saturated soil; and immobile, or residual phase, which is NAPL sorbed to soil particles that will continue to dissolve into the aquifer and is difficult to physically remove without removing soil.

Source: Interstate Technology & Regulatory Council. 2015. Integrated DNAPL Site Characterization and Tools Selection. www.itrcweb.org/DNAPL-ISC_tools-selection

The Site is located on prime upland and shoreline property that is one of the last developable properties on Lake Washington in an urban area with high development pressures. The current owners will likely work with a third party to redevelop the Site for residential and commercial uses after cleanup.

A development plan (Century Pacific LLLP, 2012) that includes multifamily housing, retail space, restaurant space, and parking is under consideration. Thus, it is important to implement a cleanup protective of residential and commercial uses.

Natural Habitat Functions of the Site

Upland vegetation consists primarily of early successional species and invasive species, including large stands of Himalayan blackberry and Scotch broom. Because of the most recent log-handling and storage uses in the uplands, large deposits of wood debris cover access roads and storage areas. Riparian vegetation is generally present across the Site shoreline.

Several wetlands are present at the Site (**Figure 3-1**), many within 100 feet of the shoreline (defined as the "habitat area").

Contamination in Site Media

The primary product manufactured at the Site was creosote—a thick, oily liquid distilled from coal tar. Creosote contains several hundred individual chemicals, including benzene, naphthalene, and benzo(a)pyrene. Most creosote present in the soil and groundwater is in the form of an oily DNAPL, which is present within the shallow alluvium (delta deposits) to depths up to approximately 30 feet bgs. Approximately 377,500 gallons of DNAPL are estimated to be present within OU1. **Figure 3-2** illustrates the estimated areal extent of Site DNAPL occurrences.

Chemicals associated with the DNAPL have dissolved into the groundwater. Contaminant concentrations measured at the Site are summarized in **Table 3-1** (soil) and **Table 3-2** (groundwater).

Benzene, naphthalene, carcinogenic polycyclic aromatic hydrocarbons (cPAHs), and arsenic are the primary COCs at the Site. The organic COCs (benzene, naphthalene, and cPAHs) originated from creosote and coal-tar releases. Arsenic is believed to have been released from natural soil deposits as the groundwater conditions changed in response to the presence of creosote and coal-tar, and due to naturally occurring organic delta deposits. Arsenic was also introduced to the surface soil through the use of sodium arsenate products for weed control over OU1 for many years (CH2M, 1983 and Hart Crowser, 1994 as referenced in Aspect and Arcadis, 2016). Arsenic in deeper groundwater may also be coming from the Barbee Mill property from the South.

In groundwater and soil, the highest concentrations of benzene, naphthalene, and cPAHs have been detected in the Shallow Aquifer (**Figure 3-3**), and at the top of the Deep Aquifer (**Figure 3-4**) within and downgradient of DNAPL-impacted soil and sediment. **Figure 3-5** presents the estimated extent of groundwater contamination for primary COCs along a representative cross section (parallel to groundwater flow in the center of the Site).

Principal-Threat Waste

CERCLA regulations establish the expectation that treatment will be used to address the principal threats posed by a site whenever practicable. EPA guidance defines principal threat waste (PTW) as source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur. EPA has determined that DNAPL and DNAPL-impacted soil (that is, either oil-wetted or oil-coated) such as those present at the Site are to be considered PTW based on the large mass present, the mobility of the DNAPL, and the toxicity of the chemicals found in the DNAPL.

How does EPA Assess Risk?

Human health and ecological risk assessments estimate the health risks to people and the environment from exposure to contaminants either now or in the future. For EPA studies, "risk" is the possible harm to people or wildlife from exposure to chemicals. Two types of health risks for people are evaluated: (1) the risks that can cause cancer and (2) the risks that can cause other health effects. EPA evaluates only noncancer risks to wildlife.

EPA uses the results of a risk assessment to evaluate whether the contamination at a site poses an unacceptable risk to human health or the environment under CERCLA. The CERCLA regulations provide a range of risk numbers to evaluate if cleanup of a site is necessary. EPA established an "acceptable" extra cancer risk range, from 1 in 10,000 (1×10^{-4}) to 1 in 1,000,000 (1×10^{-6}) of developing cancer from exposure to site contaminants at a site over a person's lifetime.

For noncancer health effects, EPA calculates a hazard quotient (HQ) or hazard index (HI) for both humans and wildlife. A hazard index is the sum of the hazard quotient for several chemicals that have the same or similar effects. The noncancer hazard index of 1 is a threshold below which EPA does not expect any noncancer health effects. If the hazard quotient or hazard index is 1 or higher, then exposure to site contaminants could be a risk to human or wildlife health.

4. Scope and Role of Operable Unit 1

This Proposed Plan identifies EPA's Preferred Alternative and other cleanup alternatives considered for OU1. OU1 remediation will address soils containing DNAPL and contaminated groundwater beneath the upland portion of the Site. OU2 cleanup will address Site-related contaminated sediment in adjacent Lake Washington. EPA split the Site into two OUs because each OU represents distinctly different geographic areas. Different but complementary cleanup strategies will be employed in the two OUs, and different factors may influence the timing of remedy implementation in each OU. EPA's Preferred Alternative for OU2 will be addressed in a separate Proposed Plan. It is likely that the OU1 and OU2 remedies will be implemented concurrently, with OU1 beginning construction first.

5. Summary of Site Risks

Baseline human health and ecological risk assessments were performed as part of the RI for the Site following standard EPA guidance. Multiple exposure pathways by which people (human receptors) or wildlife (plants and animals, or ecological receptors) could be exposed to contamination at the Site were evaluated.

Human Health Risks

The baseline human health risk assessment (HHRA) evaluated the following potential exposure scenarios:

- Future residents
- Future occupational/office workers
- Future construction/excavation workers

EPA default exposure assumptions were used to evaluate these scenarios. The HHRA evaluated the potential cancer and noncancer effects to humans (see inset on the previous page).

The results of the HHRA indicated that excess lifetime cancer risk (ELCR) estimates exceed 1 in 10,000 for all three of the scenarios, ranging from 2 in 10,000 (construction/ excavation worker) to greater than 8 in 10 (groundwater exposure for the future resident) (**Table 5-1**). The primary chemicals contributing to risk are cPAHs, naphthalene, and arsenic. The noncancer hazard index (HI) ranges from 2 (future occupational user) to nearly 8,000 (groundwater exposure via inhalation for the future resident, if a house were built over the most contaminated location found at the Site).

Ecological Risks

For the baseline ecological risk assessment (ERA), a selection of plants, invertebrates, birds, and mammals were selected as receptors of concern and further evaluated to determine whether and to what degree they may be at risk from contaminated media at the Site.

Ecological hazard quotients (HQs) were estimated using multiple lines of evidence, including comparison of bulk soil (for soil invertebrates and terrestrial plants) to screening levels, and use of an exposure model approach that compared estimated total dietary intakes with literature toxicity reference values.

Results of the baseline ERA indicated that risks for terrestrial birds (robin and red-tailed hawk) and mammals (eastern cottontail rabbit, meadow vole, short-tailed shrew, racoon, and coyote) exceed an HQ of 1. The primary risks are polycyclic aromatic hydrocarbons (PAHs) in soil. No threatened or endangered terrestrial-dependent species have been identified at the Site.

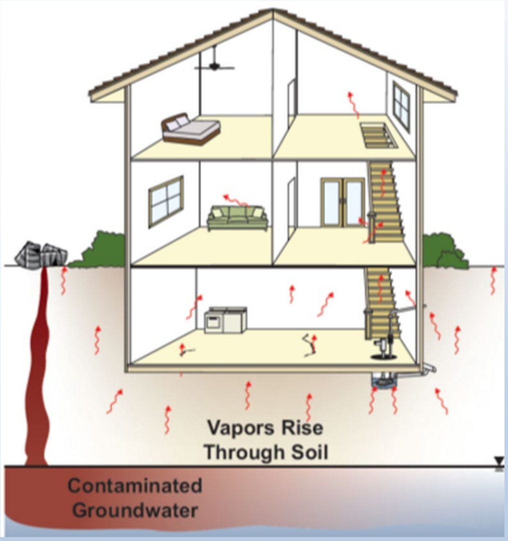
Basis for Proposing a Remedy

EPA's judgment is that the Preferred Alternative, or one of the other active measures considered in this Proposed Plan, is necessary to protect public health or welfare and the environment from actual or threatened releases of hazardous substances into the environment.

A significant volume of DNAPL is estimated to be present in Site soil (approximately 377,500 gallons). The primary objectives for taking action in OU1 are to address DNAPL in soil, prevent exposure to contaminants in soil by people and wildlife, restore Site groundwater to its highest beneficial use, and protect Lake Washington by preventing further releases of DNAPL and the associated groundwater contaminants to sediment and surface water.

WHAT IS VAPOR INTRUSION?

Vapor intrusion is a way that chemicals in soil or groundwater can get into indoor air. Some chemicals can give off vapors or "volatilize" from groundwater at or near the top of the groundwater table and travel through soil and into nearby buildings through cracks, openings, and penetrations, contaminating indoor air.



For media and pathways that pose a human health risk, the individual chemicals that pose an ELCR of 1 in 1 million (that is, 1×10^{-6}) or greater were identified as human health COCs. Chemicals that exceeded an HQ of 1 for either human or ecological receptors were also identified as COCs. **Table 6-1** lists the COCs by medium. The primary human health risks throughout the Site are cPAHs, naphthalene, benzene, and arsenic. The greatest risks are for future residents from exposure to groundwater (drinking and showering) and indoor air (vapor intrusion). The primary ecological receptor risk drivers throughout the Site are PAHs, represented as both individual chemicals and as total PAHs, with the greatest risks for small birds and mammals from exposure to surface soil (ingestion of worms and other soil invertebrates).

6. Remedial Action Objectives and Preliminary Remediation Goals

Remedial Action Objectives

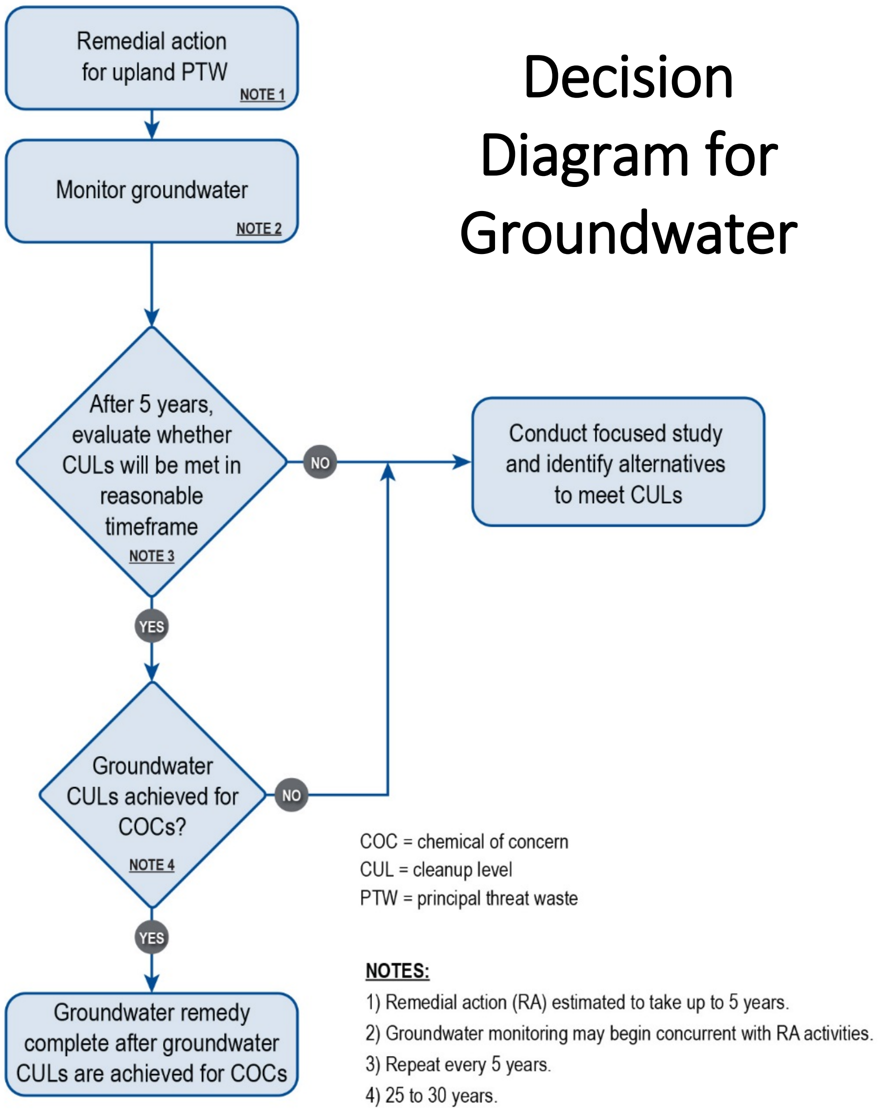
In accordance with the NCP, EPA developed remedial action objectives (RAOs) to describe what the cleanup is expected to accomplish to protect human health and the environment. RAOs help focus the development and evaluation of remedial alternatives and form the basis for establishing preliminary remediation goals (PRGs). Final RAOs and cleanup levels will be included in the ROD.

One of the expectations to be considered by EPA is the ability of remedial alternatives to address PTW to the extent practicable. PTW is defined at this Site as all DNAPL, including oil-coated and oil-wetted soil/sediment. The RAO for PTW is listed below first (RAO 1), followed by RAOs for groundwater and soil.

Following are the RAOs for OU1:

- **RAO 1**—Reduce migration of COCs from DNAPL to groundwater to levels that allow restoration of groundwater to meet PRGs.
- **RAO 2**—Restore groundwater to its highest beneficial use (drinking water) by meeting PRGs in the shallow alluvium and deeper alluvium aquifers within a reasonable period of time (see “Decision Diagram for Groundwater”).
- **RAO 3**—Reduce to acceptable levels the risk to future residents from direct contact or incidental ingestion of COCs in surface and subsurface soil.
- **RAO 4**—Reduce to acceptable levels the risk to terrestrial wildlife from direct contact or incidental ingestion of COCs in soils or soil invertebrates.
- **RAO 5**—Reduce to acceptable levels the human health risk from inhalation of vapors from groundwater and/or soils contaminated with COCs.
- **RAO 6**—Reduce concentration of COCs in soils that may migrate to surface water to meet PRGs for protection of surface water.

Decision Diagram for Groundwater



COC = chemical of concern
CUL = cleanup level
PTW = principal threat waste

NOTES:

1) Remedial action (RA) estimated to take up to 5 years.
2) Groundwater monitoring may begin concurrent with RA activities.
3) Repeat every 5 years.
4) 25 to 30 years.

Preliminary Remediation Goals

PRGs are numeric target goals (contaminant concentrations specific to a particular media) used during the initial development, analysis, and selection of cleanup alternatives. PRGs were developed during the Site investigation and cleanup planning process and are based on applicable or relevant and appropriate requirements (ARARs). Where standards do not exist, risk-based concentrations (RBCs) were developed. ARARs are briefly discussed in the section titled “Compliance with Applicable or Relevant and Appropriate Requirements.” ARARs will be outlined in detail in the ROD.

PRGs are intended to protect human health and the environment by achieving risk reductions associated with each RAO. New or different requirements may be identified during the public review process that may modify the PRGs. Remediation goals are considered preliminary until the ROD, at which time they may be revised or adopted as final cleanup levels. PRGs were identified based on the most stringent ARAR, or if no ARAR is available, the lowest RBC based on either carcinogenic effects or noncarcinogenic effects, as described below.

Table 6-1 lists PRGs for soil and groundwater. They are intended to reduce risk and comply with ARARs as follows:

- **Soil**—The PRGs for soil are primarily human health RBCs, based on cancer risk of 1×10^{-6} and an HQ of 1, calculated using the exposure assumptions of the HHRA residential scenario. Also included are a state background value (for arsenic) and ecological RBCs, back-calculated from the ERA, when they are lower than residential PRGs.

- **Groundwater**—The PRGs for groundwater are either maximum contaminant levels (MCLs) or RBCs calculated using the exposure assumptions of the HHRA residential scenario.

7. Remedial Alternatives

Several technologies were considered for use at this Site and are incorporated into the remedial alternatives that were evaluated by EPA:

- For soil containing DNAPL, three technologies were included:
    - **In Situ Solidification (ISS).** Using ISS technology, creosote/coal tar and contaminants in soil are solidified in place. This is done by injecting material very similar to cement into the ground and mixing it with the contaminated soil using large augers. This has become a common way of addressing pockets of contamination at sites with oil creosote and coal tar contaminants.
    - **In Situ Self-sustaining Smoldering Combustion.** Smoldering combustion is a thermal oxidation process that results in the destruction of the target contaminants. The net products of thermal oxidation are carbon dioxide, carbon monoxide, water, and heat.
    - **Excavation and Thermal Treatment.** Excavation removes contaminated materials. Excavated materials may be thermally treated (heated), either at the site or at an offsite facility, to destroy organic contaminants within the soil. This would be used for alternatives that excavate large amounts of soil.
- For groundwater, one technology was included:
    - **Pump and Treat.** Groundwater would be extracted and treated prior to disposal.

  A **soil cap** was included for all alternatives. Approximately 3 feet of clean material would be placed over areas of the site where soil cleanup goals are exceeded to prevent exposure to contaminated media.

These remedial technologies were packaged into five alternatives for OU1.[3] EPA evaluated these alternatives, as outlined below, along with the baseline No Action Alternative (Alternative 1):

- Alternative 1 – No Action.
- Alternative 7 – Solidification of DNAPL and soil capping.
- Alternative 7a – *In situ* smoldering combustion and/or *in situ* solidification of DNAPL, and soil capping. **This is EPA's Preferred Alternative.**
- Alternative 8 – Removal/onsite *ex situ* thermal treatment of DNAPL and soil capping.
- Alternative 9 – Solidification and Removal/onsite *ex situ* thermal treatment of DNAPL and contaminated soil, and soil capping.
- Alternative 10 – Removal/onsite *ex situ* thermal treatment of DNAPL and contaminated soil, soil capping, and active groundwater treatment.

The cost analysis in this Proposed Plan includes operations and maintenance (O&M) for 100 years. A considerable amount of preparatory and general construction work will be required to implement any of the alternatives. A set of "common elements" are described first since they are included in all alternatives, except Alternative 1 – No Action. The following section titled "Common Elements" briefly describes the common elements for each alternative.

Common Elements

The following subsections present remedial components that are common to all alternatives.

Preconstruction Activities

Preconstruction activities, including obtaining permits, developing health and safety and other work plans, mobilizing and demobilizing equipment, and developing 100 percent remedial design drawings and specifications.

Future Land Use Assumptions

The Site is currently vacant and unused. The uplands portion of the Quendall Terminals Property likely will be redeveloped upon construction completion. Based on Site zoning and the most recent development plan, the future grade would likely be higher to meet the grades on adjacent properties and to allow installation of a gravity sewer system. As a result, excess material that may be generated during some remedies (for example, an increase in soil volume during solidification) can likely remain on the Site. This was considered in developing alternatives.

---

[3] The FS included Alternatives 2 through 6 that ranged from containment (capping) to various degrees of targeted PTW treatment or removal. These alternatives did not meet RAO 2 and associated ARARs and were therefore eliminated from further consideration.

Post-remediation Site development is also assumed to include impermeable[4] engineered surfaces, such as roadways, sidewalks, parking lots, and building foundations. Future buildings would likely include deep foundation elements (for example, driven pilings) that would be designed to ensure that they are compatible with the cleanup.

Vapor intrusion will need to be assessed or mitigated for any new construction, as indoor air modeling conducted in support of the RI indicated that exceedances of air PRGs for benzene and naphthalene are possible for future structures if vapor controls are not implemented. If redevelopment occurs, installation of vapor intrusion mitigation systems will likely be more cost-effective than monitoring.

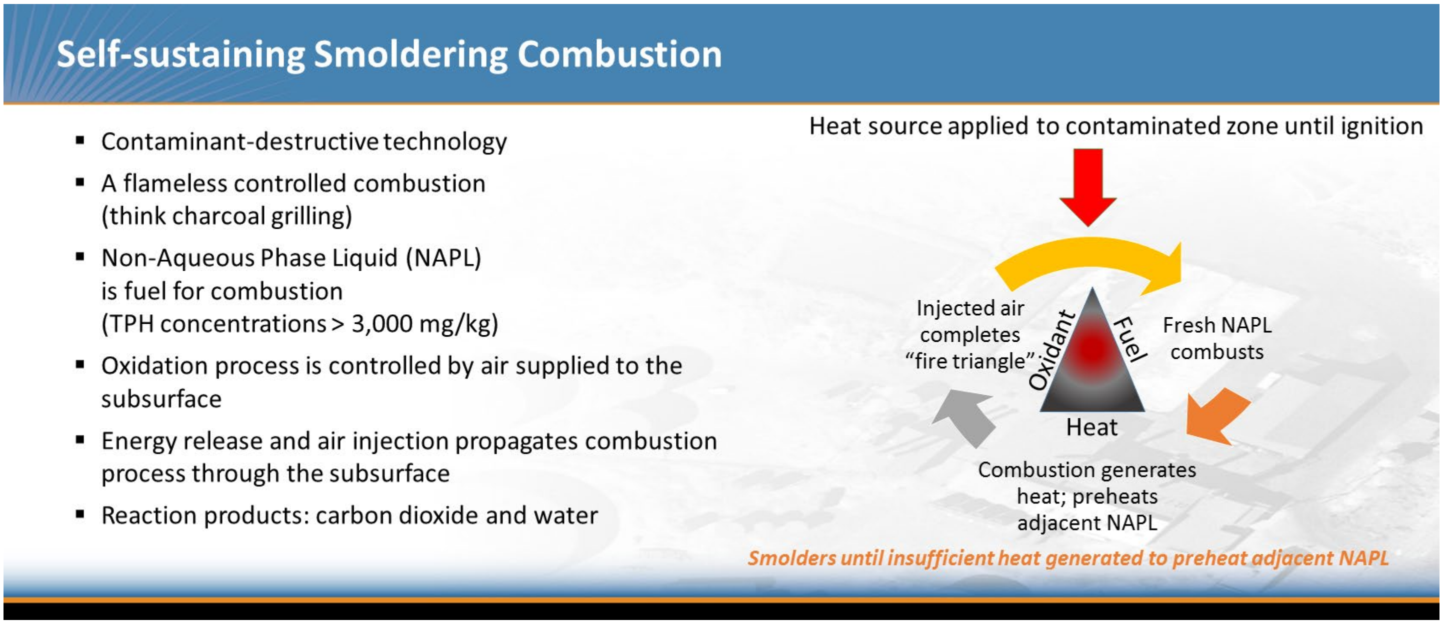
Shoreline Habitat Considerations

Several wetlands are present at the Site. All alternatives were designed to minimize filling these wetlands to the extent practicable, but some filling would be necessary under all of the alternatives (except Alternative 1). Also, impacts to existing shoreline habitats within the 100-foot shoreline area will also be minimized, but some impacts likely will be necessary to complete the Site cleanup. As a result, mitigation will be required pursuant to the Clean Water Act (CWA) Section 404(b)(1) to offset these impacts. All alternatives assume that the entire shoreline and the area landward 100 feet (the habitat area, see **Figure 3-1**) would be excavated and recontoured to allow for development of functional wetland and riparian habitat following cleanup and would remain undeveloped (about 3.5 acres). Habitat mitigation plans will be developed in the remedial design phase of the cleanup process. All alternatives (except Alternative 1) consider the CWA 404(b)(1) statute and its requirements, and all such alternatives included provisions for future habitat along the Quendall shoreline.

