CLEANUP ACTION PLAN
PORT OF SEATTLE TERMINAL 30

December 15, 2015

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Prepared by:

Washington State Department of Ecology

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1.0 INTRODUCTION

This Cleanup Action Plan (CAP) describes the cleanup action selected by the Washington State Department of Ecology (Ecology) for Terminal 30 (T30) Site. The Site is generally located at 1901 East Marginal Way South, Seattle, Washington, approximately one mile southwest of downtown Seattle, in King County, Washington on the shoreline of the East Waterway.

This CAP was developed using information presented in the Remedial Investigation/Feasibility Study (RI/FS) for the Site, which was prepared by Pacific Groundwater Group (PGG) in 2013 on behalf of the Port of Seattle (Port) in accordance with the Agreed Order (AO) entered between Ecology and Port in 1991.

The CAP:

- presents selected cleanup alternatives
- presents site cleanup standards and remediation levels
- provides the schedule to implement the cleanup action

The T30 Site is being cleaned up under the authority of Model Toxics Control Act Chapter 70.105D of the Revised Code of Washington (RCW), and the Model Toxics Control Act (MTCA) Cleanup Regulation, Chapter 173-340 of the Washington Administrative Code (WAC).

1.1 GENERAL FACILITY INFORMATION

The location and layout of T30 are presented in Figures 1-1 and 1-2.

Site Name:	Port of Seattle Terminal 30
Facility Site ID:	2055
Site Address:	1901 East Marginal Way South, Seattle, Washington
Parcel Number:	7666207830
Current Owner:	Port of Seattle, Roy Kuroiwa Project Manager
Current Operator:	SSA Marine (Port of Seattle Tenant)
Project Consultant:	Pacific Groundwater Group, Janet Knox Project Manager 2377 Eastlake Avenue East, Seattle WA 98102 206-329-0141

1.2 BACKGROUND

A Chevron Bulk fuel terminal occupied a portion of the T30 site since 1905. The Chevron bulk fuel terminal consisted of above-ground fuel storage tanks and associated piping and equipment. The Port purchased the T30 Site from Chevron on January 2, 1985. The fuel terminal was demolished between December 1984 and about November 1985. The Port redeveloped the 33.9 acres Terminal 30 as a container facility

The Port of Seattle (Port) and Ecology entered into an Agreed Order (AO) for cleanup at T30 in 1991, which was amended in 2013 to include preparation of this CAP.

As required by the 1991 AO, a draft Remedial Investigation/Feasibility Study (RI/FS) was developed in 1998 by GeoEngineers (1998 RI/FS) to document the nature and extent of contamination and to evaluate remedial alternatives. The draft RI/FS was not approved by Ecology.

A product recovery system was installed in the early 1990s that removed more than 171,000 gallons of product. As part of the redevelopment in 2007, a site-wide asphalt cover was constructed and more than 24,000 cubic yards of petroleum-impacted soil was disposed of offsite. However, substantial petroleum product remains in the soil and groundwater at the Site.

A final remedial investigation/feasibility study (RI/FS) was prepared by Pacific Groundwater Group (PGG) in 2013 to update the status of petroleum contamination at the site, to evaluate final remedial actions, and to fulfill the requirements of the 1991 AO.

1.3 SITE DESCRIPTION

T30 is located approximately one mile southwest of downtown Seattle, in King County, Washington on the shoreline of the Duwamish River East Waterway (Figure 1-1). The 2013 RI/FS and this CAP focus on approximately 11 acres in the northern portion of the larger 33.9 acre T30 property. The term “T30 site” or “site” refers to the extent of petroleum contamination in the northern portion of T30, inclusive of light non-aqueous phase liquid (LNAPL), soil, and groundwater contamination; the site boundary is shown in Figure 1-2. Soil contamination located at the West Vault and South Vault are from separate sources, and are not considered part of the Terminal 30 site.

The T30 site is bordered on the north by an area of public shoreline access to the East Waterway, on the east by East Marginal Way South, on the south by the southern portion of T30, and on the west by the East Waterway. The East Waterway is an operable unit of the Harbor Island Superfund Site as ordered by the U.S. Environmental Protection Agency (EPA).

1.3.1 Current Operations

T30 and the contiguous Terminal 25 to the south are currently operated as a 70-acre container storage and transfer facility by the Port's tenant SSA Marine, who is leasing the facility through 2023. Containerized freight is transferred between ships, trucks, and temporary terminal storage using a series of rail-mounted overhead cranes and forklifts. Activities are directed from the Vessel Tower and Gate House. The Vessel Tower is within the T30 site, while the Gate House is not (Figure 1-2). The T30 site is entirely paved with asphalt; runoff is controlled by a stormwater management system operated and maintained by SSA Marine (Figures 1-2 and 1-3).

1.3.2 Potential Future Development

The Port anticipates continued and long-term ownership of T30 and long-term use as a container facility. The Port has no plans to redevelop this property for alternate use.

1.3.3 Roads and Utilities Infrastructure

Vehicle access to T30 is directly from East Marginal Way and is controlled at the security Gate House. The City of Seattle provides water, electricity, and sanitary sewer service to T30. Stormwater runoff is managed by SSA Marine using best management practices. The stormwater management system treats runoff with oil/water separators and filtration media prior to discharge at outfalls to the East Waterway. Two of these outfalls, Hanford and Lander, enter the East Waterway south (upstream) of the site.

Utilities on the T30 site have been modified many times with varying levels of documentation. Most recently, additional subsurface utilities including electrical, sanitary sewer, and water were installed during the 2007-2009 container terminal construction (ENSR|AECOM 2010). Underground utilities documented in Port and Seattle Public Utility files are presented in Figure 1-3; additional abandoned or undocumented subsurface utility infrastructure may be present on the site.

1.3.4 Site Access

The site is accessed via the Main Gate on East Marginal Way. Site entry is managed at a staffed gate house at the Main Gate. A Transportation Worker Identification Card (TWIC) is required for access to the site to meet Department of Homeland Security regulations for access to marine port facilities. Site access must be arranged in advance with the Port of Seattle and the site tenant, which is currently SSA Terminals. Tenant contact information will be provided by the Port of Seattle as needed.

1.4 HYDROGEOLOGIC SETTING

Two stratigraphic units have been identified at the T30 site: fill and native deposits. Fill was derived at least in part from dredging and can be difficult to physically differentiate from similar native tidal flat and alluvial deposits (GeoEngineers, 1998). Key characteristics of these units include:

- Fill Unit—consists of sand and gravel with varying amounts of silt, wood, bricks, and construction debris; the unit thickens and dips westward toward the East Waterway (GeoEngineers, 1998). Fill units identified in the 1998 RI/FS by GeoEngineers were described as "laterally discontinuous" with a lower contact approximately 15 to 20 ft below ground surface (bgs) or the approximate historic MLLW tide line. Most of the fill materials tested for grain size distribution were classified as well-sorted sands and less commonly as sandy gravels, silty sand, and silts. During construction of the T30 facility in 1984-1985, additional fill for an engineered slope was placed after dredging operations were completed. This fill included sand with a surface layer of rip-rap extending to the base of the East Waterway.
- Native Deposits—consist of non-glacial, fluvial and estuarine, black, fine-to-medium sand with varying amounts of silt. Shell fragments and occasional organic materials were frequently observed in the native deposits.

Native soils and overlying fill comprise a shallow water table aquifer at the T30 site. Average depth to water ranges from 8 to 14 feet across the site. Recharge to the water table aquifer originates as precipitation in uplands and unpaved areas offsite; insignificant recharge originates at the T30 site due to the asphalt cover and the stormwater management system.

In the Duwamish Valley groundwater moves from upland recharge zones downgradient to Duwamish Waterway discharge zones. Groundwater at the T30 site generally flows toward the East Waterway, although discharge to the waterway is strongly influenced by tidal fluctuations and man-made structures. The average hydraulic gradient across the site is 0.0028 ft/ft with a slight increase near the sheet pile wall (Figure 1-2). Groundwater contours curve slightly northeast at the north end of the sheet pile wall, which is consistent with increased discharge around the end of the sheet pile wall. As tides rise and fall, flow between the East Waterway and the aquifer reverses in a tidal mixing zone that is relatively narrow; however, the zone of tidal influence on groundwater gradients is significantly wider.

Hydraulic conductivity of the shallow aquifer at the T30 site has been estimated based on tidal studies and grain size analysis (GeoEngineers, 1998). Estimates based on grain size analyses range from 0.02 to 0.1 cm/s (57 to 284 ft/day).

Estimates based on tidal studies range from 0.2 to 9 cm/s (567 to 25,500 ft/day) and likely overestimate the hydraulic conductivity of the aquifer given the native and fill lithologies observed at the T30 site. The higher tidal study estimates are typical hydraulic conductivities for clean gravels not for silty sands, which are observed in most borings at the site.

Additional discussion of the T30 hydrogeologic setting and tidal influence are included the RIFS (PGG, 2013b).

1.5 CONTAMINANTS OF CONCERN

The contaminants of concern (COC) in soil and groundwater include:

Petroleum Hydrocarbons

- Diesel-Range Organics
- Gasoline-Range Organics
- Oil-Range Organics
- BTEX: Benzene, Toluene, Ethylbenzene, Xylenes (total)

Semi-Volatile Organic Compounds

- 2-methylnapthalene

Polynuclear Aromatic Hydrocarbons (PAHs)

- Acenaphthene
- Acenaphthylene
- Anthracene
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(g,h,i)perylene
- Benzo(k)fluoranthene
- Chrysene
- Dibenzo(a,h)anthracene
- Fluoranthene
- Fluorene
- Indeno(1,2,3-cd)pyrene
- Naphthalene
- Phenanthrene
- Pyrene

1.6 POINTS OF COMPLIANCE

For soil at the T30 site, the point of compliance extends through the soil profile to a depth of 15 feet for the direct contact exposure pathway.

The standard MTCA groundwater point of compliance is groundwater throughout the site. For the T30 site, a conditional point of compliance (CPOC) for groundwater is selected to be located as close as practical to the source of the petroleum sheen area and LNAPL area. Monitoring wells MW-45, MW-46, MW-58A, MW-89, and MW-92 (Figure 1-2), located at the edge of tidal flushing and between the sheen and LNAPL area and surface water receptors, are selected as compliance monitoring wells.

1.7 CLEANUP LEVELS

Soil and groundwater cleanup levels are listed in Tables 1-1 and 1-2.

1.7.1 Soil

Soil cleanup levels in Table 1-1, applied to the T30 site, are MTCA Method A values for industrial land use or soil leaching to groundwater protective of surface water values.

1.7.2 Groundwater

The groundwater cleanup levels in Table 1-2 are surface water criteria for marine water. The marine surface water criteria are applicable for groundwater at the T30 site because groundwater discharges to the East Waterway.

Surface water criteria are not established for diesel-, heavy oil-, and gasoline-range organics, and total xylenes. Therefore, MTCA Method A groundwater criteria were selected for those parameters.

1.7.3 LNAPL

Measurable thickness of LNAPL in monitoring wells will be considered an exceedance of WAC 173-340-747(10) regardless of groundwater concentrations in samples collected from the well. A measurable thickness is 0.01-feet, the practical measurement limit with an interface probe. The presence of sheen will not be considered an exceedance of the LNAPL criteria.

1.8 REMEDIATION LEVELS

Remediation levels will be used to track remediation progress in non-CPOC wells. Remediation levels are developed for a subset of COCs that are indicative of TPH abundance, including: benzene, toluene, ethylbenzene, xylenes (BTEX); diesel range organics; and gasoline range organics. Remediation levels are used to demonstrate reduction in petroleum compound contaminant mass in the sheen area. In this context, remediation levels are a concentration reduction target for operation of the AS/SVE system, and are not a maximum concentration for compliance at performance monitoring wells. Remediation levels (RELs) in Table 1-3 are the maximum of either:

- 75% of the estimated solubility limit or
- twice the cleanup level

The composition of petroleum varies across the T30 site with variable amounts of weathered gasoline and diesel. The equilibrium concentrations of T30's COCs depend on soil and groundwater concentrations and on the petroleum mixtures in that part of the site. As shown in Table 1-3, the solubilities of individual compounds in equilibrium with different petroleum mixtures vary significantly. Therefore, a conservative EPA reference mixture is used to estimate effective solubilities rather than attempting to develop well-specific effective solubilities or one "T30 Product" effective solubility.

The solubility limit is estimated based on equilibration with an EPA 1994 Diesel Fuel Oil reference petroleum mixture. The use of 75% of the solubility is based on the assumption that petroleum at the site is primarily sorbed mass rather than residual saturation when groundwater concentrations are 75% of solubility groundwater concentrations.

Toluene, ethylbenzene and xylenes have cleanup levels above their respective effective solubilities and are not detected above cleanup levels in current groundwater data (see Table 1-4 and T30 RI/FS Table 2-4; PGG, 2013). For these compounds, the remediation level is set at twice the cleanup level. For benzene, the 75% effective solubility and twice the cleanup level criteria are nearly equivalent. Diesel and gasoline remediation levels are set as 75% of the total BTEX effective solubility. Achieving these remediation levels will indicate a significant reduction in sheen area contaminant mass to residual sorbed levels.

