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Draft Feasibility Study Report

Former Unocal Edmonds Bulk Fuel Terminal

Edmonds, Washington

January 30, 2014

ARCADIS

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Acronyms and Abbreviations

ABOx	anaerobic bio-oxidation
Agreement	Agreement of Sale of Real Property and Escrow Instructions
amsl	above mean sea level
AO	Agreed Order
ARAR	applicable or relevant and appropriate requirement
ARCADIS	ARCADIS U.S., Inc.
AST	aboveground storage tank
ASTM	ASTM International
bgs	below ground surface
BNSF	BNSF Railway
BTEX	benzene, toluene, ethylbenzene, and total xylenes
btoc	below top of casing
CAP	Cleanup Action Plan
CG	commercial general
Chevron	Chevron Environmental Management Company
COC	constituent of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
Csat	residual saturation concentrations
CSL	cleanup screening level
CSM	conceptual site model
CUL	cleanup level
cy	cubic yard(s)
DB-1	Detention Basin No. 1
DB-2	Detention Basin No. 2
DRO	diesel range organics
Ecology	Washington State Department of Ecology

EIS	Environmental Impact Statement
EPH	extractable petroleum hydrocarbon
FHWA	U.S. Department of Transportation Federal Highway Administration
Final CSM	Final Conceptual Site Model
fish hatchery	Willow Creek Fish Hatchery
FS	feasibility study
FS Report	Feasibility Study Report
ft/ft	foot per foot
gpm	gallons per minute
GRO	gasoline range organics
HI	hazard index
HO	heavy oil range organics
HPA	Hydraulic Project Approval
IAWP	Interim Action Report – Work Plan for 2007 Lower Yard Interim Action
IHS	indicator hazardous substance
inHg	inches of mercury
ISS	in-situ solidification
JARPA	Joint Aquatic Resources Permit Application
LAET	lowest apparent effects threshold
LNAPL	light nonaqueous phase liquid
mg/kg	milligrams per kilogram
mL	milliliters
mL/min	milliliters per minute
MNA	monitored natural attenuation
MP1	master plan 1
MP2	master plan 2

msl	mean sea level
MTCA	Model Toxics Control Act
NAVD 88	North American Vertical Datum of 1988
NPDES	National Pollutant Discharge Elimination System
NRWQC	National Recommended Water Quality Criteria
NTR	National Toxics Rule
OS	open space
OWS	oil/water separator
P	public use
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PID	photo ionization detector
POC	point of compliance
Point Edwards	Point Edwards condominium complex
ppm	parts per million
ppt	parts per thousand
PVC	polyvinyl chloride
REL	remediation level
RI	remedial investigation
RM-26	multifamily
RS	single-family residential
Site	Former Unocal Edmonds Bulk Fuel Terminal, located at 11720 Unoco Road, Edmonds, Washington
SMS	Sediment Management Standard
SQS	Sediment Quality Standard
SRI	supplemental remedial investigation
TEE	terrestrial ecological evaluation
TPH	total petroleum hydrocarbons

Unocal	Union Oil Company of California
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
UST	underground storage tank
VOC	volatile organic compound
VPH	volatile petroleum hydrocarbon
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WQS	Washington State Water Quality Standard
WSDOT	Washington State Department of Transportation
°F	degrees Fahrenheit
>	greater than
µg/L	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter

Executive Summary

On behalf of Chevron Environmental Management Company (Chevron), ARCADIS U.S., Inc. (ARCADIS) has prepared this Draft Feasibility Study Report (FS Report) for the Former Unocal Edmonds Bulk Fuel Terminal, located at 11720 Unoco Road, Edmonds, Washington (Site; Figure 1-1). This FS Report is being submitted under Agreed Order (No.DE 4460), which requires the Union Oil Company of California (Unocal), a wholly owned indirect subsidiary of Chevron Corporation, to conduct an interim action to remediate soil, groundwater, and sediment, and to monitor groundwater in the Lower Yard. The FS Report and the preferred alternative are summarized below.

The Washington State Department of Ecology (Ecology) will review the alternatives presented in this FS Report and select a final cleanup remedy based upon evaluation of several factors, including protectiveness, permanence, cost, long-term effectiveness, management of short term risks, technical and administrative implementability, and public concerns.

Site Background

As defined in the Agreed Order (AO), the Site consists of three areas: Upper Yard, Lower Yard, and Willow Creek Fish Hatchery (fish hatchery). Each area is currently a separate property, but was once owned by Unocal. The Upper and Lower Yards were areas of operation for the former terminal. Although the fish hatchery was included in the AO, it was not used for operations or storage at the Site and is currently owned by the City of Edmonds.

The Upper Yard was remediated to approved cleanup standards in 2003. Based on the results of the Upper Yard interim action, Ecology concluded that the Upper Yard soil had been effectively remediated (Ecology 2003a) and was redeveloped in 2006.

Site Contaminants

In collaboration with Ecology, investigations conducted at the Site since 1986 identified petroleum impacts in soil, groundwater, and the sediment in Willow Creek that exceeded Site-specific cleanup levels (CULs). The impacts have not migrated beyond the Site.

Based on available data, impacts at the Site are described below, by media:

- *Soil.* Surface and subsurface soil (0 to 15 feet below ground surface [bgs]) encountered during remedial excavations at the Site contained petroleum hydrocarbons (gasoline, diesel and heavy oil), and petroleum hydrocarbon-related constituents of concern (benzene and carcinogenic polycyclic aromatic hydrocarbons [cPAHs]) greater than Site-specific CULs. In general, metals were found in soil at concentrations less than Ecology cleanup standards. Arsenic, which was identified in the southwest Lower Yard in the area of the former Unocal loading pier, was the only metal that was detected at a concentration higher than Ecology cleanup standards.

- *Groundwater.* At present, limited amounts of light nonaqueous phase liquid (LNAPL), dissolved petroleum hydrocarbons (gasoline, diesel, and heavy oil combined), and petroleum hydrocarbon-related constituent benzene) are present in groundwater beneath the Site in limited areas. These areas are along the Washington State Department of Transportation (WSDOT) stormwater line and the Detention Basin No. 2 (DB-2) area.

- *Sediment.* Historically elevated levels of total petroleum hydrocarbon (TPH) were present in two areas of Willow Creek associated with outfall discharges from facility operations. Following sediment removal during 2007/2008 Interim Action excavations and confirmatory sediment sampling in 2012, Ecology concluded that further cleanup of Willow Creek is not required (Ecology 2012).

Cleanup Process

Site investigations and free product recovery operations were conducted at the Site between 1986 and 2001. Interim Action excavations were conducted at the Upper Yard in 2001 and at the Lower Yard in 2001, 2003, 2007, and 2008. Recent investigations were conducted at the Lower Yard between 2011 and 2013 to assess the remaining impacts at the Site. Ongoing groundwater monitoring has been conducted at the Lower Yard since 2007. A soil vapor sampling investigation was conducted as a part of the FS in 2013.

Cleanup Standards

Cleanup standards establish:

- The concentration of a hazardous substance that protects human health and the environment under specific exposure conditions (CUL).

- Location at a site where that CUL must be reached (the point of compliance [POC]).

- Other regulatory requirements that apply due to the type of cleanup action and/or location of the site.

CULs and POCs are established for soil, groundwater, and surface water and are listed in the tables below.

Indicator Hazardous Substance	Soil Cleanup Level (mg/kg)
Total TPH[1]	2,775
Benzene[1]	18
Total cPAHs[1,2]	0.14
Arsenic[3]	20

Notes:

[1] Proposed soil CUL based on soil direct contact pathway and proposed soil remediation level (REL) based on the soil leaching pathway.

[2]Total cPAHs adjusted for toxicity based on Washington Administrative Code (WAC) 173-340-708(8).

[3] Based on natural background concentrations [WAC 173-340-740(5)(c)].

Indicator Hazardous Substance	Groundwater and Surface Water Cleanup Level (µg/L)
Total TPH	-[1]
Benzene[2]	18
Total cPAHs[2,3]	0.14

Notes:

[1] Method A (WAC 173-340-900, Table 720-1); total TPH calculated on a sample-specific basis. The CUL will fall between 500 and 800 micrograms per liter (µg/L), depending upon the sample's composition.

[2] National Recommended Water Quality Criteria for human-health (organisms only) (United States Environmental Protection Agency 2012). http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm#hhtable. Accessed on March 10, 2013.

[3] Total cPAHs adjusted for toxicity based on WAC 173-340-708(8).

Points of Compliance

The POCs for groundwater at the Site are the points where hazardous substances may be released to surface water. These POCs are monitored by 23 compliance monitoring wells along the downgradient (western, northwestern, northeastern, and eastern) perimeter of the Lower Yard. POC monitoring wells are located from the southwestern corner of the Lower Yard to the northern corner of Detention Basin No. 1 (DB-1), to the southeastern corner of the Lower Yard. Surface water and groundwater CULs are required to be met at POC monitoring well locations.

Previously Remediated Areas

The majority of the Lower Yard was excavated in 2007/2008 to depths ranging from 6 to 15 feet bgs. Approximately 82,000 cubic yards (cy) of soil was excavated, laterally encompassing much of the areal extent of the Lower Yard. The excavations extended across the southwest Lower Yard, west/northwest Lower Yard, central Lower Yard, DB-1, southeast Lower Yard, and a 500-foot section of Willow Creek along the northwest boundary of the Lower Yard.

Remaining Impacts

Remaining impacts to soil and groundwater have been identified in the following areas:

- WSDOT stormwater line area
- DB-2 area
- Isolated soil samples from three locations which exceeded Site CULs and/or RELs for TPH and/or cPAHs:
  - Monitoring well MW-129R
  - Sample EX-B18-VV-1-6SW collected during Phase I of the 2007/2008 Interim Action Investigation
  - Sample EX-BI-F-44-4, collected during Phase II of the 2007/2008 Interim Action Investigation
  -

Remedial Alternatives

Eleven potential remedial technologies were reviewed and screened based on effectiveness and implementability. Based on the preliminary screening, the following five remedial alternatives were selected for detailed analysis:

- Alternative 1: Excavation and Monitored Natural Attenuation (MNA) with Environmental Covenants
- Alternative 2: Groundwater Containment System Using Groundwater Extraction Wells, and Environmental Covenants
- Alternative 3: Groundwater Containment System Using Groundwater Extraction Trench, and Environmental Covenants
- Alternative 4: Excavation with MNA

- Alternative 5: Excavation with MNA and In-Situ Solidification (ISS) with Environmental Covenants

Recommended Remedial Alternative

Based on minimum requirements for cleanup action alternatives as described by WAC 173-340-360 and the expectations for cleanup action alternatives as described by WAC 173-340-370, Remedial Alternative 1 presented in this FS Report is identified as the recommended remedial alternative for the Site.

Remedial Alternative 1 includes excavation of DB-2, and an environmental covenant placed on the impacted soils near the WSDOT stormwater line. This alternative provides a permanent solution through excavation of soil to the extent practical. It is easily implemented compared to other potential remedial alternatives, and has been proven effective in remediating soil and reducing dissolved-phase constituents of concern (COCs) at POCs. As a result of soil excavation conducted during previous remedial actions, Site groundwater has been in compliance for at least 6 quarters in all POC monitoring wells except one (MW-510), indicating that soil excavation has been a successful remedy at the Site. This alternative will provide remediation and restoration within a shorter timeframe than the other four alternatives evaluated.

An environmental covenant would be used in an area already covered by the construction easement signed in October 1971 by the Washington State's Attorney General's Office and Unocal. The construction easement is in place 25 feet from the center line of the WSDOT stormwater line. Placing an environmental covenant in this area minimizes the short-term risk to the environment by reducing the amount of off-site soil transportation, and limits the potential risk of a discharge of petroleum-impacted water to Puget Sound through a damaged stormwater line. It also eliminates substantial technical and feasibility issues associated with excavation or ISS of soil surrounding the WSDOT stormwater line.

This alternative directly remediates LNAPL within DB-2, and requires minimal long-term maintenance under the environmental covenant. Remedial Alternative 1 provides a balance of cleanup goals, regulatory requirements, restoration timeframes, protectiveness, public concerns, implementation, and certainty of success along with a relatively low cost and is recommended as the preferred alternative.

1. Introduction

On behalf of Chevron, ARCADIS prepared this FS Report for the Former Unocal Edmonds Bulk Fuel Terminal, located at 11720 Unoco Road, Edmonds, Washington (Figure 1-1). This FS Report is submitted to comply with AO No.DE 4460, under which Unocal, a wholly owned indirect subsidiary of the Chevron Corporation, has agreed to conduct an Interim Action to remediate soil, groundwater, and sediment; and to monitor groundwater in the Lower Yard. This FS Report evaluates the feasibility and effectiveness of cleanup action alternatives for remediation of hazardous substances in the Lower Yard of the Site.

Previous remedial actions conducted between 2001 and 2008 have addressed potential impacts in the Upper Yard, Lower Yard, and in the sediment of Willow Creek. Specific data and documents often referred to in this FS Report include:

- Final Conceptual Site Model (Final CSM; ARCADIS 2013a) evaluates remaining impacts, potential fate and transport of the remaining impacts, and potential receptors and exposure pathways.

- The Cleanup Levels and Remediation Levels Report (ARCADIS 2013b) evaluates and confirms the CULs for soil, groundwater, and surface water.

- The final compliance soil samples collected in 2007/2008 during remedial excavation activities and documented in the Phase I Remedial Implementation As-Built Report (ARCADIS 2009).

- Final Phase II Remedial Implementation As-Built Report (ARCADIS 2010a).

- The 2008 Site investigation work that was conducted in the vicinity of the WSDOT stormwater line and the former asphalt warehouse (ARCADIS 2010b).

- The 2011 Site investigation work that incorporated a tidal study, pumping tests, and investigation of soil conditions in the vicinity of DB-2 (ARCADIS 2012a).

- The investigation activities conducted as part of the Revised Feasibility Study Work Plan (ARCADIS 2012b) in August 2012, which included additional groundwater monitoring well installation, additional groundwater sampling, and sediment sampling.

Please refer to these documents for the historical data, tables, figures, and laboratory reports.