Remedial components planned and/or selected for the habitat area would need to consider potential access and use limitations. Accordingly, some potential remedial components of the FS alternatives may not be compatible with future habitat areas. For example, repair and replacement of sediment caps along the shoreline may require periodic use of heavy equipment that could cause degradation of the habitat area. EPA, the Muckleshoot Tribe, and Trustees would need to agree that such access for purposes of installation, operation, and maintenance were acceptable. This is considered in the evaluation of alternatives.

For alternative development and evaluation, the following assumptions regarding habitat were made:

- The habitat area would consist of a 100-foot-wide corridor along the shoreline. Remedial components requiring future access for monitoring or maintenance, such as groundwater extraction wells, would be placed outside and east of the habitat area.
- Caps in the habitat area could require clean material to a minimum depth of 3 feet below current grade. Whether or not a soil cap would be necessary for the habitat area would be determined as part of remedial design, and in conjunction with the design for habitat and wetland mitigation. For example, cap designs would need to accommodate grade changes for potential wetlands and include a root zone for plants.



Self-sustaining Smoldering Combustion

- Contaminant-destructive technology
- A flameless controlled combustion (think charcoal grilling)
- Non-Aqueous Phase Liquid (NAPL) is fuel for combustion (TPH concentrations > 3,000 mg/kg)
- Oxidation process is controlled by air supplied to the subsurface
- Energy release and air injection propagates combustion process through the subsurface
- Reaction products: carbon dioxide and water

Smolders until insufficient heat generated to preheat adjacent NAPL

---

[4] However, future "green" development regulations may require that some surfaces such roads and sidewalks be constructed of permeable or semipermeable materials.

- Filling onsite wetlands likely will be necessary to complete the Site cleanup (refer to Section 8). Mitigation for the loss of the Site wetlands will be required pursuant to CWA Section 404(b)(1). The mitigation plan will be developed and approved in concert with EPA, Ecology, Department of Natural Resources, and the Muckleshoot Tribe.

Potential Generation of Hazardous Waste During Remediation

Resource Conservation and Recovery Act (RCRA)-regulated listed wastes may be generated by remedial activities that remove soil above the groundwater table in the footprint of the north and south sumps. In addition, RCRA-regulated characteristic wastes and Washington state dangerous wastes may be generated by remedial activities that remove soil or sediment containing DNAPL. For the FS cost estimates including soil disposal, it was assumed that the RCRA-regulated wastes described above would be disposed of at a hazardous (Subtitle C) landfill and that other soil could be disposed of in a nonhazardous (Subtitle D) landfill. The final disposal site would be selected following waste characterization determination and testing.

Waste management will be carefully considered during remedial design, especially with regard to cost implications.

Institutional Controls

Institutional Controls are administrative and/or legal mechanisms intended to minimize the potential for people to be exposed to contamination by limiting land or resource use, and to maintain the integrity of the engineered components of the remedy. Institutional controls will be required for all alternatives and will be an important part of the overall Site remedy because varying degrees of contamination exceeding cleanup levels will initially remain onsite for all alternatives. EPA recommends that where it may provide greater protection, multiple institutional controls should be used in combination, referred to as “layering.”

Many types of institutional controls may be applied at the Site to control human exposure pathways, including government controls, proprietary controls, enforcement and permit tools, and informational devices. The nature and geographic extent of restrictions that may be needed will depend on the cleanup alternative selected and anticipated future uses. Institutional controls, which include monitoring for groundwater, will be required until groundwater meets PRGs.

Institutional controls will likely include surface and subsurface soil prohibitions regarding disturbance of caps and subsurface soils. Soil caps will be required for areas where COCs exceed PRGs in surface soil, to maintain protectiveness. The areas where contaminated soils have been solidified are not expected to require a soil cap but would require prohibitions against any action that may compromise the integrity of the solidified soil. As noted under redevelopment assumptions above, a vapor intrusion assessment or mitigation (engineering controls) will also be required for any new construction. Additional institutional control details will be provided in the ROD.

Accuracy of Cost Estimates:

Cost estimates in this Proposed Plan are based on conceptual designs presented in the FS and have an accuracy range of -30 to +50 percent. For an item with an estimated cost $100,000, this means that the actual cost is expected be between $70,000 and $150,000.

Inspections, Monitoring, and Reporting

At the Site, monitoring will require at a minimum:

- Inspecting soil cap integrity and sampling to determine whether uncapped areas remain below cleanup levels.
- Monitoring groundwater for site COCs to assess the interim performance of the Quendall remedy and ensure PRGs are met.

For all alternatives, monitoring activities described above would also be conducted after significant natural events, such as earthquakes; 5-year reviews will be required in perpetuity.

Alternatives

This section describes the alternatives evaluated by EPA. Alternatives 7 through 10 treat or remove DNAPL, which is expected to immediately and substantially reduce contaminant concentrations and allow for achievement of the RAO for groundwater in a reasonable timeframe. EPA believes that once the DNAPL is treated or removed, groundwater should meet cleanup levels within a reasonable timeframe (25 to 30 years), except arsenic, which naturally occurs at high levels at the site. The benzo(a)pyrene plume is closely associated with the occurrence of DNAPL; therefore, when the source is treated or removed, it is anticipated that the benzo(a)pyrene plume would be largely removed. Groundwater monitoring will be conducted as described in the Decision Diagram (see page 7). Additional details on decision criteria will be provided in the ROD. Groundwater monitoring will also include an evaluation of background arsenic concentrations.

The O&M costs and the total estimated present-value costs were developed using a 7 percent discount rate. The durations presented in this discussion include time for the remedial design.

Alternative 1—No Action

Estimated Capital Costs: $0

Estimated O&M Costs: $0

Total Estimated Present-Value Costs: $0

Estimated Construction Timeframe: 0 years

Estimated Time to Achieve RAOs: Not applicable

As required under the Superfund law, a "no action" alternative is evaluated to compare cleanup alternatives with baseline Site conditions. Under Alternative 1, no further action would be taken for OU1. Alternative 1 is not considered protective and does not meet ARARs or achieve RAOs.

Alternative 7—Solidification of DNAPL and Soil Capping

Estimated Capital Costs: $65,300,000

Estimated O&M Costs: $700,000

Total Estimated Present-Value: $66,000,000

Estimated Construction Timeframe: 4.8 years of design/construction

Estimated Time to Achieve RAOs: Ready in 5 years for anticipated reuse; RAO for groundwater expected to be met in reasonable timeframe since DNAPL is addressed

Alternative 7 includes the following components:

- Solidification of DNAPL to stabilize source material causing contamination in both the Shallow and Deep Aquifers (8.9 acres).
- Soil cap where COCs exceed PRGs in surface soil, to maintain protectiveness.

No active groundwater treatment is included in Alternative 7 because by stabilizing DNAPL in soil, contaminant concentrations will be immobilized, resulting in significant reductions to groundwater contaminants and achievement of PRGs in groundwater in a reasonable timeframe (25 to 30 years). Groundwater would be monitored to verify that the remedy is performing as intended (that is, concentrations of COCs are decreasing over time).

O&M would include cap inspections and groundwater monitoring. **Figure 7-1** provides an overview of Alternative 7.

Preferred Alternative 7a—In situ Smoldering Combustion and/or In situ Solidification of DNAPL, and Soil Capping

Estimated Capital Costs: $65,400,000

Estimated O&M Costs: $700,000

Total Estimated Present-Value: $66,100,000

Estimated Construction Timeframe: 5 years of design/construction

Estimated Time to Achieve RAOs: Ready in 5 years for anticipated reuse; RAO for groundwater expected to be met in reasonable timeframe since DNAPL is addressed

Alternative 7a for OU1 uses a phased approach that includes the application of *in situ* smoldering combustion and/or *in situ* solidification. Alternative 7a was added to the list of remedial alternatives by EPA following an effort to evaluate other *in situ* treatment technologies that may provide benefits in addition to solidification.

Self-sustaining smoldering combustion (combustion treatment) is a source control technology that targets and destroys non-aqueous phase liquid (NAPL) in place (*in situ*). It is a technology based on the principals of thermal destruction by smoldering combustion (analogous to charcoal burning in a grill). It can be used to treat NAPL above or below the water table.

In OU1, dense NAPL (DNAPL) is the primary source of contamination to soil and groundwater. By treating the DNAPL source in the subsurface with a technology such as self-sustaining combustion, groundwater is expected to meet MCLs within a reasonable timeframe.

EPA considers smoldering combustion to be more effective than solidification for addressing high strength source areas because:

- Significant DNAPL sources are destroyed instead of just immobilized.
- Groundwater cleanup levels, expected to be achieved in a reasonable timeframe, will be achieved sooner, as significant DNAPL sources are destroyed rather than solidified in place.
- Contaminants with the highest source strength are not brought to the surface during mixing, and vapors are controlled.

In summer 2018, EPA conducted a field pilot study of smoldering combustion and demonstrated that it can achieve reductions of 73 to greater than 99 percent for total petroleum hydrocarbons (TPH) and 80 to greater than 99 percent for lighter fractions, which are the contaminants impacting groundwater. These reductions are consistent with other thermal technologies and ISS. The study indicated that a single smoldering combustion ignition point where TPH concentrations are greater than

3,000 parts per million (ppm) has a radius of influence (treatment) of 7 feet (horizontally and vertically).

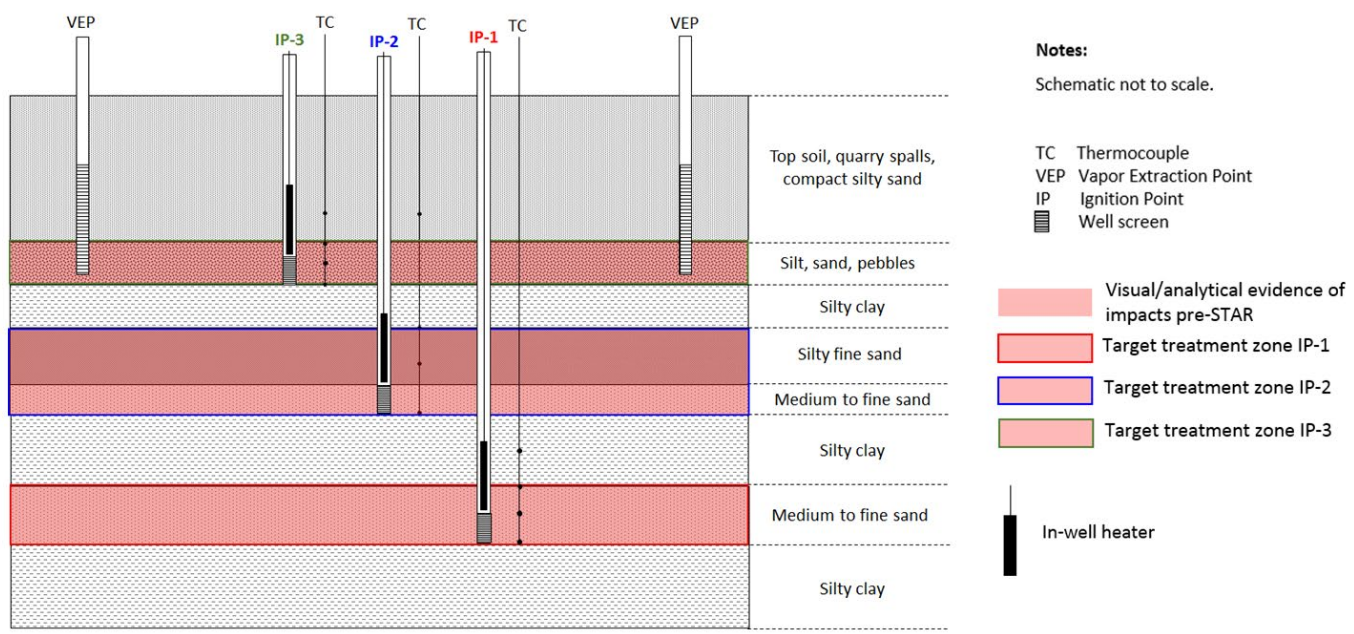
The remedy proposed will be implemented in two phases. During remedial design and prior to the implementation of the combustion treatment (Phase 1), an implementation plan would be developed to detail the implementation process (see flowcharts in Appendix A). This plan would be developed in coordination with technical experts from the Region and other EPA offices. This would include further field site characterization activities, groundwater modelling, and identification of flux-based groundwater treatment performance objectives. The plan and related activities will optimize source treatment implementation to ensure that actions will be effective and successful in treating DNAPL and achieving remedial action objectives.

Activities would include but not be limited to:

- Conducting a real-time field method survey and confirmatory soil core laboratory analysis to further refine and delineate the DNAPL subsurface architecture to identify and confirm suitable zones (soil total TPH concentrations >3,000 ppm) to target for treatment.
- Obtaining baseline groundwater flux measurements to further refine and identify zones to target for treatment.[5]
- Conducting groundwater modelling using the conceptual site model representative of post-treatment conditions to determine the mass transfer rate and estimate timeframes to achieve remedial action objectives.
- Optimizing performance objectives for the combustion treatment.

Conceptually, treatment using self-sustaining smoldering combustion uses equipment that can be moved around the site. When "parked" in one location, it can treat a sector (a circle with a diameter of about 400 feet, equaling about 125,000 square feet). Each sector may include approximately 100 cells. A cell contains 8 ignition points (IPs) spaced at 14 feet apart, covering 1,200 square feet. The 8 IPs in each cell would be activated at the same time. IPs would be installed at the base of each target treatment depth interval identified using real-time field soil core data. Multiple IPs may be required if the target treatment interval is more than 7 feet thick or if two or more treatment zones are stratigraphically separated by low-permeability materials thicker than 2.5 feet. After the cell is treated, then the same equipment would be moved to the next cell within the sector for treatment, and so on, until treatment in the sector is complete.

HOW SMOLDERING COMBUSTION TREATS MULTIPLE ZONES OF DNAPL



Based on the field pilot study at Quendall, one in-well heater may treat more than one DNAPL layer if the layers are within 1.5 to 2.5 feet of each other.

---

[5] Flux data will be used to assess remaining source strength and further refine estimated timeframes to achieve remedial action objectives and support adaptive management decisions regarding whether enough source treatment has occurred. Progress towards groundwater restoration would be assessed every 5 years and if data suggest that source control was insufficient to achieve groundwater cleanup levels in a reasonable timeframe (25 to 30 years), then EPA may consider additional actions.

Following combustion treatment of each cell, up to three soil intervals will be re-sampled, two with the highest pre-treatment TPH concentrations, and one between IPs, to confirm that no individual soil sample exceeds 3,000 ppm TPH. As part of the adaptive approach, if soil intervals are found that still exceed 3,000 ppm after the first round of combustion treatment (e.g., in highly heterogeneous areas), an additional ignition point may be installed to re-treat at that location. The performance of combustion treatment will be evaluated after each sector and will undergo an optimization evaluation before proceeding to the next sector.

A key component of an adaptive approach at Quendall is the inclusion of a second phase that uses another technology (i.e., *in situ* solidification). Depending on how the Phase 1 technology (i.e., smoldering combustion treatment) performs, the second phase may or may not be needed. Success of combustion treatment will be evaluated at each sector. If success is achieved on a sector, then subsequent combustion treatment would proceed in suitable areas moving downgradient toward Lake Washington, and the conceptual site model would be updated and treatment optimized as the remedy progresses. If combustion treatment is determined unsuccessful within a sector, then an evaluation will be made of whether combustion treatment should continue to other locations or be discontinued.

After it is determined that all combustion treatment is completed, which could occur at any point in the process of implementing all sectors initially identified in the design for combustion treatment, a relative comparison of post-treatment of groundwater flux data with the baseline groundwater flux data will be used to determine if Phase 2 *in situ* solidification is needed for additional source treatment.

Using a combination of smoldering combustion and/or solidification is superior to simply using solidification (Alternative 7), which would result in a very large solidified block covering nearly 9 acres to depths up to 36 feet. The block would alter groundwater and surface water flow and may create surface water ponding, potentially causing problems for future development.

For the purposes of developing a cost estimate, it is assumed that smoldering combustion will destroy approximately 60 percent of the significant DNAPL sources and solidification will be used to treat the remainder. As part of the implementation strategy, the actual areas for smoldering combustion will be refined with additional pre-treatment characterization during remedial design (Phase 1). If determined necessary to further reduce source strength following combustion, solidification will treat the lesser contaminated areas that are not amenable to combustion (Phase 2). The need for additional source treatment following combustion, will be determined based on passive flux monitoring results and soil core characterization data.

Smoldering Combustion Treatment Process

STEP 1:

Characterization of soil cores
↓
>3,000 ppm TPH
↓
Smoldering combustion treatment
↓
Post-treatment soil cores
(visual and analytical confirmation <3,000 ppm TPH)

STEP 2:

Passive flux monitoring – evaluate incremental reductions

STEP 3:

Determine if solidification is needed in discrete untreated areas

Like Alternative 7, Alternative 7a would include a soil cap where COCs exceed PRGs in surface soil (to maintain protectiveness). No active groundwater treatment is included in Alternative 7a because, aggressive treatment of the significant DNAPL sources is expected to immediately and substantially reduce contaminant concentrations and allow for achievement of PRGs in groundwater in a reasonable timeframe (25 to 30 years). Post-treatment data will be used to assess remaining source strength and associated groundwater impacts at various stages of the remedy, and the remedy effectiveness will be optimized as part of an adaptive site management approach. Groundwater would be monitored to verify that the remedy is performing as intended (that is, concentrations of COCs are decreasing over time).

O&M would include cap inspections and groundwater monitoring. **Figure 7-2** provides an overview of Alternative 7a.

Alternative 8—Removal and Ex Situ Thermal Treatment of DNAPL, and Soil Capping

Estimated Capital Costs: $99,400,000

Estimated O&M Costs: $600,000

Total Estimated Present-Value: $100,000,000

Estimated Construction Timeframe: 4.3 years of design/construction

Estimated Time to Achieve RAOs: Ready in 5 years for anticipated reuse; RAO for groundwater expected to be met in reasonable timeframe since DNAPL is addressed

Alternative 8 is similar to Alternatives 7 and 7a in that it addresses DNAPL and includes a soil cap. However, instead of *in situ* treatment, Alternative 8 includes:

- Removal of DNAPL by excavation to address source material causing contamination to both the Shallow and Deep Aquifers (8.9 acres).
- Onsite ex situ thermal treatment of the excavated materials (210,000 cubic yards); contaminants in the off-gas would be incinerated.
- Shoring and dewatering to facilitate the excavation.
- Soil cap where COCs exceed PRGs in surface soil, to maintain protectiveness.

It is assumed that thermal treatment of the excavated soil would remove DNAPL, but the treated soil could still exceed PRGs and require containment (such as capping).

No active groundwater treatment is included in Alternative 8 because removal of the DNAPL is expected to immediately and substantially reduce contaminant concentrations and allow for achievement of PRGs in groundwater in a reasonable timeframe (25 to 30 years). Groundwater would be monitored to verify that the remedy is performing as intended (that is, concentrations of COCs are decreasing over time).

O&M would include cap inspections and groundwater monitoring. **Figure 7-3** provides an overview of Alternative 8.

Alternative 9—Solidification and Removal/Ex Situ Thermal Treatment of DNAPL and Contaminated Soil, and Soil Capping

Estimated Capital Costs: $218,600,000

Estimated O&M Costs: $600,000

Total Estimated Present-Value: $219,200,000

Estimated Construction Timeframe: 9.3 years of design/construction

Estimated Time to Achieve RAOs: Ready in 10 years for anticipated reuse; RAO for groundwater expected to be met in reasonable timeframe since DNAPL and contaminated aquifer materials are addressed

Alternative 9 is more aggressive than Alternatives 7, 7a, and 8, and includes the following components:

- Removal of shallow upland DNAPL and contaminated soil (to 15 feet bgs) by excavation to address media causing contamination to the Shallow Aquifer (14.2 acres).
- Onsite ex situ thermal treatment of the excavated materials (340,000 cubic yards); contaminants in the off-gas would be incinerated.
- Shoring and dewatering to facilitate the excavation.
- Solidification of deep upland DNAPL and contaminated soil (14.2 acres).
- Soil cap where COCs exceed PRGs in surface soil, to maintain protectiveness.

No active groundwater treatment is included in Alternative 9 because treatment and/or removal of the DNAPL and contaminated soil is expected to immediately and substantially reduce and/or immobilize contaminant concentrations and allow for achievement of PRGs in groundwater in a reasonable timeframe (25 to 30 years). Groundwater would be monitored to verify that the remedy is performing as intended (that is, concentrations of COCs are decreasing over time).

O&M would include cap inspections and groundwater monitoring. **Figure 7-4** provides an overview of Alternative 9.

Alternative 10—Removal and Ex Situ Thermal Treatment of DNAPL and Contaminated Soil, Soil Capping, and Groundwater Extraction and Treatment

Estimated Capital Costs: $301,100,000

Estimated O&M Costs: $8,200,000

Total Estimated Present-Value: $309,300,000

Estimated Construction Timeframe: 10.8 years of design/construction

Estimated Time to Achieve RAOs: Ready in 12 years for anticipated reuse; RAO for groundwater expected to be met in reasonable timeframe since DNAPL and contaminated aquifer materials are addressed, and pump and treat provides a polishing step to accelerate the timeframe

Alternative 10 is the most aggressive alternative and includes the following components:

- Removal of DNAPL and contaminated soil by excavation to address media causing contamination to both the Shallow Aquifer and Deep Aquifer (14.2 acres).
- Onsite ex situ thermal treatment of the excavated materials (705,000 cubic yards); contaminants in the off-gas would be incinerated.
- Temporary sheet pile, shoring, and dewatering to facilitate the excavation.
- Soil cap where COCs exceed PRGs in surface soil, to maintain protectiveness.
- Groundwater extraction and onsite treatment to address contamination remaining at depth below excavated areas and speed restoration timeframe.

The addition of deep groundwater extraction and treatment is considered a polishing step, not anticipated to have a significant impact since most of the contamination is addressed via removal of the source material and contaminated aquifer materials.

O&M would consist of pumping and treating groundwater, groundwater monitoring, and cap inspections. **Figure 7-5** provides an overview of Alternative 10.

8. Comparative Analysis of Alternatives

This section summarizes the comparative analysis of alternatives using the threshold and balancing criteria listed previously.[6] More detailed analyses can be found in the FS report (Aspect and Arcadis, 2016).

Overall Protection of Human Health and the Environment

Alternative 1 does not satisfy the threshold criterion for overall protection of human health and the environment.