1.9 NATURE AND EXTENT OF CONTAMINATION

The nature and extent of contamination are described in the Terminal 30 RI/FS (PGG, 2013). For context, this section briefly describes petroleum contamination at the site pertaining to cleanup action components (Figure 1-4).

1.9.1 Soil

The extent of soil contamination is similar to the maximum historical extent of LNAPL with exceedances of cleanup levels for diesel-, oil- and gasoline-range hydrocarbons, and toluene. The extent of soil contamination is shown of Figure 1-4. Please refer to the T30 RI/FS for additional information (PGG, 2013).

1.9.2 Groundwater

Groundwater at the site has exceedances of cleanup levels for benzene, PAHs, and diesel-, oil-, and gasoline-range hydrocarbons. The most recent BTEX, diesel, and gasoline data at wells are shown on Figure 1-4, and data are summarized in Table 1-4.

There are no exceedances of cleanup levels at the CPOC in the most recent monitoring data from CPOC wells (Figure 1-4, Table 1-4).

1.9.3 LNAPL

Light non-aqueous phase liquid (LNAPL) is present in measureable quantities at MW-59. Measured product thicknesses range up to 1.3 feet at MW-59 (PGG, 2013).

2.0 CONSIDERED ALTERNATIVES

The 2013 RI/FS considered five remedial alternatives for the T30 site:

- Alternative 1: In-Situ Thermal Desorption
- Alternative 2: Expanded Sheen-Area AS/SVE with Targeted Excavation
- Alternative 3a: Sheen-Area AS/SVE Treatment with LNAPL Recovery
- Alternative 3b: Sheen-Area AS/SVE Treatment with LNAPL Recovery (Expanded Area)
- Alternative 4: Compliance Monitoring with LNAPL Recovery

All remedial alternatives included groundwater monitoring and institutional controls. Additional details for each of the considered alternatives are included in the T30 RI/FS (PGG, 2013a).

Alternative 3a was selected as the preferred alternative through a disproportionate cost analysis and is the cleanup action described in this CAP. As described in Section 3.1, some changes have been made to optimize the remedy. The cleanup actions for the Site were selected in accordance with and comply with the requirements of WAC 173-340-360, Selection of Cleanup Actions.

3.0 SELECTED CLEANUP ACTIONS

Selected cleanup actions at the T30 site will include air sparging/soil vapor extraction (AS/SVE) treatment, LNAPL recovery, long-term compliance monitoring, and institutional controls. These actions are intended to address specific cleanup goals, including:

- Protect human health and the environment
- Maintain cleanup levels at the conditional point of compliance (CPOC) for protection of surface water
- Reduce Light Non-Aqueous Phase Liquid (LNAPL) thickness near MW-59 to sheen
- Reduce contaminant mass in the sheen area

AS/SVE will reduce groundwater concentrations in the portion of the sheen area between MW-42 and MW-36 (Figure 3-1). LNAPL recovery will address the last remaining area with free product at the water table near MW-59. A later phase of AS/SVE will reduce contaminant mass in the MW-59 area after product thickness has been reduced to sheen. In addition, natural attenuation processes will reduce groundwater concentrations across the site. Institutional controls will prevent contact with subsurface soil and groundwater contamination by maintaining the asphalt cap as a protective barrier and by establishing procedures that prevent exposure below the asphalt cap without appropriate health and safety procedures and Ecology notification.

Targeted groundwater monitoring will confirm compliance with cleanup levels at the CPOC, track performance of the AS/SVE system, and document concentration trends in the interior of the site. Details of the cleanup action components are described in the following sections.

3.1 AS/SVE SYSTEM

The purpose of the AS/SVE system is to reduce contaminant mass in the sheen area. The AS/SVE system is not intended to reduce CPOC concentrations; concentrations are currently below cleanup levels at the CPOC. The AS/SVE system will extend from near MW-42 to MW-36 (Figure 3-1), bounded on the north by the extent of groundwater exceedances and on the south by the edge of the LNAPL area. The AS/SVE will extend into the LNAPL area once the LNAPL thickness is reduced to sheen as sparging could increase LNAPL migration.

AS/SVE will reduce contaminant mass in the sheen area to address primarily gasoline-range organics (Figures 3-1 and 3-2). Contaminant mass reduction will be achieved through a combination of direct extraction of volatile-phase petroleum compounds within the SVE radius of influence and biostimulation in the area downgradient of the AS/SVE system. The AS/SVE system is not expected to reduce contaminant mass upgradient of the sparge well radius of influence (nominally 20 feet).

3.1.1 System Configuration

The AS/SVE system will be operated in two arrays (Figure 3-1):

- Phase 1 array extending from near MW-36 north to near MW-42
- Phase 2 array extending from near MW-36 to near MW-59

Phase 2 will be implemented after LNAPL in the area near MW-59 has been reduced to sheen. Sparging in this area before LNAPL is reduced to sheen could result in LNAPL mobilization. AS/SVE distribution piping for Phase 2 will be installed during Phase 1 construction, but SVE trenching and sparge wells will not be installed until LNAPL has been reduced to sheen.

The AS/SVE system has been modified from the layout presented in the 2013 RI/FS based on subsequently collected soil and groundwater quality and further communications with Ecology (PGG, 2013a; 2013b; 2014).

3.1.2 Phase 1 AS/SVE Configuration

The Phase 1 AS/SVE system will include 14 air sparge wells, soil vapor extraction piping in distribution trenches, an equipment shed, and trenching to connect the system components to the equipment shed (Figure 3-1). The location of the equipment shed and other infrastructure will be established in the Engineering Design Report based on evaluation of site operations, electrical infrastructure, and underground utilities. The location of the equipment shed will not substantially influence the operation of the system. Air sparge (AS) wells will be constructed with 2-inch PVC riser pipe and screens 12- to 14-feet below the water table or approximately 21- to 23-feet below ground surface (Figure 3-2). Compressed air will be delivered to groups of AS wells (sparge zones) through 2-inch, horizontal PVC or HDPE pipes running below ground surface from a distribution manifold in the equipment shed. Each AS wellhead will be instrumented with a pressure gauge and valve to allow adjustment of air sparge rates at each sparge well.

Soil vapor extraction will include a horizontal 4-inch slotted pipe set approximately 4 to 5 feet below ground surface in trenches parallel to AS well alignments (Figures 3-1 and 3-2).

The air sparge compressor, soil vapor extraction blower, and exhaust gas treatment/filtering equipment will be housed in an on-site equipment shed just north of monitoring well MW-87A at the approximate location shown on Figure 3-1. The location of the equipment shed may be revised to accommodate tenant terminal operations or to facilitate connection to electrical infrastructure. Equipment location and utility infrastructure details will be refined in the Engineering Design Report, but will not alter the in-situ function of the AS/SVE system.

3.1.3 Phase 2 AS/SVE Configuration

The Phase 2 AS/SVE system will include 6 air sparge wells and soil vapor extraction piping in the distribution trenches. The system will connect to distribution piping near MW-36 installed during Phase 1 construction (Figure 3-1). Phase 2 AS/SVE wells and extraction lines will be operated from equipment in the equipment shed established during Phase 1.

3.1.4 System Operation

The 14 Phase 1 air sparge wells will be operated in three zones. Zones will initially be sparged sequentially with 30-minutes on and 60-minutes off to allow sparging-induced air channels to close between sparge cycles; sparge cycling may be adjusted based on operational data. The duration of sparging and recovery is based on empirical observations at other AS/SVE systems and run times may be further optimized based on pressure trends observed during system startup and operation. Phase 1 sparge zones will include (Figure 3-1):

- Zone 1: AS-1 through AS-5
- Zone 2: AS-6 through AS-9
- Zone 3: AS-10 through AS-14

Phase 2 sparge zones will be operated as separate zones after installation. Phase 2 sparge zones will include (Figure 3-1):

- Zone 4: AS-15 through AS-17
- Zone 5: AS-18 through AS-20

Figure 3-1 shows conceptual Phase 2 locations. Actual Phase 2 locations will be proposed based on the improved understanding of subsurface contamination and air-flow from several years of Phase 1 AS/SVE operation and the LNAPL recovery operations. The proposed Phase 2 design will be provided to Ecology for approval prior to implementation.

Each sparge zone will have a cumulative air flow of 40-60 standard cubic feet per minute (scfm). Each zone will be supplied air from a central manifold at the air compressor in the equipment enclosure. Pressure drop between the compressor and wellheads is estimated to be less than 2 pounds per square inch (psi) assuming 17 psi at the wellhead, 60 scfm flow rate, and 500 feet of 2-inch distribution pipe.

The air sparge system will be operated at wellhead pressures of approximately 15 psi. With screens located at 12 to 14 feet below the water table, approximately 5.2 to 6 psi will be required to displace water from the well to the screen interval. The remaining pressure will overcome capillary forces in the aquifer and force air into the formation. Each well will be sparged at 10 to 20 scfm.

The SVE system will withdraw a minimum of twice the sparge air quantity to control vapor migration from the treatment area. For example, if the AS system delivers 50 scfm, the SVE system will extract a minimum of 100 scfm. A vacuum blower installed in the equipment shed will draw the extracted vapors into treatment (Section 3.1.3). The onsite stormwater system is the primary accumulation point for vapors that may migrate away from the AS/SVE system. Air spaces in the adjacent stormwater system will be checked for accumulated vapors with a PID during system startup when the potential for elevated vapor concentrations is greatest. The AS and SVE flow rates will be adjusted if vapors above acceptable limits are detected in the stormwater system; monitoring criteria will be specified in the EDR.

3.1.5 Vapor Treatment

Exhaust vapors from the SVE system will require treatment prior to discharge because of elevated volatiles. Initial vapor concentrations are likely to exceed 1,000 parts per million by volume (ppmV), above which thermal oxidation is generally the most cost-effective treatment technology. Thermal oxidation air treatment uses either a catalytic oxidizer or propane flame to combust volatile-laden exhaust vapors; thermal oxidizers typically achieve approximately 99% reduction in VOC concentrations. SVE exhaust vapor concentrations will be periodically monitored in the airstream before treatment to estimate mass loss from the SVE system. The system will be transitioned to carbon filtration as concentrations decrease to below 1,000 ppmV. Exhaust treatment equipment will be specified in the EDR.

Soil vapor extraction discharge concentrations will likely require a permit from the Puget Sound Clean Air Authority (PSCAA) as a condition of operation. The permit may require additional vapor concentration monitoring unrelated to achieving remedial objectives.

3.1.6 Operation Criteria

The AS/SVE system will be operated in the following progression:

- Operate system until groundwater concentrations at performance wells MW-36, MW-39, MW-42, and RW-9 achieve remediation levels (Table 1-3).
- Collect SVE exhaust vapor field photoionization detector (PID) measurements during routine system operations and maintenance visits to estimate mass removal rate, coupled with the SVE flow rate.
- Cycle the AS/SVE system on as concentrations rebound at MW-36, MW-39, MW-42, and RW-9. Rebound from upgradient groundwater influx is anticipated to occur over a 3- to 9-month timeframe.

- Discontinue AS/SVE on-off cycling when the system is no longer significantly reducing contaminant mass in the sheen area, or remediation levels are maintained. Rebound concentrations may exceed remediation levels for some constituents even once the AS/SVE is no longer significantly reducing contaminant mass because of the proximity of performance wells to the upgradient edge of the treatment area. If the system is no longer effectively removing contaminant mass beyond the contaminant mass influx from upgradient, then AS/SVE cycling will be discontinued even if rebound exceeds remediation levels. Efficiency of mass removal will be evaluated from AS/SVE system operational data and groundwater data from performance monitoring wells. With Ecology approval, the AS/SVE system may be decommissioned at this time.
- Operational criteria for Phase 1 and Phase 2 of the AS/SVE system may be met and/or evaluated independently.

The AS wells will be decommissioned in accordance with WAC 173-160.

3.2 LNAPL RECOVERY

The area with remaining free-product is in an active portion of the shipping terminal operations, with most of the area between the rubber tire gantry runways (Figure 3-1). Vacuum-enhanced recovery is preferred over other technologies such as skimmers because it has the smallest equipment footprint, does not require trenching across sensitive structures, and is an effective recovery option.

LNAPL will be recovered from a network of recovery wells by vacuum-truck total fluids recovery. Recovery wells will be installed across the area where wells have measurable LNAPL thickness (Figure 3-1). Recovery events will include purging the wells with a vacuum truck. The recovery program will continue until equilibrium LNAPL remains below measurable thickness. Recovery event frequency will decrease with LNAPL thickness to allow the wells time to recover to equilibrium thicknesses between recovery events.