Previous remediation actions conducted between 2001 and 2008 have addressed potential impacts in the Upper Yard, Lower Yard, and the sediment of Willow Creek. ARCADIS evaluated the location, concentrations, and distributions of remaining hydrocarbon impacts in the Lower Yard at the Site using the 2012 investigation results and historical data. There are minimal areas of remaining impacts to soil and groundwater in the Lower Yard. As part of this FS Report ARCADIS evaluated the conceptual site model, CULs, remaining impacts, and remedial alternatives to address the remaining impacts.

The remaining sections of this FS Report are described below:

- *Section 2 – Background*. Describes the three areas of the Site and historical facilities, operations, and releases. Summarizes historical property ownership and regulatory actions including the AO.
- *Section 3 – Nature and Extent of Contamination*. Describes COCs and remaining soil and groundwater impacts.
- *Section 4 – Conceptual Site Model*. Evaluates fate and transport, potential receptors, and potential exposure pathways.
- *Section 5 – Cleanup Standards*. Describes cleanup standards and development of cleanup levels for sediment, soil, groundwater, and surface water.
- *Section 6 – Development of Remedial Alternatives*. Identifies and describes the potentially applicable remediation technology types considered for the Site.
- *Section 7 – Evaluation of Remedial Alternatives*. Evaluates the proposed remedial alternatives based on applicable regulations, cost analysis, expectations and implementation.
- *Section 8 – Recommended Remedial Alternative.* Presents the recommended remedial alternative for the Site.

2. Background

2.1 Site Description

As defined in the AO, the Site consists of three areas: Upper Yard, Lower Yard, and the fish hatchery. Each area is currently a separate property, once owned by Unocal. The Upper and Lower Yards were areas of operation for the former terminal. Although the fish hatchery was included in the AO, it was not used for operations or storage at the Site and is currently owned by the City of Edmonds.

The Upper Yard was remediated to cleanup standards in 2003 (Ecology 2003) and is now the location of a condominium complex, including several high-occupancy residential buildings, administrative buildings, parking areas, landscaping areas, a stormwater retention pond, and an outdoor walking path. The Upper Yard is fully developed, including underground and overhead utilities and a stormwater system. The Upper Yard area is shown on Figure 2-1. Based on the results of the Upper Yard Interim Action, Ecology determined that the Upper Yard soil had been effectively remediated (Ecology 2003a) as discussed in Section 2.7.2. Background information for the Upper Yard, Lower Yard, and fish hatchery is provided below. Table 2-1 presents a chronology of Site investigation activities.

2.1.1 Upper Yard

The approximately 25-acre Upper Yard is located to the south of the Lower Yard. East of the Upper Yard is the fish hatchery and State Route 104. Beyond State Route 104 are residential and commercial areas in the town of Edmonds, Washington. South of the Upper Yard is a large residential area in the town of Woodway, Washington. To the west of the Upper Yard are the Puget Sound and a public park. The elevation of the Upper Yard is approximately 90 to 100 feet above mean sea level (amsl). The Upper Yard elevation is approximately 75 to 80 feet higher than the majority of the Lower Yard.

Unocal sold the Upper Yard to Point Edwards, LLC in October 2003. Currently, the Upper Yard contains the Point Edwards condominium complex (Point Edwards), which includes several high-occupancy residential buildings, administrative buildings, parking areas, landscaping areas, a stormwater retention pond, and an outdoor walking path. Point Edwards is fully developed, including underground and overhead utilities and a stormwater system. The Upper Yard area is zoned master plan 1 (MP1), which allows for residential and commercial uses.

The northern boundary of the Upper Yard is a steep decline in elevation into the Lower Yard. The slope from the Upper Yard to the Lower Yard is covered by immature growth of vegetation planted by Point Edwards, LLC, during construction of the Point Edwards development. The Upper Yard is shown on Figure 2-1.

Remediation of the Upper Yard began in 2001. In 2003, upon the completion of remedial actions described in Section 2.7.2, Ecology issued a letter indicating that the Upper Yard Interim Action had met direct contact for soil cleanup criteria as specified in the Interim Action Report (Ecology 2003). However, the Upper Yard is included within the Site as defined in the AO.

2.1.2 Lower Yard

The approximately 22-acre Lower Yard is located north of the Upper Yard. The western boundary of the Lower Yard is the BNSF Railway (BNSF) property, and the northwestern boundary is Willow Creek and BNSF Railway property. Further west of the Lower Yard is the Port of Edmonds Marina and Puget Sound. North and northeast of the Lower Yard are the Edmonds Marsh and Willow Creek. East of the Lower Yard is the Edmonds Marsh and Willow Creek, and southeast is the fish hatchery. At its nearest point (the southwest corner of the Lower Yard), the Lower Yard boundary is approximately 160 feet from the Puget Sound shoreline.

The surface elevation of the Lower Yard ranges from approximately 10 to 35 feet amsl based on North American Vertical Datum of 1988 (NAVD 88). The southeastern-most portion of the Site, on Unoco Road near the Lower Yard entrance, is approximately 35 feet amsl. Unoco Road continues along the southern boundary of the Site, and drops in elevation to approximately 16 feet amsl in the south-central portion of the Site. On the south side of the upper portion of Unoco Road there is a large paved area along the property boundary.

The majority of the Lower Yard area ranges between approximately 10 and 19 feet amsl and is relatively flat. The Lower Yard is currently a vacant property, with no permanent aboveground structures. A temporary storage shed is located along Unoco Road in the central portion of the Lower Yard. The ground surface is compact dirt, gravel, and natural vegetative cover. The Lower Yard is currently zoned master plan 2 (MP2), which allows for mixed general residential and commercial uses.

Two stormwater detention basins (DB-1 and DB-2) are located at the Site: DB-1 is located in the east/northeast Lower Yard and west/northwest Lower Yard and DB-2 is located south of DB-1, as shown on Figure 2-1. A stormwater system consisting of 12 stormdrains collects surface water runoff and conveys collected stormwater directly into DB-2 via gravity flow. DB-2 serves as a stormwater collection area from which Lower Yard stormwater is discharged into Willow Creek under Industrial Stormwater General Permit No. SO3-002953C. DB-1 acts as a retention pond for overflow from DB-2 during storm events. DB-1 is bounded to the northwest, northeast, and southeast by a manmade berm. The berm runs along the eastern property boundary, adjacent to Willow Creek. DB-1 and DB-2 form depressions approximately 6 and 4 feet deep, respectively. DB-1 is an unlined pond with one aboveground pump and a piping system to the DB-2 outfall on the bank of Willow Creek. DB-2 has an impermeable liner, two submersible pumps, and a piping system to the DB-2 outfall.

Willow Creek runs along the northern portion of the western boundary and the entire eastern boundary of the Lower Yard. Willow Creek is approximately 10 feet wide and is underlain by silt and sand material. The creek banks on the property boundary are steeply sloped and vegetated with native and non-native vegetation. Water depths in Willow Creek vary from 0 to 4 feet deep, depending on season and tidal cycles (ARCADIS 2012a).

A WSDOT stormwater line with a changing diameter and construction crosses beneath the Lower Yard and discharges collected stormwater to Puget Sound. The WSDOT stormwater line is made of corrugated metal and crosses the Lower Yard at depths of 9 to 12 feet bgs to the top of the pipe. The WSDOT stormwater line generally runs along the northern edge of lower Unoco Road and trends west across the Lower Yard to the tidal basin leading to Puget Sound. The WSDOT stormwater line was installed between 1972 and 1975 and is a major stormwater drainage structure for State Route 104. In addition, a stormdrain line connects the Point Edwards stormwater retention pond and the tidal basin leading to Puget Sound. The Point Edwards stormdrain line runs parallel to the WSDOT stormwater line across the Lower Yard. The Point Edwards stormdrain line is made of corrugated metal and crosses the Lower Yard at depths of approximately 3 to 5 feet bgs. The Lower Yard is shown on Figure 2-1 and the areas of the Lower Yard discussed in this FS Report are outlined on Figure 2-2.

2.1.3 Willow Creek Fish Hatchery

The southeast portion of the Site, near the entrance to the Lower Yard, was leased by Unocal to the Edmonds Chapter of Trout Unlimited in 1984. In 1985, an easement was issued by Unocal for development of the property as a fish hatchery. This property is now owned by the City of Edmonds. The property was formerly known as the Deer Creek Fish Hatchery and is currently known as the Willow Creek Fish Hatchery.

The fish hatchery currently consists of a building that is approximately 50 feet long and 20 feet wide, a circular fish rearing pond approximately 40 feet in diameter, and a small pump house. The remainder of the developed property is composed of a compact gravel driveway and grass and landscaped areas. Surface water runoff from the property drains directly into Willow Creek.

This area was not used by Unocal and remained undeveloped until 1985 when the fish hatchery was constructed. Historical information was reviewed prior to development of the Remedial Investigation Work Plan (EMCON 1995), which indicated that field investigations of the fish hatchery property were not warranted.

2.2 Site History

Unocal operated the terminal from 1923 to 1991. Petroleum products were brought to the terminal on ships, pumped to the storage tanks in the Upper Yard, and loaded from the tanks into rail cars and trucks for delivery to customers. In addition, an asphalt plant operated at the terminal from 1953 to the late 1970s.

In 2001, Unocal conducted an Interim Action in the Lower Yard, removing LNAPL and petroleum-impacted soil and groundwater from four areas of the Lower Yard. The results of the 2001 Interim Action are summarized in Lower Yard Interim Action As-Built Report (Maul, Foster, and Alongi [MFA] 2002). Additional Interim Actions conducted in 2003 included soil excavations in the southwest Lower Yard and DB-1. The results of the 2003 Interim Action are summarized in 2003 Lower Yard Interim Action As-Built Report (MFA 2004a). Previous excavations are shown on Figure 2-1.

In June 2007, Unocal entered into an AO with Ecology to conduct an Interim Action in the Lower Yard. Specific objectives of the Interim Action included removal of soil with petroleum impacts in excess of the soil remediation levels (RELs) established for the terminal, removal of LNAPL, extraction of groundwater that is in contact with LNAPL, and removal of soil with arsenic concentrations in excess of the CULs from the southwest Lower Yard. The soil RELs were calculated to provide a concentration that is protective of direct contact. RELs are believed to be protective of groundwater as well. Groundwater monitoring, to be conducted following soil remediation to the RELs, was to provide empirical evidence to assess whether RELs was protective of groundwater. Soil CULs and RELs were established in the Interim Action Report – Work Plan for 2007 Lower Yard Interim Action (IAWP; SLR 2007a), and are summarized in Table 5-2 in Section 5.5.2.

2.2.1 Lower Yard Creation

Prior to 1923, when the main facility structures of the terminal were constructed (as discussed below) the area of the Lower Yard was tidal marshland. To provide usable working and building surfaces, backfill material was placed over the marsh, presumably beginning in the early 1920s. As seen in aerial photos of the Site (EMCON 1994), in 1947 only the southwest Lower Yard area was developed and contained structures and facilities. The central, eastern, northeastern, and southeastern portions of the Lower Yard were undeveloped marshland at this time. By 1955, backfilled areas, structures, and facilities had expanded to the central area of the Lower Yard. The northeastern and southeastern portions of the Lower Yard were still undeveloped marshland. By 1965, the Lower Yard was filled and developed in all areas, as it remained for the duration of facility operations. The southeast Lower Yard appears to have remained undeveloped.

2.2.2 Historical Facilities and Operations

Historical operations at the Site conducted by Unocal included the storage and distribution of petroleum products, and the production, storage, and distribution of asphalt products. Facilities at the Site included a loading/unloading dock in Puget Sound, railcar unloading areas, an aboveground tank farm, piping systems, an air-blown asphalt plant, asphalt warehouse, laboratory, truck loading racks, oil/water separators (OWSs), underground storage tanks (USTs), and stormdrain and sewer systems (EMCON 1994).

A series of aboveground and underground pipelines, valves, and manifolds were used at the Site to move product between areas of receipt, storage, blending, packaging, and distribution in both the Upper and Lower Yards. All product pipes and valves were made of steel and ranged in diameter from 1.5 to 12 inches. Product was received at the terminal and distributed via barge, ship, tanker, railcar, truck, drums, and cartons.

Major Site operations and facilities are discussed in this FS Report; detailed operations and historical activities are presented in the Background History Report, UNOCAL Edmonds Bulk Fuel Terminal (EMCON 1994). Historical facility operations areas and structures discussed in this section are presented on Figure 2-3.

2.2.3 Former Upper Yard Facilities

Construction of the Upper Yard began in 1923, along with the main terminal structures and loading dock. The Upper Yard consisted of 23 aboveground storage tanks (ASTs), two USTs, abovegrade piping, a garage, and a warehouse. Abovegrade piping carried petroleum materials up the hill from the loading dock in the Lower Yard to the ASTs in the Upper Yard. The ASTs ranged in capacity from 9,726 to 3,491,754 gallons. The ASTs in the Upper Yard were primarily used to store and blend products.

The Upper Yard ASTs were contained within soil berms coated with emulsified asphalt. Except for the bermed areas and paved roads, the Upper Yard had a gravel surface. Precipitation infiltrated the gravel, and stormwater was collected in catch basins that drained to an OWS in the Lower Yard (EMCON 1994).

2.2.4 Lower Yard Facilities

2.2.4.1 Former Loading Dock and Pier

Unocal owned and operated a 275-foot dock and 860-foot pier extending westward into Puget Sound from the southwest corner of the Lower Yard. The piping from the pier passed over the BNSF railroad line via a trestle at the end of the pier. The dock, pier, and trestle were constructed in 1923. The dock facilities included a system of pipes and valves, including ten 2- to 12-inch-diameter steel pipes. Pipelines from the dock ran aboveground to the shoreline manifold area, in the southwest corner of the Lower Yard. The piping then ran southeast up the hillside to the southwest portion of the Upper Yard, as well as northeast along the toe of the hillside to the north-central portion of the Upper Yard. The dock loading area received daily deliveries of gasoline, fuel oils, and crude oils from tanker ships in Puget Sound (EMCON 1994).

2.2.4.2 Former Railcar Unloading Areas

Two railcar loading/unloading areas were located in the southwest Lower Yard. The southern railcar loading/ unloading area was constructed in the early 1930s. The time of construction of the northern railcar unloading area is unknown. Railcar service to the Lower Yard was discontinued in the 1960s and the unloading areas were dismantled in 1974 (EMCON 1994).