Alternatives 7 through 10 treat or remove DNAPL, the primary source of groundwater contamination. While there are some uncertainties regarding restoration timeframes for Alternatives 7 through 10, it is expected that these alternatives would achieve PRGs within a reasonable amount of time (25 to 30 years). The residual dissolved groundwater plume (benzene and naphthalene) remaining after source treatment is expected to be reduced by >86% by volume and >98% by mass (FS model, Table A-7). Groundwater monitoring will be conducted to verify that concentrations are declining and that PRGs will be met.

Alternative 7 would solidify DNAPL, limiting leachability, but does not remove the contaminants. Alternatives 7a through 10 include either *in situ* thermal destruction (smoldering combustion) in addition to solidification (Alternative 7a) or removal followed by *ex situ* thermal destruction (Alternatives 8 through 10). Institutional controls that specifically limit the use of groundwater as a drinking water source and vapor intrusion assessment or engineering controls for vapor intrusion may be required for any new construction until monitoring demonstrates that it is no longer needed.

Compliance with Applicable or Relevant and Appropriate Requirements

Preliminary ARARs are discussed in detail in the FS report (Aspect and Arcadis, 2016). Key ARARs for OU1 include the Federal Safe Drinking Water Act and Washington State Dangerous Waste Regulations. Identifying ARARs is an iterative process, which will continue until final ARAR determinations are made by EPA during preparation of the ROD.

Alternative 1 does not satisfy the threshold criterion for compliance with ARARs.

Alternatives 7 through 10 would satisfy the threshold criterion for compliance with ARARs, and while there is uncertainty about the ability of Alternatives 7 to 10 to meet MCLs everywhere in groundwater, EPA expects that when the DNAPL in soil is stabilized, destroyed, or removed, the benzene and cPAH mass in groundwater will be reduced up to 95 to 100 percent. This assessment is based on Site groundwater data for benzene and cPAHs (COCs with MCLs) that indicate a close association of MCL exceedances with the occurrence of DNAPL. EPA also expects that when the DNAPL in soil is removed, arsenic will be addressed, as the presence of DNAPL in the subsurface allows arsenic to more readily leach from soil (at naturally-occurring concentrations) into the groundwater, and is the primary reason that arsenic is above the MCL in groundwater at the Site. There is no MCL for naphthalene, the other primary COC in groundwater; however, EPA expects that when the DNAPL in soil is removed, the naphthalene plume will also dissipate in a reasonable time frame (25 to 30 years).

Long-term Effectiveness and Permanence

The long-term effectiveness and permanence rating is based on consideration of both the magnitude of residual risk associated with any contamination remaining at the Site following implementation of the remedy and the reliability of controls. The magnitude of residual risk was evaluated in the context of achieving RAOs, and considered the total volume of DNAPL removed or treated in each alternative.

A high rating was given to Alternatives 7 through 10, all of which would remove or treat DNAPL. Alternative 7a employs a smoldering combustion technology to destroy significant DNAPL sources *in situ* while avoiding the significant cost of contaminated soil removal included in Alternatives 9 and 10. Alternatives 9 and 10 remove or treat more contaminated soil, providing the greatest long-term effectiveness and permanence, but at the highest cost.

---

[6] Alternatives 2 through 10, excluding Alternative 7a, underwent a comparative analysis in the FS (Aspect and Arcadis, 2016). Alternative 7a was evaluated by EPA following the FS, as documented in EPA (2017).

Nine Superfund Evaluation Criteria:

In accordance with CERCLA and Section 300.430(f)(5)(i) of the NCP, EPA evaluates remedial alternatives using the following nine criteria:

- **Threshold Criteria—**These criteria specify what an alternative must meet to be eligible for selection as a remedial action:
  - **Overall protection of human health and the environment—**Determines whether a remedial action eliminates, reduces, or controls threats to public health and the environment through treatment, engineering controls (such as fencing), or institutional controls (such as deed restrictions).
  - **Compliance with ARARs—**In addition to ensuring that human and ecological receptors are protected, remedial actions to cleanup a site must attain legally applicable, or relevant and appropriate federal, and state standards and requirements unless such ARARs are waived under CERCLA Section 121(d)(4).
- **Balancing Criteria—**These criteria represent technical considerations upon which the detailed analysis is based:
  - **Long-term effectiveness and permanence—**Considers the ability of a remedial alternative to maintain protection of human health and the environment over time and the reliability of such protection.
  - **Reduction of toxicity, mobility, and volume through treatment—**Evaluates using treatment to reduce the harmful effects of contaminants and the ability of contaminants to move in the environment. More specific considerations include the amount of hazardous substances that would be destroyed, treated, or recycled; the degree to which treatment is irreversible; and the degree to which treatment reduces the inherent hazards posed by principal threat waste.
  - **Short-term effectiveness—**Considers both the length of time required to implement a remedial alternative and the risk that constructing and maintaining the remedy would pose to workers, residents, and the environment until cleanup levels are achieved.
  - **Implementability—**Considers the technical and administrative feasibility of implementing a remedial alternative, such as relative availability of goods and services. This criterion also considers whether the technology has been used successfully at other similar sites.
  - **Cost—**Considers both estimated capital costs and long-term operations and maintenance costs. Costs are expected to be accurate within a range of +50 to -30 percent.
- **Modifying Criteria—**These criteria are evaluated at the end of the public review and comment period; they are not discussed in this Proposed Plan.
  - **State and Tribal acceptance—**Considers whether the state and tribes support EPA's analyses and recommendations of the FS report (Aspect and Arcadis, 2016) and the Proposed Plan.
  - **Community acceptance—**Considers whether the local community agrees with EPA's analyses and recommendations of the FS report (Aspect and Arcadis, 2016) and the Proposed Plan.

Reduction of Toxicity, Mobility, or Volume Through Treatment

This balancing criterion evaluates the degree to which each remedial alternative reduces toxicity, mobility, or volume through treatment. *In situ* solidification of upland DNAPL (Alternatives 7 and 9), *in situ* thermal destruction of significant DNAPL sources with *in situ* solidification if needed for additional source treatment (Alternative 7a), and onsite *ex situ* thermal treatment of DNAPL (Alternatives 8, 9, and 10) are the three primary treatment approaches considered for DNAPL. In addition, a groundwater pump-and-treatment system to actively treat Site groundwater along the shoreline (Alternative 10) was considered.

Alternatives 7 through 10 received a high rating for this criterion by greatly reducing the volume and mass flux of contaminated groundwater through treatment or removal of DNAPL. Inclusion of treatment by thermal destruction technologies (Alternatives 7a, and 8 through 10) was rated higher than *in situ* solidification (Alternative 7, and select use in Alternative 9) because technologies that destroy the COCs provide more reduction of toxicity, mobility, and volume than technologies that bind COCs. Alternative 7a provides *in situ* thermal destruction of COCs in high source strength areas and avoids the significant cost of soil excavation required by Alternatives 8 through 10. Alternative 10 would achieve the greatest reduction in groundwater plume volume given the inclusion of a groundwater pump-and-treat system.

Short-Term Effectiveness

The remedial design for each alternative would include measures to minimize impacts to workers, community, and environment during the remedy implementation phase. The primary difference between alternatives is the duration of construction and the potential for exposures if construction equipment and/or protective controls fail, a risk that generally increases with the quantity of contaminated material removed or handled.

Alternative 7a receives a high rating for this criterion as it has a relatively short design/construction duration (5 years) and presents the lowest risk to workers, the community, and the environment due to limited handling of DNAPL-containing materials above ground.

A moderate rating was given to Alternative 7. While it has a design/construction duration of approximately 4.8 years, DNAPL is only addressed through *in situ* solidification, which has more short-term impacts relative to Alternative 7a, but fewer short-term impacts than the *ex situ* thermal treatment options of Alternatives 8 through 10, which received a low rating for this criterion. In addition to the greater potential for exposure through a higher level of material handling for these last three alternatives, the construction period is also longer, ranging from approximately 4.3 years for Alternatives 8 to 9 and nearly 11 years for Alternatives 9 and 10, respectively.

Implementability

All alternatives pose technical implementation challenges. All alternatives use proven technologies that have been implemented at other similar sites. Bench and/or pilot testing of *in situ* solidification would be carried out prior to implementation of Alternatives 7, 7a, and 9; however, the need for these preliminary tests are not considered to be implementability concerns.

For Alternative 7a, a laboratory-scale demonstration and field pilot study have both confirmed that NAPL-impacted soil from the Site can be effectively treated by smoldering combustion (CH2M, 2018; Savron, 2018).

The deep excavations and *ex situ* thermal treatment included in Alternatives 8 through 10 would have substantially increased complexity. The excavations would require robust shoring and dewatering systems, including 95-foot-long sheet piles for Alternative 10, which are not readily available and could result in transportation challenges. Thermal treatment requires air emission controls and extensive monitoring.

During remedial design, all alternatives would require coordination with numerous federal and state regulatory agencies to ensure that all ARARs, policies, and regulations are met. Alternatives with longer construction durations and/or more construction elements would generally require more administrative coordination and have a greater potential for technical problems and schedule delays.

Alternatives 7 and 7a are rated moderate for implementability. Alternatives 8 through 10 are rated low for implementability due to the significantly greater challenges of shoring and dewatering extensive excavations and providing onsite thermal treatment of a large volume of material. Longer durations of construction activities would also perpetuate severe technical and administrative challenges.

Cost Estimates and Discount Rates:

The cost estimates in this Proposed Plan are present-value costs, calculated using a 7 percent discount rate, as required by EPA policy and guidance. Applying a discount rate to calculate the present value of future construction costs impacts the overall cost estimate and has the greatest effect on alternatives with high costs in the future.

Cost

Table 8-1 presents costs for Alternatives 7 through 10. The table shows the present-value cost of each alternative, calculated using a 7 percent discount rate.

Appendix B presents alternative cost assumptions.

9. Preferred Alternative

This section presents EPA's Preferred Alternative for OU1 (uplands) of the Site and the basis for the agency's selection. The goal of the remedy-selection process, as stated in 40 *Code of Federal Regulations* 300.430(a)(1)(i) of the NCP, is to select remedies that protect human health and the environment, maintain protection over time, and minimize untreated waste.

Preferred Alternative 7a

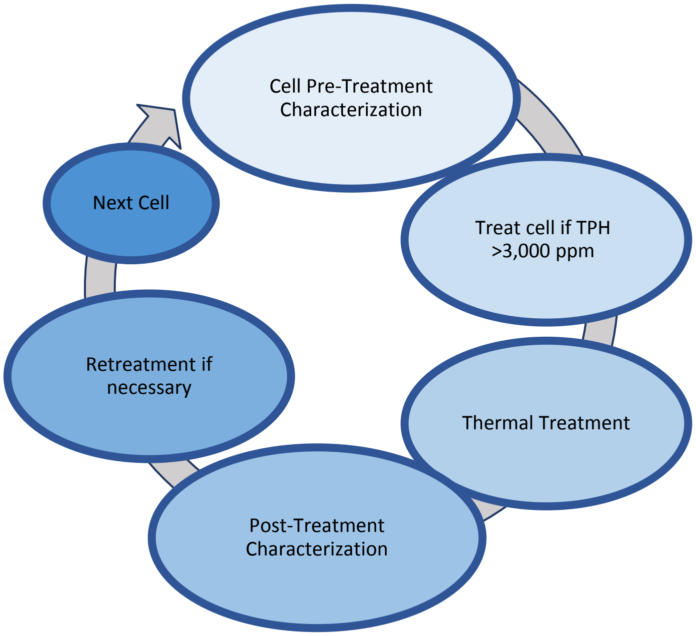
EPA proposes Alternative 7a as the Preferred Alternative for OU1. The primary objective of this alternative is to destroy or solidify significant DNAPL sources contributing contamination to both the Shallow and Deep Aquifers.

Alternative 7a includes the following components for OU1:

- Use of a phased approach that includes *in situ* smoldering combustion and/or *in situ* solidification to treat significant DNAPL sources causing contamination in both the Shallow and Deep Aquifers (8.9 acres).
- Soil cap where COCs exceed PRGs in surface soil, to maintain protectiveness.
- Institutional controls to help ensure the effectiveness of engineering controls.

Components of smoldering combustion (Phase 1) include the following:

- Temporary installation of electrically powered heaters and air injectors to initiate and promote combustion of subsurface DNAPL and propagation of the smoldering combustion front.
- Installation of temporary air injection wells to promote combustion and subsurface propagation of the smoldering combustion front.
- Collection and treatment of soil vapors to minimize the potential for nuisance odor migration or fugitive emissions during treatment.
- Monitoring of subsurface conditions before, during, and after smoldering combustion treatment to assess performance.



Components of solidification (Phase 2, if needed) include the following:

- Use of a large-diameter shrouded auger to mix Portland cement into coal tar-contaminated materials.
- Collection of vapors from the auger shroud and treatment with a thermal oxidizer.
- Installation of a temporary enclosure for solidification areas near properties boundaries to control nuisance odors.
- Installation of perimeter real-time air monitoring stations.

The estimated design/construction timeframe for Alternative 7a is 5 years, at which time the Site would be ready for anticipated reuse.

No active groundwater treatment is included in Alternative 7a because aggressive treatment of the significant DNAPL sources in soil is expected to immediately and substantially reduce contaminant concentrations and allow for achievement of the RAO for groundwater in a reasonable timeframe.

O&M would include cap inspections and groundwater monitoring.

Figure 9-1 presents the Preferred Alternative. The estimated cost for Alternative 7a is $66.1 million.[7] The FS-level accuracy range, based on -30/+50 percent, using a discount rate of 7 percent, is $46.3 to $99.2 million.

Rationale for Selection of Preferred Alternative

To address the significant DNAPL sources and achieve the RAOs, Alternative 7a meets the threshold criteria and provides the best tradeoffs among the balancing criteria, as compared to other upland FS alternatives as follows:

- With the incorporation of smoldering combustion, Alternative 7a would elevate overall protectiveness above Alternative 7 in that high source strength contaminants are permanently destroyed. The remedy is more effective in the short-term as contaminants in thermally treated areas are not brought to the surface, minimizing exposure to site workers. In addition, both smoldering combustion treatment and solidification incorporate vapor capture for the control of toxic and nuisance odors. None of the significant DNAPL sources would be left in place onsite as untreated waste.
- Alternative 7a can be designed to meet the substantive requirements of the ARARs. While there is uncertainty about the ability of Alternative 7a to meet MCLs everywhere in groundwater, EPA believes that if the significant DNAPL sources in soil are destroyed, then the benzene and cPAH plumes should be effectively addressed. Groundwater monitoring will be required to ensure the protectiveness of the remedy and continued until groundwater achieves MCLs.
- Compared with Alternative 7, less reliance on institutional controls is also expected for Alternative 7a as high source strength contaminants are permanently destroyed versus immobilized.

---

[7] Calculated using a 7 percent discount rate, as required by EPA policy and guidance.

- Alternative 7a satisfies the statutory preference for treatment.
- Alternative 7a satisfies the requirement that remedial alternatives consider using an innovative technology when such technology offers the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse impacts than other available approaches, or lower costs for similar levels of performance than demonstrated technologies.
- Alternatives 8, 9, and 10 all include more expansive work that realizes a nominal incremental benefit beyond that provided by Alternative 7a with respect to overall protection of human health and the environment. Alternative 8 would cost more than half again that of Alternative 7a, and while Alternatives 9 and 10 would be expected to result in reduced timeframes to achieve the groundwater MCLs in OU1, the construction duration would nearly double, and the costs would be several times that of Alternative 7a.

Preferred Alternative Summary

Based on the information currently available, the Preferred Alternative described in this Proposed Plan is a final action that meets the threshold criteria and provides the best balance of tradeoffs with respect to the balancing and modifying criteria. EPA expects the Preferred Alternative to satisfy the following statutory requirements of CERCLA §121(b): (1) be protective of public health and the environment; (2) attain ARARs; (3) be cost-effective; (4) use permanent solutions and alternative treatment (or resource recovery) technologies to the maximum extent practicable; and (5) satisfy the preference for treatment as a principal element, or explain why the preference for treatment will not be met. The OU1 Preferred Alternative will achieve substantial risk reduction by both treating the source materials constituting principal threats at the site and providing safe management of remaining material. This combination reduces risk sooner and costs less than the other alternatives.

10. References

Anchor QEA, LLC and Aspect Consulting, LLC (Anchor QEA and Aspect). 2012. *Final Remedial Investigation Report, Quendall Terminals Site, Renton, Washington.* Prepared for U.S. Environmental Protection Agency, Region 10, on behalf of Altino Properties, Inc and J.H. Baxter & Company. September. Accessed July 15, 2018. https://semspub.epa.gov/work/10/500010867.pdf.

Aspect Consulting, LLC and Arcadis US (Aspect and Arcadis). 2016. *Feasibility Study, Quendall Terminals Site.* Prepared for: U.S. Environmental Protection Agency, Region 10 on behalf of Altino Properties and J.H. Baxter & Co. December. Accessed July 15, 2018. https://semspub.epa.gov/work/10/100043827.pdf.

Century Pacific, LLLP. 2012. *Quendall Terminals: Environmental Cleanup, Habitat Restoration, Economic and Waterfront Sustainable Development*. Accessed July 15, 2018. http://www.quendallterminals.com/contact.html.

CH2M HILL Engineers, Inc. (CH2M). 2018. *Quendall Terminals Superfund Site, Results from the Self-Sustaining Treatment for Active Remediation Bench-Scale Treatability Study.* Prepared for U.S. Environmental Protection Agency, Region 10. May 30.

Grette Associates, LLC (Grette). 2016. *Baseline Habitat Technical Memorandum for Quendall Terminals*. October 18.

Savron. 2018. *Self-sustaining Treatment for Active Remediation (STAR) Pre-Design Evaluation (PDE) Report, Quendall Terminals, Renton, Washington.* October 18.

U.S. Environmental Protection Agency (EPA). 2017. Addition of STAR Technology for Quendall Terminal Site. From Kathryn Cerise, EPA Region 10, Office of Environmental Cleanup, to Site File. September 11. Accessed July 15, 2018. https://semspub.epa.gov/work/10/100101660.pdf

Washington State Department of Ecology (Ecology). 1994. *Natural Background Soil Metals Concentrations in Washington State*. Publication 94-115. October. Accessed July 15, 2018. https://fortress.wa.gov/ecy/publications/summarypages/94115.html.

Abbreviations and Acronyms

§	Section
µg/L	micrograms per liter
Anchor QEA	Anchor QEA LLC
ARAR	Applicable or Relevant and Appropriate Requirement
Arcadis	Arcadis US
Aspect	Aspect Consulting, LLC
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CH2M	CH2M HILL Engineers, Inc.
COC	contaminant of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CWA	Clean Water Act
DNAPL	dense nonaqueous phase liquid
Ecology	Washington State Department of Ecology
ELCR	excess lifetime cancer risk

EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
FS	Feasibility Study
HHRA	human health risk assessment
HI	hazard index
HPAH	high-molecular weight polycyclic aromatic hydrocarbon
HQ	hazard quotient
IP	ignition point
ISS	in situ solidification
LPAH	low molecular weight polycyclic aromatic hydrocarbon
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
NAPL	nonaqueous-phase liquid
NCP	National Contingency Plan
O&M	operations and maintenance
OU	Operable Unit
PAH	polycyclic aromatic hydrocarbon
ppm	parts per million
PRG	preliminary remediation goal
Proposed Plan	Proposed Plan for the Quendall Terminals Superfund Site, Operable Unit 1
PTW	principal threat waste
RAO	remedial action objective
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
ROD	Record of Decision
Site	Quendall Terminals Superfund Site
STAR	Self-sustaining Treatment for Active Remediation
TPH	total petroleum hydrocarbon

Glossary of Terms

Applicable or Relevant and Appropriate Requirements (ARARs):
Applicable requirements, as defined in 40 CFR § 300.5, are those clean-up standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by the state in a timely manner and that are more stringent than federal requirements may be applicable.

Relevant and appropriate requirements, as defined in 40 CFR § 300.5, means those clean-up standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not “applicable” to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at a CERCLA site that their use is well suited to the particular site. Only those state standards that are identified by the state in a timely manner and that are more stringent than federal requirements may be relevant and appropriate.

Chemicals of concern (COCs): Site-specific chemicals that are identified for evaluation in the site assessment process that pose unacceptable human health or ecological risks.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA):
A federal law, commonly referred to as the “Superfund” Program. CERCLA provides for clean-up and emergency response in connection with existing inactive hazardous waste disposal sites that endanger public health and safety or the environment.

Dense Nonaqueous Phase Liquid (DNAPL): An organic substance in liquid form that is relatively insoluble in water and denser than water. DNAPLs tend to sink vertically through sand and gravel aquifers and pool above an underlying, less-permeable layer.

Exposure Pathway: The pathway for a chemical from the source of contamination to the exposed individual or receptor, such as dermal contact, ingestion, or inhalation.

Feasibility Study (FS): A comprehensive process to screen, develop, and evaluate potential alternatives for remediating contamination.

Groundwater: Subsurface water that occurs in fully saturated soil and geologic formations.

Hazard Index (HI): Summation of the noncancer risks to which an individual is exposed. An HI value of 1.0 or less indicates that noncancer adverse human health effects are unlikely to occur.

Human Health Risk Assessment (HHRA): An assessment of the risks posed to human health through potential contaminant exposures, based on site-specific exposure scenarios.

Institutional Controls: Non-engineered controls, such as administrative and legal controls, that help minimize human exposure to contamination and/or protect the integrity of the remedy.

In Situ Solidification (ISS): A treatment process that immobilizes contaminants by mixing amendments into soil using a large-diameter auger. The amendments solidify the soil into a stabilized mass, similar to a concrete block.

Operation and Maintenance (O&M): Activities conducted after the remedial action to maintain the effectiveness of the response action.

Operable Unit: A designation based on geography or other characteristics that defines a specific area of a site. The cleanup of a site can be divided into a number of operable units and enables the cleanup process to address geographical portions of the site, specific site problems, and proceed with cleanup at different times.

Principal Threat Wastes (PTW): Source materials that generally cannot be reliably contained or would present a significant risk to human health or the environment should an exposure occur.

Proposed Plan: A plan for site remedial action or other action that is available to the public for comment.

Radius of Influence: The distance away from a center point that is affected by an action at the center point.

Receptors: Humans, animals, or plants that may be exposed to risks from contaminants present at a given site.

Record of Decision (ROD): A legal document that describes the clean-up action or alternative selected for a site, the basis for choosing that alternative, and public comments on the selected alternative.

Remedial Action Objectives (RAOs): Specific goals for protecting human health and the environment. RAOs are developed by evaluating ARARs protective of human health and the environment and the results of remedial investigations and risk assessments.

Preliminary Remediation Goals (PRGs): Clean-up goals developed during the cleanup planning process based on the ARARs. They also are used during analysis of remedial alternatives in the remedial investigation/feasibility study (RI/FS).

Remedial Investigation (RI): Extensive technical study conducted to characterize the nature and extent of contamination and the risks posed by contaminants present at a site.

Residual Risk: Hazards which remain on site after a remedial action has been completed.

Self-Sustaining Treatment for Active Remediation (STAR): A remediation technology that uses a smoldering combustion reaction to destroy certain types of oily contaminants like creosote and coal tar. The combustion process can be used to treat DNAPL above or below the water table by converting the contaminants into carbon dioxide, carbon monoxide, and water, which are then captured and treated.