3.2.1 Conceptual Model for System Operation

LNAPL is present in pore spaces above and below the water table near MW-59. Recoverable LNAPL estimates are based on the soil type, LNAPL density and viscosity, and historic maximum LNAPL thickness. LNAPL that can drain from pore spaces through gravity drainage accumulates in monitoring wells as recoverable LNAPL. LNAPL that cannot drain from pore spaces under gravity is residual LNAPL. The historic maximum LNAPL thickness and pore size distribution of the aquifer determine the residual saturation. Greater LNAPL thicknesses are able to push LNAPL into smaller pore spaces (greater capillary pressure). The resulting capillary forces to push LNAPL into pore spaces can exceed the gravity drainage forces and leave LNAPL trapped in small pore spaces as residual saturation. Intuitively, LNAPL from small pores will drain more slowly than LNAPL from larger pores will drain. Therefore, the amount of LNAPL observed in a well and the maximum historic saturation together provides the best estimates of LNAPL recovery.

LNAPL recovery estimate calculations and modeling estimates are included in Appendix A. Modeling results and empirical field data indicate that:

- Recovery will reduce the LNAPL pore-space saturation by approximately 0.1 based on modeling the LNAPL maximum and current thickness at MW-59.
- Approximately 275 gallons of LNAPL in the vicinity of MW-59 is recoverable.
- At a measurable LNAPL thickness of 0.5 feet, a two hour vacuum-enhanced recovery event is expected to recover between 3 and 15 gallons of LNAPL per well; range includes both modeled recovery rates and recorded recovery volumes at RW-12.
- The optimal recovery well will have a nominal 17 foot radius of influence (well spacing of 35 feet) to balance between LNAPL recovery rate and number of wells installed in an infrastructure-dense portion of the site.

Applied vacuum in the well casing will increase the head (pressure) gradient from the surrounding aquifer into the well (Charbeneau, 2007a,b). The increased head gradient will increase flow of LNAPL into the well proportional to the LNAPL transmissivity (e.g. proportional to the LNAPL conductivity corrected for physical properties and degree of saturation). LNAPL transmissivity will decrease with progressive product recovery, which will decrease LNAPL saturation.

Vacuum enhanced recovery does not rely on volatilization of LNAPL for enhanced recovery. The SVE effect of vacuum extraction events is expected to be negligible relative to fluid recovery due to the low vapor pressure of weathered diesel.

LNAPL recovery rate is expected to vary between wells depending on the local variations in grain size within the soil matrix and distribution of LNAPL saturation. Therefore some wells will reach the endpoint for LNAPL recovery before others, even if the product thickness is similar at the beginning of the vacuum recovery program (see Section 3.2.4).

3.2.2 Recovery Well Design

Recovery wells will be constructed to enhance LNAPL migration from the surrounding aquifer and to accommodate vacuum enhanced extraction (Figure 3-

3). The recovery well network will include 10 new wells and will continue recovery at existing wells MW-59 and RW-12. New recovery wells will be constructed of 4-inch diameter Schedule 40 PVC in a 12-inch borehole. Well screens will extend from 2 feet above the water table at the combined seasonal and tidal high to 2 feet below the seasonal low at low tide. Combined seasonal and tidal variation near MW-59 is approximately 1.5 feet (nominal 6 foot screen). A 3 foot sump will be installed below the screen to allow the contingent use of alternate skimmer or pump configurations.

Between recovery events, the recovery wells will be capped with 4-inch diameter expanding well caps and protected by flush-to-grade well monuments. During recovery events, temporary vacuum-caps will be placed in the wellheads that are capable of maintaining a vacuum and yet have ports for extraction piping, an air-bleed valve that can also pass a sounder or interface probe, and a pressure gauge (Figure 3-3).

3.2.3 Vacuum-Enhanced Recovery

LNAPL will be removed using a vacuum truck to pump total fluids from recovery wells. Total fluids will be extracted from the wells through a siphon tube with the inlet set below the LNAPL-water interface. A vacuum-cap will be placed at the top of the PVC well casing to maintain negative pressure inside the recovery well, and the vacuum-cap will have an air-bleed valve to regulate pressure in the well. The air bleed valve will be used to reduce pressure in the well if adverse effects such as drawing excessive sediment through the well screen are observed. The top of the siphon tube will be connected to the vacuum truck by a flexible hose. The vacuum truck will apply approximately 5 psi of negative pressure to the well. The negative pressure will create a pressure gradient in the aquifer that will draw LNAPL and water into the well enhancing LNAPL recovery rates (Appendix A).

Vacuum enhanced recovery will be conducted for approximately 1 to 2 hours at each well each event, and initially may recover about 250 gallons of total fluid per event. Wells will be allowed to recover to equilibrium LNAPL thickness between events. Equilibration/recovery times will increase as LNAPL saturation and transmissivity decrease. Because of uncertainties in equilibration/recovery times, the following schedule of recovery events is subject to change based on actual recovery rates:

Project Year	Event Frequency	Cumulative Events
1	Monthly	12
2	Bi-Monthly	18
3	Bi-Monthly	24
4	Bi-Monthly	30
5	Bi-Monthly	36
6	Based on Review	--

Approximately 5 to 10 gallons of product per well will be recovered in the initial recovery events and is expected to decrease to less than 0.5 gallons per well in the later events. Equilibrium product thickness is estimated to approach 0.01 feet after approximately 34 extraction events (Appendix A); Phase II AS/SVE system may be installed at the end of Project Year 5 pending review of LNAPL recovery progress. Individual recovery wells may be removed from the recovery events when they meet termination criteria (Section 3.2.4).

LNAPL thickness will be measured at the beginning and end of each extraction event. Recovery wells that do not have measurable thickness (0.01 ft) will not be pumped during that recovery event.

3.2.4 LNAPL Recovery Termination

LNAPL recovery events at a well will be terminated when product thickness has been reduced to less than a measureable thickness (0.01 feet) for a period of one year of quarterly measurements. Product thickness will be measured with an interface probe. A clear plastic bailer will be used to measure product thickness if a reliable measurement cannot be obtained with the interface probe.

This recovery termination criterion will result in sequential removal of recovery wells from recovery events as the area with measureable LNAPL thickness shrinks. Wells will be left in place for 1 year after the last well meets the termination criteria, after which they will be decommissioned consistent with WAC 173-160.

3.2.5 Recovery Documentation

LNAPL remediation progress will be monitored by documenting total recovered fluids per well and per event, estimated product recovery per event, and LNAPL thickness at each recovery well at the start and finish of each recovery event. Direct measurement of recovered product is unlikely to be feasible due to emulsification of total fluids during recovery. Therefore, a sample of the total recovered fluids will be collected from the vacuum truck tank and the concentration used to estimate the recovered product quantity; for example 1,000 gallons total fluids at 5,000 mg/L is the equivalent of approximately 5.8 gallons of recovered product, based on a LNAPL density of 0.876 g/mL.

Recovered LNAPL will be recycled or disposed of off-site by the vacuum truck contractor.

3.2.6 Phase II AS/SVE System Installation

At the end of Project Year 5, the equilibrium product thickness is estimated to approach 0.01 feet. The Phase II AS/SVE system may be then installed to further extract lighter fraction petroleum.

4.0 MONITORING

Monitoring will include measurements of LNAPL thickness and groundwater monitoring at wells across the site (Table 3-1). Groundwater will be monitored at conditional point of compliance (CPOC) wells, performance monitoring wells, and interior groundwater monitoring wells. Wells are grouped as follows:

- LNAPL Thickness: MW-59 and adjacent LNAPL recovery wells
- CPOC Wells: MW-45, MW-46, MW-58A, MW-89, and MW-92
- Performance Monitoring Wells : MW-36, MW-39, MW-42, and RW-9
- Interior Monitoring Wells: RW-1, RW-5A, and MW-38

The following contaminants of concern (COC) will be analyzed in performance and compliance monitoring wells.

Petroleum Hydrocarbons

- Diesel-Range Organics
- Gasoline-Range Organics
- Oil-Range Organics
- BTEX: Benzene, Toluene, Ethylbenzene, Xylenes (total)

Semi-Volatile Organic Compounds

- 2-methylnapthalene

Polynuclear Aromatic Hydrocarbons (PAHs) (filtered and unfiltered)

- Acenaphthene
- Acenaphthylene

- Anthracene
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(g,h,i)perylene
- Benzo(k)fluoranthene
- Chrysene
- Dibenzo(a,h)anthracene
- Fluoranthene
- Fluorene
- Indeno(1,2,3-cd)pyrene
- Naphthalene
- Phenanthrene
- Pyrene

Key elements of the monitoring are described below.

4.1.1 LNAPL Monitoring

LNAPL thickness will be measured at MW-59 during groundwater compliance monitoring events and at MW-59 and surrounding LNAPL extraction wells at the beginning of LNAPL recovery events.

4.1.2 CPOC Groundwater Monitoring

Groundwater monitoring at the CPOC will be used to assess concentrations of site COCs at the CPOC relative to cleanup levels. Due to the considerable sorbed mass contributing to the dissolved phase exceedances, natural attenuation processes are expected to take between 30 and 60 years to reach cleanup levels across the site. Calculations for petroleum hydrocarbon degradation to cleanup levels indicated approximately 30 years based on typical T30 site soil concentrations and estimated groundwater degradation rates from monitoring well data trends (PGG, 2013; AECOM, 2008).

Based on the petroleum degradation calculations, groundwater quality will be monitored at the CPOC for 30 years (Table 3-1). Groundwater monitoring at the CPOC may be continued beyond 30 years depending on the status of site-wide groundwater concentrations.

Groundwater concentrations above cleanup levels may persist in some non-CPOC wells after the estimated 30 year natural attenuation period due to residual hotspots or physical characteristics of COCs. Residual contamination associated with buried utilities or infrastructure may leave hot spots with localized elevated groundwater concentrations after the majority of the site has reached cleanup levels. PAHs have lower biodegradation rates and higher soil sorption coefficients than gasoline-, diesel-, and oil-range hydrocarbons. Therefore, natural attenuation of PAHs is expected to be slower than for the petroleum hydrocarbons and may persist as localized hotspots in areas where gasoline- through oil-range hydrocarbons have reached cleanup levels. However, because PAHs sorb more strongly to soil particles than petroleum hydrocarbons, they are not as mobile in groundwater; therefore, the downgradient extent of residual PAH hotspots is expected to be limited.

4.1.3 Performance Groundwater Monitoring

Performance monitoring wells are located within the AS/SVE system radius of influence and will be used to track system effectiveness. Concentrations are expected to decline as contaminant mass is reduced within the AS/SVE treatment area. Groundwater concentrations are expected to rebound over 3- to 9-months after the AS/SVE system is cycled off and groundwater with elevated concentrations from the interior area flows through the AS/SVE treatment area.

4.1.4 Interior Groundwater Monitoring

Interior monitoring wells are located upgradient of the AS/SVE system within the portion of the site with sheen but no measureable product thickness. Interior monitoring wells will be used to track long-term reductions in contaminant mass. Concentrations at the wells furthest upgradient (RW-1 and RW-5A) are expected to first decline to remediation and then to cleanup levels. Groundwater concentrations at MW-38 are expected to decline more slowly due to the downgradient position, and may remain static for 10 or more years due to the persistence of sheen that may maintain groundwater concentrations near saturation for the residual petroleum mixture.

4.1.5 Schedule

Monitoring wells will be sampled on a schedule consistent with the anticipated rate of change at that location and a well’s role in operational decision making. Biodegradation processes will continue to reduce groundwater concentrations in the interior sheen area in year to multi-year time scales. AS/SVE will locally reduce groundwater concentrations in month-to-year time scales. Proposed monitoring includes (Table 3-1):

Performance Monitoring

- Performance monitoring will be conducted when the AS/SVE system (Phase I and II) is in operation and when the AS/SVE system is temporarily shut down.

- Performance monitoring wells will be sampled semi-annually when the AS/SVE system is in operation (Phase I and II) and when the AS/SVE system is temporarily shut down.
- The CPOC wells will be sampled biannually when the AS/SVE system is in operation and when the AS/SVE system is temporarily shut down.
- The AS/SVE system is estimated to be in operation for seven years. At the end of seventh year, the system will be temporarily shut down.

Compliance Monitoring

- Once both Phase I and Phase II AS/SVE system are permanently shut down, long term compliance monitoring begins.
- The CPOC wells will be sampled annually for the first 5 years of compliance monitoring, bi-annually for years 5-10, and every 5 years for year 10 and beyond.
- Supplemental monitoring may be conducted to inform AS/SVE operational decision making.

Interior Monitoring

- Interior monitoring wells will be sampled biannually for the first 7 years (4 events), followed by sampling every 5 years. The Interior monitoring well schedule is independent of the transition from Performance to Compliance monitoring at CPOC and Performance monitoring wells.

Individual performance or interior groundwater monitoring wells may be removed from the monitoring program early if concentrations achieve cleanup levels for two consecutive sampling events; this does not apply to CPOC wells or wells within the AS/SVE treatment zone while the AS/SVE system is operating.