The southern loading/unloading area was approximately 40 feet wide by 310 feet long, and was located along the property boundary in the southwest Lower Yard. This loading/unloading area consisted of two railroad spurs parallel to the BNSF railroad, with loading/unloading racks parallel to the railroad spurs. The northern loading/unloading area was located immediately south of the Tidal Basin leading to Puget Sound, and was approximately 10 feet wide by 70 feet long (EMCON 1994). Railcar tankers were loaded and unloaded in these areas on a regular basis for approximately 30 years.

2.2.4.3 Former Air-Blown Asphalt Plant

The air-blown asphalt plant was constructed in approximately 1953 and covered a large portion of the west/ northwest Lower Yard, adjacent to DB-1 and the former slops pond area (further described in section 2.2.4.5). Various grades of air-blown asphalt were produced in this facility including crack-pouring compound, sub-sealing compound, and canal-lining asphalt. The plant was designed to produce up to 100 tons per day and the asphalt products were packaged into 100-pound cartons or steel drums. Materials used in the manufacturing of air-blown asphalt included tank bottom material from the facilities' existing crude distillation column and flux oil shipped to the Site by tanker or rail.

2.2.4.4 Former Asphalt Warehouse

The asphalt warehouse was a steel-framed building that was constructed in 1953, along with the asphalt plant. The 80- by 280-foot warehouse was located in the central Lower Yard, parallel to the southern edge of DB-1. Operations in the asphalt warehouse consisted of packaging asphalt from the air-blown asphalt plant. Asphalt was pumped from cooling tanks into a 6-inch-diameter pipe that ran in a trench down the centerline of the building. The asphalt was then pumped into containers using a loading arm. These containers were then loaded and distributed via truck and trailer.

2.2.4.5 Detention Basins No.1 and No.2

DB-1 is located in the East/Northeast Lower Yard and is approximately 200 by 600 feet in size. DB-1 was constructed in 1952; the original layout was an L-shape with a leg extending south along the northeastern property boundary. DB-1 was constructed by dredging sediment from the northeastern and northwestern Site perimeters, creating a drainage channel (Willow Creek) to carry the flow from small creeks draining surface water from upland areas in the City of Edmonds.

In the late 1960s, DB-1 was modified by partitioning off the southern leg and creating an impoundment area to contain refinery and asphalt sludges and runoff (EMCON 1994). The impoundment area became known as the "slops pond." In 1974, the slops pond was backfilled and DB-2 was constructed. DB-2 is fully lined with polyvinyl chloride (PVC) liner material and contains outfall pumps that discharge to Willow Creek (EMCON 1994).

2.2.4.6 Former Truck Loading Racks

Two truck loading racks were located in the Lower Yard. A two-lane gasoline and diesel loading rack was located in the central Lower Yard and a single-lane loading rack was located in the southwest Lower Yard along the toe of the slope leading to the Upper Yard. It is unclear when the loading racks were constructed, but in approximately 1977 they were modified from top-loading racks to bottom-loading racks. This reportedly minimized the potential for accidental releases and product loss during truck loading. Spill containment controls at each rack consisted of a concrete pad, concrete curbs, and strip drains that led to a 10,000-gallon UST separator tank (EMCON 1994).

2.2.4.7 Former Oil/Water Separators

Two OWSs were located in the Lower Yard, approximately 150 feet south of DB-2. The OWSs were used to remove oil from the Site's wastewater prior to its discharge into Willow Creek.

The main OWS was built in approximately 1950 and was a concrete vault approximately 45 feet long, 18 feet wide, and 11 feet deep. It had an open top at ground surface, with baffles and skimmers to remove oil product as wastewater passed through the vault. Product removed from the OWS was pumped into one of the ASTs in the Lower Yard. The Upper and Lower Yard stormwater drains flowed to the main OWS since its construction in 1950. Prior to 1950, wastewater treatment and disposal practices at the Site were not documented.

The secondary OWS was located immediately northwest of the main OWS. The secondary separator was made of steel, consisted of a series of four cells, and contained a full-length float skimmer. This unit was installed in approximately 1974 when DB-2 was constructed and was used for additional treatment of wastewater to meet National Pollutant Discharge Elimination System (NPDES) discharge standards (EMCON 1994).

2.2.4.8 Former Underground Storage Tanks

Eleven USTs operated at the Site until 1985. UST capacity varied from 200 to 10,000 gallons and the USTs were installed at various times from the pre-1950s to 1985.

Ten of the USTs were located throughout the Lower Yard and one was located in the Upper Yard. All of the USTs were made of welded steel, except for the delivery truck slops tank installed in 1985, which was made of fiberglass.

The UST located in the Upper Yard was removed in 1984; its installation date and intended use are unknown. Three USTs in the Lower Yard were located near the facilities garage and were used to fuel Site trucks and equipment. One UST in the Lower Yard contained diesel fuel and was used to fuel the onsite boiler. One of the Lower Yard USTs contained fuel additive that was mixed during truck loading at the two truck loading racks. One Lower Yard UST was a delivery truck petroleum slops tank, where delivery lines from ingoing and outgoing trucks were drained. Two of the Lower Yard USTs collected truck loading rack overflow, spills, and rainwater from the strip drains at each of the truck loading racks. Two of the Lower Yard USTs served as vapor recovery tanks that collected condensed vapor from the vapor recovery system.

2.2.5 Historical Releases

Facility operations began in the early 1920s with the construction of the Unocal pier and main facilities of the Upper and Lower Yards. Although no spills were documented during this time, data collected during the 2007/2008 Interim Action excavations indicated that soil impacts were present at depths deeper than Site groundwater fluctuations. Specifically, impacts were found in layers of beach and marsh deposits below 1929 Fill materials, suggesting that releases potentially occurred in either the undeveloped marshland areas of the Lower Yard prior to backfill placement, from the early 1920s to the 1950s, or were transported vertically through the saturated zone by a fluctuating groundwater table through time.

From 1954 to 1990, several documented spills occurred at the terminal, totaling approximately 155,000 gallons. Spilled quantities ranged from a few gallons to 80,000 gallons and involved fuel oils, heavy oils, gasoline, off-specification asphalt, and diesel products. Periodic product releases (approximately 0.2 gallon to 2 gallons) reportedly occurred from valves, flanges, and pumps in the Upper and Lower Yards throughout the terminal history. Records and documentation of these smaller releases are not available.

2.2.6 Lower Yard Regulatory and Ownership History

2.2.6.1 Agreed Order No. DE 92TC-N328

In 2001, Unocal entered into AO No. DE92TC-N328 with Ecology. Under the AO, interim actions were conducted in the Lower Yard during 2001 and 2003, as discussed in Section 2.7.3.1 and 2.7.3.2. This AO was later superseded by the current AO (No. DE 4460) as discussed in Section 2.2.6.3.

2.2.6.2 Property Transfer

In January 2005, WSDOT and Unocal signed an Agreement of Sale of Real Property and Escrow Instructions (Agreement). Ecology is not a party to this agreement. The Agreement, and the three amendments to the Agreement, set forth the conditions precedent to the transfer of the property. Unocal's first step was the preparation of a Proposed Interim Action Report. The report outlined the Capital Remediation Work Unocal was to perform, and was submitted to Ecology as the Interim Action Report - Work Plan for 2007 Lower Yard Interim Action. This document is included in the 2007 AO (discussed below).

Once the Capital Remediation Work required under the approved Interim Action Report is performed, the Agreement calls for a Proposed Remediation Plan. This plan is in the form of this FS Report, and identifies a set of remedial alternatives and monitoring work. Once this FS Report is approved, a Cleanup Action Plan (CAP) will be prepared. The CAP may require additional Capital Remediation Work. If Capital Remediation Work is required, once it has been completed and its performance has been verified by compliance monitoring, the Agreement between Unocal and WSDOT calls for Ecology to provide a written acknowledgement that Unocal has completed all required Capital Remediation Work. The Agreement between Unocal and WSDOT states that Ecology's acknowledgment is deemed conclusive evidence that Unocal has satisfied its obligations to perform the Capital Remediation Work called for under the Agreement.

2.2.6.3 Agreed Order No. DE 4460

In July 2007, Unocal entered into AO No. DE 4460 with Ecology to conduct an interim remedial action at the Lower Yard. This AO superseded AO No. DE92TC-N328. AO No. DE 4460 required Unocal to conduct an interim action to remediate soil, groundwater, and sediment; and to monitor groundwater in the Lower Yard. The purpose of the interim action was to reduce potential threats to human health and the environment, to provide for completion of the FS for the Lower Yard, and to gather information to design additional cleanup actions, if necessary. Specific objectives of the interim action included:

- Remediation of the petroleum hydrocarbon-impacted soil within the Lower Yard that contains petroleum hydrocarbon concentrations greater than the soil RELs or soil CULs based on direct contact

- Removal of LNAPL
- Extraction of groundwater that is in contact with LNAPL
- Removal of soil with arsenic concentrations in excess of the soil CUL based on natural background
- Removal of sediment in the drainage ditch (Willow Creek) at locations near the Site's two stormwater outfalls that failed toxicity tests in 2003
- Obtain the data necessary to determine if the remaining soil concentrations are sources of LNAPL on the groundwater table
- Obtain the data necessary to determine if the remaining soil concentrations will cause an exceedance of the groundwater CULs at the groundwater POCs
- Obtain the data necessary to determine if petroleum hydrocarbon concentrations in groundwater beneath the Lower Yard will naturally attenuate to below the CULs at the groundwater POCs

Per the AO, the 2007 Interim Actions were conducted in two phases in 2007 and 2008, as described in Section 2.7.3.3.

2.2.7 Land Use and Zoning

The Lower Yard is zoned MP2, which allows for use as a multi-modal transportation facility as well as other general commercial uses. The Upper Yard is zoned MP1, which allows for residential and commercial uses. Properties surrounding the Lower Yard consist of various commercial, industrial, recreational, and residential sites. The property immediately north-northeast of the Site (Edmonds Marsh) is designated open space (OS). Farther north, Harbor Square (a commercial development is zoned commercial general (CG). Land use in the town of Woodway, immediately south of the Site, is primarily single-family residential. The properties east of the Lower Yard, to the east of State Route 104, are zoned under public use (P), multifamily (RM-26), and single-family residential (RS) designations. The BNSF right of way, Port of Edmonds Marina, Marina Beach Park, and Puget Sound shoreline to the west-northwest of the Site are zoned commercial waterfront.

2.3 Current Lower Yard Physical Characteristics

2.3.1 Topography

The surface elevation of the Lower Yard ranges from approximately 10 to 35 feet amsl, based on NAVD 88. The southeastern most portion of the Site, on Unoco Road near the Lower Yard entrance, is approximately 35 feet amsl. Upper Unoco Road continues along the southern property boundary, drops in elevation, and turns into Lower Unoco Road at the south-central portion of the Site. From upper Unoco Road near the Lower Yard entrance, the ground surface drops in elevation to the north from approximately 35 feet amsl to approximately 16 feet amsl in the south-central portion of the Site. On the south side of upper Unoco Road, there is a large paved area along the property boundary.

The majority of the Lower Yard ranges between approximately 10 and 19 feet amsl and is relatively flat. The Lower Yard is currently a vacant property, with no permanent aboveground structures. A temporary storage shed is located along Unoco Road in the central portion of the Lower Yard. Two stormwater detention basins (DB-1 and DB-2) are located at the property: DB-1 is located in the east/northeast Lower Yard and west/northwest Lower Yard and DB-2 is located between the west/northwest Lower Yard and central Lower Yard. DB-1 is bounded to the northwest, northeast, and southeast by a manmade berm. The berm runs along the eastern property boundary, adjacent to Willow Creek. DB-1 and DB-2 are approximately 6 and 4 feet deep, respectively. DB-1 is an unlined pond with one aboveground pump and a piping system to the DB-2 outfall on the bank of Willow Creek. DB-2 has an impermeable liner, two submersible pumps, and a piping system to the DB-2 outfall.

Willow Creek runs along the northern portion of the western boundary and the entire eastern boundary of the Lower Yard. Willow Creek is approximately 10 feet wide and is underlain by silt and sand material. The creek banks on the boundary are steeply sloped and vegetated with native and non-native vegetation. Water depths in Willow Creek vary from 0 to 4 feet deep, depending on season and tidal cycles (ARCADIS 2012a).

2.3.2 Utilities/Easements

The Upper Yard is served by a drainage system operated by Point Edwards, LLC that conveys stormwater to a sedimentation/detention pond located in the northern part of the former Upper Yard. This system connects the Point Edwards stormwater retention pond and the tidal basin leading to Puget Sound via a 36-inch-diameter underground drainpipe that runs beneath the Lower Yard, and discharges into the tidal basin. The Point Edwards stormdrain line is made of corrugated metal, is located approximately 3 to 5 feet bgs, and runs parallel to the WSDOT stormwater line across the Lower Yard.

The WSDOT stormwater line which is constructed of an asphalt coated corrugated metal pipe which increases in diameter from 48-inches to 72-inches crosses beneath the Lower Yard at a reported depth of 9 to 12 feet bgs to the top of the pipe, and discharges to Puget Sound. The WSDOT stormwater line generally runs along the northern edge of lower Unoco Road and trends west across the Lower Yard to the tidal basin leading to Puget Sound. The WSDOT stormwater line was installed between 1972 and 1975 and is a major stormwater drainage structure for State Route 104.

2.3.3 Surface Cover

The only paved areas of the Site are Unoco Road and the large paved area to the south of upper Unoco Road. The majority of the Site is covered with 3-inch quarry spall stones and silty sand and gravel backfill material. Natural vegetation such as grasses, alder saplings, and native blackberries have begun to reclaim the Site around its perimeter and throughout most of the southeast Lower Yard. The berm surrounding DB-1 is covered by natural vegetation.

Upon completion of 2008 Interim Action activities, the banks of Willow Creek were restored. Native estuarine wetlands species were planted in the floodplain areas of the creek, comprising areas not in the creek channel but below the high water mark. In addition to the floodplain species, trees, shrubs, and grasses (meant to stabilize and protect the bank from erosion and invasive species) were planted on the Lower Yard side of the creek, above the high water line. The plantings were installed through cuts made in BioNet, a woven biodegradable straw mat material used as an erosion control measure, at a density and pattern designated by a wetland biologist. Maintenance monitoring of the plants in Willow Creek continued until the restoration planting goals of re-establishing a riparian wetland community and ensuring a survival rate of 75 percent of planted species were met.