U.S. Environmental Protection Agency (EPA): The federal agency responsible for administration and enforcement of CERCLA (and other environmental statutes and regulations), and with final approval authority for the selected remedial alternative.

Vapor Intrusion: The movement of volatile chemicals in soil and groundwater into indoor air.

Tables

Table 3-1. Contaminant Concentrations in Soil

Proposed Plan for the Quendall Terminals Superfund Site, Operable Unit 1

Contaminant of Concern	PRG (mg/kg)	PRG Source	Number of Detections/ Samples	Number of Detects Exceeding PRGs	Number of Non-Detects Exceeding PRGs	Average Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)
Metals							
Arsenic	7.3	Ecology, 1994*	44/81	21	2	12	110
Chromium	51	ERA RBC HQ=1	10/10	2	--	35	65.3
Lead	37	ERA RBC HQ=1	50/66	17	--	106	1,120
Polycyclic Aromatic Hydrocarbons							
2-Methylnaphthalene	240	HHRA RBC HQ=1	63/106	6	--	166	5,200
Benz(a)anthracene	1.1	HHRA RBC 10^{-6}	81/106	47	2	70	1,500
Benzo(a)pyrene	0.11	HHRA RBC 10^{-6}	81/106	76	3	97	2,100
Benzo(b)fluoranthene	1.1	HHRA RBC 10^{-6}	82/106	48	2	74	1,700
Benzo(k)fluoranthene	11	HHRA RBC 10^{-6}	80/106	29	1	58	1,400
Chrysene	110	HHRA RBC 10^{-6}	85/106	9	--	106	2,500
Dibenz(a,h)anthracene	0.11	HHRA RBC 10^{-6}	53/106	44	14	16	190
Indeno(1,2,3-c,d)pyrene	1.1	HHRA RBC 10^{-6}	73/106	43	3	53	1,500
Naphthalene	3.8	HHRA RBC 10^{-6}	80/117	38	1	308	11,000
Total cPAHs	0.11	HHRA RBC 10^{-6}	85/106	80	1	119	2,751
Total HPAHs	3.7	ERA RBC HQ=1	88/106	62	--	904	21,955
Total LPAHs	65	ERA RBC HQ=1	93/106	31	--	704	25,820
Volatile Organics							
Ethylbenzene	5.8	HHRA RBC 10^{-6}	15/46	4	--	9.9	92

Notes:

Based on soil data to depths of 15 feet or less.

*Washington State Department of Ecology. 1994. *Natural Background Soil Metals Concentrations in Washington State*. Publication 94-115. October.

cPAH = carcinogenic PAH – calculated based on benzo(a)pyrene equivalents

ERA RBC HQ=1 = Ecological Risk Assessment Risk-Based Concentration, based on noncancer hazard quotient of 1.

HHRA RBC 10^{-6} = Human Health Risk Assessment Risk-Based Concentration based on cancer risk of 1 x 10^{-6}.

HHRA RBC HQ=1 = Human Health Risk Assessment Risk-Based Concentration based on noncancer hazard quotient of 1.

HPAHs = high-molecular-weight PAHs (benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[g,h,i]perylene, chrysene, dibenz[a,h]anthracene, indeno[1,2,3-c,d]pyrene, fluoranthene, and pyrene)

LPAH = low-molecular-weight PAH (acenaphthylene, acenaphthene, anthracene, fluorene, naphthalene, and phenanthrene)

mg/kg = milligram per kilogram

PAH = polynuclear aromatic hydrocarbon

PRG = Preliminary Remediation Goal

Table 3-2. Contaminant Concentrations in Groundwater

Proposed Plan for the Quendall Terminals Superfund Site, Operable Unit 1

Contaminant of Concern	PRG (µg/L)	PRG Source	Number of Detections/ Samples	Number of Detects Exceeding PRGs	Number of Non-Detects Exceeding PRGs	Average Detected Concentration (µg/L)	Maximum Detected Concentration (µg/L)
Metals							
Arsenic	10	MCL	25/25	10	--	32	389
Polycyclic Aromatic Hydrocarbons							
2-Methylnaphthalene	36	HHRA RBC HQ=1	25/25	13	--	278	2,200
Acenaphthene	530	HHRA RBC HQ=1	21/25	--	--	103	390
Benz(a)anthracene	0.03	HHRA RBC 10^{-6}	5/25	4	20	41	170
Benzo(a)pyrene	0.2	MCL	3/25	3	12	97	290
Benzo(b)fluoranthene	0.25	HHRA RBC 10^{-6}	4/25	2	12	53	210
Benzo(k)fluoranthene	2.5	HHRA RBC 10^{-6}	4/25	1	9	53	210
Chrysene	25	HHRA RBC 10^{-6}	4/25	1	5	68	270
Dibenz(a,h)anthracene	0.025	HHRA RBC 10^{-6}	1/25	1	23	0.13	0.13
Fluoranthene	800	HHRA RBC HQ=1	9/25	--	--	61	250
Fluorene	290	HHRA RBC HQ=1	18/25	--	--	55	290
Indeno(1,2,3-c,d)pyrene	0.25	HHRA RBC 10^{-6}	1/25	1	13	0.45	0.45
Naphthalene	0.17	HHRA RBC 10^{-6}	27/28	26	1	2,637	16,000
Pyrene	120	HHRA RBC HQ=1	10/25	2	--	86	330
Total cPAHs	0.2	MCL	6/25	5	10	65	362
Semivolatile Organics							
Dibenzofuran	7.9	HHRA RBC HQ=1	15/25	12	--	44	180
Volatile Organics							
Benzene	5	MCL	15/28	13	--	3,337	31,000
Ethylbenzene	700	MCL	15/28	4	--	694	2,900
Total Xylenes	10,000	MCL	16/28	1	--	1,433	10,600

Notes:

Based on data collected during the 2008/2009 Remedial Investigation (RI).

µg/L = micrograms per liter

cPAH = carcinogenic PAH – calculated based on benzo(a)pyrene equivalents

HHRA RBC 10^{-6} = Human Health Risk Assessment Risk-Based Concentration based on cancer risk of 1×10^{-6}.

HHRA RBC HQ=1 = Human Health Risk Assessment Risk-Based Concentration based on noncancer hazard quotient of 1.

MCL = Maximum Contaminant Level

PAH = polynuclear aromatic hydrocarbon

PRG = Preliminary Remediation Goal

Table 5-1. Summary of Risk and Hazard Estimates for Human Exposure Scenarios

Proposed Plan for the Quendall Terminals Superfund Site, Operable Unit 1

		Human Exposure Scenarios					
		Residential		**Occupational Worker**		**Construction/ Excavation Worker**	
Exposure Medium	**Exposure Route**	**HI**	**ELCR**	**HI**	**ELCR**	**HI**	**ELCR**
Soil (0 to 15 feet bgs)	Ingestion	1	2×10^{-2}	0.4	1×10^{-3}	1	1×10^{-4}
	Dermal	0.5	7×10^{-3}	0.3	8×10^{-4}	0.4	5×10^{-5}
	Inhalation	6	3×10^{-4}	1	5×10^{-5}	1	2×10^{-6}
	Total	8	3×10^{-2}	2	2×10^{-3}	3	2×10^{-4}
Groundwater	Ingestion	602	8×10^{-1}	--	--	--	--
	Dermal	175	5×10^{-4}	--	--	0.00001	1×10^{-5}
	Inhalation	7,218	3×10^{-1}	--	--	--	--
	Total	7,995	$>8 \times 10^{-1}$	--	--	0.00001	1×10^{-5}
Indoor Air	Inhalation	280	2×10^{-2}	--	--	--	--
Trench Vapor	Inhalation	--	--	--	--	486	8×10^{-4}

Notes:

bgs = below ground surface

ELCR = excess lifetime cancer risk

HI = hazard index

Table 6-1. Preliminary Remediation Goals

Proposed Plan for the Quendall Terminals Superfund Site, Operable Unit 1

Chemical of Concern	Soil (mg/kg)	PRG Source	Groundwater (µg/L)	PRG Source
2-methylnaphthalene	240	HHRA RBC HQ=1	36	HHRA RBC HQ=1
Acenaphthene	--	--	530	HHRA RBC HQ=1
Arsenic	7.3	Ecology, 1994[a]	10	MCL
Benzene	--	--	5	MCL
Benz(a)anthracene*	1.1	HHRA RBC 10^{-6}	0.03	HHRA RBC 10^{-6}
Benzo(a)pyrene*	0.11	HHRA RBC 10^{-6}	0.2	MCL
Benzo(b)fluoranthene*	1.1	HHRA RBC 10^{-6}	0.25	HHRA RBC 10^{-6}
Benzo(k)fluoranthene*	11	HHRA RBC 10^{-6}	2.5	HHRA RBC 10^{-6}
Chromium	51	ERA RBC HQ=1	--	--
Chrysene*	110	HHRA RBC 10^{-6}	25	HHRA RBC 10^{-6}
Dibenz(a,h)anthracene*	0.11	HHRA RBC 10^{-6}	0.025	HHRA RBC 10^{-6}
Dibenzofuran	--	--	7.9	HHRA RBC HQ=1
Ethylbenzene	5.8	HHRA RBC 10^{-6}	700	MCL
Fluoranthene	via HPAH	ERA RBC HQ=1	800	HHRA RBC HQ=1
Fluorene	via LPAH	ERA RBC HQ=1	290	HHRA RBC HQ=1
Indeno(1,2,3-c,d)pyrene*	1.1	HHRA RBC 10^{-6}	0.25	HHRA RBC 10^{-6}
Lead	37	ERA RBC HQ=1	--	--
Naphthalene	3.8	HHRA RBC 10^{-6}	0.17	HHRA RBC 10^{-6}
Phenanthrene	via LPAH	ERA RBC HQ=1	--	--
Pyrene	via HPAH	ERA RBC HQ=1	120	HHRA RBC HQ=1
Total cPAHs	0.11	HHRA RBC 10^{-6}	0.2	MCL
Total HPAHs	3.7	ERA RBC HQ=1	--	--
Total LPAHs	65	ERA RBC HQ=1	--	--
Total Xylenes	--	--	10,000	MCL

Notes:

[a] Washington State Department of Ecology. 1994. *Natural Background Soil Metals Concentrations in Washington State*. Publication 94-115. October.

-- = not a chemical of concern for medium listed
µg/L = microgram(s) per liter

cPAH = carcinogenic PAH – calculated based on benzo(a)pyrene equivalents (indicated by asterisk).

HPAHs = high-molecular-weight PAHs (benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[g,h,i]perylene, chrysene, dibenz[a,h]anthracene, indeno[1,2,3-c,d]pyrene, fluoranthene, and pyrene)

LPAH = low-molecular-weight PAH (acenaphthylene, acenaphthene, anthracene, fluorene, naphthalene, and phenanthrene)

mg/kg = milligram per kilogram

PAH = polynuclear aromatic hydrocarbon

PRG = Preliminary Remediation Goal

HHRA RBC 10^{-6} = Human Health Risk Assessment Risk-Based Concentration based on cancer risk of 1 x 10^{-6}.

HHRA RBC HQ=1 = Human Health Risk Assessment Risk-Based Concentration based on noncancer hazard quotient of 1.

ERA RBC HQ=1 = Ecological Risk Assessment Risk-Based Concentration, based on noncancer hazard quotient of 1.

MCL = Maximum Contaminant Level

Table 8-1. Costs for the Operable Unit 1 Alternatives

Proposed Plan for the Quendall Terminals Superfund Site, Operable Unit 1

Alternative	**Remedial Construction**	**Operations and Maintenance Using 7.0 Percent Discount Rate[a]**	**Total Present Value Using 7.0 Percent Discount Rate**	**FS-Level Accuracy Range (-30%)**	**FS-Level Accuracy Range (+50%)**
7	65,300,000	700,000	**66,000,000**	46,200,000	99,000,000
7a	65,400,000	700,000	**66,100,000**	46,300,000	99,200,000
8	99,400,000	600,000	**100,000,000**	70,000,000	150,000,000
9	218,600,000	600,000	**219,200,000**	153,400,000	328,800,000
10	301,100,000	8,200,000	**309,300,000**	216,500,000	464,000,000

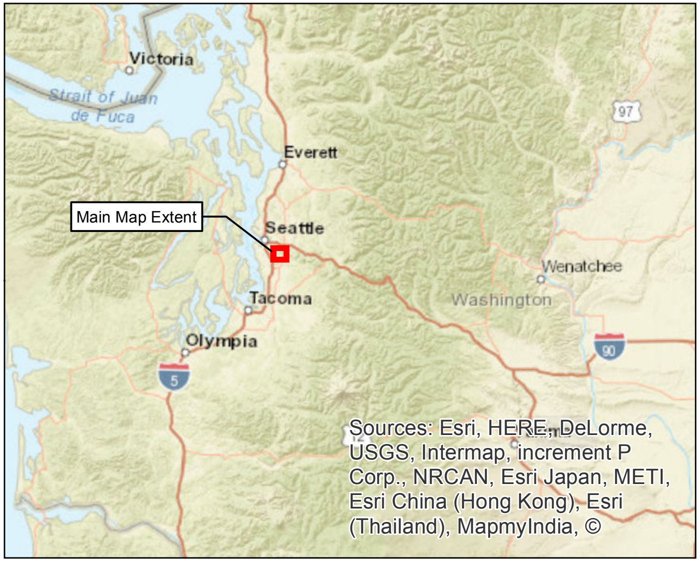
Notes:

[a] For estimating operations and maintenance cost, the FS cost estimate assumed operations and maintenance would be conducted for 100 years.

Figures

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

VICINITY MAP



Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, ©

LEGEND

🟧 Quendall Terminals Site Boundary

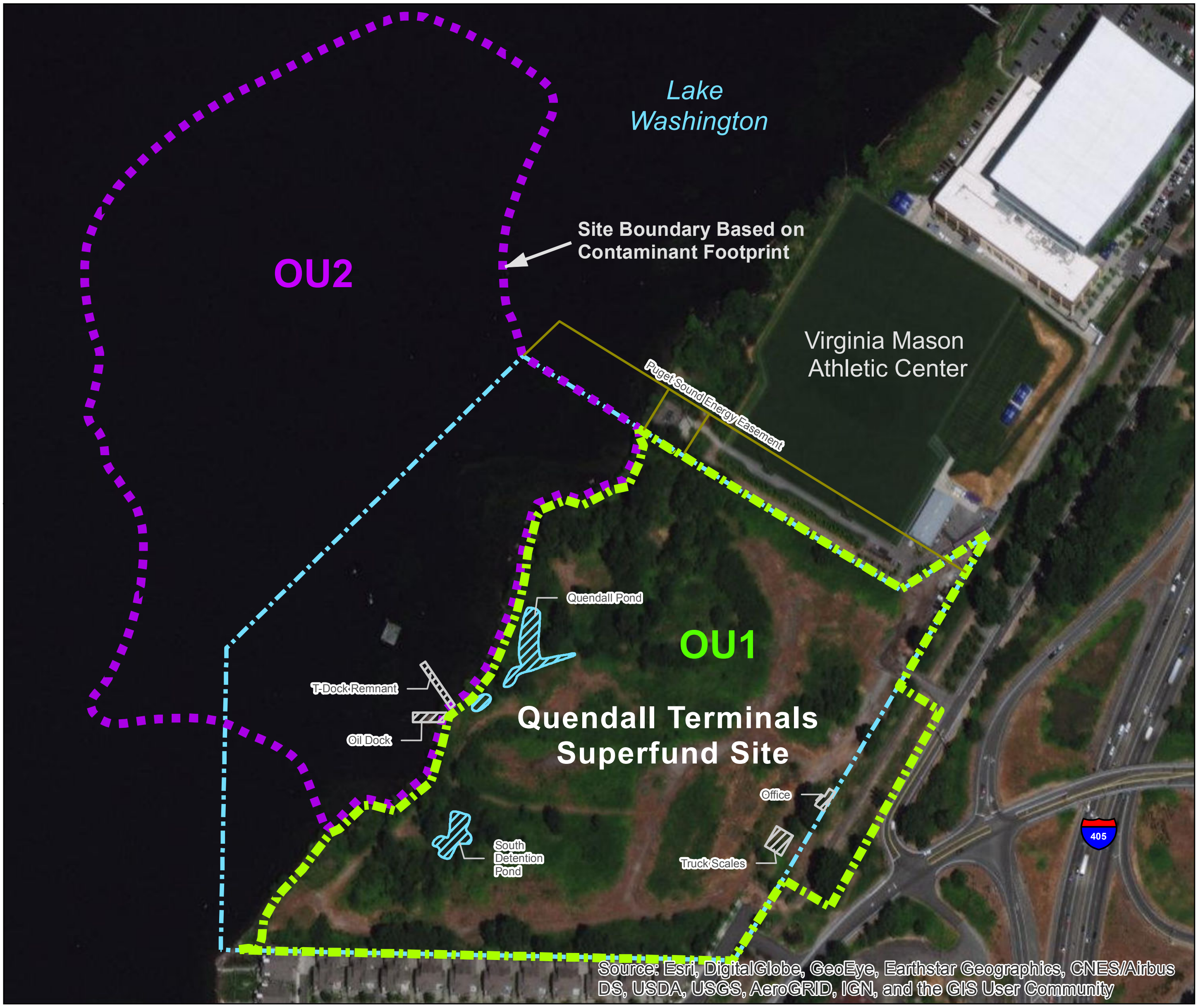
0 0.25 0.5 1 Miles

N

Figure 1-1
Quendall Terminals Site Location and Vicinity Map

Proposed Plan for the Quendall Terminals Superfund Site Operable Unit 1
Renton, Washington

\\SEAFPP01\PROJ\USENVIRONMENTALPROTE\682283QUENDALL\DELIVERABLESBYTASK\TASK12_FS\2016-12_FINAL_FS\GISFILES\QUENDALL_FS_FIGURE_FILES\MAPFILES\2019\OU1_PP\FIGURE_1-1_VICINTYMAP.MXD GGEE 9/4/2019 7:59:10 AM



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

VICINITY MAP

Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors,

LEGEND

- ▭ OU1 Boundary
- ▭ OU2 Boundary
- -·- Quendall Property Line
- ▨ Existing Structure

0 125 250 500 Feet

N

Figure 2-1
Current Site Features and Operable Units

Proposed Plan for the Quendall Terminals Superfund Site Operable Unit 1
Renton, Washington

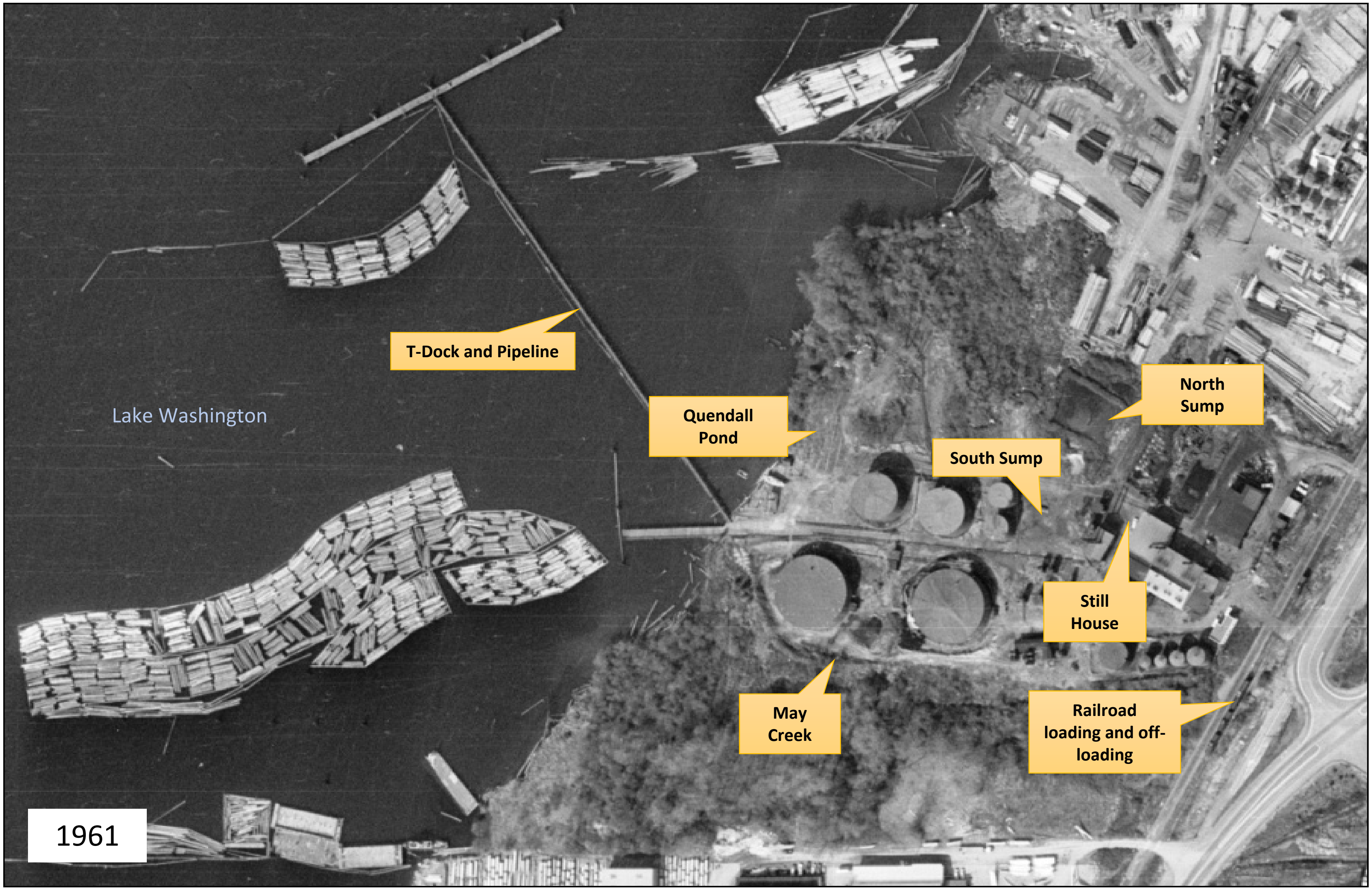


Figure 2-2
Summary of Historical Site Features
Proposed Plan for the Quendall Terminals Superfund Site Operable Unit 1
Renton, Washington