4.2 INSTITUTIONAL CONTROLS

A restrictive environmental covenant consistent with the requirements of WAC 173-340-440 will be filed after construction of the AS/SVE and LNAPL recovery systems.

4.3 CONTAMINATED MATERIAL LEFT ON-SITE

The selected remedy may leave concentrations of COCs elevated above soil cleanup levels on site. WAC 173-340-380(1)(a)(ix) requires that remedies with on-site containment specify the amount of hazardous substances left on site and the measures that will be used to prevent migration.

The volume of impacted soil or material left on site above cleanup levels is estimated to be the volume of soil between the base of asphalt and the water table within the historic extent of measurable LNAPL. This calculation over-estimates the amount of material left on site because LNAPL initially spread laterally at the water table from the release area. We estimate that approximately 63,000 cubic yards of impacted soil will remain on site following completion of the selected remedy.

5.0 SCHEDULE

The schedule for major deliverables and work tasks associated with cleanup actions is included as Exhibit C to this Consent Decree. The schedule provides anticipated submittal task duration for deliverables and actions associated with site cleanup, including progress reports, financial assurances, engineering design documents. Refer to Exhibit C for details on project deliverables and schedules.

5.1 ENGINEERING DESIGN REPORT

The forthcoming T30 Engineering Design Report (EDR) will provide technical details and drawings for system installation including equipment specifications, construction drawings, connections to utility infrastructure, and specific permitting issues. The EDR will be completed within the schedule in the new Consent Decree for the cleanup actions.

The EDR will include specifications for the Port of Seattle bidding process, which is expected to take between 3 and 6 months from Port Commissioner approval to proceed.

5.2 AS/SVE

After construction contract award, the AS/SVE system will be installed. Construction activities will be coordinated with tenant operations.

The AS/SVE system will operate until groundwater monitoring meets the shutdown criteria. The system is nominally expected to operate for 5 years in the Phase 1 and Phase 2 areas.

5.3 LNAPL RECOVERY

After construction contract award, the LNAPL recovery wells will be installed. LNAPL recovery will continue until measurable LNAPL thickness is less than 0.01 feet at MW-59, RW-12, and additional recovery wells installed during system setup. Recovery operations are anticipated to continue for 10 years with a nominal completion date in 2026 assuming system startup in 2016.

5.4 GROUNDWATER MONITORING

Groundwater monitoring will be conducted for 30 years, with possible extension at selected wells based on monitoring results at that time. The forthcoming T30 Compliance Monitoring Plan will describe long term- and operational-groundwater monitoring associated with the AS/SVE and LNAPL recovery actions. The groundwater monitoring schedule for CPOC wells and additional operational groundwater monitoring for the AS/SVE system will be detailed in the plan.

6.0 CONTINGENCY ACTIONS

The selected remedial actions are expected to meet remedial objectives within a reasonable time frame. However, contingency actions may be implemented during the course of remedial activities in response to changes in site conditions, identification of previously unrecognized environmental conditions, or if remedial objectives are not met (Figures 6-1 and 6-2). Section 6.1 describes the process to determine if a contingency action is appropriate. If a contingency action is appropriate, Section 6.2 describes the process for selecting the contingency action. Section 6.3 describes the notification schedule for beginning the contingency action evaluation process.

6.1 CONTINGENCY ACTION EVALUATION

This section describes the process for evaluating if a contingency action is appropriate. Broadly speaking, a contingency action is appropriate if the selected remedial actions are not adequately protective of human health and the environment. This situation could arise due to the following conditions:

- Identification of a previously unrecognized environmental condition
- Change in site conditions
- Groundwater concentrations of site COCs above cleanup level(s) at the CPOC
- Remedial actions not achieving remedial objectives in a reasonable timeframe

Not all occurrences of the conditions listed above will trigger a contingency action. Figure 6-1 diagrams an evidence-driven decision framework for evaluating if contingency action is appropriate. The process and context for evaluating conditions that might trigger a contingency action is described in the following sections.

6.1.1 Unrecognized Environmental Condition

Substantial characterization has been completed at the T30 site since environmental investigations began in the 1980s. It is unlikely that substantial new environmental conditions will be identified at the site. The most probable scenario for an unrecognized environmental condition is discovery of localized hot-spots associated with historic buried materials. These would most likely be encountered during excavation associated with utility work[1] or construction of the AS/SVE or LNAPL recovery systems.

Unrecognized environmental conditions will be assessed on a case by case basis in the following steps:

1. Do CPOC groundwater concentrations exceed site cleanup levels? Contingency action is not appropriate under MTCA if concentrations are below cleanup levels.

2. If CPOC groundwater concentrations exceed site cleanup levels, do existing remedial actions adequately address the contamination? Contingency action is not appropriate within the site context if remedial actions already in progress will address the contamination in a reasonable timeframe.

Contingency action will be initiated if an environmental condition is recognized with concentrations above groundwater cleanup levels that will not be addressed by ongoing remedial actions.

6.1.2 Change in Site Conditions

Changes in site conditions that alter potential exposure pathways could trigger contingency action specific to the exposure pathway. Examples could include:

- Change in groundwater flow system
- Change in site infrastructure resulting in an increased exposure potential
- Natural disaster (flood, earthquake, etc.) causes redistribution of contamination or site boundaries

[1] Future excavation work will be conducted consistent with institutional controls discussed in Section 4.2

Changes in site conditions will be evaluated on a case by case basis with consideration of concentrations relative to T30 site cleanup levels and whether remedial actions already in progress will address the change in site conditions.

6.1.3 Concentrations Above Cleanup Levels

Contingency action could be initiated if groundwater concentrations of site COCs are both above cleanup levels at COPC wells and are demonstrated to have a statistically significant increasing trend. An increasing trend at concentrations below cleanup levels, or exceedances at performance or interior monitoring wells would not trigger contingency action.

Concentrations may exceed site cleanup levels at some CPOC wells at the beginning of remedial action. Therefore, an exceedance of cleanup levels at the CPOC will not automatically trigger a contingency action if remedial measures to reduce concentrations are already in progress. Satisfactory progress towards cleanup objectives is discussed in Section 6.1.4.

Increasing trends will be evaluated using the statistically-based methods for evaluating plume status (Ecology, 2005). The method uses the non-parametric Mann-Kendall and Whitney-U tests to evaluate if constituent concentration trends at monitoring wells are increasing, stable, or decreasing. These tests require four or more independent sampling events to produce valid results.

6.1.4 Remedial Action Progress

Remedial progress will be tracked through groundwater monitoring described in Section 4 and the forthcoming T30 Compliance Monitoring Plan.

Progress relative to remedial objectives will be evaluated during Ecology periodic reviews. Contingency actions will be considered if remedial actions do not meet the remedial goals.

6.2 CONTINGENCY ACTION PROCESS

This section describes the process for planning contingency actions if a contingency action is appropriate after the evaluation in Section 6.1. The contingency action process is divided into three phases:

1. **Action Selection**: this phase describes the nature and extent of the exceedance triggering contingency action and selects an appropriate remedy. This phase may determine that a contingency action is not required to meet remedial objectives.

2. **Design**: this phase prepares the necessary engineering and design plans and reports, addendum to the Compliance Groundwater Monitoring Plan, or other documentation to implement the contingency action.

3. **Implementation**: this phase implements the selected contingency action.

The contingency action process parallels the remedial investigation and feasibility process under MTCA, but is intended to be streamlined towards efficient implementation. Steps may be combined for efficiency.

The action selection phase will define the media to be addressed, the nature and extent of the contamination to be addressed, and the objectives of the contingency action. Depending on the scope of the identified environmental issue, this first phase may also include investigation to fill data gaps and focused assessment of contingency action alternatives.

6.3 CONTINGENCY ACTION SCHEDULE

The Port of Seattle will notify Ecology within 14 days of identifying an environmental issue that potentially meets the criteria for contingency action. The Port of Seattle will provide a schedule and preliminary plan for moving through contingency action selection in consultation with Ecology. The plan may include additional investigation and characterization prior to selecting a contingency action.

Environmental issues that do not meet the criteria for contingency action will be discussed as appropriate in routine monitoring reports submitted to Ecology under the forthcoming T30 Compliance Monitoring Plan.

7.0 REFERENCES

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Table 1-1. Soil Cleanup Levels

Port of Seattle Terminal 30

Constituent	Cleanup Levels (mg/kg)
BTEX Compounds	
Benzene	**0.03**
Toluene	**7**
Ethylbenzene	**6**
Xylenes (total)	**9**
Semivoliatile Organic Compounds	
2-Methylnaphthalene	**NV**
PAH Compounds	
Acenaphthene	**NV**
Acenaphthylene	**NV**
Anthracene	**NV**
Benzo[a]anthracene	**NV**
Benzo[a]pyrene	**0.35**
Benzo[b]fluoranthene	**0.44**
Benzo[g,h,i]perylene	**NV**
Benzo[k]fluoranthene	**0.44**
Chrysene	**0.14**
Dibenzo[a,h]anthracene	**0.64**
Fluoranthene	**89**
Fluorene	**547**
Indeno[1,2,3-cd]pyrene	**1.25**
Phenanthrene	**NV**
Pyrene	**3,532**
Naphthalene	**5**
Petroleum Hydrocarbons	
Tph, diesel range organics	**2,000**
Tph, heavy oils	**2,000**
Tph: gasoline range organics, benzene present	**30**
Tph: gasoline range organics, no detectable benzene	**100**

"NV" indicates that no value is available.

Table 1-2. Groundwater Cleanup Levels
Port of Seattle Terminal 30

Constituent	Cleanup Levels (ug/L)
BTEX Compounds	
Benzene	**23**
Toluene	**15,000**
Ethylbenzene	**2,100**
Xylenes (total)	**1,000**
Semivoliatile Organic Compounds	
2-Methylnaphthalene	**NV**
PAH Compounds	
Acenaphthene	**643**
Acenaphthylene	**NV**
Anthracene	**25,900**
Benzo[a]anthracene	**0.018**
Benzo[a]pyrene	**0.018**
Benzo[b]fluoranthene	**0.018**
Benzo[g,h,i]perylene	**NV**
Benzo[k]fluoranthene	**0.018**
Chrysene	**0.018**
Dibenzo[a,h]anthracene	**0.018**
Dibenzofuran	**NV**
Fluoranthene	**90**
Fluorene	**3,460**
Indeno[1,2,3-cd]pyrene	**0.018**
Phenanthrene	**NV**
Pyrene	**2,590**
Naphthalene	**4,940**
Petroleum Hydrocarbons	
Tph: gasoline range organics, no detectable benzene*	**1,000**
Tph: gasoline range organics, benzene present*	**800**
Tph, diesel range organics	**500**
Tph, heavy oils	**500**

"NV" indicates that no value is available.

Table 1-3. Remediation Levels

Port of Seattle Terminal 30

Constituent	Units	Cleanup Level	Remediation Level**	75% Effective Solubility***	EPA Effective Solubility Reference Values					
					1994 Diesel Fuel Oil	No. 1 Diesel	No. 2 Diesel	Diesel Fuel Oil (Alaska)	87 Octane Gasoline	93 Octane Gasoline
Benzene	ug/L	23	47	47	62	138	436	1450	20,000	14,600
Toluene	ug/L	15,000	30,000	1,080	1,440	366	1,120	2,440	23,400	73,200
Ethylbenzene	ug/L	2,100	4,200	76.5	102	57	144	407	1,490	2,450
Xylenes (total)	ug/L	1,000	2,000	878	1,170	1,110	272	2,630	8,740	13,700
Total BTEX	ug/L	--	--	2,085	2,780	1,670	1,980	6,940	52,500	105,000
Gasoline Range Organics*	ug/L	1,000	2,085	--	--	--	--	--	--	--
Diesel Range Organics	ug/L	500	2,085	--	--	--	--	--	--	--

BTEX is Benzene, Toluene, Ethylbenzene, and Xylenes.

Effective solubility of a constituent in water in contact with a petroleum mixture is lower than when in contact with a pure source, such as a pure benzene release.

Effective solubilities are calculated using the EPA Effective Solubility Calculator at: http://www.epa.gov/athens/learn2model/part-two/onsite/es.html

The remediation level for light non-aqueous phase liquid (LNAPL) will be reduction to sheen (no measurable thickness).

*Cleanup Level is 800 ug/L if benzene is present.

** The remediation level for groundwater is taken as the higher of either twice the cleanup level, or 75% of the effective solubility. For diesel and gasoline ranges, this is taken as the effective solubility of total BTEX compounds, which is conservative as BTEX compounds constitute less than 100% of those petroleum mixtures. The EPA 1994 Diesel Fuel Oil reference is used as the effective solubility reference. Other effective solubilities are also included for comparison.