2.3.4 Stormwater Drainage System

A stormwater system consisting of 12 stormdrains throughout the Lower Yard collects surface water runoff and discharges directly into DB-2 via gravity flow. From DB-2, stormwater is discharged into Willow Creek under an Industrial Stormwater General Permit (SO3-002953C) and excess stormwater is stored in DB-1. When DB-1 is full, excess water from DB-1 is pumped to the DB-2 outfall.

2.4 Regional Environmental Setting

2.4.1 Climate

The Site is located on the eastern shore of Puget Sound, less than 100 miles inland from the Pacific Ocean. The Puget Sound lies in a basin between the Olympic Mountains on the west, which form a significant barrier to onshore wind flow from the Pacific, and the Cascade Mountains to the east, which shields the area against westerly flow of colder and drier continental air masses. As a result, the climate of the Puget Sound is temperate, with mild to moderate precipitation and temperatures year-round in the Edmonds area.

Occasionally, winter storms will bring heavy rainfall, strong winds, or snowfall. Average temperatures are typically in the 30s and 40s degrees Fahrenheit (°F) during winter, and range from the 50s to 70s (°F) during spring, summer, and fall. The annual precipitation is approximately 36 inches and consists mostly of rain that falls between October and March.

2.4.2 Regional Geology

The Edmonds area is located in the Puget Sound Lowland, bound by the North Cascade Mountains to the east, South Cascade Mountains to the south, and Puget Sound and Olympic Mountains to the west. Continental glaciers advanced into the region several times during the Pleistocene Epoch (between 2 million and 10,000 years ago). This part of the Cordilleran ice sheet is known as the Puget Lobe. The most recent period of glaciation, the Vashon Stade, began approximately 15,000 years ago. As the climate cooled during the Vashon Stade, the continental ice sheet in Canada expanded and the Puget Lobe slowly advanced southward into western Snohomish County and beyond. The ice of this Vashon Glacier blanketed the entire Puget Sound Basin before halting and retreating (Thomas 1997).

As the Vashon Glacier advanced southward, streams and melting ice in front of the glacier deposited sediment throughout the Puget Sound Lowland. As the glacier continued its advance, it overrode these advance outwash deposits and covered them with glacial till. This till, also known as hardpan, consists of reworked older deposits and rocks scoured by the bottom and sides of the advancing glacier. Because of the pressure of thousands of feet of overlying ice, the till is very compact and cemented in some areas, with a texture much like concrete. However, in areas where the till was subjected to the influence of sub-glacial water during deposition, resulting in local deposits of fine- and coarse-grained sediment. Approximately 13,500 years ago, the climate began to warm and the Vashon Glacier started to retreat. During this retreat, recessional outwash sediment was deposited, filling in discontinuous depressions and channels in front of the glacier. Subsequent to the deposition of glacial sediment, alluvial sediment of Holocene age (10,000 years ago to the present) was deposited. These are predominantly fluvial deposits of sand and gravel in stream and river valleys. During the same time, bog, marsh, and peat deposits were formed in small low-lying and poorly drained areas (Thomas 1997).

As a result of the glacial and fluvial activity and erosion during the Pleistocene Epoch, the study area is underlain by unconsolidated sediment of both glacial and non-glacial origin. Beneath these deposits are consolidated Tertiary rocks. The thickness of the entire assemblage of unconsolidated deposits varies considerably, but averages about 500 feet thick, with a maximum thickness of more than 1,200 feet. The deposits are thickest in western Snohomish County and are thinner to the east where the Tertiary bedrock is at or near land surface (Thomas 1997).

The Upper Yard is located on top of a bluff and the Lower Yard is situated at the foot of the bluff, along its northern edge. The Upper Yard bluff consists of three main types of deposits: interglacial deposits termed the “Whidbey Formation,” alluvial/lacustrine pre-glacial deposits termed “Transitional Beds” and “Advance Outwash,” and glacial deposits termed “till” (Minard 1983). The Lower Yard bounding the bluff is composed of marsh deposits to the northeast and “modified land” that has been dredged and filled to the north and northwest (MFA 2004c).

2.4.3 Regional Hydrogeology

Groundwater flow in the Puget Sound region generally, and at the Site in particular, can be divided into large- and small-scale flow systems. Large-scale flow systems in the vicinity of the Site exist in unconsolidated, glacially derived units, and in the marine sediment and volcanic rocks underlying them. These systems are recharged by precipitation in upland areas, east of the sound, where the units are exposed. Large-scale, regional system discharge is into Puget Sound. Small-scale, local flow systems occur in the uppermost deposits of alluvial and lacustrine pre-glacial sediment, glacial sediment, and post-glacial alluvium, as well as in construction-related backfill. Precipitation and deeper flow systems are the chief methods of recharge for these local flow systems. Discharge of local systems is to adjacent surface water bodies, which for the Site, is also into the Puget Sound.

2.4.4 Water Supply Wells

According to a review of Ecology and Snohomish Health District files, no potable water supply wells exist within ¼ mile of the Site. One abandoned test well is located approximately ⅓ mile northeast of the Site boundary and was used for dewatering during construction of the Edmonds wastewater treatment plant. The nearest domestic supply well, installed in 1995, is approximately ¼ mile south of the Site boundary. This well is upgradient from the Site, and therefore, could not be affected by the impacted groundwater beneath Site.

2.5 Site Environmental Setting

2.5.1 Site Geology

Five hydrostratigraphic units have been identified in the Lower Yard and are discussed in detail below:

- *2008 Fill*. The 2007-2008 Interim Action excavations were backfilled to 6 to 12 inches above the observed groundwater table in the open excavations with poorly graded coarse gravels (⅜ to 1 inch) with little to no fines. Backfill material above the coarse gravel to ground surface was a mixture of very fine to medium sand, trace silt, and fine to medium gravel materials.

- *1929 Fill*. This unit consists of silty sands with gravel and sandy silts with gravel. During the 2007-2008 Interim Action excavations, subsurface materials encountered from ground surface to a depth of 8 to 15 feet bgs were mostly fill material placed circa 1929 or later, during creation of the Lower Yard facility.

- *Marsh Deposits*. In many areas of the Lower Yard, beneath the 1929 Fill, a 1 to 15-foot-thick layer is present and is composed of silt and sandy silt with large amounts of organic matter such as peat and wood debris. This layer is encountered at depths ranging from 8 to 14 feet bgs, directly below the 1929 Fill material, and is interpreted to be representative of the former marsh horizon beneath the Lower Yard. This layer is typically demarcated by a 6- to 12-inch-thick layer of decomposing vegetation.

- *Beach Deposits*. Below the 1929 Fill and Marsh Deposits, a poorly graded sand formation of very fine to medium sand with fine gravel is present, containing organic material such as driftwood and seashells. This layer is interpreted to be representative of the former beach environment in the area prior to creation of the Lower Yard.

- *Whidbey Formation*. This material is a poorly graded sand layer consisting of very fine to medium sand with fine gravel and is distinct from the overlying materials in the Lower Yard. It is present to the maximum depth explored by Unocal (41.8 feet bgs). This unit contains interbedded sand with silt, and interbedded silt and sandy silt. The interbeds range in thickness from less than 1 inch to several feet and appear to be laterally discontinuous. This unit is interpreted to be alluvium and is likely part of the Whidbey Formation.

The current uppermost stratigraphic unit of the Lower Yard consists primarily of 2008 Fill. The 2007/2008 Interim Actions excavations were extended to reach Beach Deposits, Marsh Deposits, or Whidbey Formation materials. Remaining unexcavated areas are most likely 1929 Fill material, underlain by the hydrostratigraphic units described above. Cross sections of the Lower Yard are presented on Figures 2-4 through 2-8. Elevations of the 2008 gravel backfill material in all of the 2007/2008 excavation areas are shown on Figures 2-9 and 2-10.

2.5.2 Site Hydrology

2.5.2.1 Groundwater Elevations

Groundwater elevations throughout the Lower Yard have remained consistent throughout the period of record (October 2008 to June 2013), with average groundwater elevations ranging between 5 and 9 feet amsl. This does not include groundwater elevation data collected in the southeast Lower Yard where groundwater elevation data indicate an area of localized groundwater mounding is occurring, as discussed in Section 2.5.2.2.1. Average groundwater elevations in the southeast Lower Yard are between 9 and 11 feet amsl.

Historical groundwater elevations throughout the Site (excluding the southeast Lower Yard) have varied from 2.24 feet amsl at well MW-147 in September 2011 to 11.20 feet amsl at well MW-109 in December 2011. The highest average historical groundwater elevations (8.70 and 8.88 feet amsl) are observed in monitoring wells MW-203 and MW-134X (in the upper Unoco Road portion of the southeast Lower Yard). The lowest average historical groundwater elevations (5.50 and 5.61 feet amsl) are observed in monitoring wells MW-147 and MW-149R in the southwest Lower Yard.

Historical groundwater elevations in the southeast Lower Yard have ranged from 6.21 feet in well MW-136 in August 2009 to 15.21 feet amsl in piezometer P-1 in January 2010. Historical average groundwater elevation in the southeast Lower Yard is 9.82 feet amsl.

Groundwater elevation data from September 2013 were contoured and are presented on Figure 2-11. In general, the seasonal variation includes the highest groundwater elevations observed during January and the lowest groundwater elevations observed between June and September.

2.5.2.2 Groundwater Flow Directions and Velocity

Quarterly water level data from October 2008 to June 2012 were evaluated to assess the long-term hydraulic gradient and overall groundwater flow direction in the Lower Yard. Groundwater elevations during this time period ranged from approximately 2 to 15 feet amsl and generally decreased from south to north-northwest, primarily toward Puget Sound and Edmonds Marsh (east). Depth to water values range from approximately 0.6 to 27 feet below top of casing (btoc). In general, the greatest depth to water values are measured near the entrance to the Lower Yard (on upper Unoco Road) and in the vicinity of the central portion of the Site, decreasing with proximity to Puget Sound (to the north) and Edmonds Marsh (southeastern portion of the Lower Yard). Using the quarterly data to calculate a Site-wide gradient (Devlin 2003), the analysis indicates that the overall, average gradient is 0.002 foot per foot (ft/ft) toward the west-northwest. This evaluation did not include the newly installed monitoring wells (installed in June 2012), MW-500, MW-501, or the “P” series piezometers.

The 2011 Site investigation activities included evaluation of potential tidal influence on groundwater and surface water (ARCADIS 2012a). As described in Section 2.8.2, the results indicate that tidal variations in water levels in the Puget Sound exert an influence on groundwater elevations at the Site perimeter.

Groundwater flow in the southeast portion of the Lower Yard is also influenced by the 2007/2008 Interim Action excavations and subsequent 2008 Fill. After the 2008 Fill was in place and monitoring wells were installed, groundwater elevations at wells MW-500 and MW-501 were observed to be approximately 5 to 7 feet higher than surrounding wells. Further investigation in the area indicated that water levels at piezometers screened partially in the 2008 Fill and the underlying 1929 Fill also exhibit these higher groundwater elevations. This is discussed in Section 2.5.2.2.1.

Horizontal gradients in the surficial materials of the Lower Yard measured during tidal study activities conducted in 2011 ranged in magnitude from 0.0053 to 0.0058 ft/ft, with an overall direction to the west-northwest toward Puget Sound (ARCADIS 2012a).

2.5.2.2.1 Southeast Lower Yard Groundwater Mounding

Groundwater elevations in monitoring wells MW-500 and MW-501 are generally several feet higher (5 to 7 feet) than elevations at surrounding wells. Wells MW-500 and MW-501 are partially installed in 2008 Fill, but are also partially screened in the underlying 1929 Fill material.

In July 2009, in an effort to understand the higher groundwater elevations, eight piezometers were installed in the southeast Lower Yard in the vicinity of monitoring wells MW-500 and MW-501. The piezometers were installed in pairs, with each piezometer approximately 1 to 2 feet from each other. One piezometer of each pair was installed as a deep well (ranging from 25 to 22 feet bgs) and one as a shallow well (ranging from 12 to 13 feet bgs). The deep piezometers are constructed with 5 feet of well screen and the shallow piezometers are constructed with 10 feet of well screen. The piezometers and wells MW-500 and 501 are presented in Table 2-2.

Table 2-2. Southeast Lower Yard Well Screen Interval Summary

Well ID	Classification	Well Screen Interval (Geologic Material)
P-1	Shallow	2008 Fill/1929 Fill
P-2	Deep	1929 Fill
P-3	Shallow	2008 Fill
P-4	Deep	1929 Fill
P-5	Shallow	2008 Fill
P-6	Shallow	2008 Fill/1929 Fill
P-7	Deep	1929 Fill/Whidbey Formation
P-8	Deep	1929 Fill/Whidbey Formation
MW-500	Shallow (Monitoring Well)	2008 Fill/1929 Fill
MW-501	Shallow (Monitoring Well)	2008 Fill/1929 Fill

All shallow piezometers, which are installed in either the 2008 Fill or both the 2008 Fill and the 1929 Fill, have groundwater elevations consistent with those observed in monitoring wells MW-500 and MW-501. The groundwater elevations in the shallow piezometers are also several feet higher than the corresponding deeper piezometers, which are installed in the 1929 Fill or both the 1929 Fill and the Whidbey Formation.

2008 Fill material is a higher permeability material than the 1929 Fill that underlies and surrounds the 2007/2008 Interim Action excavation areas in the southeast Lower Yard. The 2008 Fill appears to have created a distinct zone in which shallow groundwater responds more rapidly to recharge than the surrounding and underlying 1929 Fill. Movement of groundwater from the 2007/2008 Interim Action excavation area (both laterally and vertically) is restricted due to the presence of the lower permeability 1929 Fill. Additionally, surface water runoff from the bluff along the Upper Yard may also be a contributing some recharge to this portion of the Site. As a result, water levels in the vicinity of the 2007/2008 Interim Action excavation area indicate a limited area of groundwater mounding due to the differential permeabilities. Cross sections of the southeast Lower Yard, with historical groundwater elevation data are shown on Figures 2-7 and 2-8. Groundwater elevation contours and data from the September 2013 gauging event are presented on Figure 2-11.