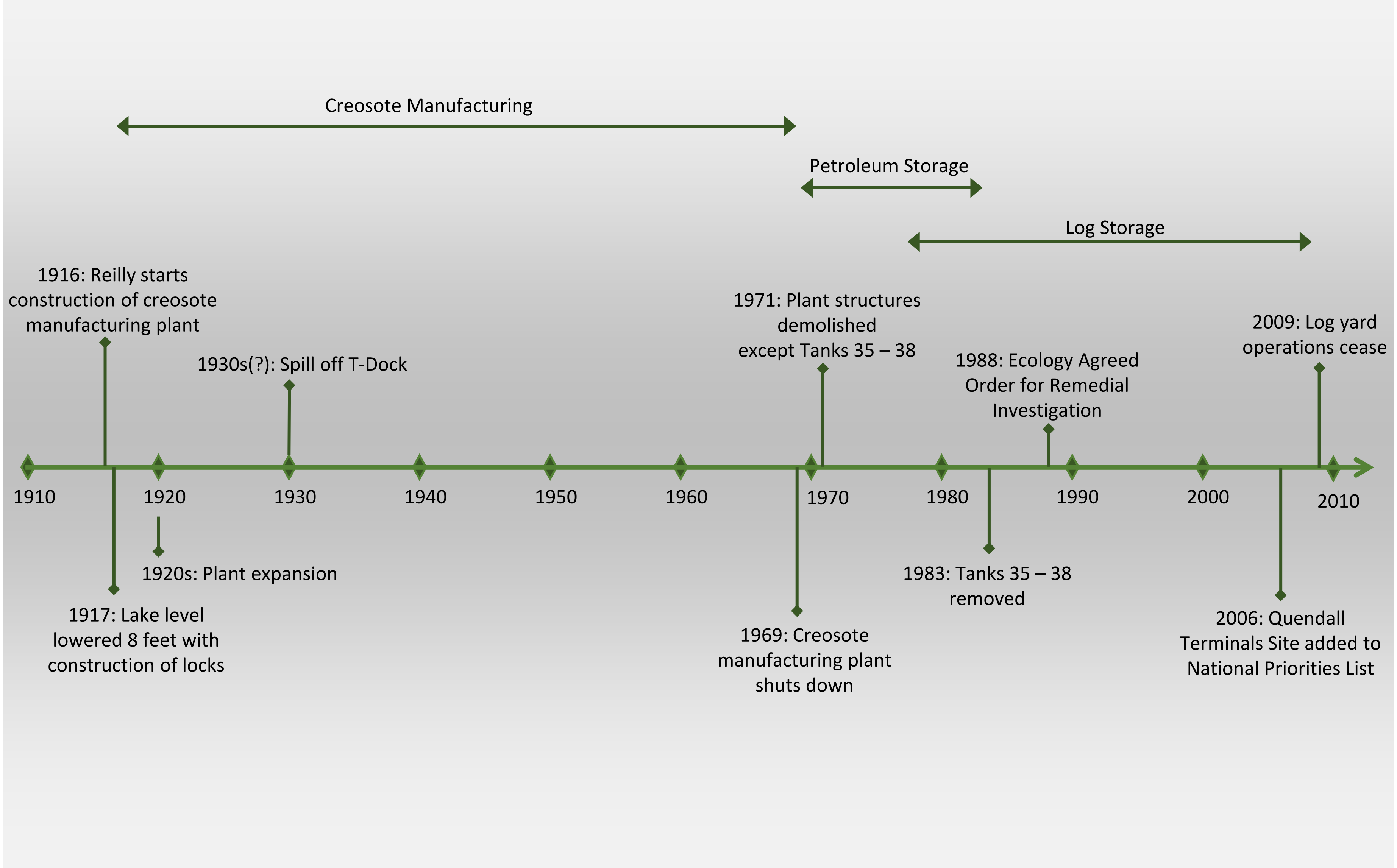


Figure 2-3
Timeline of Site Operations
Proposed Plan for the Quendall Terminals
Superfund Site Operable Unit 1
Renton, Washington

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

VICINITY MAP

Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand),

LEGEND

- ‐·‐· Quendall Property Line
- ▨ Wetlands
- ▨ Habitat Area

Sources:
Wetlands digitized from *Quendall Terminals Baseline Habitat Technical Memorandum* (Grette Associates, 2016)

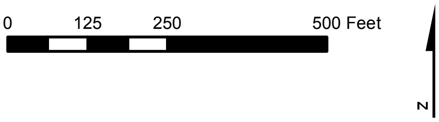


Figure 3-1
Habitat Area and Site Wetlands

Proposed Plan for the Quendall Terminals
Superfund Site Operable Unit 1
Renton, Washington

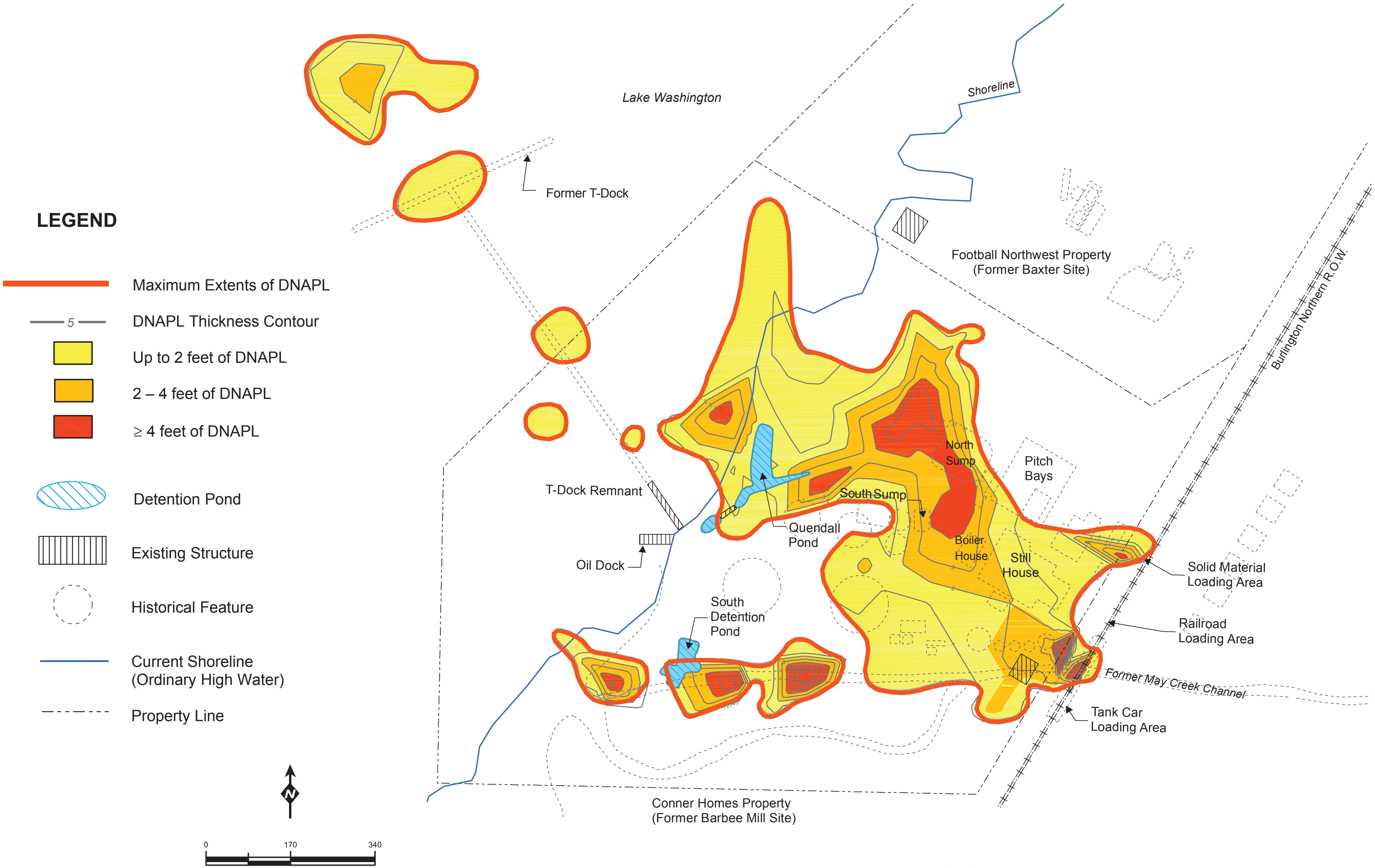
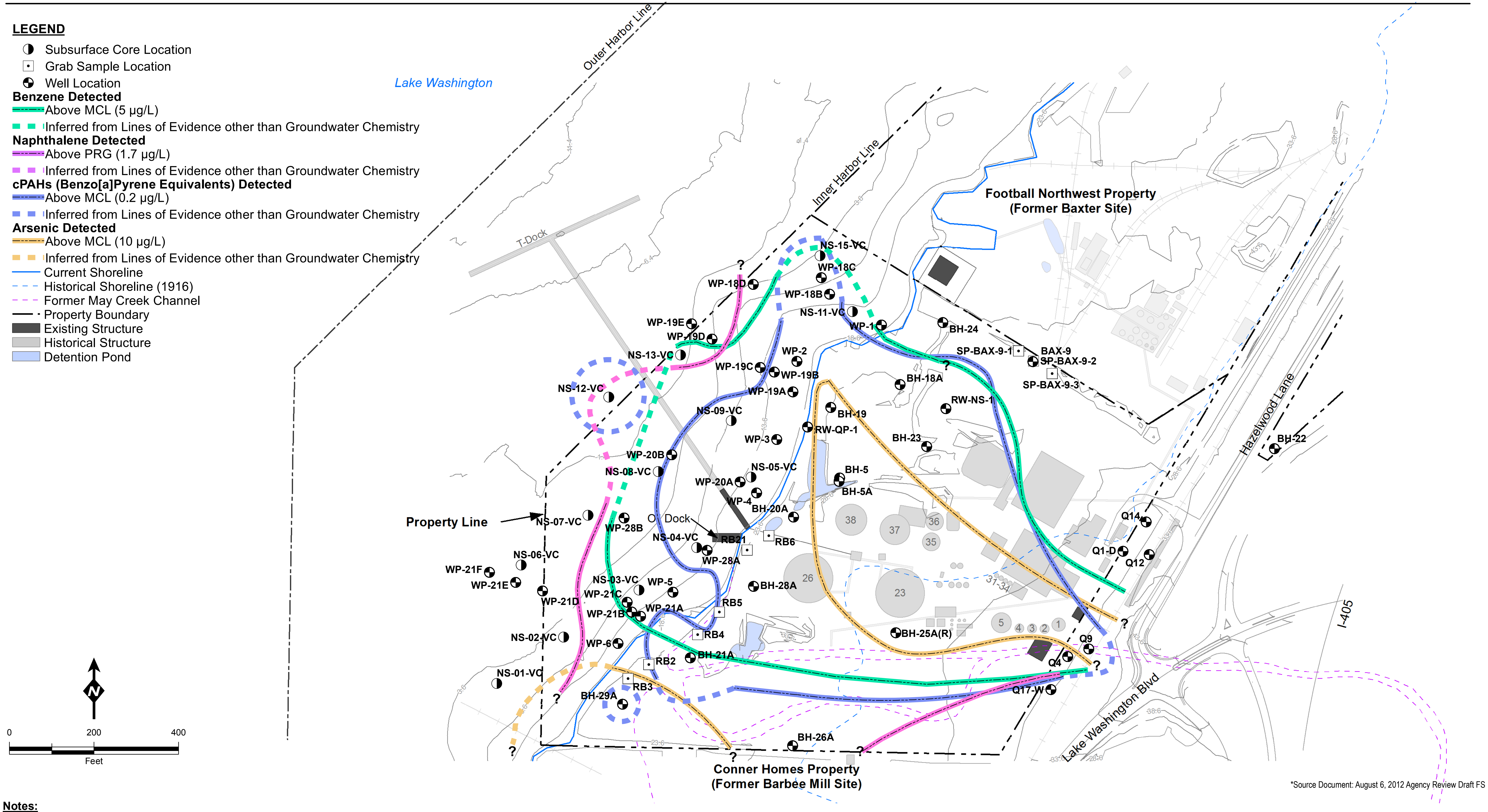


Figure 3-2
Approximate Extent and Thickness of DNAPL

Proposed Plan for the Quendall Terminals
Superfund Site Operable Unit 1
Renton, Washington



*Source Document: August 6, 2012 Agency Review Draft FS

Notes:

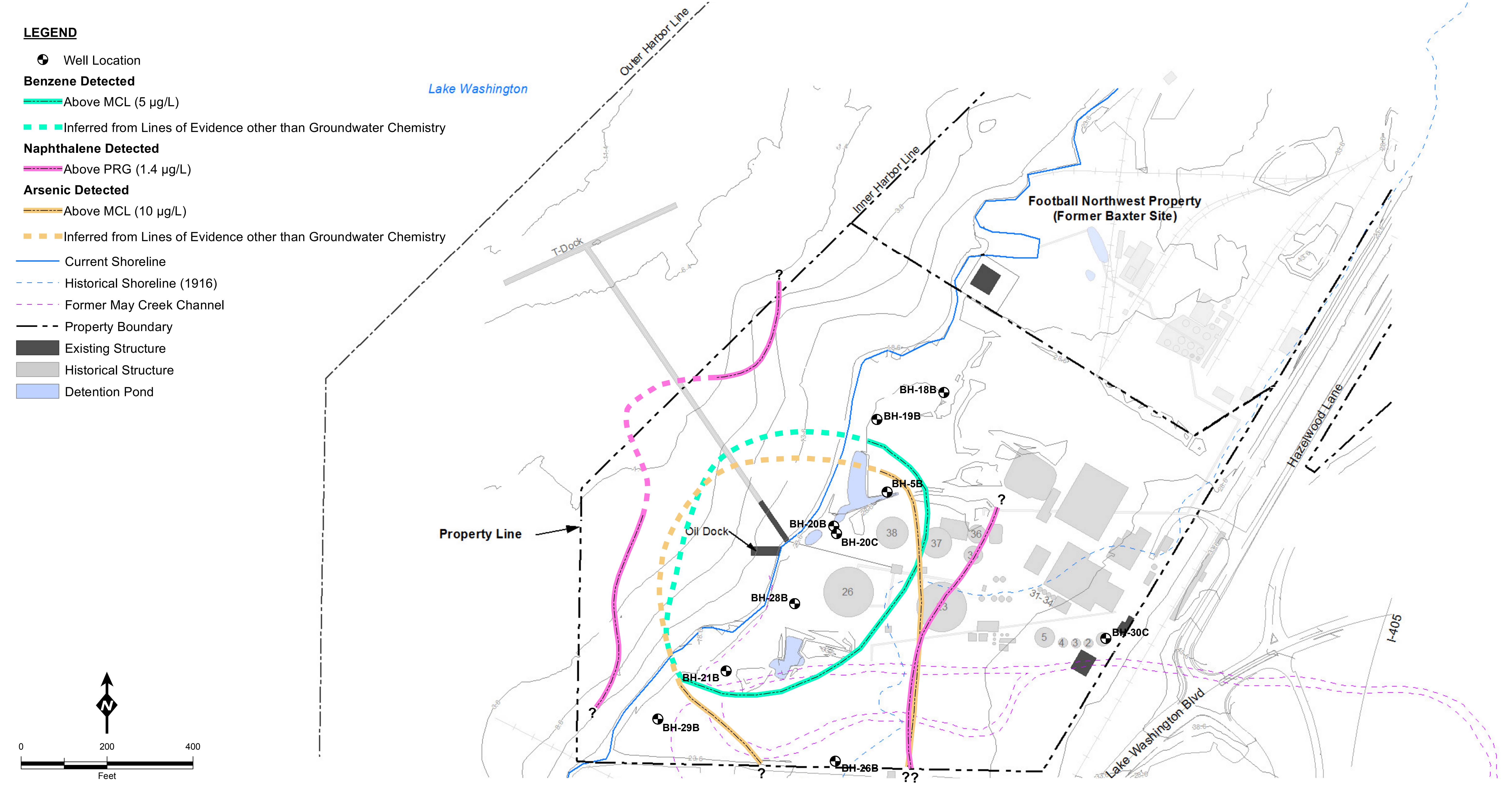
1. Contour Intervals are 5 ft, NAVD 88.
2. See Figures 5.2-1, 5.2-8, 5.2-14, and 5.2-16 of the RI Report for basis of approximate extents (Anchor QEA and Aspect 2012). Naphthalene extent has been adjusted from the RI Report based on its lower PRG for the FS (lower PRG based on cancer risk of 10^{-5}). Estimated extents do not consider dispersion.

Figure 3-3

Approximate Extent of Groundwater Contamination in the Shallow Aquifer

Proposed Plan for the Quendall Terminals
Superfund Site Operable Unit 1
Renton, Washington

EPA

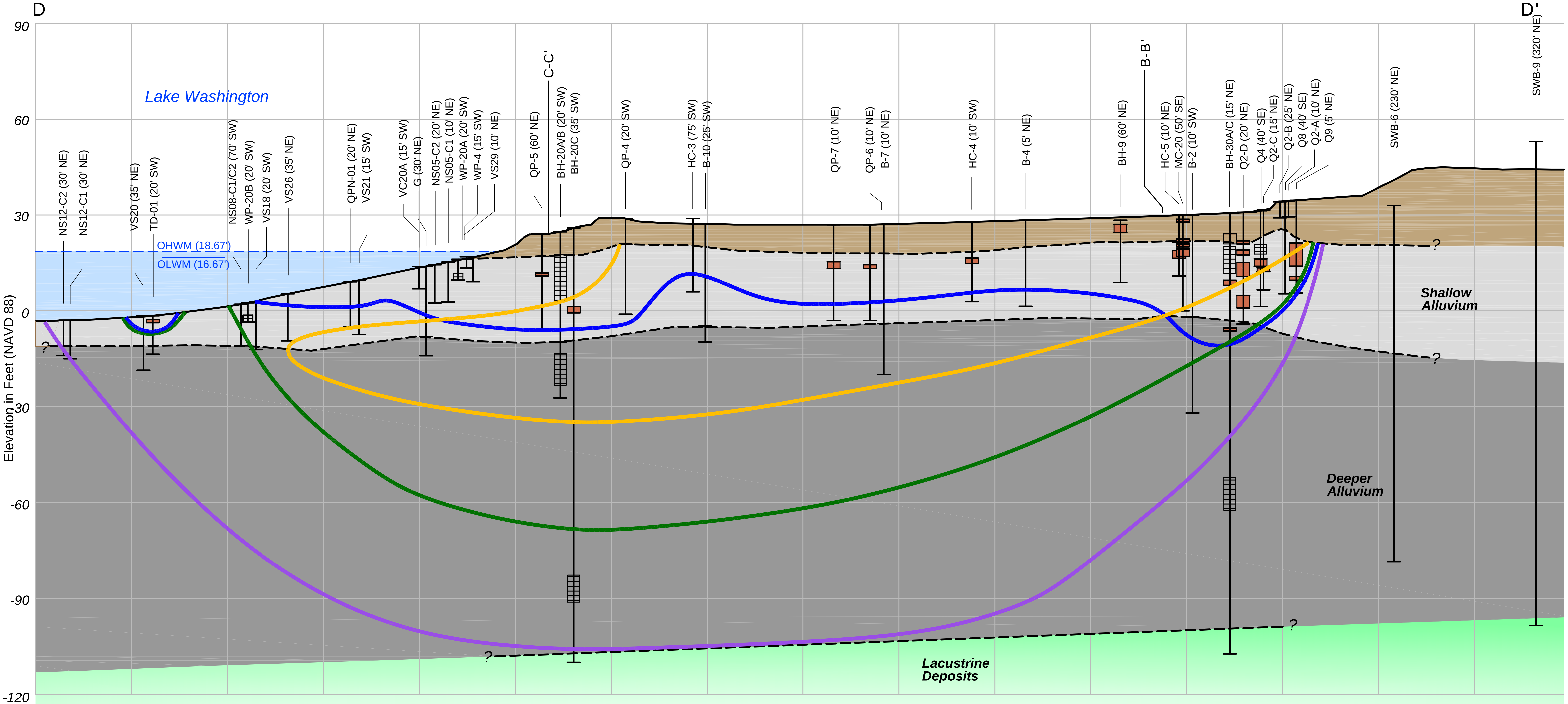


*Source Document: August 6, 2012 Agency Review Draft FS

Notes:

1. Contour intervals are 5 ft, NAVD 88.
2. cPAHs (Benzo[a]pyrene Equivalent) have not been detected above the PRG in wells completed in the Deep Aquifer.
3. See Figures 5.2-2, 5.2-9, 5.2-15, and 5.2-17 of the RI Report for basis of approximate extents (Anchor QEA and Aspect 2012). Naphthalene extent has been adjusted from the RI Report based on its lower PRG for the FS. Estimated extents do not consider dispersion.

Figure 3-4
Approximate Extent of Groundwater Contamination in the Deep Aquifer
Proposed Plan for the Quendall Terminals
Superfund Site Operable Unit 1
Renton, Washington



Legend

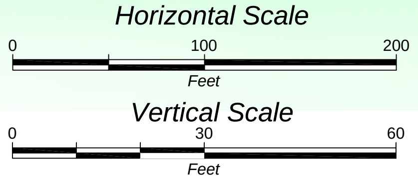
NS12-C2 (30' NE)	Exploration ID and Offset from Cross Section
🟥	Non-Aqueous Phase Liquid
▤	Well Screen

🟫	Fill or Surface Sediment: Silt, Sand, Gravel, Wood and Mixed Debris
⬜	Shallow Alluvium: Stratified Organic Silt, Peat, Sand
⬛	Deep Alluvium: Sand and Gravels
🟩	Lacustrine Deposits: Silt and Clay

🟩	Estimated extent of Benzene exceeding PRG in groundwater and porewater (5 ug/L)
🟪	Estimated extent of Naphthalene exceeding PRG in groundwater and porewater (1.4 ug/L)
🟦	Estimated extent of cPAHs (Benzo[a]pyrene Equivalents) exceeding PRG in groundwater and porewater (0.2 ug/L)
🟨	Estimated extent of Arsenic exceeding PRG in groundwater and porewater (10 ug/L)

Notes:

1. Refer to Figure 3-1 for exploration locations.
2. Vertical extents generally based on groundwater data from wells BH-20A, BH-20B, and BH-20C (Figures 5.2-1, 5.2-2, 5.2-8, 5.2-9, 5.2-14, 5.2-15, 5.2-16, and 5.2-17 of the RI Report (Anchor QEA and Aspect 2012)) and groundwater grab samples at BH-20C and BH-30C (Appendix A of the RI Report). Vertical extent of Benzo(a)pyrene approximate based on model predictions (Appendix A of this FS), adjusted to account for empirical data and artifacts from model cell size. Vertical extent of Naphthalene based on base of Deeper Alluvium.
3. Vertical extents of PRG exceedances on this figure consider fate and transport predictions of the RI groundwater model (Anchor QEA and Aspect 2012). Therefore, the estimated boundaries shown do not exactly match the estimated extent of contamination in Deep and Shallow groundwater shown on Figures 3-6 and 3-7.