*** These values are 75% of the 1994 Diesel Fuel Oil effective solubility.

Table 1-4. Summary of Most-Recent Analytical Results
Port of Seattle Terminal 30

Well	Sample Date	Benzene	Toluene	Ethylbenzen	m, p-Xylene	o-Xylene	Total	Gasoline	Diesel	Motor Oil
		ug/L	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*mg/L*	*mg/L*	*mg/L*
	Cleanup Level	*23*	*15000*	*2100*	*1000*	*1000*	*1000*	*0.8*	*0.5*	*0.5*
Conditional Point of Compliance (CPOC) Wells										
MW-45	4/19/2011	0.5 U	0.5 U	0.5 U	1 U	1 U	1 U	0.05 U	0.05 U	0.25 U
MW-46	4/19/2011	0.5 U	0.5 U	0.5 U	1 U	1 U	1 U	0.05 U	0.05 U	0.25 U
MW-58A	10/14/2013	1 U	1.6	1 U	--	--	3 U	0.25	0.18	0.25 U
MW-89	10/14/2013	1 U	2.7	1.6	1.4	0.5 U	4.2	0.59	0.17	0.25 U
MW-92	10/14/2013	1 U	1 U	2.4	--	--	3 U	0.36	0.15	0.25 U
Performance Monitoring Wells										
MW-36	4/19/2011			*Sheen Present, No Measurable Product Thickness, No Analytical Data Available*						
MW-39	10/13/2004	**28**	1 U	2.7	4.3	1 U	--	**1.7**	**120**	**28**
MW-42	10/14/2013	18	5	1.1	2.9	0.7	5.6	0.65	0.17	0.25 U
RW-9	4/19/2011			*Sheen Present, No Measurable Product Thickness, No Analytical Data Available*						
Interior Wells										
MW-38	4/19/2011			*Sheen Present, No Measurable Product Thickness, No Analytical Data Available*						
RW-5A	5/5/2008	1 U	1 U	1.6	1 U	1 U	--	**1.3**	0.25 U	0.5 U
RW-1	4/19/2011			*Sheen Present, No Measurable Product Thickness, No Analytical Data Available*						

Bold indicates exceedance of the cleanup level (CUL).
Wells where sheen or product was observed were typically not sampled.

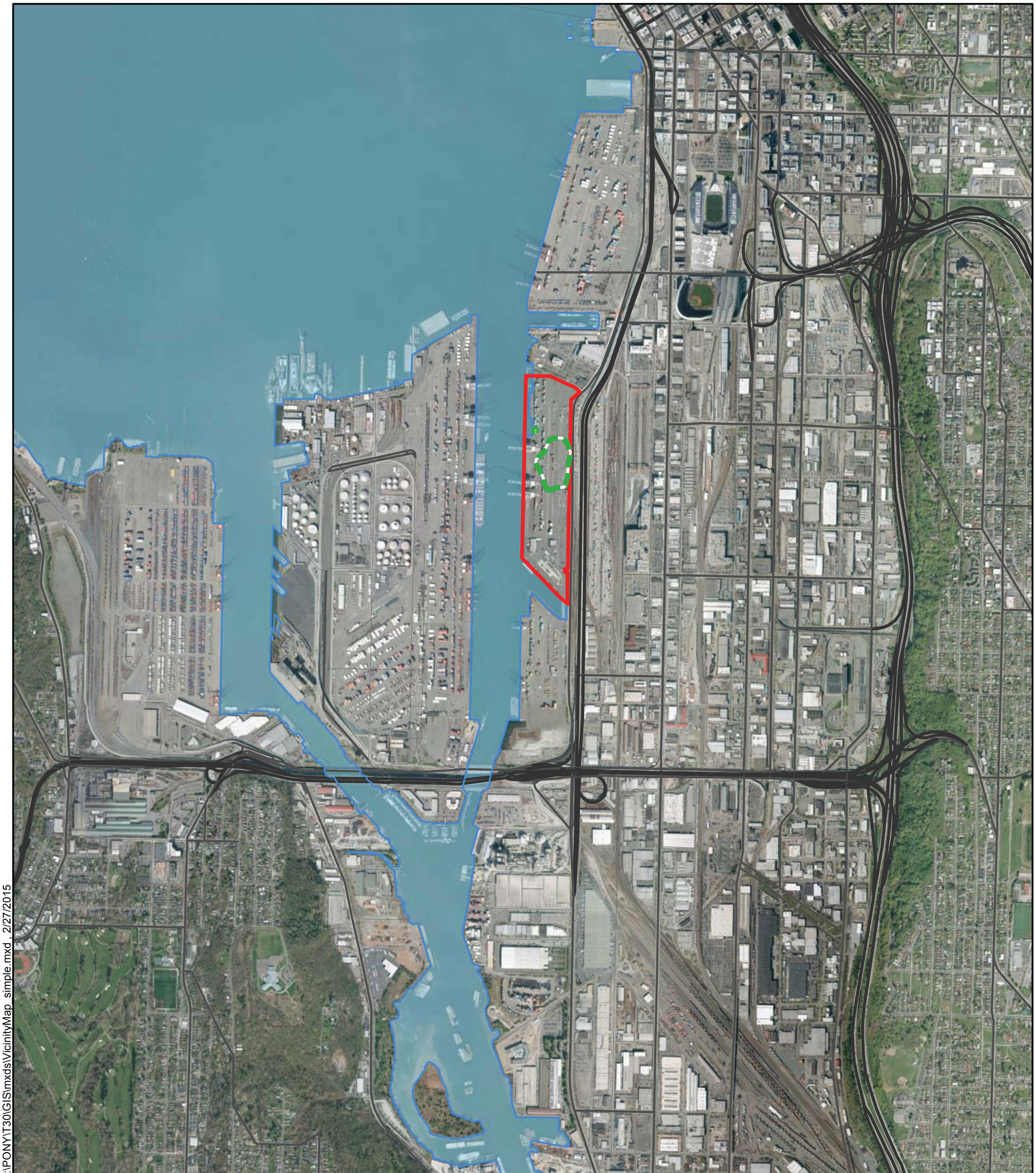
Table 3-1. Groundwater Monitoring Schedule

Port of Seattle Terminal 30

Project Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	22	27	32
Interior Monitoring Wells *																				
	Bi-Annual							*5-Year Interval*												
MW-38	x		x		x		x					x					x	x	x	x
RW-1	x		x		x		x					x					x	x	x	x
RW-5A	x		x		x		x					x					x	x	x	x
	Performance Monitoring Period **							*Compliance Monitoring Period*												
Conditional Point of Compliance Wells								*Year :* *1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*15*	*20*	*25*
	Bi-Annual							*Annual*					*Bi-Annual*				*5-Year Interval*			
MW-45	x		x		x		x	x	x	x	x	x	x		x		x	x	x	x
MW-46	x		x		x		x	x	x	x	x	x	x		x		x	x	x	x
MW-58A	x		x		x		x	x	x	x	x	x	x		x		x	x	x	x
MW-89	x		x		x		x	x	x	x	x	x	x		x		x	x	x	x
MW-92	x		x		x		x	x	x	x	x	x	x		x		x	x	x	x
Performance Monitoring Wells																				
	Semi-Annual																			
MW-36	x	x	x	x	x	x	x													
MW-39	x	x	x	x	x	x	x													
MW-42	x	x	x	x	x	x	x													
RW-9	x	x	x	x	x	x	x													

Notes:

Project Year 1 sampling will be conducted just prior to AS/SVE system startup.
* The Interior monitoring well schedule is independent of the transition from Performance to Compliance monitoring at CPOC and Performance monitoring wells.
** The duration of the Performance monitoring period is determined by the operation of the AS/SVE system. The bi-annual and semi-annual monitoring frequency at CPOC and Performance monitoring wells will continue until Compliance monitoring begins.
LNAPL thickness will be measured at MW-59 and surrounding wells will on the recovery event schedule.
Sampling may continue beyond year 32 on the 5-year compliance monitoring schedule, as discussed in text.
Monitoring may be discontinued at individual monitoring wells when concentrations achieve cleanup levels for two consecutive events.
x indicates a year with sampling at the indicated wells



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Site Boundary

Terminal 30

0 Feet 2,000

0 Miles 0.5

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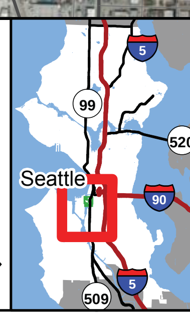
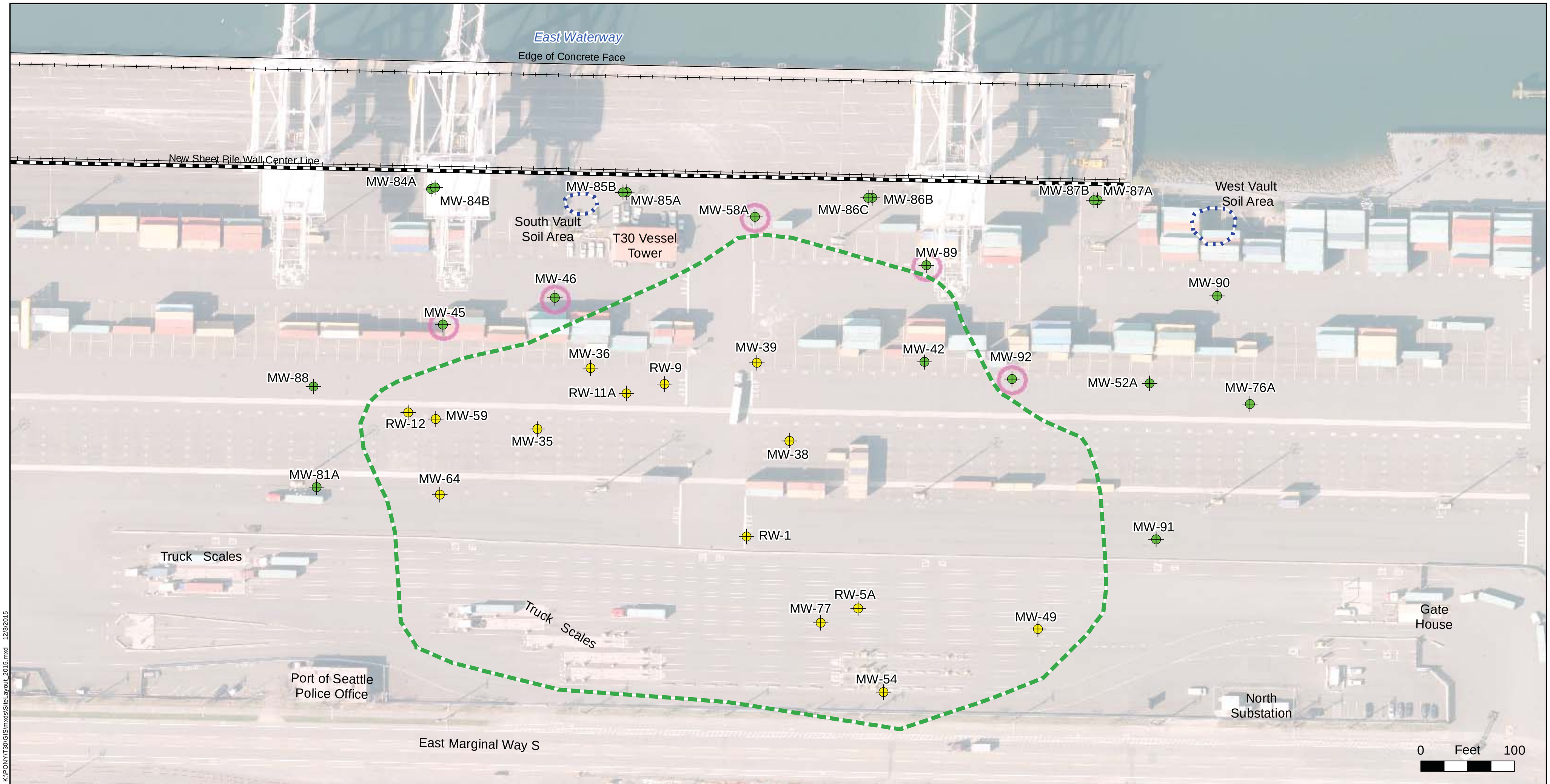


Figure 1-1

Site Location Map

Port of Seattle
Terminal 30



- Gaging/Recovery Well
- Water Quality Monitoring Well
- Conditional Point of Compliance (CPOC) Wells
- T-30 Site Boundary
- Soil Areas Not Associated with T-30 Site