2.5.2.3 Hydraulic Conductivity

Results of the hydraulic conductivity testing conducted during the 2011 Site investigation indicate that hydraulic conductivity varies throughout the Lower Yard, and corresponds to the heterogeneity of the subsurface materials. The 1929 Fill is of much lower permeability than the 2008 Fill material. Wells completed in the 2008 Fill have relatively higher hydraulic conductivity values than those completed in the 1929 Fill (ARCADIS 2012a). Hydraulic conductivity testing results from 2011 Site investigation activities range from 0.06 foot/day to 345 feet/day, with hydraulic conductivity values at wells completed in the 1929 Fill ranging from 0.2 foot/day to 15 feet/day and hydraulic conductivity values at wells completed in the 2008 Fill ranging from 2.5 to 345 feet/day (ARCADIS 2012a).

Appendix G of the 2011 Site Investigation Completion Report (ARCADIS 2012a) presented incorrect hydraulic conductivity values for some of the wells. The analysis for the wells was appropriate; however, a lookup function in the summary table incorrectly referenced the values in the cells. Therefore a revised summary table is submitted in this FS Report as Table 2-3. Additionally, the 2011 Site Investigation Report indicates that step test data from LM-2 were analyzed, but a valid result could not be obtained from the analysis. Therefore the value estimated at LM-2 was only from the slug testing.

Hydraulic conductivity from all hydraulic testing activities including step drawdown tests, short duration hydraulic conductivity tests, long duration hydraulic conductivity tests, and slug tests is presented in Table 2-3, along with the screened interval lithology.

Table 2-3. Revised Summary of Hydraulic Conductivity Results

Tested Well	Minimum Estimated Hydraulic Conductivity (ft/day)	Maximum Estimated Hydraulic Conductivity (ft/day)	Arithmetic Mean Hydraulic Conductivity (ft/day)	Well Screen Interval (Geologic Material)
LM-2	0.3	0.4	0.3	1929 Fill
MW-104	4.7	15	10	1929 Fill
MW-129R	0.2	0.5	0.3	1929 Fill
MW-149R	2.5	2.5	2.5	2008 Fill
MW-500	0.06	0.2	0.1	2008 Fill/1929 Fill
MW-518	5.8	10	8	2008 Fill
MW-8R	186	345	259	2008 Fill

Source: 2011 Site Investigation Report (ARCADIS 2012a).

2.5.2.4 Surface Water – Groundwater Interaction

The 2011 Site Investigation included a study to evaluate the potential interaction between Puget Sound, groundwater at the Lower Yard, and surface water in Willow Creek. The results were included in the 2011 Site Investigation Report (ARCADIS 2012a) and summarized below.

Based on the tidal study, the Lower Yard perimeter wells (located within approximately 62 feet of the property boundary) are tidally influenced. Shallow monitoring wells with observable response to tidal influence indicated a range in amplitude from 0.07 foot to 1.15 feet. Deeper monitoring well MW-122, completed in the Whidbey Formation, indicated a range in amplitude from 0.02 to 0.33 foot (ARCADIS 2012a). In addition, an incorrect range in elevations during the tidal study was reported in the 2011 Site Investigation Report (ARCADIS 2012a) and was based on data from the malfunctioning transducer that was first installed at MW-122. The correct range in elevations during the monitored period was from 8.60 to 8.93 feet amsl. Please note that the graph for MW-122 provided in the 2011 Site Investigation Report (ARCADIS 2012a) was correctly reported.

Wells monitored during the tidal study indicate higher tidal efficiency factors (or the ratio of the change in water level in a groundwater well compared to the change in water level in tidally affected water body) along the northwest boundary wells adjacent to the Puget Sound versus southeast boundary wells adjacent to the marsh. Results indicate that the average tidal efficiency varied between approximately 0.003 (LM-2 and MW-515) and 0.09 (MW-149R). The average tidal efficiency of all the wells studied was 0.03. The values are relatively low, likely due to the low permeability and heterogeneity of material at the Site. The relatively low tidal efficiency values observed at Site monitoring wells indicates that groundwater levels at the Site are not significantly influenced by tidal changes in the Puget Sound (ARCADIS 2012a).

A comparison of groundwater elevations to Puget Sound water elevations measured during the 2011 tidal study indicates that the short-term groundwater flow direction varies with the tidal stage. At most of the observed perimeter locations during high tide, the Puget Sound water elevation is higher than groundwater elevations in the Lower Yard, indicating an inward flow direction. At low tide the opposite is true, and groundwater flows toward the Puget Sound. Exceptions to this occur at MW-122, MW-500, and MW-501. At these locations, during the tidal study, elevations were higher than the Puget Sound except at the “high” high tide stage (ARCADIS 2012a).

Data collected during the 2011 tidal study from transducers installed at staff gauges in Willow Creek indicate that Willow Creek is tidally influenced. At locations where Willow Creek was monitored with transducers, the flow direction is such that at high tide, the Puget Sound elevation is greater than surface water elevations in Willow Creek, and at low tide Willow Creek elevations are greater than those in Puget Sound. Puget Sound flows into Edmonds Marsh at high tide and Edmonds Marsh drains into Puget Sound at low tide. This is consistent with the observations of groundwater elevation compared to Puget Sound elevations.

Salinity was also measured in Willow Creek during the tidal study. Salinity variations were observed to correlate the tidal stage at staff gauges with observable tidal influence. As observed during 2011 tidal study activities, flow during high tide in the Puget Sound flow is directed toward Willow Creek and salinity concentrations in Willow Creek increase. During low tide in Puget Sound, the flow direction reverses and flows from Willow Creek toward Puget Sound while salinity concentrations decrease. During some tidal cycles in the 2011 tidal study monitored period, surface water elevations in Willow Creek were greater than those in Puget Sound during both low and low high tides. Staff gauge D-6R (located in DB-1) did not indicate any observable tidal influence, indicating that DB-1 has very little to no connection to Puget Sound. Staff gauges with an observable response to tidal influence indicated a range in amplitude from 0.02 foot to 3.73 feet. Fluctuations in surface water elevations in Willow Creek ranged from 3.06 to 8.76 feet amsl (ARCADIS 2012a).

Based on the water level data and salinity collected during the 2011 tidal study, not only does the flow direction vary with tide, but water from Puget Sound is mixing with water in Willow Creek and to a lesser extent with groundwater. This is indicated by the water level response to tidal fluctuations and also the varying salinity concentrations observed at the staff gauge locations. This is also occurring at the tidally influenced monitoring wells; however, the magnitude of responses to tidal fluctuations and salinity concentrations are less at the wells than observed in Willow Creek. Willow Creek is directly hydraulically connected to Puget Sound through a culvert running under the Port of Edmonds, which also likely contributes to the greater tidal response and higher salinity concentrations. Therefore, based on groundwater elevations, surface water elevations, and salinity changes, the data from the tidal study indicate that groundwater flow is directed to surface water over the long term. However, local, transient flow direction also changes as a result of tidal stage fluctuations in Puget Sound where surface water is directed to groundwater. This unique hydraulic and hydrogeological setting creates a mixing zone along the western boundary where groundwater, fresh water, and saline sea water interact, at times stagnating and ultimately reversing groundwater gradient at the western Site boundary.

2.5.3 Surface Water

At its nearest point (the southwest corner of the Lower Yard), the Site is approximately 160 feet from the Puget Sound shoreline. The Site is bounded by Willow Creek, which runs along the northern portion of the western boundary and the entire eastern boundary of the Lower Yard. To the north and northeast of the Lower Yard is Edmonds Marsh, which is a 23-acre freshwater and brackish-water marsh. This tidally influenced marsh is also fed by Shellabarger Creek on the southeast side of the marsh, and drains a portion of the City of Edmonds stormwater system. Willow Creek connects Edmonds Marsh to Puget Sound and carries surface water into a tidal basin, where the water is conveyed beneath the Port of Edmonds through a culvert, to Puget Sound. Willow Creek and Edmonds Marsh are directly connected to Puget Sound and are tidally influenced. During periods of high tide, flow in Willow Creek will be toward Edmonds Marsh, and Edmonds marsh partially fills with water. During low tide, Edmonds Marsh will drain into Puget Sound.

2.5.4 Upland Sediment

Upland sediment on the banks of Willow Creek, the tidal basin, and the berm surrounding DB-1 are partially to fully inundated during flood tides. During ebb tides, these areas are fully exposed. Observations during field activities conducted since 2007 indicated that the sediment at the bottom of the main channel of Willow Creek is constantly submerged. The water covering the upland sediment is generally brackish (1 to 30 parts per thousand [ppt] salinity) as a result of the mixing of surface water runoff with salt water from tidal incursion. In June 1995, upland sediment pore water salinities measured between 11 and 21 ppt at depths of up to 10 centimeters (MFA 2001b).

In 1995, upland sediment was investigated and sampled to determine the soil characteristics. The results of this investigation were reported in the Draft Remedial Investigation Report (MFA 2001b) and are summarized below:

Upland sediment observed along the northeast boundary of the Site was highly organic, very soft to firm, olive brown to black sandy silts (MFA 2001b). Upland sediment that was at an elevation high enough to support perennial vegetation retained a peat-like composition. Sediment located in the bottom of the drainage ditch and also along the northwest Site boundary were generally loose, olive gray to gray, silty sands. Tidal basin sediment was loose, gray to brown, gravelly sand. Reducing sediment indicative of anoxic conditions was observed along the northeast Site boundary. Amphipods were observed in the upland sediment (MFA 2001b).

Sediment samples in Willow Creek were collected for indicator hazardous substance (IHS) analysis in 1996, 2003, and 2012, as discussed in Section 3.5.

2.5.5 Wetlands

In 2004, CH2M HILL prepared an Environmental Impact Statement (EIS) for the U.S. Department of Transportation Federal Highway Administration (FHWA) and WSDOT in preparation for the possible construction of the Edmonds Crossing multi-modal transportation center on the Lower Yard property. The EIS (CH2M HILL 2001) included a wetland delineation of the Lower Yard, and Edmonds Marsh and its surrounding areas. During development of the EIS (CH2M HILL 2001), three wetland areas were identified at or adjacent to the Site. Edmonds Marsh, a freshwater marsh on the east side of Highway 104 that was part of Edmonds Marsh before construction of the highway, and the DB-1 area of the Lower Yard were identified as wetlands areas. Two riparian corridors were also identified: one associated with Shellabarger Creek at the north end of Edmonds City Park, and the Willow Creek riparian corridor that runs through the Deer Creek Fish Hatchery.

Edmonds Marsh is classified by the City of Edmonds as a Category I (high-quality) wetland based on its uniqueness, large size, and habitat for a state monitor species (great blue heron) (CH2MHILL 2001). It is also designated as a Priority Habitat in the WDFW Priority Habitat and Species Database. Edmonds Marsh is 23 acres in size and its primary functions are flood storage and desynchronization sediment trapping, nutrient removal, water quality improvement, wildlife habitat, fish habitat, and passive recreation. Edmonds Marsh is tidally influenced, receiving saltwater during high tides from Willow Creek and freshwater from Shellabarger Creek.

The 3.7-acre freshwater marsh on the east side of Highway 104 is rated as a Category II wetland. Its primary functions are flood storage and desynchronization sediment trapping, nutrient removal, water quality improvement, and limited biological support. This wetland receives freshwater from Shellabarger Creek and from upland areas to the south and southeast.

The 2.3-acre DB-1 wetland area is located within the Lower Yard. The DB-1 area would likely be classified as a Category I wetland due to its small size, lack of vegetative diversity, disturbed condition, and lack of hydraulic connectivity to Edmonds Marsh. The only source of freshwater to DB-1 is precipitation and surface runoff during heavy precipitation events.

2.6 Historical Site Investigations

Historical site investigations indicated that in general, the areas of petroleum hydrocarbon-impacted soil at the Site coincided with historical Site operations. Impacts in the Upper Yard were found in the vicinity of AST basins, stormdrain lines, product piping lines and facility operations areas. In the Lower Yard, impacts were generally found in the vicinity of the asphalt plant, railcar loading racks, truck loading racks, and fuel storage and distribution areas. Areas of the Lower Yard containing soil impacted with metals (specifically arsenic) were found in places where tanks and pipes had been sandblasted with arsenic-containing sandblast grit. Impacts were found in the southeast Lower Yard, although historical facility activities were not conducted in this area. During 2007/2008 Interim Action excavation activities, it was observed that the southeast Lower Yard was used as a disposal area for impacted soil, construction debris, and other waste material. These historical Site investigations are summarized in Table 2-1 and in the various reports referenced in this FS Report. Pertinent data tables from historical Site investigations are included in Appendix A.

2.7 Previous Cleanup Actions

Cleanup actions and site investigations have been ongoing at the Site since1986. In 2001, Unocal entered into AO No. DE-92TC-N328, which was superseded by 2007 AO No. DE 4460, as discussed in Section 2.2.6. In accordance with the AO, Unocal conducted Interim Action cleanup activities at both the Upper and Lower Yards, as described below.

2.7.1 Free Product Recovery Interim Action

Free product recovery operations were conducted by EMCON from 1992 to 1998 and by MFA during 1999 and 2000. Recovery operations consisted mainly of skimming, bailing, and pumping the product out of monitoring wells, as well as installing and operating two recovery well systems located along the northwest border of the Site. Between December 1992 and December 2000, these operations removed approximately 1,970 gallons of free product (MFA 2001a).

2.7.2 Upper Yard Interim Action

The Upper Yard Interim Action was conducted between July 2002 and May 2003, in accordance with AO No. DE92TC-N328, and consisted of the excavation of petroleum-impacted soil, metals-impacted surface soil, and asphalt/polyurethane coating material. Approximately 113,034 tons of petroleum impacted soil, 7,320 tons of metals-impacted soil, and 4,021 tons of asphalt/polyurethane coated material were excavated and removed from the Upper Yard (MFA 2003a).

Model Toxics Control Act (MTCA) Method B CULs of 200 milligrams per kilogram (mg/kg) for gasoline range organics (GRO), 460 mg/kg for diesel range organics (DRO), and a combined 2,959 mg/kg for total petroleum hydrocarbons (TPH) in all ranges (GRO, DRO, and heavy oil range organics [HO]) were used for petroleum-impacted soil in the Upper Yard. A total of 842 confirmation samples were collected along the floors and sidewalls of the excavation areas. Confirmation samples containing concentrations exceeding the Method B CULs triggered additional excavation. At the final extent of each excavation area, no confirmation samples exceeded the Method B CULs for TPH (MFA 2003a).