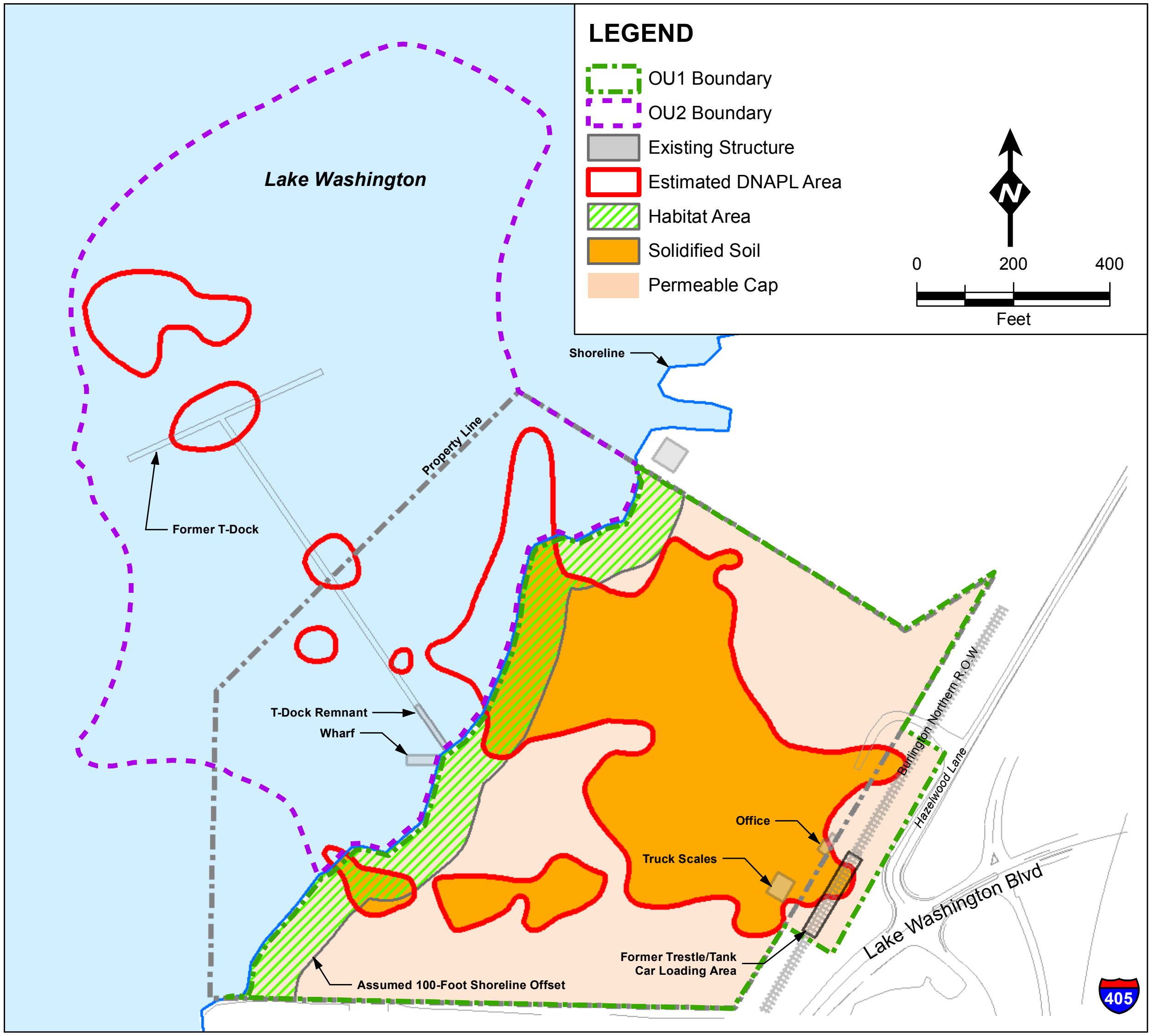


Vertical Exaggeration X3.33

Figure 3-5
Cross-Section Showing Extent of Groundwater Exceeding PRGs

Proposed Plan for the Quendall Terminals
Superfund Site Operable Unit 1
Renton, Washington

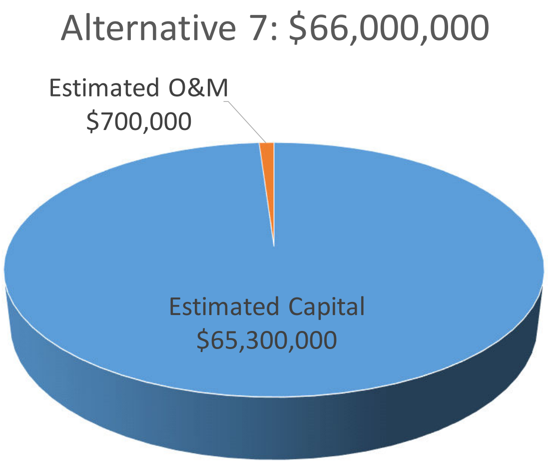
EPA



DNAPL Area Remedial Technology	% DNAPL Addressed by Technology (by vol.)
Solidification	100%
Excavation	0%

Note: A three-foot soil cap will be placed over areas of the site where soil cleanup goals are exceeded.

Acronyms:
DNAPL = dense nonaqueous phase liquid
O&M = operations and maintenance
OU = operable unit



Implementation Sequence

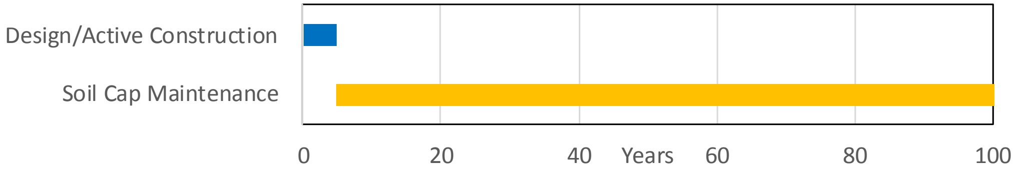
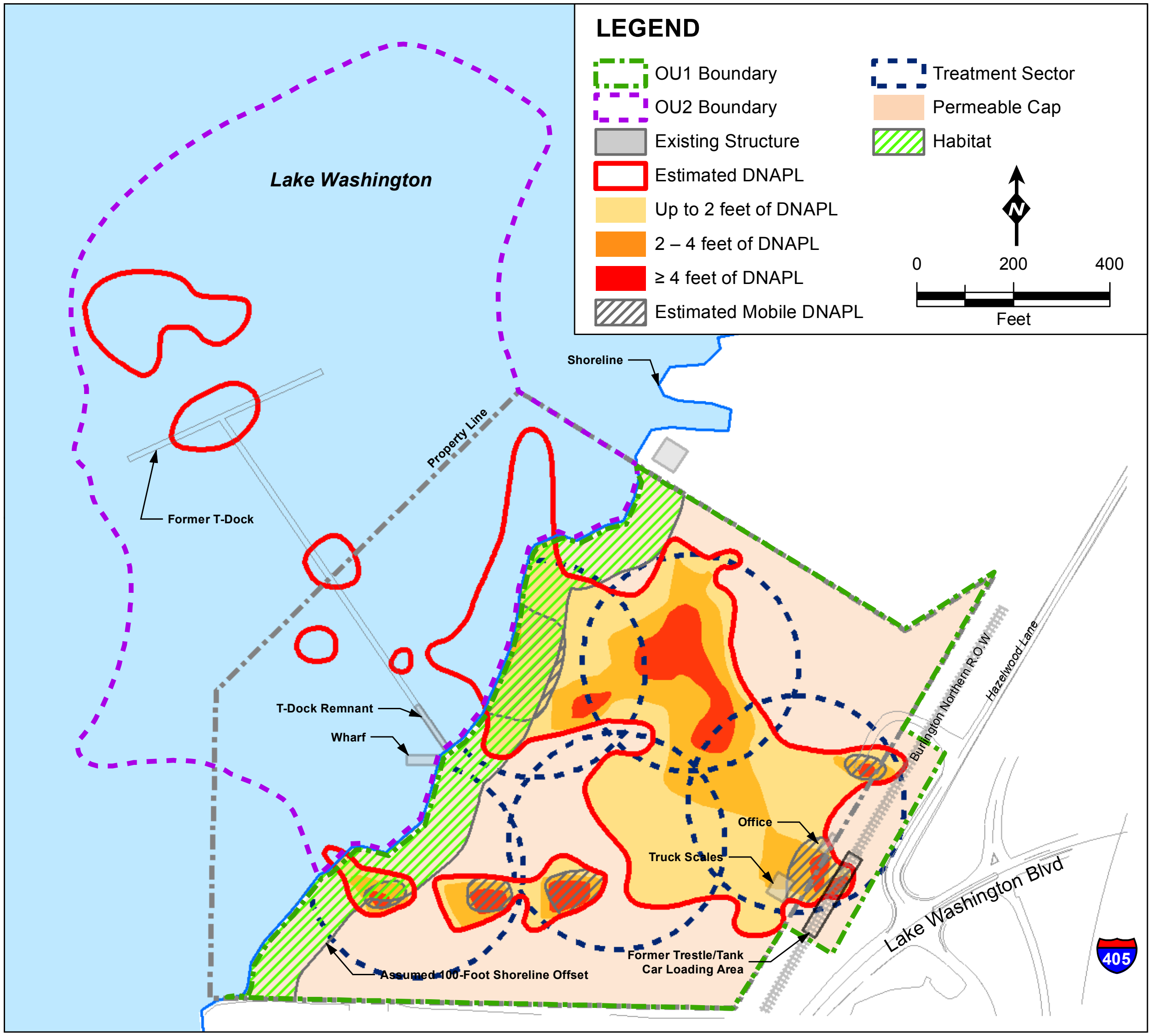


Figure 7-1
Alternative 7 – Solidification of DNAPL and Soil Capping

Proposed Plan for the Quendall Terminals
Superfund Site Operable Unit 1
Renton, Washington

\\SEAFPP01\PROJ\USENVIRONMENTALPROTE\682283QUENDALL\DELIVERABLESBYTASK\TASK12_FS\2016-12_FINAL_FS\GISFILES\QUENDALL_FS_FIGURE_FILES\MAPFILES\2019\FIGURE_7-1_ALTERNATIVE7_OU1.MXD GGEE 7/31/2019 9:41:53 AM



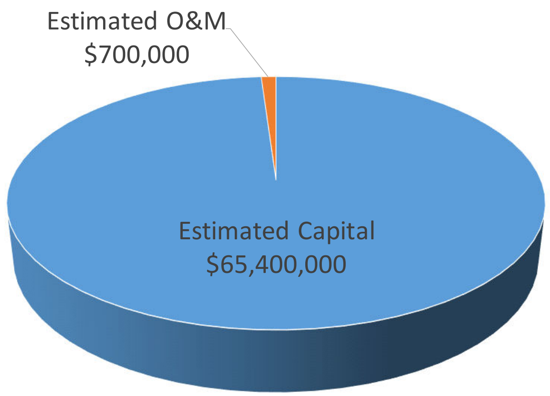
DNAPL Area Remedial Technology*	% DNAPL Area Addressed by Technology* (by vol.)
Smoldering Combustion	57%
Solidification	43%

Note:
*The percent of DNAPL to be treated via smoldering combustion versus solidification is an estimate made solely for the purpose of cost estimating.

Note: A three-foot soil cap will be placed over areas of the site where soil cleanup goals are exceeded.

Acronyms:
DNAPL = dense nonaqueous phase liquid
O&M = operations and maintenance
OU = operable unit

Alternative 7a: $66,100,000



Implementation Sequence

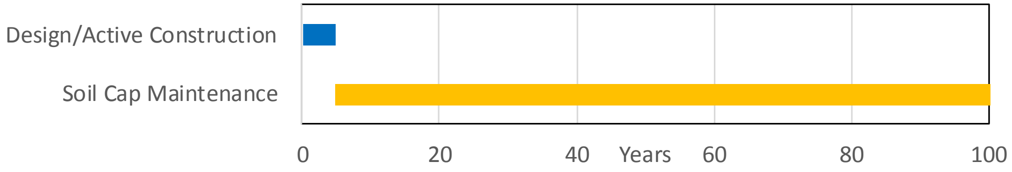
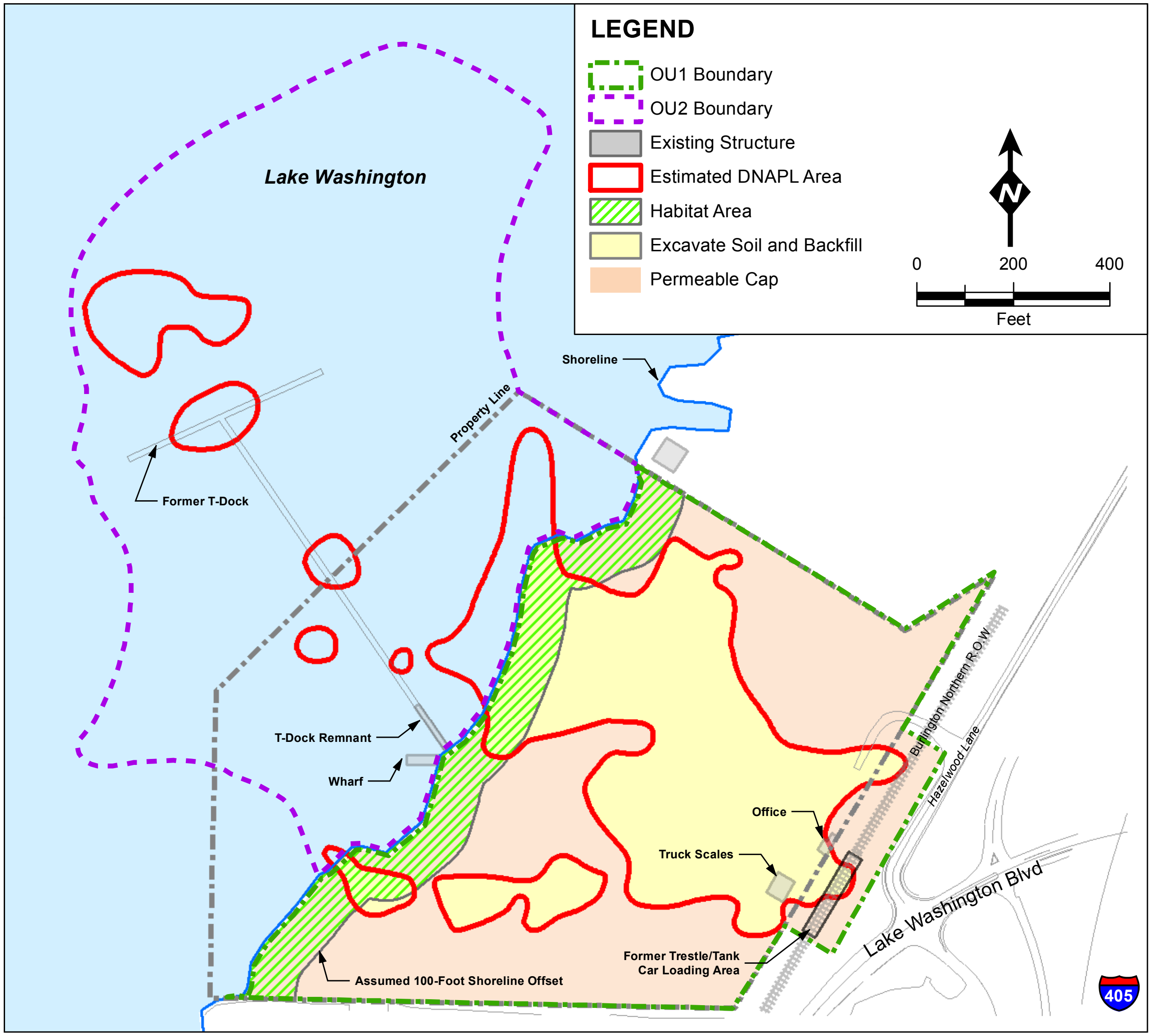


Figure 7-2
Alternative 7a – In situ Smoldering Combustion and/or In Situ Solidification of DNAPL, and Soil Capping

Proposed Plan for the Quendall Terminals
Superfund Site Operable Unit 1
Renton, Washington

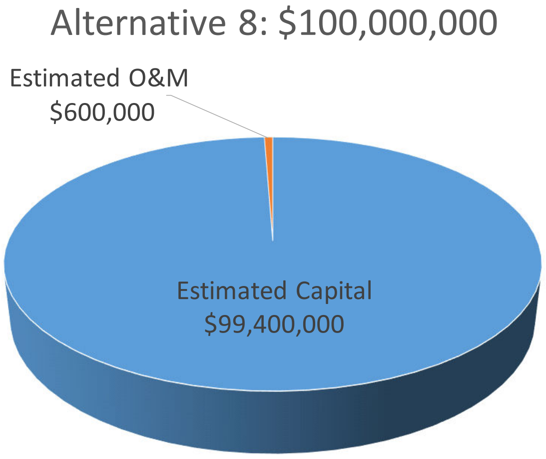
\\SEAFPP01\PROJ\USENVIRONMENTALPROTE\682283QUENDALL\DELIVERABLESBYTASK\TASK12_FS\2016-12_FINAL_FS\GISFILES\QUENDALL_FS_FIGURE_FILES\MAPFILES\2019\FIGURE_7-2_REVISEDALTERNATIVE7A_OU1.MXD GGEE 7/31/2019 2:30:54 PM



DNAPL Area Remedial Technology	% DNAPL Addressed by Technology (by vol.)
Solidification	0%
Excavation	100%

Note: A three-foot soil cap will be placed over areas of the site where soil cleanup goals are exceeded.

Acronyms:
DNAPL = dense nonaqueous phase liquid
O&M = operations and maintenance
OU = operable unit



Implementation Sequence

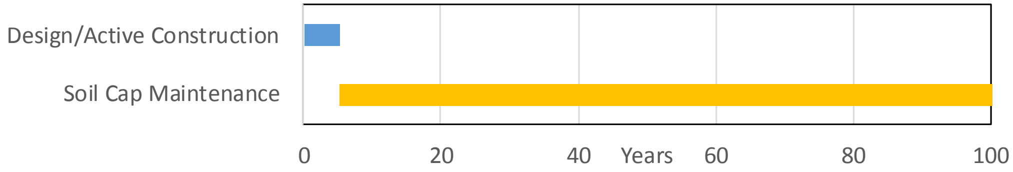
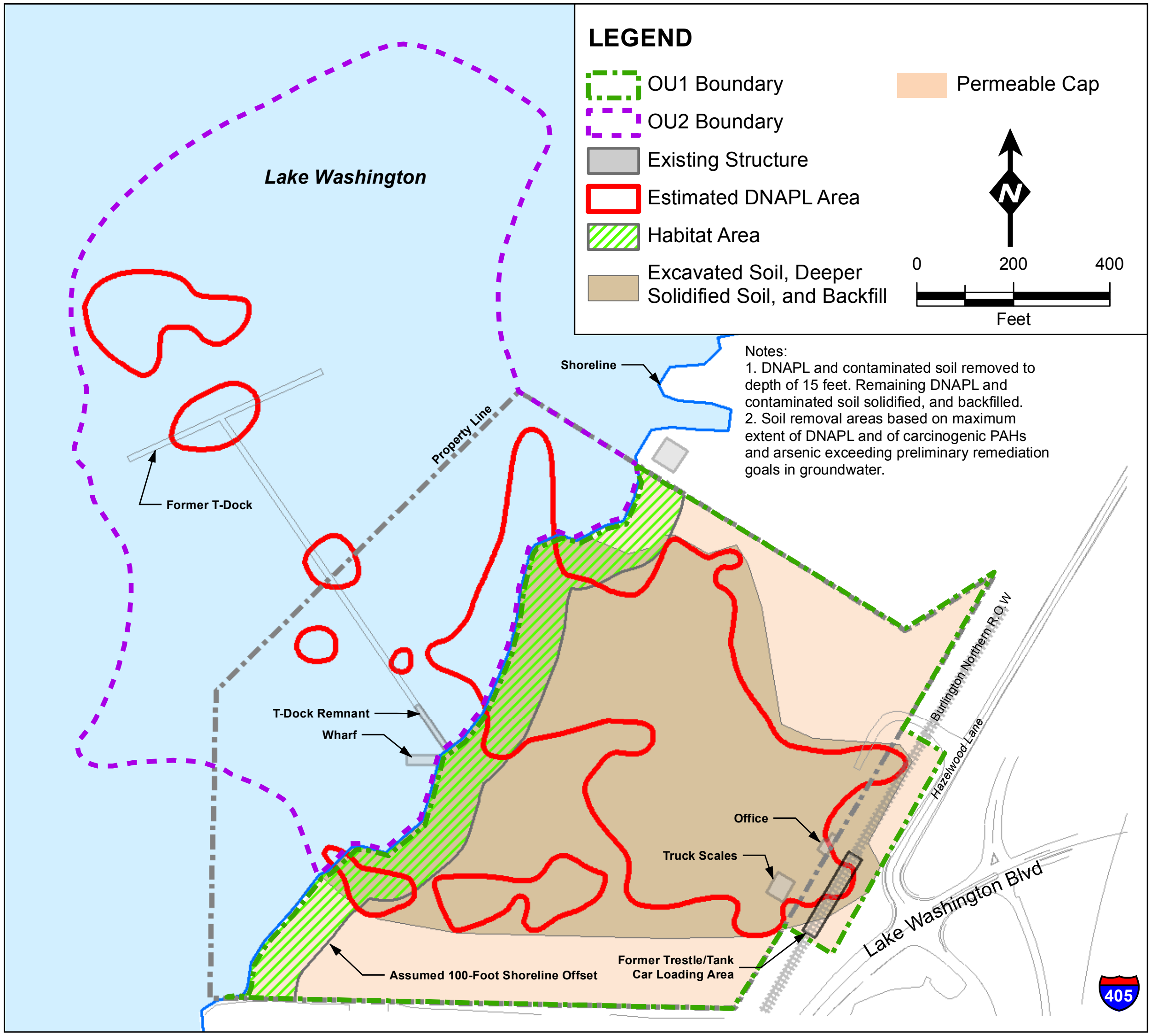


Figure 7-3
Alternative 8 – Removal/Onsite Thermal Treatment of DNAPL, and Soil Capping

Proposed Plan for the Quendall Terminals
Superfund Site Operable Unit 1
Renton, Washington



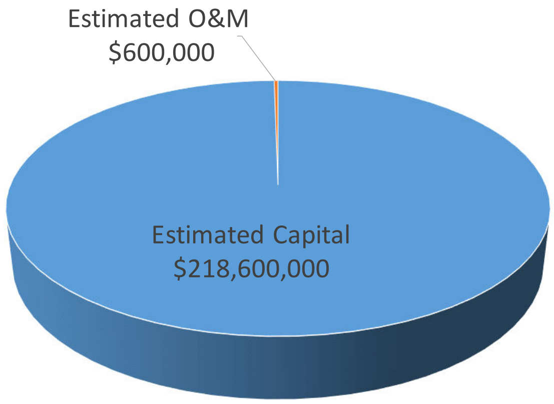
Notes:
1. DNAPL and contaminated soil removed to depth of 15 feet. Remaining DNAPL and contaminated soil solidified, and backfilled.
2. Soil removal areas based on maximum extent of DNAPL and of carcinogenic PAHs and arsenic exceeding preliminary remediation goals in groundwater.

DNAPL Area Remedial Technology	% DNAPL Addressed by Technology (by vol.)
Solidification	28%
Excavation	72%

Note: A three-foot soil cap will be placed over areas of the site where soil cleanup goals are exceeded.