2012 USGS Orthophoto

Figure 1-2
Site Layout

Port of Seattle
Terminal 30

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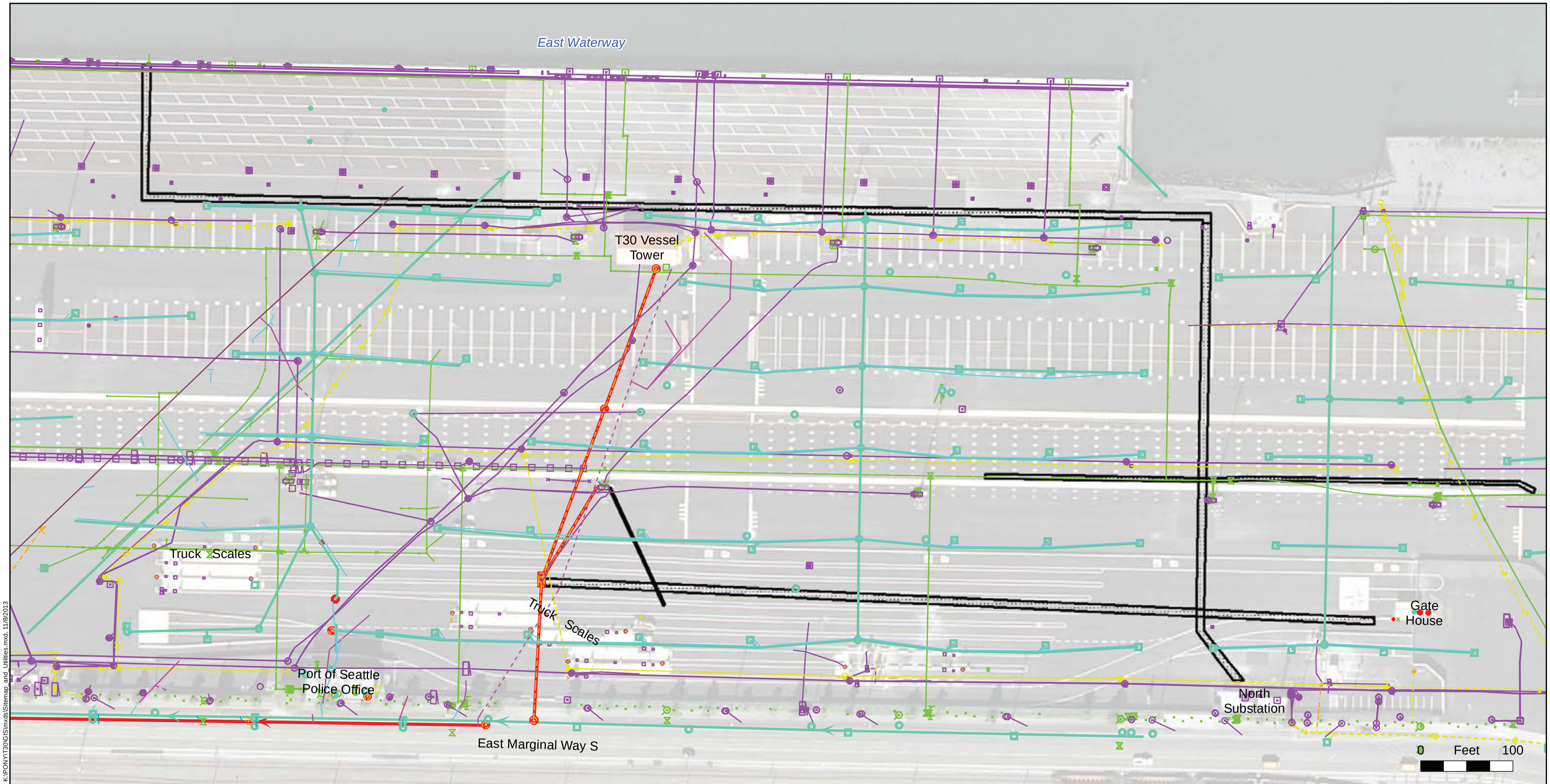

Underground Utilities (As Documented by Port of Seattle and SPU)

- Unknown
- Power
- Sanitary Sewer
- Stormwater
- Telephone
- Water
- Construction Completion Report Utility Replacment Areas (ENSR|AECOM, 2010)

Notes:
Co-located utilities may plot on top of each other;
Isolated catch basins or apron drains may not show connections to stormwater system;
Isolated power utilities marked on map may have connecting buried utilities lines that are not documented in available records

N

2009 USGS Orthophoto

Figure 1-3
Site Map with Utilities

Port of Seattle
Terminal 30

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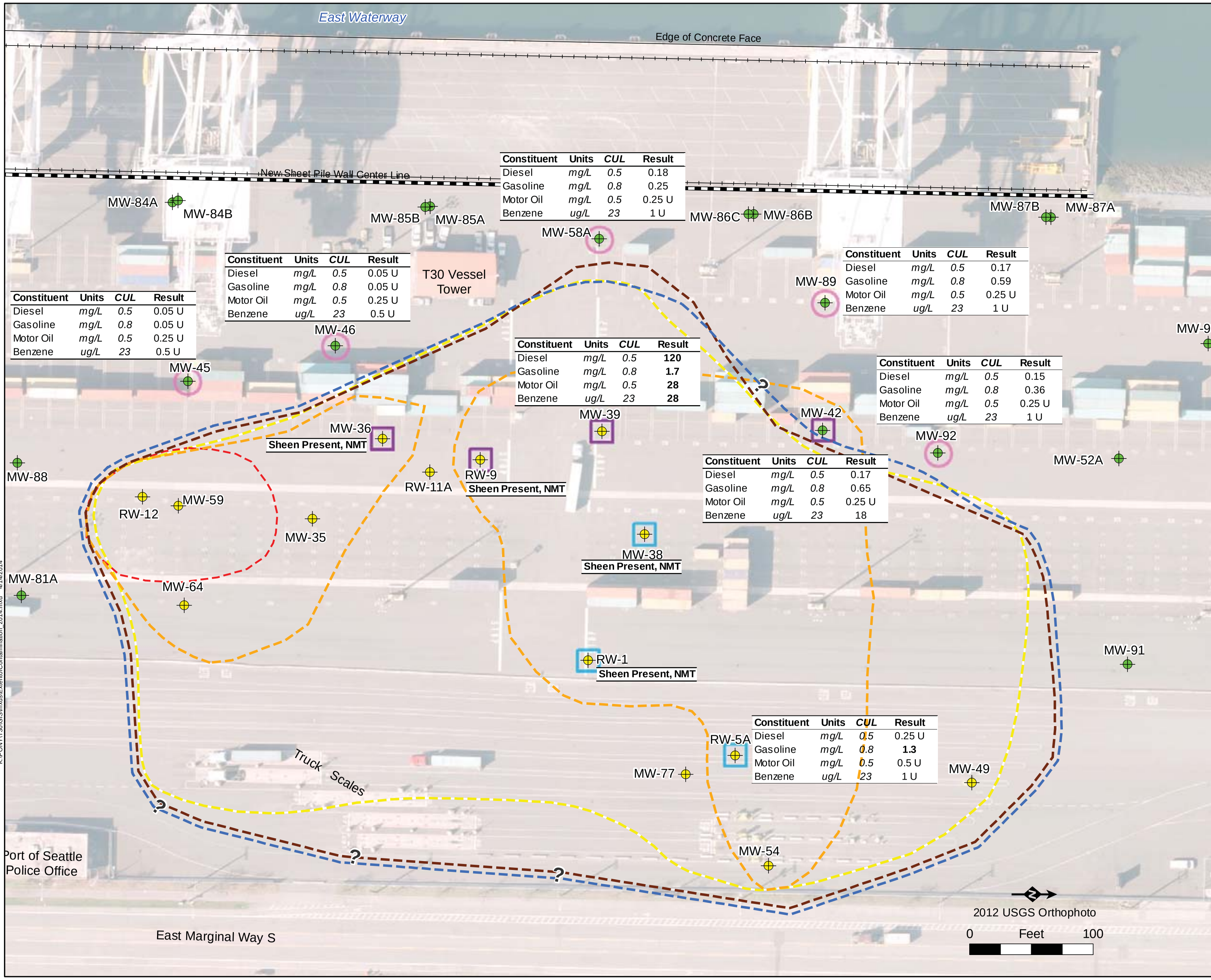


Figure 1-4

Extent of Contamination

Port of Seattle
Terminal 30

PgG

Site Extent of Contamination
Gaging/Recovery Well
Water Quality Monitoring Well
Conditional Point of Compliance (CPOC) Wells
Maximum Extent of Produce Plume 1984-1991 (GeoEngineers, 1998)
LNAPL > 0.1 Feet 2011
Sheen Area 2011

Extent of Contamination*

Groundwater Extent
Soil Extent
Performance Monitoring Wells
Interior Wells

Bold indicates exceedance of the cleanup level
CUL: Cleanup Level
Analytical data shown are most recent results, as summarized in Table 1-4.
Analytical data not available for MW-36, MW-38, RW-1 and RW-9
NMT: No Measurable Thickness

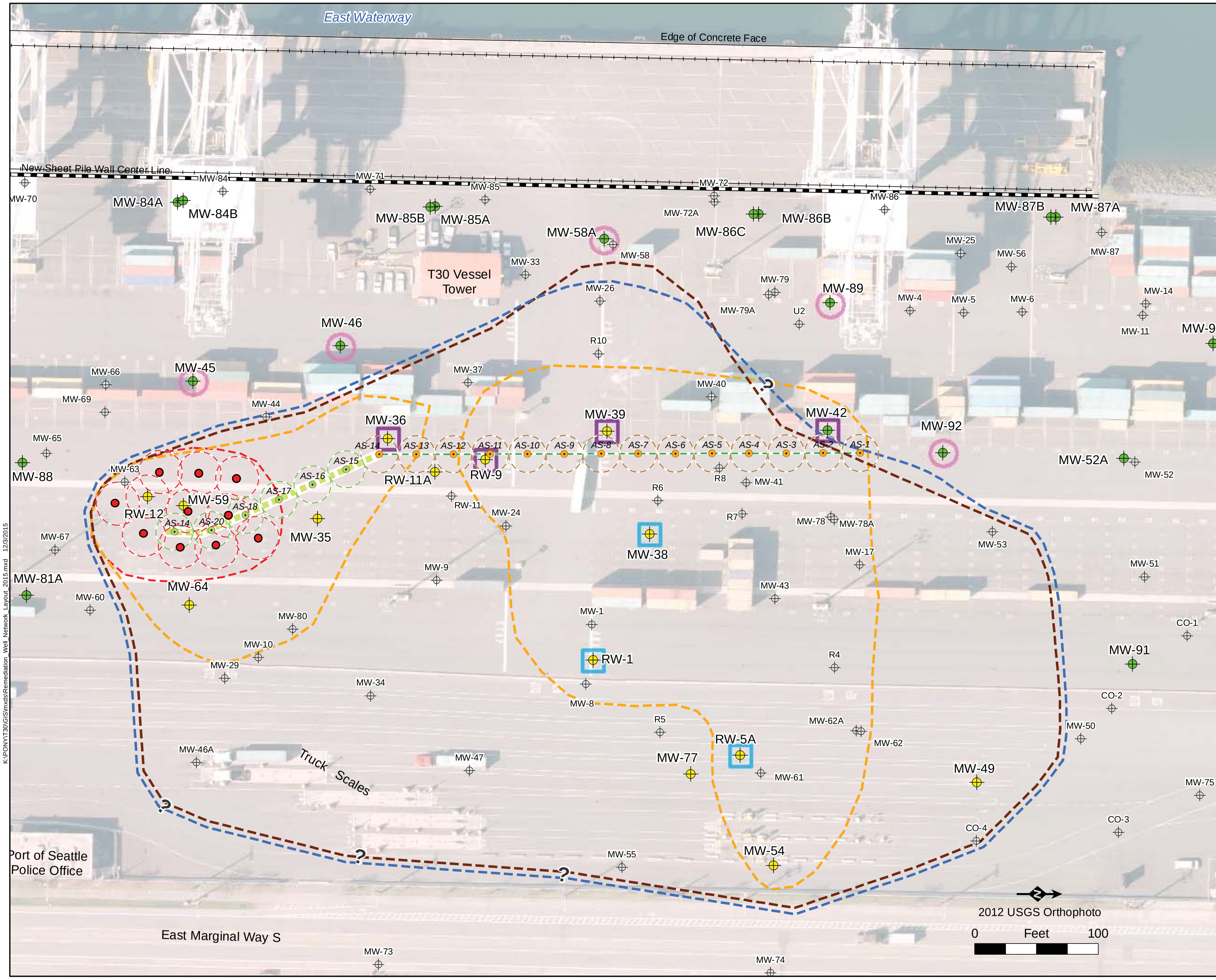
*Extents based on a combination of the historic extent of LNAPL, historic and recent data, and distribution of exceedances. Isolated "hot spots" may exist beyond the outlined soil and groundwater extent.

Figure 3-1

Cleanup Action Components

Port of Seattle
Terminal 30

PgG



- Site Extent of Contamination
- Gaging/Recovery Well
- Water Quality Monitoring Well
- Decommissioned Wells
- Conditional Point of Compliance (CPOC) Wells
- LNAPL > 0.1 Feet 2011
- Sheen Area

Extent of Contamination*

- Groundwater Extent
- Soil Extent

Remediation Elements

- LNAPL Extraction Well with Radius of Influence
- Phase I Air Sparge Well with Radius of Influence
- Phase II Air Sparge Well with Radius of Influence
- Phase I SVE Pipe in Trench
- Future Phase II AS/SVE
- Performance Monitoring Wells
- Interior Wells

*Extents based on a combination of the historic extent of LNAPL, historic and recent data, and distribution of exceedances. Isolated "hot spots" may exist beyond the outlined soil and groundwater extent.