A MTCA Method B CUL of 20 mg/kg for arsenic was used in metals-impacted surface soils excavation areas of the Upper Yard. A total of 500 metals confirmation samples were collected, which met the Method B CUL for arsenic. The single exceeding sample contained an arsenic concentration of 48.1 mg/kg, which was associated with naturally occurring arsenic in the native soil. In 2003, 21 soil samples were collected to a maximum depth of 4 feet bgs and confirmed that arsenic is naturally present in the Upper Yard ramp area, where the concentration exceeds the Method B CUL. Details of the Upper Yard Interim Action are reported in the Upper Yard Interim Action As-Built Report (MFA 2003a).

In September 2003, Ecology accepted the Upper Yard Interim Action as having met cleanup criteria in the 2001 AO (Ecology 2003). No additional cleanup or monitoring activities have been conducted in the Upper Yard since this date.

2.7.3 Lower Yard Interim Actions

2.7.3.1 2001 Excavation

In 2001, Unocal entered into AO No. DE92TC-N328 with Ecology. Unocal conducted an Interim Action in the Lower Yard to remove LNAPL and petroleum-saturated soil and groundwater from four areas of the Lower Yard. These areas were in the vicinity of the former railcar loading rack (Excavation A), in the vicinity of the former asphalt plant (Excavation B), and in the north-central area in the vicinity of the former slops pond (Excavations C and D) (Figure 2-1). The results of the 2001 Interim Action are summarized in Lower Yard Interim Action As-Built Report (MFA 2001a).

Each excavation extended laterally until LNAPL-saturated soil was no longer observed on the excavation sidewalls, or until structural concerns would not allow further excavation. The excavation areas were left open for approximately 1 month to allow LNAPL to enter the excavations and be recovered. Final excavation depths ranged between 6.5 and 10.5 feet bgs (MFA 2002).

Soil samples were collected from the sidewalls of each excavation, although no CULs or minimum concentration criteria were required to be met. Excavated material from above the top of the smear zone was stockpiled and sampled for laboratory analysis. Stockpiles with soil concentrations of TPH less than 5,000 mg/kg were used as backfill material above the top of the smear zone (MFA 2002).

The 2001 Interim Action resulted in the excavation and removal of 10,764 tons of LNAPL-saturated soil and 76,237 gallons of LNAPL and groundwater from these four areas of the Lower Yard (Figure 2-1).

2.7.3.2 2003 Excavation

Additional Interim Actions were conducted in 2003 under AO No. DE92TC-N328, including soil excavations in the Southwest Lower Yard, Detention Basin No.1, Metals Area 3 (located adjacent to the Southwest Lower Yard Excavation Area), and the Stormdrain Line Area (MFA 2004a). The Interim Action excavations conducted in the Southwest Lower Yard, DB-1 and Metals Area 3 were implemented to reduce potential threats to human health and the environment, and to provide additional information for the FS and design of the final cleanup action (MFA 2004a). The Stormdrain Line Excavation was conducted to facilitate installation of a new stormwater outfall for the Point Edwards condominium complex (Figure 2-1).

Depths of each excavation area were approximately 6 feet bgs in the DB-1 Excavation, approximately 7.5 feet bgs (up to 1.5 feet below the groundwater table) in the Southwest Lower Yard Excavation Area, approximately 1 foot bgs in the Metals Area 3 Excavation, and approximately 8.5 feet bgs in the Stormdrain Line Excavation Area (MFA 2004a).

The lateral extents of the excavations were determined by a REL for total TPH (GRO, DRO, and HO) of 3,000 mg/kg and an arsenic CUL of 20 mg/kg. Soil samples were collected along the sidewalls and floors of each excavation area, except those areas that extended below the groundwater table, where floor samples were not collected (the Southwest Lower Yard Excavation Area). Floor samples were later collected during Phase I Interim Actions in 2007. Laboratory analysis of soil samples at the extents of the excavations indicated that soil containing concentrations greater than CULs was left in place in two locations in the DB-1 Excavation Area, five locations in the Southwest Lower Yard Excavation Area, and two locations in the Stormdrain Line Excavation Area. These locations were addressed during subsequent remedial excavations in 2007 and 2008. The Stormdrain Line Excavation was conducted to facilitate installation of a new stormwater outfall for Point Edwards, and was not specifically intended as a remedial action. Therefore, no further excavation was planned at that time. MFA (2004a) identifies the locations of soil left in place in this area during the Stormdrain Line Excavation.

During the 2003 Interim Action excavations, 39,130 tons of soil were excavated from DB-1, the southwest Lower Yard, Metals Area 3, and the Stormdrain Line Area, and approximately 1,861,520 gallons of groundwater were extracted from the DB-1 and southwest Lower Yard Areas and treated onsite. MFA (2004a) summarized the results of the 2003 Interim Action.

2.7.3.3 2007/2008 Excavation

The 2007/2008 Interim Action excavation activities were conducted in two phases from July 2007 to April 2008 (Phase I), and July 2008 to October 2008 (Phase II), in accordance with AO No. DE 4460 (SLR 2007b). Phase I Interim Action work consisted of the removal of 108,000 tons of petroleum-impacted soil for offsite disposal, and the removal of approximately 9,700 gallons of LNAPL from the groundwater surface in open excavations.

During Phase I excavation activities, 438 confirmation soil samples were collected from the floors and sidewalls of the excavation areas for TPH analysis. CULs/RELs were met in 430 of 438 confirmation samples, and eight of the confirmation samples contained concentrations of IHSs exceeding applicable CULs/ RELs. Soil in the area where those samples were taken were not over-excavated during Phase I activities to preserve the integrity of onsite structures or due to Site constraints (ARCADIS 2009).

Soil in the areas of two of these samples was over-excavated during Phase II activities; however, six of the locations were not over-excavated because of Site constraints. One sample location in the southwest Lower Yard (EX-B18-VV-1-6SW) contained a TPH concentration of 4,980 mg/kg, exceeding the REL of 2,975 mg/kg. Soil in the area of this sample was not over-excavated because of its location on the property boundary between the Lower Yard and BNSF right-of-way. Soil was removed up to the property boundary, but excavation activities were ceased to maintain the integrity of the BNSF rail line. The remaining five soil sample locations containing IHS concentrations greater than Site CULs/RELs are located adjacent to, and north of the WSDOT stormwater line, which is located in the south portion of the central Lower Yard, along lower Unoco Road. The remaining five soil sample locations exceeding the Site REL for TPH of 2,975 mg/kg and/or CUL for cPAHs of 0.14 mg/kg are: samples EX-B11-U-SSW-5 (0.159 mg/kg, cPAH), EX-Q2-Q-14-6 (3,060 mg/kg, total TPH), EX-A2-O-15-SSW-6 (7,540 mg/kg, TPH), EX-A2-N-16-SSW-6 (7,550 mg/kg, TPH), and EX-B20-M-17-SSW-6 (0.166 mg/kg cPAH and 15,700 mg/kg, TPH). These sample locations were not over-excavated to preserve the integrity of the WSDOT stormwater line.

In April 2008, 65 confirmation soil borings were completed in the southwest Lower Yard to confirm that the soil on the floor of the 2003 excavation (discussed in Section 2.7.3.2) meet the CULs/RELs. Sixty-three of the 65 borings did not contain concentrations of IHSs in excess of the CULs/RELs. The two borings that contained soil in excess of the CULs/RELs were completed in a previously unexcavated area of the southwest Lower Yard where the former pipeline trestle existed. These two borings (SB-63 and SB-64) were later over-excavated during Phase II excavation activities. Subsequent over-excavation confirmation soil samples contained concentrations of Site IHSs less than applicable Site CULs and RELs.

At the completion of Phase I excavation activities, the excavation sidewall along the WSDOT stormwater line was demarcated with 20 thousandths of an inch (20-mil) -thick plastic sheeting prior to backfilling. This sheeting extends from the ground surface (13.5 feet amsl) to approximately 7.5 feet amsl. Groundwater elevations in the vicinity of the sheeting, as measured at MW-511 and MW-512, have ranged from 5.5 to 9.14 feet amsl during the current groundwater monitoring program.

As part of Phase I activities, arsenic-impacted soil was excavated and removed from the southwest Lower Yard, beneath the former Unocal railroad trestle. This area contained arsenic-impacted soil associated with sandblasting of the pipelines prior to their removal, and was the only remaining metals-impacted area at the Site. This area was excavated to 2.5 feet bgs, where confirmation samples were collected containing concentrations of arsenic less than the arsenic CUL of 20 mg/kg.

During Phase I construction activities, approximately 9,700 gallons of LNAPL were recovered and removed from the Site, and approximately 2 million gallons of groundwater were extracted, treated onsite, and discharged under a NPDES permit to Willow Creek. The complete results of the 2007/2008 Phase I Interim Actions are summarized in Phase I Remedial Implementation As-Built Report (ARCADIS 2009).

Phase II Interim Action work was performed between July and October 2008 and consisted of the removal of 14,825 tons of petroleum-impacted soil for offsite disposal, removal of 131 gallons of LNAPL, removal and treatment of approximately 520,000 gallons of groundwater, and removal of 2,000 tons of sediment from Willow Creek. The excavation areas of Phase II were based on areas of the Lower Yard that could not be excavated during Phase I and areas where impacts were discovered during 2008 investigation activities (as discussed in Section 2.8.1). These areas included the northwest perimeter of the Site adjacent to Willow Creek where three soil samples containing concentrations of IHSs greater than Site CULs/RELs were left in place during Phase I activities, the southeast Lower Yard, and impacted soil in the Former Asphalt Warehouse Area (ARCADIS 2010a).

During Phase II, 71 confirmation soil samples were collected from the floors and sidewalls of the excavation areas. Seventy confirmation soil samples met the Site CULs/RELs, and one confirmation sample (EX-B1-F-44-4) contained concentrations of cPAHs (0.212 mg/kg), exceeding Site CULs. Soil in the area of this sample was not over-excavated during Phase II due to a calculation error in the field. The location of this sample is in the southeast Lower Yard. Approximately 850 tons of concrete and metal debris were excavated from the southeast Lower Yard, including pilings, footings, large concrete blocks, scrap metal, steel I-beams, sheet metal, metal wiring, and lumber debris. In addition, approximately 18 steel drums and drum remnants were encountered in this area, some of which were filled or coated with tar-like substances. Much of this excavation area contained large quantities of tar-like substances intermixed with the soil and debris.

Phase II construction activities also included the removal of 2,000 tons of impacted sediments, and subsequent restoration of approximately 420 feet of Willow Creek. The sediment removal in Willow Creek was based on 2003 toxicity testing, during which three sampling locations in Willow Creek failed toxicity tests. Two of these locations (US-05 and US-07) were located near the Lower Yard’s stormwater outfalls

#001 and #002. Both locations were excavated during the sediment removal portion of the Phase II 2007/2008 excavation activities. The complete results of the 2007/2008 Phase II Interim Actions are summarized in Phase II Remedial Implementation As-Built Report (ARCADIS 2010a). Limits of excavation for all areas of the Phase I and Phase II excavations, as well as quantities of soil removed, are presented on Figure 2-12.

During Phase I and Phase II of the 2007/2008 excavation activities, a total of 512 confirmation soil samples were collected from sample locations at the final extent of the excavation areas. Results from confirmation soil samples are as follows:

- Concentrations of all TPH constituents (GRO, DRO, and HO) were less than laboratory detection limits in 261 of these samples.
- TPH concentrations were less than one-half of the TPH REL of 2,975 mg/kg in 227 of the samples and greater than one-half of the REL in 17 of the samples.
- Concentrations of TPH exceeded the REL in five samples, with concentrations in two samples greater than the REL but less than two times the REL (EX-A2-Q-14-6 [3,060 mg/kg] and EX-B18-VV-1-6SW [4,980 mg/kg]), and concentrations in three samples exceeded two times the REL (EX-A2-O-15-SSW-6 [7,540 mg/kg], EX-A2-N-16-SSW-6 [7,550 mg/kg], and EX-B20-M-17-SSW-6 [15,700 mg/kg]).
- Two additional samples exceeded the CUL for cPAHs adjusted for toxicity, with concentrations that are greater than the CUL but less than two times the CUL (EX-B11-U-10-SSW-5 [0.159 mg/kg] and EX-B1-F-44-4 [0.212 mg/kg]).
- Grid sampling on a 25-foot spacing of the floors and sidewalls confirmed that the lateral and vertical extents of soil impacts had been addressed in all but two distinct areas of the Lower Yard (DB-2 and the WSDOT stormwater line area).
- The 2007/2008 Interim Action excavation areas included areas from the 2003 excavations that exceeded the TPH CUL and were not over-excavated in 2003.

2.8 Recent Investigations

2.8.1 2008 Lower Yard Site Investigation

In 2008, additional soil investigation activities were conducted to collect data and evaluate the nature and extent of limited remaining petroleum impacts in discrete areas of the Lower Yard, including the areas to the south and southwest of the WSDOT stormwater line and the Former Asphalt Warehouse Area, near monitoring well MW-129R. Fourteen soil borings were advanced to the south and southwest of the WSDOT stormwater line, five of which contained soil with concentrations of TPH and/or cPAHs exceeding Site CULs/RELs. Three of these boring locations are located between the WSDOT stormwater line and the Point Edwards stormdrain line, in the south-central portion of the Lower Yard. One of the borings is located to the southwest of Point Edwards stormdrain line and one is located south of the WSDOT stormwater line where upper and lower Unoco Road meet. Three soil borings collected in the Former Asphalt Warehouse Area, in the east-central portion of the Lower Yard, contained soil with concentrations of TPH and/or cPAHs exceeding Site CULs/RELs. Soil in the area of the soil borings located near the asphalt warehouse was subsequently excavated during Phase II excavation activities. The complete results of the 2008 investigation activities are summarized in 2008 Additional Site Investigation and Groundwater Monitoring Report (ARCADIS 2010b). Soil sample locations and analytical results from 2008 soil investigation activities are presented on Figure 2-13.