Acronyms:
DNAPL = dense nonaqueous phase liquid
O&M = operations and maintenance
OU = operable unit

Alternative 9: $219,200,000



Implementation Sequence

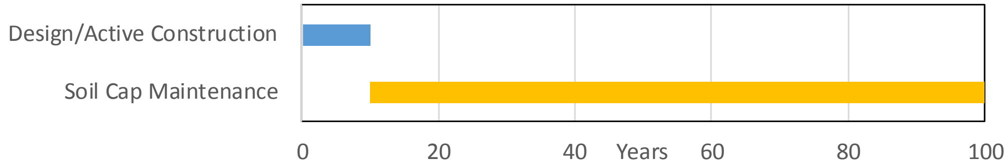
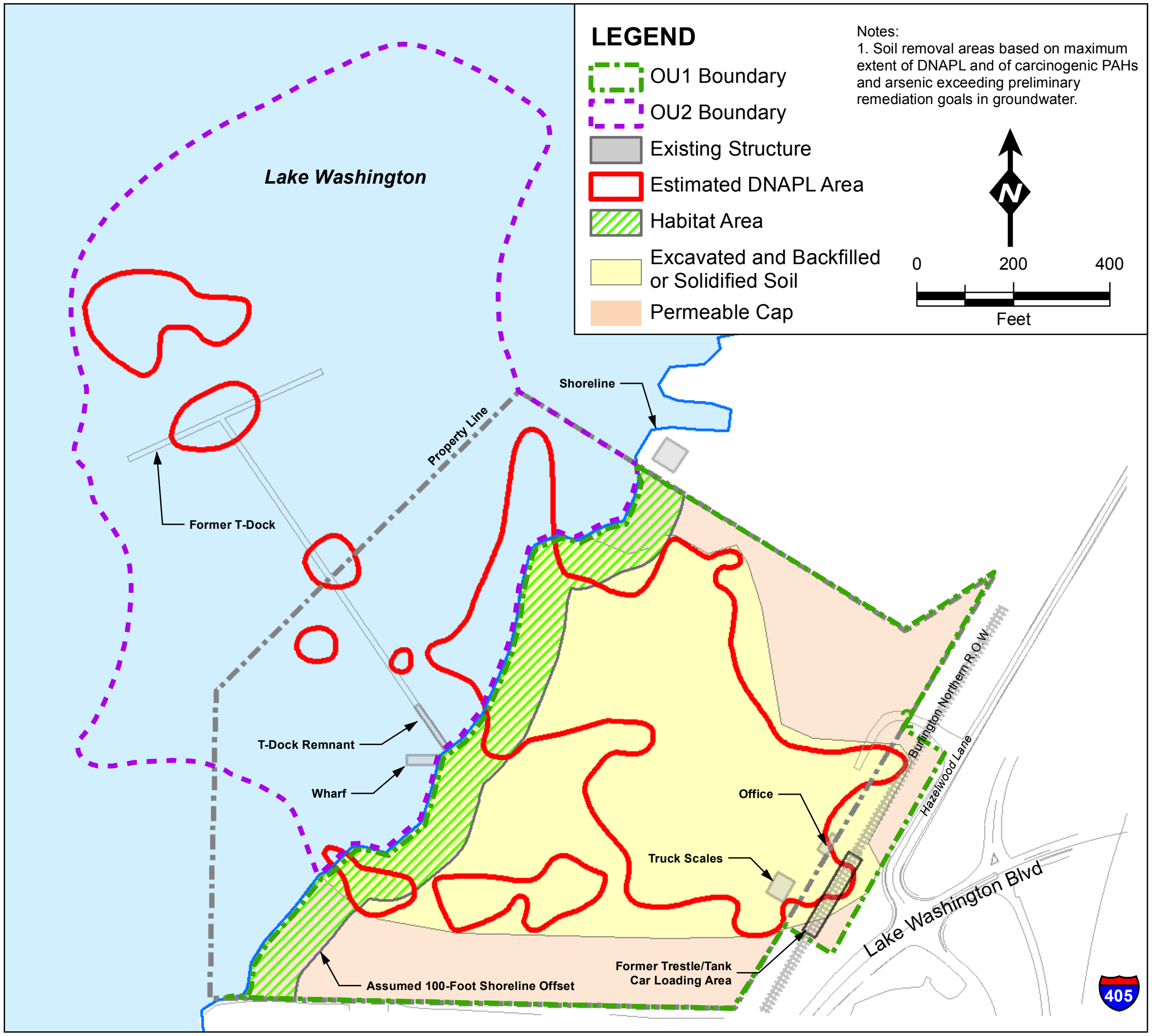


Figure 7-4
Alternative 9 – Solidification and Removal/Onsite Thermal Treatment of DNAPL and Contaminated Soil, and Soil Capping

Proposed Plan for the Quendall Terminals
Superfund Site Operable Unit 1
Renton, Washington



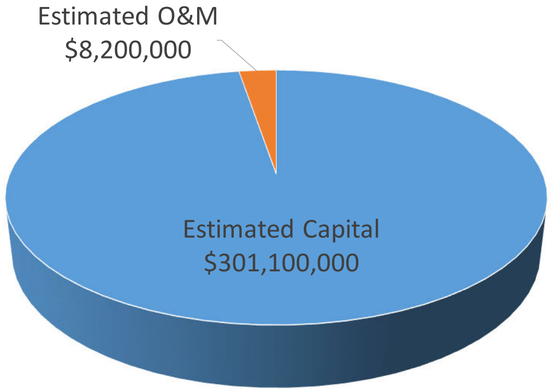
Notes:
1. Soil removal areas based on maximum extent of DNAPL and of carcinogenic PAHs and arsenic exceeding preliminary remediation goals in groundwater.

DNAPL Area Remedial Technology	% DNAPL Addressed by Technology (by vol.)
Solidification	0%
Excavation	100%

Note: A three-foot soil cap will be placed over areas of the site where soil cleanup goals are exceeded.

Acronyms:
DNAPL = dense nonaqueous phase liquid
O&M = operations and maintenance
OU = operable unit

Alternative 10: $309,300,000



Implementation Sequence

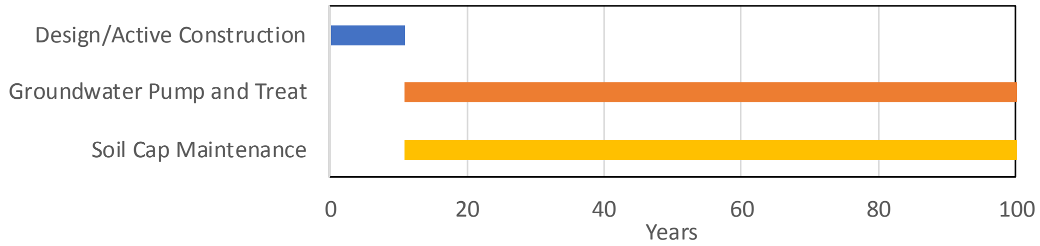
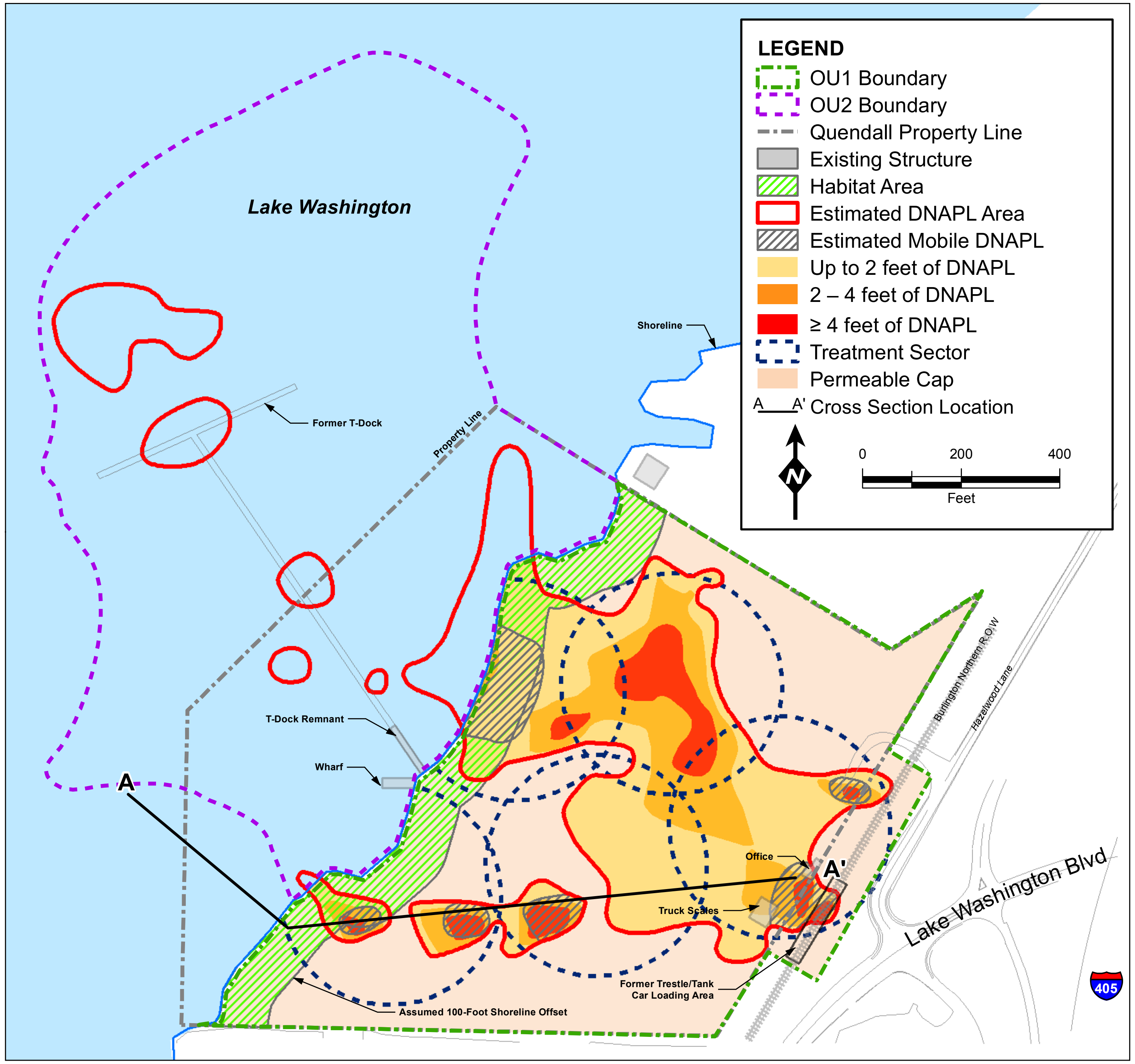
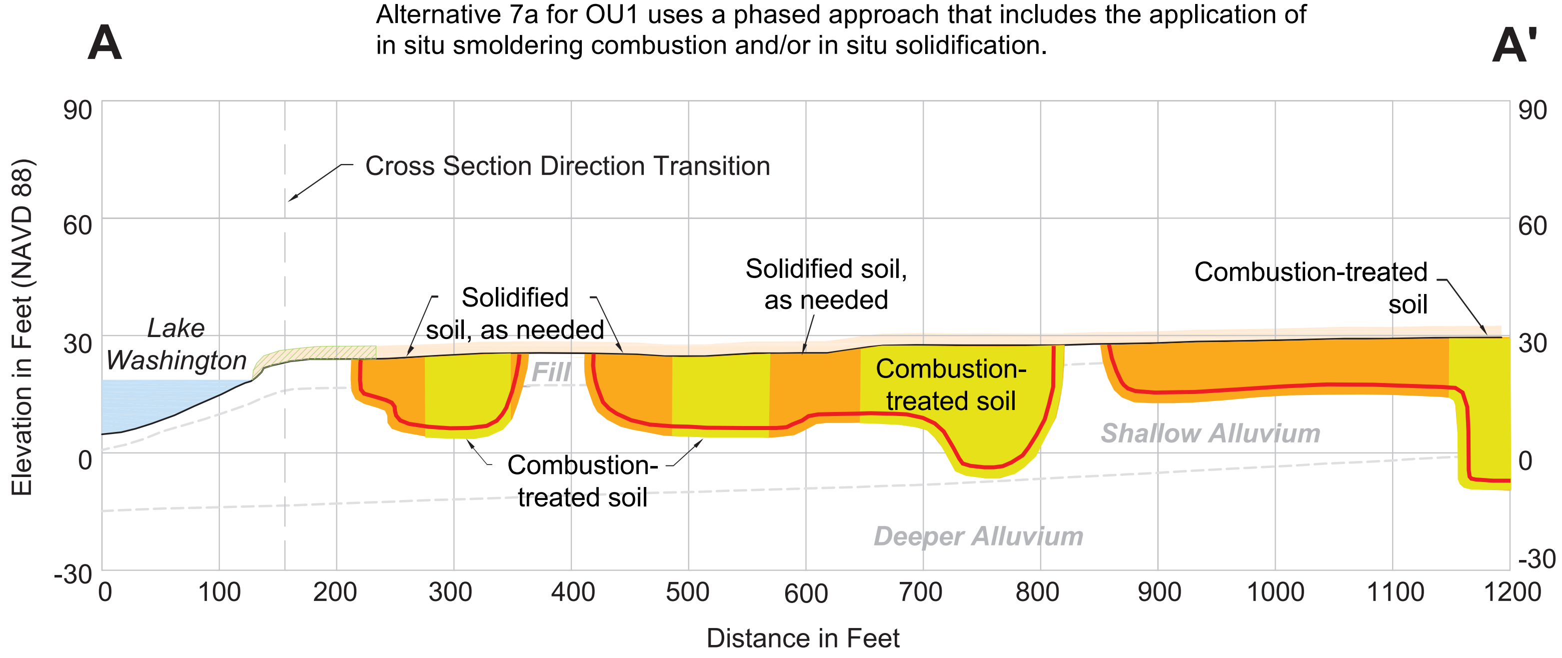


Figure 7-5
Alternative 10 – Removal/Onsite Thermal Treatment of DNAPL and Contaminated Soil, Soil Capping, and Active Groundwater Treatment

Proposed Plan for the Quendall Terminals
Superfund Site Operable Unit 1
Renton, Washington

\\SEAFPP01\PROJ\USENVIRONMENTALPROTE\682283QUENDALL\DELIVERABLESBYTASK\TASK12_FS\2016-12_FINAL_FS\GISFILES\QUENDALL_FS_FIGURE_FILES\MAPFILES\2019\FIGURE_7-5_ALTERNATIVE10_OU1.MXD GGEE 7/31/2019 9:18:18 AM

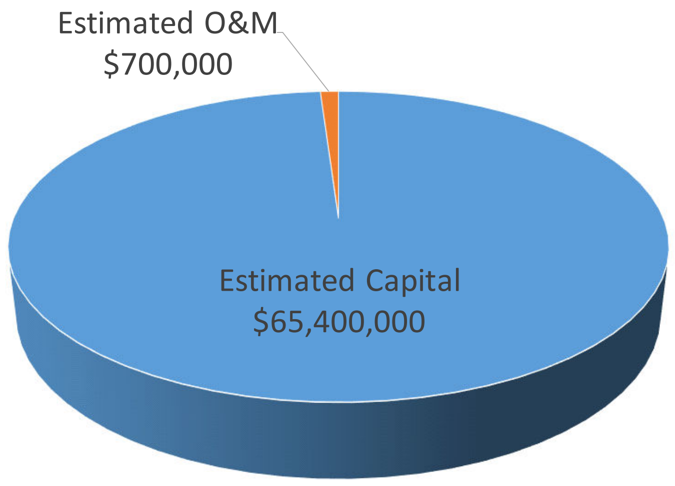




Alternative 7a for OU1 uses a phased approach that includes the application of in situ smoldering combustion and/or in situ solidification.

Note: A three-foot soil cap will be placed over areas of the site where soil cleanup goals are exceeded.

Alternative 7a: $66,100,000



DNAPL Area Remedial Technology*	% DNAPL Area Addressed by Technology* (by vol.)
Smoldering Combustion	57%
Solidification	43%

Notes:
*The percent of DNAPL to be treated via smoldering combustion versus solidification is an estimate made solely for the purpose of cost estimating.

Acronyms:
DNAPL = dense nonaqueous phase liquid
NAVD 88 = North American Vertical Datum 1988
O&M = operations and maintenance
OU = operable unit

Implementation Sequence

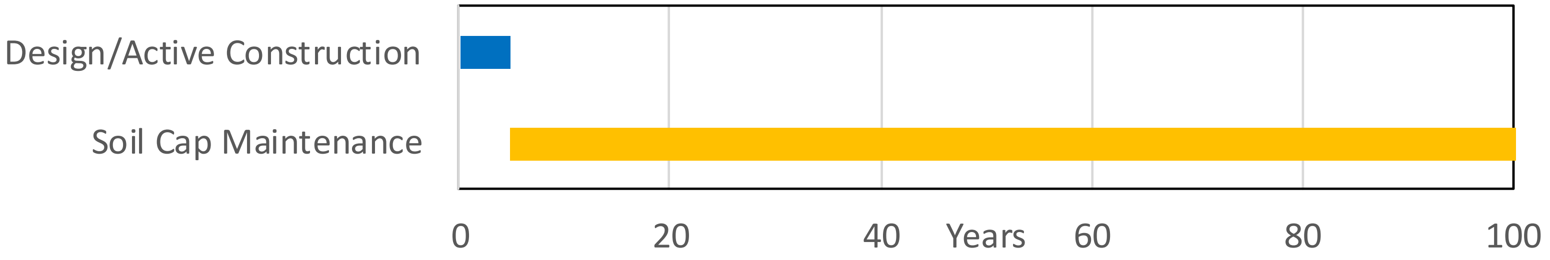


Figure 9-1
Preferred Alternative 7a – In situ Smoldering Combustion and/or In Situ Solidification of DNAPL, and Soil Capping
Proposed Plan for the Quendall Terminals
Superfund Site Operable Unit 1
Renton, Washington

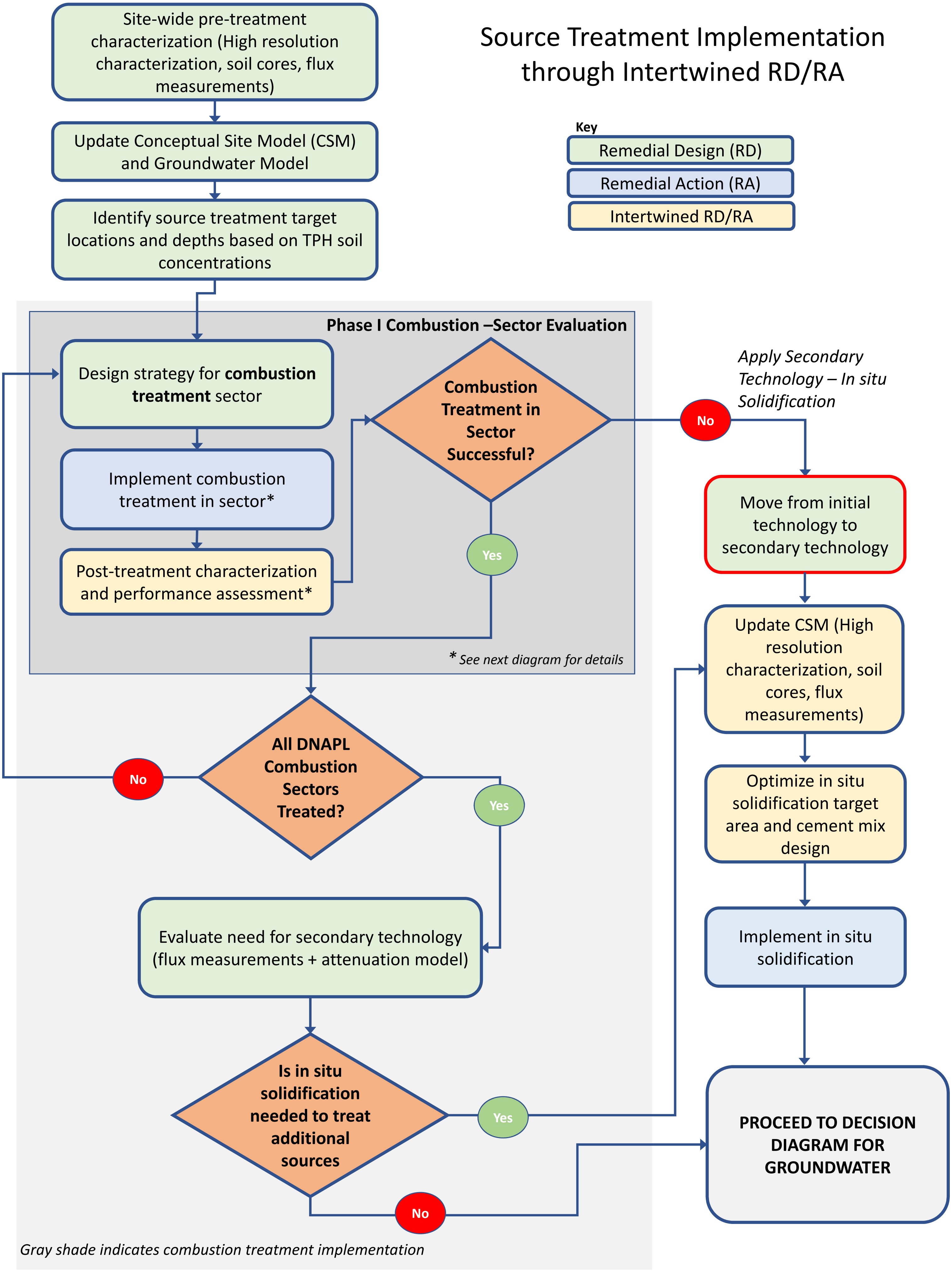
Appendix A
Source Treatment Implementation

APPENDIX A

Source Treatment Implementation

This appendix includes two flow charts that explain how adaptive site management would be used to implement the source treatment remedy for Alternative 7a. The first flow chart describes the process for beginning source treatment with thermal treatment and using adaptive site management to make decisions regarding if and when to move from thermal to in situ solidification. The second flow chart details thermal source treatment by cell and sector and describes the optimization steps to be performed as the remedy progresses.

Source Treatment Implementation through Intertwined RD/RA



Key

- 🟩 Remedial Design (RD)
- 🟦 Remedial Action (RA)
- 🟨 Intertwined RD/RA

Site-wide pre-treatment characterization (High resolution characterization, soil cores, flux measurements)

Update Conceptual Site Model (CSM) and Groundwater Model

Identify source treatment target locations and depths based on TPH soil concentrations

Phase I Combustion –Sector Evaluation

Design strategy for **combustion treatment** sector

Implement combustion treatment in sector*

Post-treatment characterization and performance assessment*

Combustion Treatment in Sector Successful?

Yes

No

Apply Secondary Technology – In situ Solidification

Move from initial technology to secondary technology

Update CSM (High resolution characterization, soil cores, flux measurements)

Optimize in situ solidification target area and cement mix design

Implement in situ solidification

** See next diagram for details*

All DNAPL Combustion Sectors Treated?