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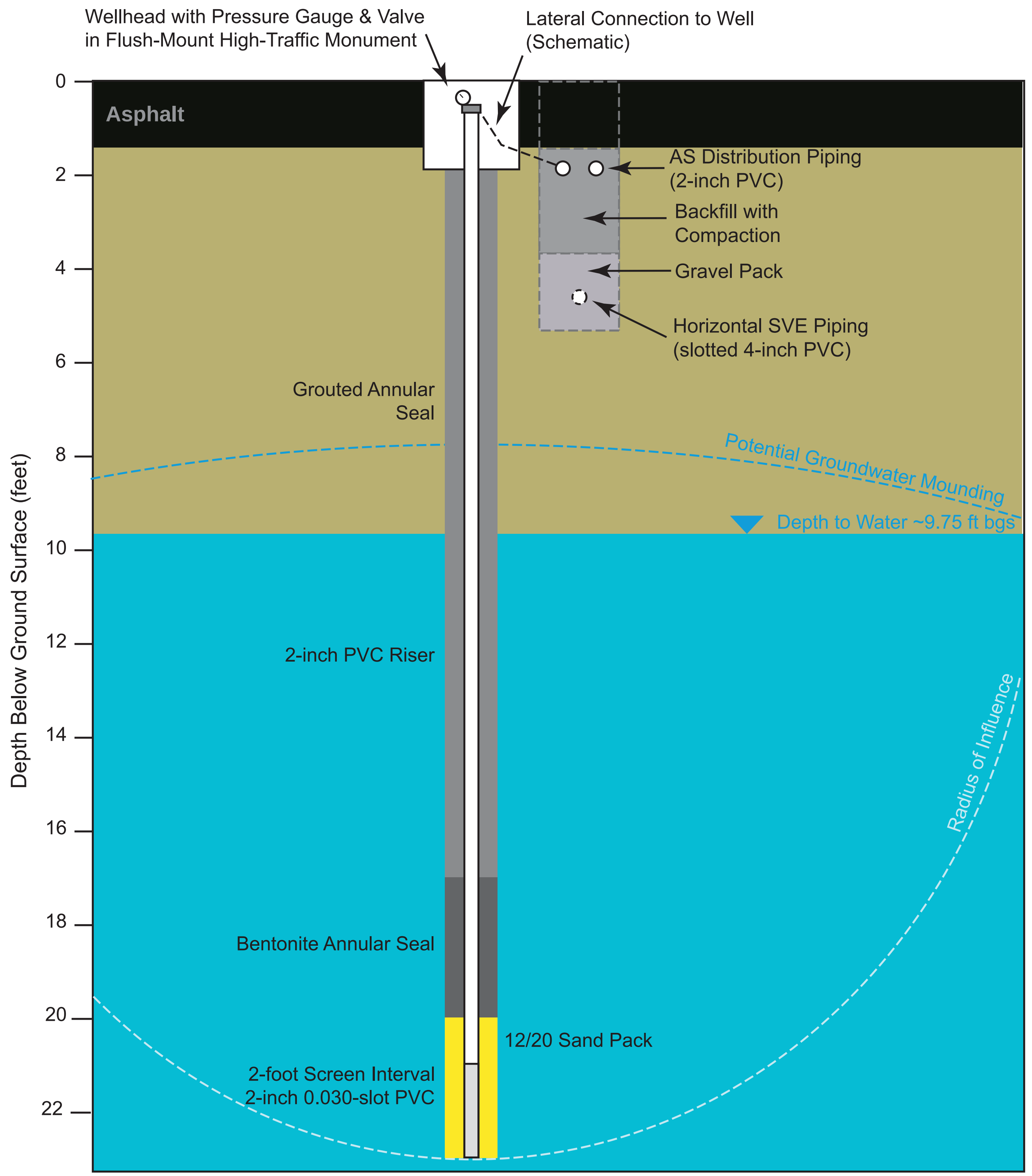
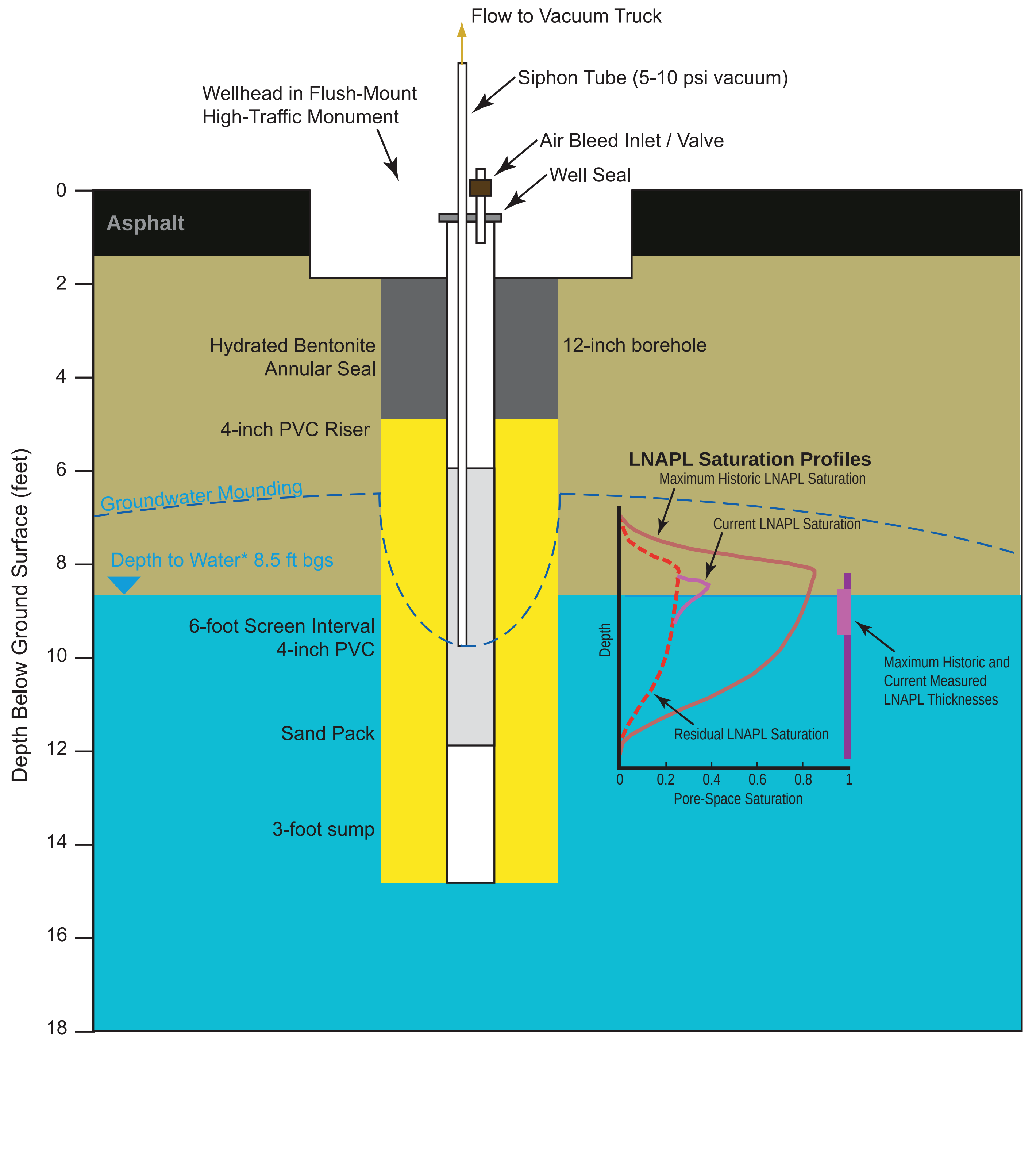


1 inch = 3 feet

Figure 3-2. AS/SVE Subsurface Components

Port of Seattle
Terminal 30

PgG



Well not drawn to horizontal scale; vertical scale: 1 inch = 3 feet
Depth to water is the estimated equilibirum water level accounting for LNAPL with density of 0.87 g/mL
LNAPL saturation profiles based on API model of product at MW-59
Groundwater mound schematic, not quantitative

Figure 3-3. High-Vacuum LNAPL Recovery Components

Port of Seattle
Terminal 30

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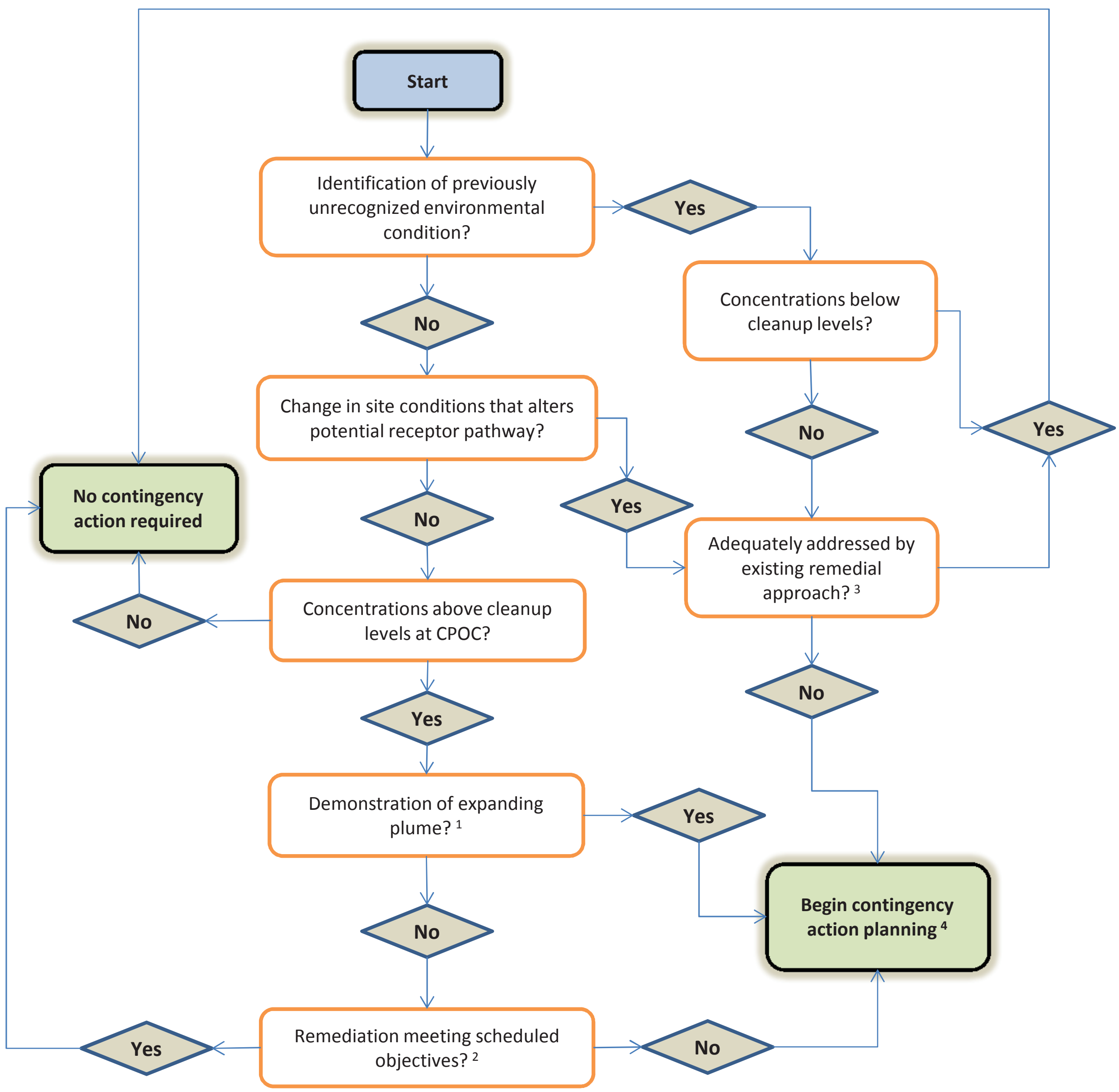
Figure 6-1. Contingency Action Decision Framework
Port of Seattle Terminal 30



Notes:

[1] Plume expansion to be evaluated using the statistical approach described in Appendix D of Ecology Publication 05-09-091, *Guidance on Remediation of Petroleum-Contaminated Ground Water By Natural Attenuation* . July 2005. Evaluation will include at least 5 years of monitoring data.