2.8.2 2011 Lower Yard Site Investigation

In 2011, Site investigation activities conducted in the Lower Yard included a tidal study, hydraulic conductivity testing, and soil boring advancement in the limited area of impact in the vicinity of DB-2. Tidal study data were collected from 17 locations in Site monitoring wells and staff gauges in Willow Creek to evaluate the potential influence of Puget Sound and Willow Creek on Site surface water and groundwater gradients, and groundwater chemistry. Hydraulic conductivity pumping tests including step tests, short-duration tests, and one long-term test were conducted in 10 Site monitoring wells.

Soil investigation activities included the advancement of 17 soil borings and the installation of nine piezometers in the vicinity of DB-2, monitoring well MW-510, and Willow Creek. These areas were investigated to assess the recurring, but minimal amount of LNAPL present in monitoring well MW-510. LNAPL was not encountered in nine of the 17 borings, and was only encountered in eight of the 17 soil borings at the time of installation as either residual or free-phase LNAPL. Free-phase LNAPL subsequently appeared in two of the piezometers. Soil containing concentrations of Site IHSs exceeding their respective CULs and/or RELs were encountered in 11 of the soil borings. Details of the 2011 Site investigation activities are summarized in the 2011 Site Investigation Completion Report (ARCADIS 2012a). Soil sample locations and analytical results from 2011 soil investigation activities are presented on Figure 2-14.

2.8.3 2012 Lower Yard Investigation

In 2012, eight monitoring wells were installed in the Lower Yard to assess groundwater conditions in areas of known and potential remaining soil impacts. Four wells (MW-525, MW-526, MW-531, and MW-532) were installed to the north and south of the WSDOT stormwater line to monitor for the possible presence of LNAPL and dissolved-phase TPH concentrations in groundwater in the unexcavated soil in this area. Specifically, wells MW-525, MW-526 and MW-532 were installed in previously impacted soils not removed during remedial Interim Actions. Monitoring wells MW-527 and MW-528 were installed in the southeast Lower Yard, in the vicinity of the single confirmation soil sample that contained cPAH concentrations in excess of the CUL. Monitoring wells MW-529 and MW-530 were installed on the southeast bank of Willow Creek, directly downgradient of monitoring wells MW-510 and LM-2, respectively. These wells were installed to monitor the potential for contaminant migration in groundwater offsite into Willow Creek. Soil samples collected during monitoring well installation contained concentrations of benzene, cPAHs, and/or TPH exceeding site CULs/RELs in MW-525 and MW-532 only. Monitoring well locations and soil sample analytical data from 2012 site investigation activities are presented on Figure 2-15.

In July 2012, three sediment samples were collected from Willow Creek to assess sediment toxicity conditions in the vicinity of 2003 sediment sampling location US-15. Based on the evaluation of these data, Ecology determined that further cleanup of Willow Creek was not needed. Sediment sampling locations and analytical results are presented on Figure 2-16. The complete results of the 2012 investigation activities are summarized in Final CSM (ARCADIS 2013a).

2.8.4 2013 Soil Vapor Sampling

Soil vapor sampling was conducted in October and November 2013 in selected locations to evaluate worst-case scenarios vapor intrusion and to support remedial strategy decisions at the Lower Yard. Soil vapor analytical results are presented in Table 2-5. Soil vapor probe locations are presented on Figure 2-17 and a soil vapor probe schematic is presented on Figure 2-18. Soil vapor sampling procedures and chemical analytical data are presented in Appendix B and C respectively.

2.8.4.1 Soil Vapor Probe Installation

ARCADIS installed three permanent single-level onsite soil vapor probes (VP-1, VP-2, and VP-3) on October 8, 2013 to assess the potential for soil vapor in the Lower Yard adjacent to remaining impacts in soil and groundwater.

The vapor probe locations are near areas of maximum TPH detection and/or areas of remaining impacts onsite to represent worst-case scenarios for volatile organic compounds (VOCs and GRO)..

- Soil vapor probe VP-1 is located near MW-525 (TPH [17,850 mg/kg], GRO [1,400 mg/kg]) to evaluate potential soil vapor adjacent to the WSDOT stormwater line.
- Soil vapor probe VP-2 is located near B-7 (TPH [111,400 mg/kg], GRO [1,400 mg/kg]) to evaluate potential soil vapor adjacent to DB-2 and groundwater monitoring well MW-510 (LNAPL observed).

- Soil vapor probe VP-3 is located adjacent to monitoring well MW-129R (TPH [3,010 mg/kg], GRO [nondetect]) to evaluate potential soil vapor in the adjacent area.

A vapor probe in the location of sample EX-B18-VV-1-6SW (TPH [4,980 mg/kg]) in the southwest portion of the Lower Yard was considered but not selected for two reasons: vicinity to the BNSF active railroad tracks and low likelihood of building a structure on the Site boundary.

In accordance with the approved work plan, each soil vapor probe was set at 5 feet bgs or 1 foot above groundwater, whichever was encountered first. Vapor probe boreholes were cleared to the target depth using hand auger and vacuum truck methods. When each boring was advanced to its maximum depth of 5 feet bgs, a 6-inch-long, 0.375-inch-outer-diameter stainless steel soil vapor screen was set in a 1-foot interval of standard sand pack, allowing approximately 3 inches of sand above and below the screen, with the exception of VP-1 which was set within a 1.5-foot sand pack due to over-clearance of the boreholeTeflon® tubing was then connected to the soil vapor screen and capped with a vapor-tight cap at the surface to eliminate the potential for barometric pressure fluctuations to induce vapor transport between the subsurface and the atmosphere. The cap was installed in the closed position to allow equilibration of soil vapor concentrations to commence immediately after installation.

A 1-foot interval of dry, granular bentonite was placed above the sand pack followed by hydrated bentonite to within 1 foot of the surface. Sand pack was used around the screened interval of each sample probe to allow soil vapor from the adjacent soil to reach the probes. Dry granular bentonite was used to ensure that the hydrated bentonite did not seal the vapor probe screen and inhibit the collection of soil vapor. The surface of each vapor probe location was then fitted with a concrete cap and a flush-mounted, traffic-rated well box with sufficient room to store the tubing lines and valves or caps.

Continuous soil samples were collected for field screening from a hand auger at each soil vapor probe location during advancement. The collected intervals were screened in the field using a photo ionization detector (PID), and were described by the supervising geologist using visual and manual methods of the Unified Soil Classification System (USCS).

2.8.4.2 Soil Vapor Sampling

Due to the introduction of atmospheric oxygen into the vadose zone during soil vapor probe installation, an equilibration time was required to allow the sand pack and tubing to equilibrate with the subsurface. Soil vapor samples were collected on November 21, 2013.

To assure sampling train integrity, a shut-in leak detection test was implemented. One vapor-tight two-way ball valve was installed closest to the soil vapor port (port valve) and another vapor-tight two-way ball valve was installed on the opposite end of the sampling train as a purge valve (purge valve). While the port valve was left in the closed position, a laboratory-provided syringe was used to remove approximately 25 milliliters (mL) of air from the purge port, inducing a vacuum of -8 inches of mercury (inHg [approximately -107 inches of water]) within the sampling train. The purge valve was then closed and the vacuum within the sampling train was monitored for a minimum of 2 minutes. If there was any observable loss in the vacuum within the sampling train after 2 minutes, fittings were adjusted and the test was repeated until the vacuum in the sampling train did not dissipate.

Purging consisted of removing approximately 3 volumes of stagnant soil vapor at a flow rate of ≤ 200 milliliters per minute (mL/min). The purge volume was calculated based on the dimensions of the aboveground gauges, tubing, sampling equipment, belowground tubing, soil vapor probe, and sand pack annulus pore space. Purge volume calculation, field conditions, flow rate, pump specifics, and other applicable information was recorded by field personnel on soil vapor sample collection logs.

Purged air was measured for oxygen, carbon dioxide, and methane with a GEM2000 landfill meter during the sampling event. Purged air was also measured with a PID (for VOCs) and a helium meter (for leaks). Fixed gas measurements were compared to laboratory analytical results and support potential biodegradation evaluation.

A leak test was conducted to verify the integrity of the sampling system. The well head and entire sampling train (valves, tubing, gauges, manifold, and sample canister) were placed in an enclosure. A tracer check compound (helium) was admitted into the enclosure. A helium concentration was maintained in the enclosure, as measured using a portable helium detector. The helium shroud concentration was maintained between 10 and 20 percent with the exception of VP-3 during the sampling event which was maintained between 30 to 40 percent. Analysis for the tracer compound in the soil vapor sample was used to assess if leakage occurred. The soil vapor samples were then collected using 1-liter, batch-certified SUMMA™ canisters (or an acceptable alternative) at a flow rate of ≤ 200 mL/min. Soil vapor sampling stopped when the canister vacuum had dropped to 5 inHg, as measured by the vacuum gauge attached to the SUMMA™ canister.

Sampling was conducted in accordance with the Chevron ToolKit and ARCADIS Standard Operating Procedure (#112409) for Soil-Gas Sampling and Analysis using United States Environmental Protection Agency (USEPA) Methods TO-17 and TO-15. Additionally, one duplicate sample was collected in-line with its respective parent sample for each day of sampling and one equipment blank sample collected using a laboratory-supplied air source was also submitted to the laboratory for quality assurance purposes. Purge volume calculation, field conditions, flow rate, VOC concentrations, pump specifics, and other applicable information were recorded by field personnel on soil vapor sample collection logs. The soil vapor samples were shipped under appropriate chain of custody protocols to Eurofins Air Toxics Ltd. in Folsom, California for analysis of the following:

- Benzene and GRO (with specific carbon ranges: C5-C6 aliphatic hydrocarbons, greater than (>) C6-C8 aliphatic hydrocarbons, >C8-C10 aliphatic hydrocarbons, >C10-C12 aliphatic hydrocarbons, >C8-C10 aromatic hydrocarbons, >C10-C12 aromatic hydrocarbons), and naphthalene by Modified USEPA Method TO-15.

- Oxygen, carbon dioxide, methane, and helium by Modified ASTM International (ASTM) Method D-1946.

TPH was not analyzed because this compound is not directly comparable to Method B CULs presented in the Draft Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action (Ecology 2009).

2.8.4.3 Soil Vapor Sampling Results

Soil vapor samples were collected on October 9, 2013, however; soil vapor data collected during this sampling event is considered questionable due to VOC concentrations detected in quality control samples. Due to this occurrence, the soil vapor data is not considered for the evaluation of this feasibility study. Soil vapor samples were collected again on November 21, 2013. The November 2013 soil vapor sampling data were used for evaluation in this feasibility study.

2.8.4.3.1 Soil Vapor Analytical Results

Soil vapor data from the November, 2013 vapor sampling event were compared to health-based screening criteria (Ecology Method B soil gas screening levels presented in Table 2-4 of the DOE *Review DRAFT Guidance for Evaluation Soil Vapor Intrusion in Washington State: Investigation and Remedial Action* (Ecology 2009). These screening criteria define levels that the regulatory agencies have deemed safe for human exposure under a vapor intrusion scenario. Ecology provides draft soil gas screening values for samples collected at depths of less than 15 feet bgs and soil gas screening values for samples collected at 15 feet bgs or deeper.

Table 2-4. Soil Vapor Data Screening Levels

Measured Concentration (µg/m^3)	Screening Criteria (µg/m^3)
Benzene	3.2
Naphthalene	14
Σ(C5-C6AL)+(>C6-C8AL)	27,000
Σ(>C8-C10AL)+(>C10-C12AL)	1,400
Σ(C8-C10AR)+(>C10-C12AR)	1,800

Note: µg/m3 (Micrograms per cubic meter)

Concentrations of aliphatic carbon rages C5-C6 + >C6-C8 were detected greater than screening criteria in the samples collected from VP-1(35,000,000 µg/m^3), VP-2 (33,700 µg/m^3) and VP-3 (529,000 µg/m^3). Concentrations of aliphatic carbon ranges >C8-C10 + >C10-C12 were detected greater than screening criteria in the sample collected from VP-1 (6,600,000 µg/m^3), VP-2 (36,000 µg/m^3) and VP-3 (305,000 µg/m^3). Concentrations of benzene were detected greater than screening criteria in the samples collected from VP-1 (710,000 µg/m^3), VP-2 (340 µg/m^3) and VP-3 (46 µg/m^3). Concentrations of aromatic carbon ranges C8-C10 + >C10-C12 were detected greater than screening criteria in the sample collected from VP-1 (34,000 µg/m^3). Due to sample dilution the laboratory reporting limits for the analysis of naphthalene in all samples and for aromatic carbon ranges C8-C10 + >C10-C12 in the sample collected from VP-3 were greater than their respective MTCA screening criteria. Laboratory analytical results are included in Appendix C, and are summarized in Table 2-5.

2.8.4.3.2 Fixed Gases and Biodegredation

The presence and concentration of fixed gases including oxygen, carbon dioxide and methane can be indications of biodegradation of soil vapor in the subsurface. Typically, an increase in carbon dioxide and methane concentrations combined with a decrease in oxygen indicate potential biodegradation of soil vapors in the subsurface. Oxygen concentrations detected in soil vapor collected from soil vapor probes VP-1 and VP-2 are below the ideal range (three to four percent by volume) for aerobic biodegradation. However, the relatively high methane concentrations (29 percent by volume in VP-1 and 23 percent by volume in VP-2) potentially indicate the utilization of carbon dioxide in an anaerobic stage of biodegradation.

2.8.4.3.3 Soil Vapor Sampling Data Quality Assurance

For data quality assurance (QA) purposes, multiple QA techniques were employed during the November 2013 soil vapor sampling event. A leak test was performed during each sample collection period to ensure integrity of the sampling system and to demonstrate that ambient air was not being permitted into the sampling train or entering the subsurface, potentially biasing the samples. In addition, an equipment blank was submitted during the event to assess background contamination due to equipment or bias due to contamination during transport to and from the laboratory.

2.8.4.3.4 Equipment Blank Analytical Results

There were no detections of the analyzed compounds in the equipment blank sample above the respective laboratory reporting limit. This confirms the integrity of the sampling train equipment and further validates soil vapor data collected during the November 2013 sampling event.