No

Yes

Evaluate need for secondary technology (flux measurements + attenuation model)

Is in situ solidification needed to treat additional sources

Yes

No

PROCEED TO DECISION DIAGRAM FOR GROUNDWATER

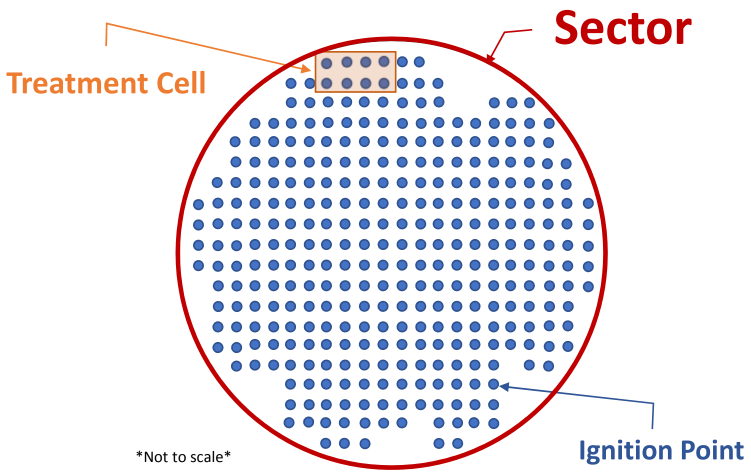
Gray shade indicates combustion treatment implementation

Details for Combustion Source Treatment Implementation By Cell and Sector

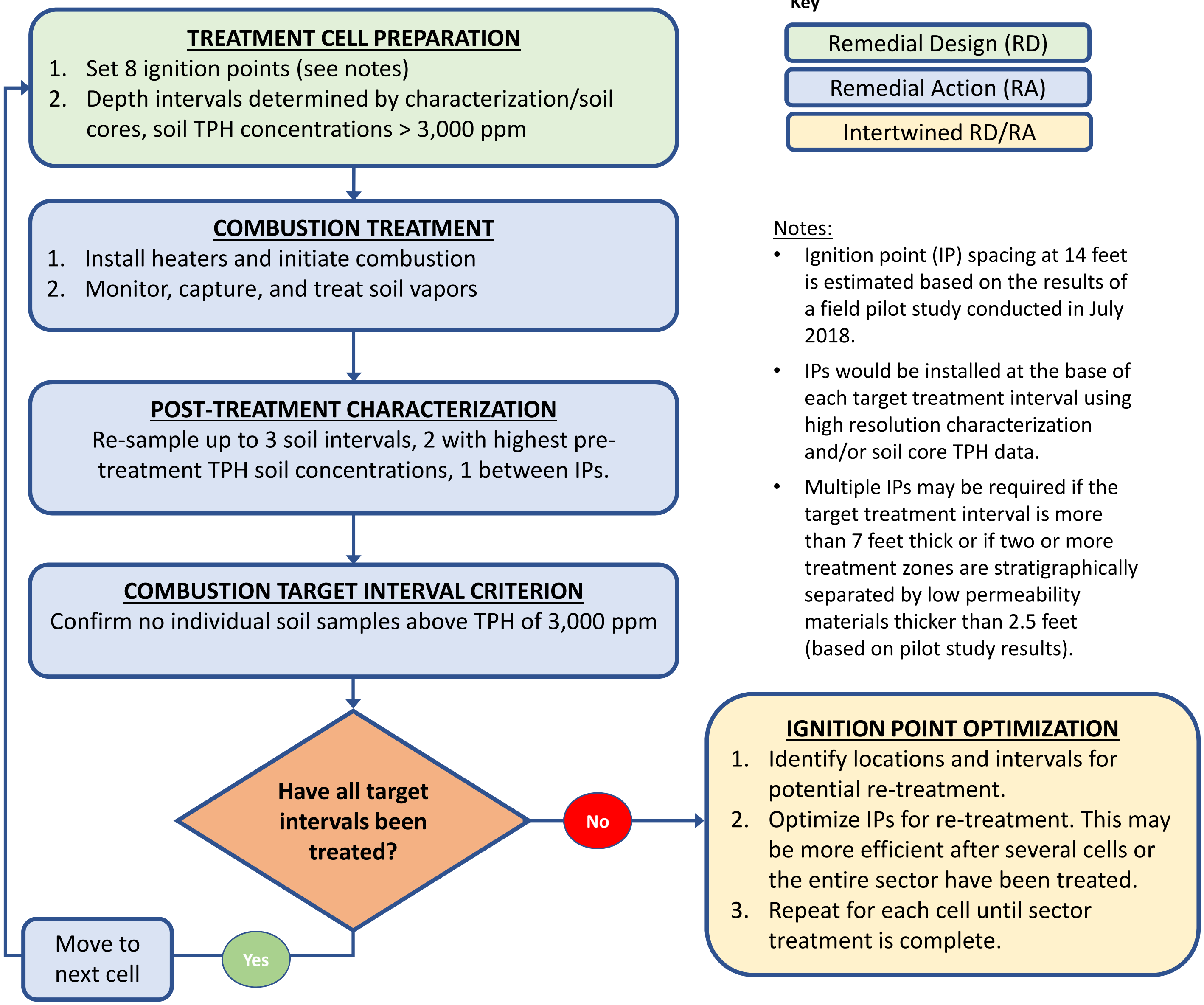
DEFINITIONS

Ignition Point:	Location of down-hole heater placement and compressed air injection
Cell:	Group of approximately 8 injection points treated at the same time
Sector:	Area of treatment (200 foot radius) that is operated on from a modular centralized location, able to treat ~100 cells.

Schematic of a Combustion Treatment Sector



CELL BY CELL TREATMENT WITHIN EACH SECTOR



TREATMENT CELL PREPARATION

1. Set 8 ignition points (see notes)
2. Depth intervals determined by characterization/soil cores, soil TPH concentrations > 3,000 ppm

COMBUSTION TREATMENT

1. Install heaters and initiate combustion
2. Monitor, capture, and treat soil vapors

POST-TREATMENT CHARACTERIZATION

Re-sample up to 3 soil intervals, 2 with highest pre-treatment TPH soil concentrations, 1 between IPs.

COMBUSTION TARGET INTERVAL CRITERION

Confirm no individual soil samples above TPH of 3,000 ppm

Have all target intervals been treated?

Move to next cell

Key

- 🟩 Remedial Design (RD)
- 🟦 Remedial Action (RA)
- 🟨 Intertwined RD/RA

Notes:

- Ignition point (IP) spacing at 14 feet is estimated based on the results of a field pilot study conducted in July 2018.
- IPs would be installed at the base of each target treatment interval using high resolution characterization and/or soil core TPH data.
- Multiple IPs may be required if the target treatment interval is more than 7 feet thick or if two or more treatment zones are stratigraphically separated by low permeability materials thicker than 2.5 feet (based on pilot study results).

IGNITION POINT OPTIMIZATION

1. Identify locations and intervals for potential re-treatment.
2. Optimize IPs for re-treatment. This may be more efficient after several cells or the entire sector have been treated.
3. Repeat for each cell until sector treatment is complete.

Appendix B
Alternative Cost Assumptions

APPENDIX B

Alternative Cost Assumptions

This appendix includes the general assumptions used to estimate costs for the alternatives described in this Proposed Plan.

- All unit costs are identical to those presented in the Feasibility Study (FS) (Aspect and Arcadis, 2016), except for in situ solidification (ISS) and for smoldering combustion (Self-sustaining Technology for Active Remediation [STAR]).
- All FS costs, except for ISS and STAR unit costs are based on 2015 dollars.
- All contingency and mobilization assumptions, and percentages based on construction costs are identical to those presented in the FS.

ISS unit costs for 8-inch and 4-inch auger solidification were revised from $70 and $90 per bulk cubic yard (BCY) to $129 and $149, respectively, accounting for vapor extraction and treatment and air monitoring during all ISS operations, and subsurface debris removal and temporary enclosure (for odor control) during a portion of the ISS operations.

The FS-level cost estimate detail for Alternative 7a, which includes STAR in addition to ISS, is provided in Table B-1 for Phase 1, and in Table B-2 for Phases 1 and 2. Costs for STAR are from the vendor based on the results of the STAR Pre-Design Evaluation (PDE), with assumptions provided in Table B-3.

Reference

Aspect Consulting, LLC and Arcadis US (Aspect and Arcadis). December 2016. *Feasibility Study, Quendall Terminals Site.* Prepared for: U.S. Environmental Protection Agency, Region 10 on behalf of Altino Properties and J.H. Baxter & Co. Available at https://semspub.epa.gov/work/10/100043827.pdf.

Table B-1 - Alternative 7a Cost Estimate: Phase 1 Only

Quendall Terminals
Renton, Washington

Site:	Quendall Terminals		
Remedial Action Description:	Alternative	7a	**PTW Smoldering Combustion or Solidification: Phase 1 Only**
Cost Estimate Accuracy:	FS Screening Level (+50/-30 percent)		
Key Assumptions and Quantities:	Capping of Upland Soil		
(refer to Quendall FS Report Appendix E for calculations)	21.6	acre	total area
	940,896	SF	total area
	133,521	SF	permeable area along shoreline
	14,836	BCY	habitat excavation overlap
	104,544	BCY	total volume based on 3' cap thickness
	Soil/Sediment Density		
	1.6	tons/BCY	soil density
	1.3	tons/BCY	sediment density
	0.7	tons/CY	organoclay density
Red font indicates revisions from 2016 Feasibility Study (FS)	**Solidification in areas with less than 4 cumulative ft of DNAPL**		
	-	**BCY**	**volume of soil to be solidified**
All other quantities, unit costs, and assumptions based on percentages of other costs are unchanged from the FS.	**-**	**BCY**	**volume of soil at shallow depths to be solidified**
	-	**BCY**	**volume of deeper soil to be solidified**

Item	Quantity	Unit	Unit Cost	Total Cost	Source	Notes
CAPITAL CONSTRUCTION COSTS						
Upland Soil Excavation and Capping						
Mobilization/Demobilization(1)	1	LS	$ 388,439	$ 388,439	percentage of construction costs	includes temporary facilities for duration of construction
Site Preparation	22	acre	$ 6,900	$ 149,040	Costworks	clearing, grubbing brush and stumps
Geotextile marker layer	104,544	SY	$ 2	$ 158,907	Costworks	non-woven, 120lb tensile strength
Import Fill - Permeable Cap	104,544	BCY	$ 30	$ 3,136,320	project experience	
Compaction	104,544	BCY	$ 5	$ 522,720	project experience	
Habitat Area - excavation	14,836	BCY	$ 6	$ 89,014		
Habitat Area - non-hazardous transport and disposal	23,737	ton	$ 60	$ 1,424,224		
Hydroseeding	14,836	SY	$ 1	$ 8,901	Costworks	includes seed and fertilizer for wetland area
Stormwater collection and detention system	1,500	LF	$ 40	$ 60,000	project experience	media filter drain
Subtotal				*$ 5,937,565*		
Tax	9.5%		$ 5,937,565	$ 564,069		Sales Tax
Contingency(2)	25%		$ 6,501,634	$ 1,625,408		
Total Upland Soil Cap Cost				$ 8,127,042		
Solidification in areas with less than 4 cumulative ft of DNAPL						
Mobilization/Demobilization(1)	1	LS	$ -	$ -	percentage of construction costs	includes temporary facilities for duration of construction
Solidification - 8-ft diameter auger	**-**	**BCY**	$ 129	$ -	project experience	8-ft auger used to cost-effectively treat shallower soils
Solidification - 4-ft diameter auger	**-**	**BCY**	$ 149	$ -	project experience	4-ft auger used to treat deeper soils, below 8-ft auger limit
Subtotal				*$ -*		
Tax	9.5%		$ -	$ -		Sales Tax
Contingency(2)	30%		$ -	$ -		
Total Upland Soil Solidification Cost				$ -		
STAR						
STAR Application (RR, MC, and QP-U DNAPL Areas and >4-foot Thickness)	**1**	**LS**	**$ 14,900,000**	**$ 14,900,000**	**vendor estimate**	**includes mob/demob and contingency**
Subtotal				***$ 14,900,000***		
Tax	***9.5%***		**$ 14,900,000**	**$ 1,415,500**		Sales Tax
Total STAR Cost				**$ 16,315,500**		
Subtotal Construction Costs				**$ 24,442,542**		
Professional Services (as percent of construction and contingency costs)						
Project management	5%		$ 24,442,542	$ 1,222,127		
Remedial design	6%		$ 24,442,542	$ 1,466,553		Includes treatability studies for remedy components as necessary
Construction management	6%		$ 24,442,542	$ 1,466,553		
Subtotal				*$ 4,155,232*		
Total Estimated Capital Cost				**$ 28,597,774**		Updated cost to include STAR
O&M COSTS						
1st Year O&M						
GW Monitoring	1	LS	$ 80,000	$ 80,000	Project experience	
Subtotal				*$ 80,000*		
Tax	9.5%		$ 80,000	$ 7,600		Sales Tax
Contingency(2)	25%		$ 87,600	$ 21,900		
Total 1st Year O&M Cost				$ 109,500		
Annual O&M						
Groundwater Monitoring	1	LS	$ 25,000	$ 25,000	Project experience	20 wells annually
Upland Cap inspection	6	hour	$ 80	$ 480	labor estimate	
Subtotal				*$ 25,480*		
Tax	9.5%		$ 25,480	$ 2,421		Sales Tax
Contingency(2)	25%		$ 27,901	$ 6,975		
Total Annual O&M Cost				$ 34,876		
Professional Services (as percent of Annual O&M costs)						
Project management/Reporting	10%		$ 34,876	$ 3,488		
Total, Annual O&M:				**$ 38,363**		
Total Estimated O&M, 100 Years, No NPV Analysis:				**$ 3,945,833**		
Periodic Costs						
TOTAL ESTIMATED COST, NO NPV ANALYSIS				**$ 32,543,607**		
OMB Circular Net Present Value Analysis						
Annual O&M	100	year	$ 38,363	$ 2,057,910		
1st year O&M	1	LS	$ 109,500	$ 109,500		
Discount rate for NPV	1.4%					
Total Estimated O&M and OMB Periodic NPV				**$ 2,167,410**		
TOTAL ESTIMATED COST				**$ 30,765,185**		
Alternate Net Present Value Analysis						
Annual O&M	100	year	$ 38,363	$ 547,416		
1st year O&M	1	LS	$ 109,500	$ 109,500		
Alternate discount rate for NPV	7.0%					
Total Estimated O&M and Alternative Periodic NPV				**$ 656,916**		
TOTAL ESTIMATED COST				**$ 29,254,690**		

Notes:
1. Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance.
2. Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction.
2. A 1.4% discount rate was used in the net present value analysis based on the 2015 OMB Circular real interest rate.
3. A 7.0% discount rate was used in the alternate net present value analysis as directed by EPA based on guidance found in OSWER No. 9355.0-75.

Table B-2 - Alternative 7a Cost Estimate: Phase 1 and Phase 2

Quendall Terminals
Renton, Washington

Site:	Quendall Terminals			
Remedial Action Description:	Alternative	7a	**PTW Smoldering Combustion or Solidification: Phase 1 and Phase 2**	
Cost Estimate Accuracy:	FS Screening Level (+50/-30 percent)			
Key Assumptions and Quantities:	Capping of Upland Soil			
(refer to Quendall FS Report Appendix E for calculations)	21.6	acre	total area	
	940,896	SF	total area	
	133,521	SF	permeable area along shoreline	
	14,836	BCY	habitat excavation overlap	
	104,544	BCY	total volume	based on 3' cap thickness
	Soil/Sediment Density			
	1.6	tons/BCY	soil density	
	1.3	tons/BCY	sediment density	
	0.7	tons/CY	organoclay density	
Red font indicates revisions from 2016 Feasibility Study (FS)	**Solidification in areas with less than 4 cumulative ft of DNAPL**			
	160,300	**BCY**	**volume of soil to be solidified**	
All other quantities, unit costs, and assumptions based on percentages of other costs are unchanged from the FS.	**160,300**	**BCY**	**volume of soil at shallow depths to be solidified**	
	-	**BCY**	**volume of deeper soil to be solidified**	

Item	Quantity	Unit	Unit Cost	Total Cost	Source	Notes
CAPITAL CONSTRUCTION COSTS						
Upland Soil Excavation and Capping						
Mobilization/Demobilization(1)	1	LS	$ 388,439	$ 388,439	percentage of construction costs	includes temporary facilities for duration of construction
Site Preparation	22	acre	$ 6,900	$ 149,040	Costworks	clearing, grubbing brush and stumps
Geotextile marker layer	104,544	SY	$ 2	$ 158,907	Costworks	non-woven, 120lb tensile strength
Import Fill - Permeable Cap	104,544	BCY	$ 30	$ 3,136,320	project experience	
Compaction	104,544	BCY	$ 5	$ 522,720	project experience	
Habitat Area - excavation	14,836	BCY	$ 6	$ 89,014		
Habitat Area - non-hazardous transport and disposal	23,737	ton	$ 60	$ 1,424,224		
Hydroseeding	14,836	SY	$ 1	$ 8,901	Costworks	includes seed and fertilizer for wetland area
Stormwater collection and detention system	1,500	LF	$ 40	$ 60,000	project experience	media filter drain
Subtotal				*$ 5,937,565*		
Tax	9.5%		$ 5,937,565	$ 564,069		Sales Tax
Contingency(2)	25%		$ 6,501,634	$ 1,625,408		
Total Upland Soil Cap Cost				$ 8,127,042		
Solidification in areas with less than 4 cumulative ft of DNAPL						
Mobilization/Demobilization(1)	1	LS	$ 1,447,509	$ 1,447,509	percentage of construction costs	includes temporary facilities for duration of construction
Solidification - 8-ft diameter auger	**160,300**	**BCY**	$ 129	$ 20,678,700	project experience	8-ft auger used to cost-effectively treat shallower soils
Solidification - 4-ft diameter auger	**-**	**BCY**	$ 149	$ -	project experience	4-ft auger used to treat deeper soils, below 8-ft auger limit
Subtotal				*$ 22,126,209*		
Tax	9.5%		$ 22,126,209	$ 2,101,990		Sales Tax
Contingency(2)	30%		$ 24,228,199	$ 7,268,460		
Total Upland Soil Solidification Cost				$ 31,496,659		
STAR						
STAR Application (RR, MC, and QP-U DNAPL Areas and >4-foot Thickness)	**1**	**LS**	**$ 14,900,000**	**$ 14,900,000**	**vendor estimate**	**includes mob/demob and contingency**
Subtotal				***$ 14,900,000***		
Tax	***9.5%***		**$ 14,900,000**	**$ 1,415,500**		Sales Tax
Total STAR Cost				**$ 16,315,500**		
Subtotal Construction Costs				**$ 55,939,201**		
Professional Services (as percent of construction and contingency costs)						
Project management	5%		$ 55,939,201	$ 2,796,960		
Remedial design	6%		$ 55,939,201	$ 3,356,352		Includes treatability studies for remedy components as necessary
Construction management	6%		$ 55,939,201	$ 3,356,352		
Subtotal				*$ 9,509,664*		
Total Estimated Capital Cost				**$ 65,448,865**		Updated cost to include STAR
O&M COSTS						
1st Year O&M						
GW Monitoring	1	LS	$ 80,000	$ 80,000	Project experience	
Subtotal				*$ 80,000*		
Tax	9.5%		$ 80,000	$ 7,600		Sales Tax
Contingency(2)	25%		$ 87,600	$ 21,900		
Total 1st Year O&M Cost				$ 109,500		
Annual O&M						
Groundwater Monitoring	1	LS	$ 25,000	$ 25,000	Project experience	20 wells annually
Upland Cap inspection	6	hour	$ 80	$ 480	labor estimate	
Subtotal				*$ 25,480*		
Tax	9.5%		$ 25,480	$ 2,421		Sales Tax
Contingency(2)	25%		$ 27,901	$ 6,975		
Total Annual O&M Cost				$ 34,876		
Professional Services (as percent of Annual O&M costs)						
Project management/Reporting	10%		$ 34,876	$ 3,488		
Total, Annual O&M:				**$ 38,363**		
Total Estimated O&M, 100 Years, No NPV Analysis:				**$ 3,945,833**		
Periodic Costs						
TOTAL ESTIMATED COST, NO NPV ANALYSES				**$ 69,394,697**		
OMB Circular Net Present Value Analysis						
Annual O&M	100	year	$ 38,363	$ 2,057,910		
1st year O&M	1	LS	$ 109,500	$ 109,500		
Discount rate for NPV	1.4%					
Total Estimated O&M and OMB Periodic NPV				**$ 2,167,410**		
TOTAL ESTIMATED COST				**$ 67,616,275**		
Alternate Net Present Value Analysis						
Annual O&M	100	year	$ 38,363	$ 547,416		
1st year O&M	1	LS	$ 109,500	$ 109,500		
Alternate discount rate for NPV	7.0%					
Total Estimated O&M and Alternative Periodic NPV				**$ 656,916**		
TOTAL ESTIMATED COST				**$ 66,105,781**		

Notes:
1. Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance.
2. Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction.
2. A 1.4% discount rate was used in the net present value analysis based on the 2015 OMB Circular real interest rate.
3. A 7.0% discount rate was used in the alternate net present value analysis as directed by EPA based on guidance found in OSWER No. 9355.0-75.

Table B-3

Alternative 7a Smoldering Combustion Assumptions

Treatment Area (ft^2)	101,495
Number of Ignition Points (IPs)	660
Number of Cells (IP clusters)	83
Number of Nodes (cell clusters)	6
Operating Time for 1 Treatment System (yrs)	2
Base Cost ($)	8.0M
Operation Cost/Cell ($)	82.6k - 87.9k
Total Cost - Base Case ($)*	14.9M

k = thousand (dollars)
M = million (dollars)

* Using a **base case** of 1 ignition point (IP) per location within each treatment cell is supported as follows:

- Pre-design evaluation (PDE) findings indicate that, within a given treatment cell, the number of IPs that would not be installed based on lower total petroleum hydrocarbon (TPH) concentrations is approximately balanced by the number of additional IPs that may be required to address multiple layers of contamination.

- Remedial Investigation (RI) data indicate approximately 25 percent of the total DNAPL treatment area may include multiple layers of contamination.

Costs Include:

- Remedy design, contracting, subcontracting;
- System installation, shakedown, operation; and,
- Project and construction management.

Assumptions:

- Site is accessible and secured by others;
- Soil is amenable to STAR treatment (greater than 3,000 to 5,000 mg/kg TPH);
- Weighted average treatment depth of 19 ft bgs assumed -- note that total treatment areas and depths are based on ISS assumptions used for Alternative 5, found in the 2016 FS Tables E-7 (maximum DNAPL depth) and E-10 through 12 (square footage for Alternative 5 Thiessen polygons);
- Post-characterization performed by others;
- All permitting performed by others;
- Utility clearances performed by others;
- Removal of any drilling obstructions (foundations, utilities, wells, etc.) by others;
- Installation of ignition points using direct push;
- A surface cap is required;
- Sheet piling is not required and costs have not been included;
- 7 feet radius of influence and 1.4 feet per day propagation velocity;
- 8 wells operating at a time (as a treatment “cell”);
- Thickness of 3 to 6 ft impacts can be treated from a single depth;
- Waste disposal by others;
- All costs in US$;
- The Site will be powered by diesel/generators;
- Vapor treatment by regenerative thermal oxidation (RTO);
- Electricity cost of US $0.08 per kWh, propane cost of $1.10 per gallon, and diesel cost of $3.00 per gallon has been included;
- Operational cycle time = 7 days per cell (5 day ignition and burn period, 2 days for setup/teardown/contingency);
- Operation will be staffed for 10 hours per day and remotely monitored otherwise;
- Treatment operations and drilling can occur concurrently.