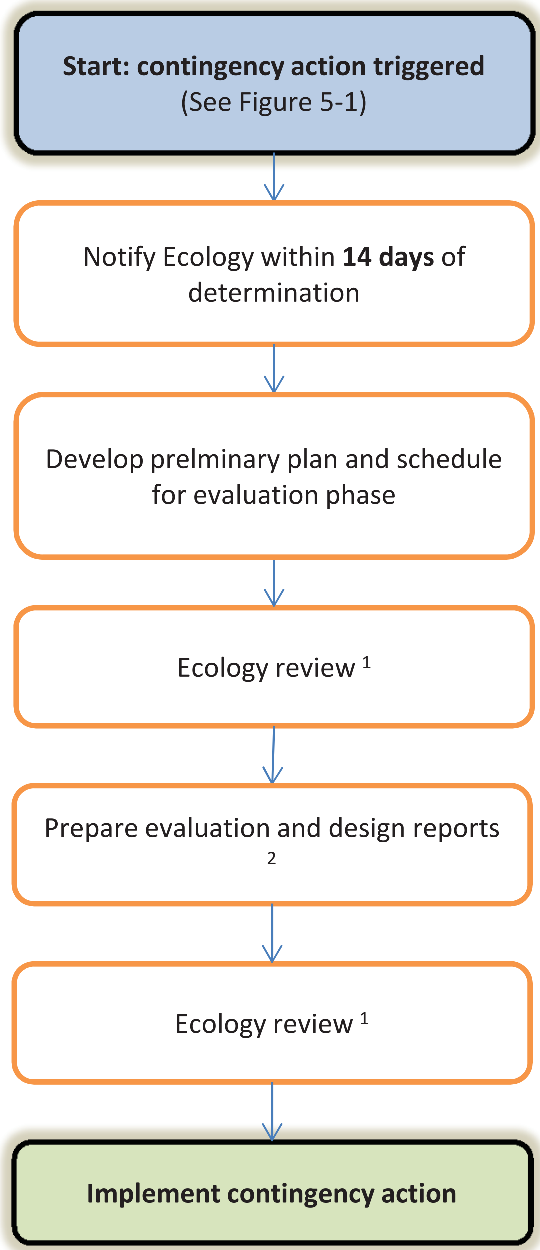
[2] Scheduled objectives described in Sections 4 and 5, including objectives for LNAPL removal, AS/SVE system biostimulation, and compliance monitoring.

[3] This will be assessed through a combination of technical analysis and professional judgement in communication with Ecology.

[4] Contingency action will be selected to address the identified environmental condition. See Figure 5-2.

Additional data beyond groundwater monitoring described in the Compliance Monitoring Plan (not yet complete) may be required to evaluate if contingency action is warranted.

Figure 6-2. Contingency Action Process
Port of Seattle Terminal 30



Notes:
[1] Ecology review step includes revision to address Ecology comments.
[2] Evaluation report may be submitted separately depending on complexity of selected contingency action, or if the evaulation demonstrates that no additional contingency actions are required to meet remedial objectives. Evaluation and design reports described in Secton 5.2.

APPENDIX A
SUPPORTING LNAPL INFORMATION

LNAPL RECOVERY CALCULATIONS

This appendix outlines calculations and modeling results conducted in support of LNAPL recovery planning for the Terminal 30 Draft Cleanup Action Plan (PGG, 2013). Modeling was performed using the API LDRM model (Charbeneau, 2007).

Baseline LNAPL saturation is based on historic LNAPL measurements at MW-59 and RW-12 (GeoEngineers, 1998; ENSR|AECOM, 2008). LNAPL saturation models were used to estimate current LNAPL saturation profiles, which form the basis for estimating recoverable LNAPL at MW-59 and RW-12. Other wells to be installed in the vicinity are expected to have similar or thinner LNAPL thicknesses and similar soil conditions.

Baseline LNAPL saturation modeling inputs are listed in Table A1:

Table A1. LNAPL Input Parameters

Input Parameter	Value	Units	Source
Maximum LNAPL Thickness	1.25	m	GeoEngineers (1998)
Current LNAPL Thickness at (t)	0.3	m	PGG (2011)
Ground Surface	0	m	Assigned
Water Table Depth	2.5	m	Assigned based on nominal depth
Water Vertical Gradient	0	--	Assumed zero
LNAPL Density	0.876	g/mL	PGG (2013)
LNAPL Viscosity	9.6	cp	PGG (2013)
Air-Water Surface Tension	65	dyne/cm	Literature
Air-LNAPL Surface Tension	25	dyne/cm	Literature
LNAPL-Water Surface Tension	15	dyne/cm	Literature
Porosity	0.403	--	Default for selected vanGenuchten Parameters
Hydraulic Conductivity	3.77	m/d	PGG (2013)
VanGenuchten "N"	2.75	--	ENSR|AECOM (2008)
VanGenuchten "a"	4.3	1/m	ENSR|AECOM (2008)
Irreducible Water Saturation	0.04	--	ENSR|AECOM (2008)
Residual LNAPL Saturation	Variable	--	Calculated
Residual LNAPL f-factor	0.3	--	Default

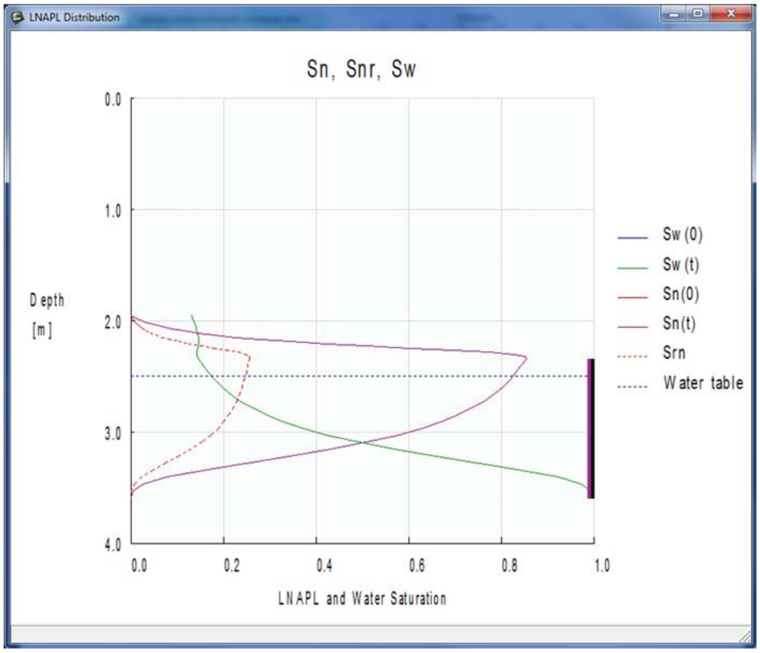
Table A2 lists the symbols used in the API LDRM output plots.

Table A2. LNAPL Plot Parameters

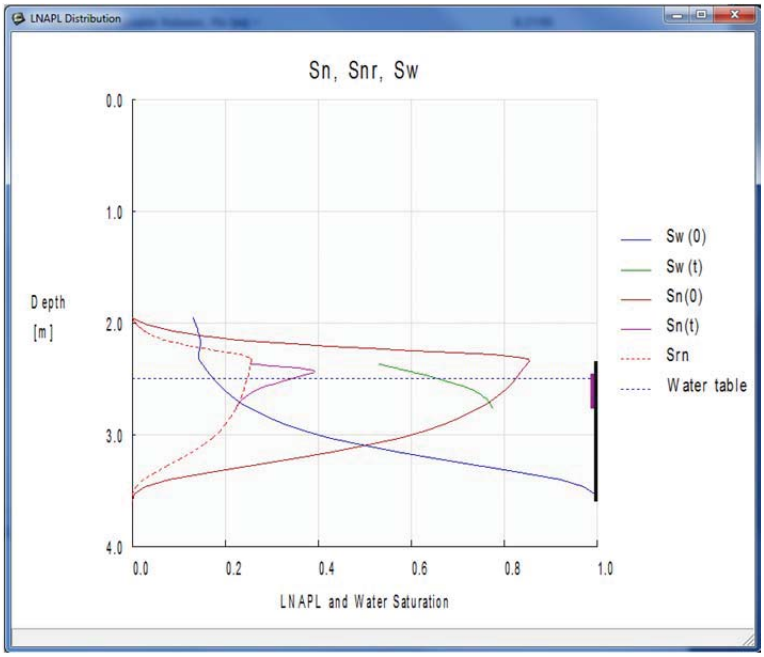
Parameter	Description
Sw (0)	Water Saturation at Initial LNAPL Thickness
Sw (t)	Water Saturation at Intermediate Time (t)
Sn (0)	LNAPL Saturation at Initial LNAPL Thickness
Sn (t)	LNAPL Saturation at Intermediate Time (t)
Srn	Residual LNAPL Saturation
Water Table	Elevation of Equilibrium Water Table

LNAPL and water saturation is measured as the fraction of pore space filled by LNAPL or water while porosity is the fraction of the aquifer not occupied by solids. An LNAPL saturation of 0.1 in an aquifer with a porosity of 0.4 is equivalent to 0.04 of the total soil volume being filled with LNAPL.

Modeled LNAPL saturation curves at peak measured LNAPL thickness (Sn (0)) in the MW-59 area (1.25 meters, or 4.1 feet shown as vertical bars at the right of plots) are:



Product thickness at MW-59 ranged from 0.59 to 0.21 meters (1.93 to 0.69 feet) in 13 measurements between 2006 and 2008 with an average of 0.3 meters (1.0 foot) (ENSR|AECOM, 2008). LNAPL saturation curves at 0.3 meters LNAPL thickness (current condition, time t) after the peak LNAPL thickness of 1.25 meters is:

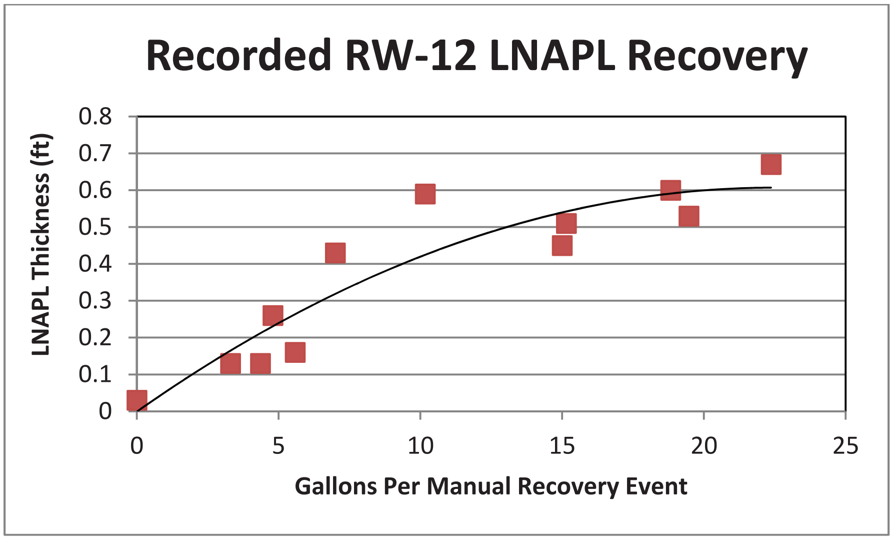


The maximum recoverable product by gravity drainage at each well is the difference in saturation between the current saturation (Sn(t)) and the residual saturation (Srn). The total volume of recoverable product is the difference in saturation scaled to the recovery radius. For the plot above with an average 0.1 difference between current and residual LNAPL saturation, and a recovery radius of 17 feet (well spacing), there is approximately 275 gallons of recoverable LNAPL in the vicinity of MW-59. Note that this likely overestimates the practically recoverable LNAPL because LNAPL transmissivity will decrease with LNAPL thickness and LNAPL may not be adequately mobile to migrate even under the gradient induced by the applied vacuum. Uncertainties in recovery rate increase as the recovery progresses because small-scale heterogeneity becomes more important in overall LNAPL migration.

PRODUCT RECOVERY

The API model predicts approximately 2.25 gallons of recovery per well, per event with an initial product thickness of 0.3 meters (1.0 foot); 5 psi vacuum; an assumed water production rate of 1 gpm; and a 2 hour duration.

Records of manual recovery events at MW-59 and RW-12 suggest that the modeled recovery rates are overly conservative. Approximately 3 gallons of product were manually recovered from MW-59 starting at an initial thickness of 0.96 feet in November 2008. Recovery rates and product thickness relative to actual recovery at RW-12 suggest that recovery rates on the order of 5 to 20 gallons per well per event are reasonable during initial recovery events. Recovery rates will decrease to less than a gallon per event as product thickness decreases to below 0.1 feet. Vacuum-truck total fluids recovery is a more aggressive approach than manual purging and recovery rates are expected to be greater than manual recovery.



Assuming a nominal 8 gallons of LNAPL per recovery event, approximately 34 extraction events would be required to remove the estimated 275 gallons of recoverable LNAPL in the vicinity of MW-59. LNAPL recovery rates will decrease substantially as product thickness declines below 0.1 feet, and 50 LNAPL recovery events are assumed. The actual number of product recovery events is likely to vary due to the uncertainties in the actual LNAPL saturation at MW-59 and at the new recovery wells to be installed.