3. Nature and Extent of Contamination

This section describes the type of contaminants at the Site (nature) and the distribution of these contaminants vertically and horizontally across the Site (extent). The nature and extent of contamination was determined based on data collected during the remedial investigation (RI) (MFA 2001b), the supplemental remedial investigation (SRI) (MFA 2003b), 2008 Site investigations (ARCADIS 2010b), 2011 Site investigations (ARCADIS 2012a), 2012 Site investigations (ARCADIS 2013a), and 2013 vapor sampling conducted as part of this FS Report.

The primary COCs in the Lower Yard are petroleum hydrocarbons. During Lower Yard investigation activities conducted from 2001 to 2012, soil, groundwater, sediment, and surface water samples were analyzed for GRO, DRO, and/or HO. Selected samples were also analyzed for benzene, toluene, ethylbenzene, and total xylenes (BTEX); polycyclic aromatic hydrocarbons (PAHs), and volatile and extractable petroleum hydrocarbon (VPH/EPH) fractions.

Prior to the 2001 and 2003 Lower Yard Interim Action excavations, LNAPL was present in six areas of the Lower Yard (near the southwestern former railroad loading rack area, near the northeastern former truck loading rack area, beneath the northeastern most office building, beneath the former asphalt plant, to the north-northeast of the former asphalt plant, and to the south-southwest of DB-1) (MFA 2001a). Petroleum hydrocarbon constituents in the soil and dissolved in groundwater were present primarily in the vicinity of the LNAPL areas and in areas where residual LNAPL was trapped in the unsaturated zone above the groundwater table. Prior to the 2003 Interim Action, petroleum hydrocarbons were present in soil and groundwater throughout the Lower Yard and DB-1 (Figure 3-1). After completion of the Phase I and Phase II Interim Actions in 2007 and 2008, only localized areas of impacted soil remain along the WSDOT stormwater line and the vicinity of DB-2.

During a storm event in April 1996, petroleum hydrocarbons were detected in stormwater samples from the Lower and Upper Yards. The samples contained DRO, GRO, and total BTEX concentrations of up to 950, 630, and 200 micrograms per liter (µg/L), respectively (MFA 2001b).

During the pre-2008 Lower Yard investigation activities, selected soil, groundwater, sediment, and surface water samples were analyzed for metals (arsenic, antimony, cadmium, chromium, copper, lead, mercury, and zinc). Soil and groundwater beneath the Lower Yard contained concentrations of metals. Low concentrations were also detected in sediment and surface water from Willow Creek and the tidal basin. The highest metals concentrations in soil were present in areas associated with sandblast grit and paint chips occurring near pipe runs in the southwest Lower Yard. The majority of the metals-impacted soil in the Lower Yard was removed during the 2003 Interim Action. During the 2007 and 2008 excavation activities, the remaining arsenic-impacted soil was removed from the Lower Yard. During the RI, the highest dissolved and total metals concentrations in groundwater were present in isolated locations that typically were not associated with sources of metals. Based on the distribution of the metals concentrations, the sources of the metals in the surface water and sediment appear to be impacted stormwater from onsite and offsite sources. During a storm event in April 1996, metals were detected in stormwater samples from the Lower and Upper Yards. The samples contained detectable concentrations of arsenic, chromium, copper, lead, and zinc (MFA 2001b).

The following sections that describe the nature and extent of contamination focus mainly on the IHSs that were screened for the Lower Yard during development of the Draft FS (MFA 2004c). These chemical are: TPH (combined GRO, DRO, and HO); benzene, chrysene, arsenic, and toxicity-adjusted total cPAHs for soil and TPH (combined GRO, DRO, and HO); benzene, chrysene, and toxicity-adjusted total cPAHs for groundwater and protection of surface water.

3.1 Soil Quality

Rigorous soil sampling activities have been completed from locations throughout the Lower Yard and limited soil investigation has been conducted in offsite locations (to the northwest of the terminal). The soil samples were collected as part of several Site investigations, including the 2008 additional Site investigation (ARCADIS 2010b), 2011 Site investigation (ARCADIS 2012a), RI (MFA 2001b), SRI (MFA 2003b), 2003 assessment (MFA 2004b), and investigations that were conducted prior to the RI and are described in the Background History Report (EMCON 1994). Soil samples were also collected as part of the 2001 Interim Action (MFA 2002) and the 2003 Interim Action (MFA 2004a).

The vertical and lateral distribution of petroleum hydrocarbons, benzene, chrysene, and arsenic in soil was presented in the Draft FS (MFA 2004c). All COCs except petroleum hydrocarbons were profiled at depths from ground surface to greater than 6 feet bgs. The distribution of petroleum hydrocarbons was profiled in three depth intervals: 0 to 3 feet bgs, 3 to 6 feet bgs, and greater than 6 feet bgs (MFA 2004c).

3.1.1 Petroleum Hydrocarbons

Historically, gasoline, diesel, and heavy oil were stored and used at the terminal. The TPH concentrations observed in soil are a mixture of GRO, DRO, and/or HO in varying proportions; therefore, this discussion focuses on TPH (combined GRO, DRO, and HO concentrations) and not the individual product ranges. Prior to the 2007/2008 Phase I Interim Action activities, TPH was present in the shallow soil above the groundwater table throughout most of the Lower Yard (MFA 2004c). Generally, the areas of TPH-impacted soil coincided with historical terminal operations conducted in the asphalt plant, and fuel storage and distribution areas, except the southeastern Lower Yard. The southeastern Lower Yard was used as a waste soil stockpile area for material removed from two local Unocal service stations (EMCON 1994).

The 2001 Interim Actions removed the impacted soil in four areas of the Lower Yard. These areas were in the vicinity of the former railcar loading rack (Excavation A), in the vicinity of the former asphalt plant (Excavation B), and in the north-central area in the vicinity of the former slops pond (Excavations C and D) (Figure 2-1). Each excavation extended laterally until LNAPL-saturated soil was no longer observed on the excavation sidewalls, or until structural concerns would not allow further excavation. Final excavation depths ranged between 6.5 and 10.5 feet bgs (MFA 2002). Excavation confirmation soil samples collected during the 2001 Interim Actions contained TPH concentrations ranging from 724 to 3,203 mg/kg. Soil samples were collected from the sidewalls of each excavation although no CULs or minimum concentration criteria were required to be met. Excavated material from above the top of the smear zone was stockpiled and sampled for laboratory analysis. Stockpiles with soil concentrations of TPH less than 5,000 mg/kg were used as backfill material above the top of the smear zone (MFA 2002).

The 2003 Interim Actions removed impacted soil from DB-1, the Point Edwards Stormdrain Line, Metals Area 3 (located adjacent to the Southwest Lower Yard Excavation Area), and the Southwest Lower Yard. Depths of each excavation area were approximately 6 feet bgs in the DB-1 Excavation, approximately 7.5 feet bgs (up to 1.5 feet below the groundwater table) in the Southwest Lower Yard Excavation Area, approximately 1 foot bgs in the Metals Area 3 Excavation, and approximately 8.5 feet bgs in the stormdrain line excavation (MFA 2004a). Lateral extents of the excavations were determined by COC concentrations in soil samples collected along the sidewalls and floors of each excavation. Concentrations of TPH ranged from less than laboratory detection limits to 17,439 mg/kg in these samples.

Prior to 2007/2008 Interim Action excavation activities, soil containing TPH greater than 5,000 mg/kg at depths from ground surface to greater than 6 feet bgs were found throughout the majority of the Lower Yard. Areas of remaining impacted soil included the central and south-central Lower Yard (the former location of the asphalt plant and northern truck loading rack area), the northwestern property boundary adjacent to Willow Creek (asphalt plant area), the southwest property boundary adjacent to the BNSF right-of-way (the former railcar loading areas and southern truck loading rack), and the southeast Lower Yard. Areas with elevated concentrations of TPH in the Lower Yard also included 2001 Interim Action excavation areas B, C, and D, and under the stormwater excavation, adjacent to excavation area A (Figure 2-1).

Prior to 2007/2008 Interim Action excavation activities, maximum concentrations of TPH were found at depths from 0 to 3 feet bgs in the north-central Lower Yard (31,600 mg/kg), from 3 to 6 feet bgs in the south-central Lower Yard (147,230 mg/kg), and at depths greater than 6 feet bgs in the southeast Lower Yard (18,852 mg/kg). TPH impacts were most laterally extensive at depths from 3 to 6 feet bgs throughout the Lower Yard (SLR 2007a).

Areas excavated during the 2007/2008 Interim Actions are shown on Figure 2-12. These areas cover the majority of the Lower Yard, including the western boundary of the southwest Lower Yard, the majority of the central and west/northwestern, and southeastern Lower Yard. Excavation areas from the 2003 Interim

Actions were re-excavated at this time, except the Point Edwards stormdrain line area and DB-1. Excavation depths ranged from 4 to 15 feet bgs. Limits of excavation extended until LNAPL saturated soil was removed and confirmation soil samples collected at the extent of excavation were less than the site REL of 2,975 mg/kg. TPH concentrations in soil samples collected during the 2007/2008 Interim Action excavations ranged from less than laboratory detection limits to 17,100 mg/kg. In general, maximum remaining concentrations of TPH are generally found along the WSDOT stormwater line.

The majority of remaining hydrocarbon impacts in soil is in two localized areas of the Lower Yard: the WSDOT stormwater line and DB-2. Concentrations of TPH remaining in the WSDOT stormwater line range from 3,060 to 16,900 mg/kg, at depths between 4 and 8 feet bgs. Soil samples collected in the DB-2 area contain saturated LNAPL in some areas and concentrations of TPH ranging from 4,413 to 220,400 mg/kg in some areas. Impacts are found between 4 to 14 feet bgs in the DB-2 area. Remaining TPH impacts are also present in one sample location in the southwest Lower Yard (4,980 mg/kg TPH) at 6 feet bgs, in monitoring well MW-129R (3,010 mg/kg TPH) at 7 feet bgs, and along the Point Edwards stormdrain line (4,660 mg/kg TPH) at 7.5 feet bgs.

Concentrations of TPH in all of the soil samples located northwest of the Site (offsite) were less than 500 mg/kg, except samples from two borings located in Admiral Way (SB-1 and SB-4). Samples from SB-1 and SB-4 contained TPH concentrations of up to 2,694 and 3,203 mg/kg, respectively (MFA 2003b, Table 5-1). Based on the localized distribution of impacted soil beneath Admiral Way and the low to nondetect petroleum hydrocarbon concentrations in soil and/or groundwater samples from the borings/wells (MW-28, MW-106, and MW-107) located between the Lower Yard and Admiral Way, it appears that the impacted soil beneath Admiral Way is from offsite sources (MFA 2003b).

3.1.2 Benzene

Prior to the 2007/2008 Interim Action excavations, benzene in soil was present in localized areas of the Lower Yard. Benzene concentrations exceeding 1 mg/kg were present in localized areas in the southeastern, central, and west-northwestern parts of the Lower Yard. Areas of the Lower Yard where benzene concentrations existed typically also contained elevated concentrations of TPH. The maximum detected concentration of benzene in soil in the Lower Yard was 78 mg/kg. Benzene in soil was not detected at concentrations greater than laboratory detection limits in samples collected during the offsite soil investigation, to the northwest of the Site.

Benzene concentrations detected in confirmation soil samples during the 2007/2008 Interim Action excavation ranged from less than laboratory detection limits to 14.90 mg/kg. The sample containing the highest concentrations of benzene was collected from the excavation sidewall, adjacent to the WSDOT stormwater line in the south-central portion of the Lower Yard and was not over-excavated in order to avoid damage to the WSDOT stormwater line. In 2012, monitoring wells MW-525, MW-526, and MW-532 were installed along the WSDOT stormwater line in soils that had not been disturbed during prior excavation activities and one soil sample collected from the boring for well MW-525 at a depth of 6 feet bgs that contained a benzene concentration of 34 mg/kg. The soil sample collected from MW-525 contained the highest benzene concentration in soil that has been detected in the Lower Yard during or after the 2007/2008 Interim Action excavations, and is the only soil sample to exceed the Site-specific benzene CUL of 18 mg/kg.

3.1.3 Carcinogenic Polyaromatic Hydrocarbons

Prior to the 2007/2008 Interim Action excavations, cPAHs were found in large areas beneath the central and eastern-southeastern parts of the Lower Yard, and in more localized areas beneath the northern and western-southwestern parts of the Lower Yard (MFA 2004c). Areas of cPAH concentrations typically contained elevated concentrations of TPH. The maximum chrysene concentration in the soil beneath the Lower Yard prior to the 2007/2008 Interim Action was 631.4 mg/kg.

Since the 2007/2008 Interim Action excavations, cPAH concentrations in soil detected in the Lower Yard have ranged from less than laboratory detection limits to 116 mg/kg. The maximum concentration of cPAHs detected during the 2007/2008 Interim Action activities contained 1.14 mg/kg of cPAH and was from a sample collected in the southeast Lower Yard. This sample location was later over-excavated. Three soil sample locations with concentrations of cPAHs exceeding the site CUL of 0.14 mg/kg remained after the 2007/2008 Interim Actions. Two of these sample locations were located on the excavation sidewall along the WSDOT stormwater line at depths of 5 and 6 feet bgs, with concentrations of 0.16 and 0.17 mg/kg, respectively, and one was located in the southeast Lower Yard at a depth of 4 feet bgs, with a concentration of 0.21 mg/kg.

During 2011 Site investigation activities in the DB-2 area, concentrations of cPAHs were detected at concentrations ranging from less than laboratory detection limits to 116 mg/kg. Concentrations were detected greater than the Site CUL in eight borings. Thirteen soil samples contained concentrations of cPAHs greater than the Site CUL, at depths ranging from 0.5 to 14 feet bgs. Concentrations of cPAHs greater than the site CUL ranged from 0.14 to 116 mg/kg, which is the highest concentration of cPAHs currently found in the Lower Yard.

3.1.4 Arsenic

Arsenic was identified as the only metal IHS in soil in the Lower Yard. The majority of the arsenic-impacted soil in the Lower Yard was removed during the 2003 Interim Action. Upon completion of the 2003 Interim Action, arsenic was present only at concentrations greater than 20 mg/kg in the southwestern corner of the southwestern Lower Yard. The maximum arsenic concentration in this area was 1,900 mg/kg.

During the 2007/2008 Interim Action excavations, the arsenic-impacted area of the southwestern Lower Yard was excavated and confirmation samples were collected. Confirmation samples in one sample location exceeded the CUL of 20 mg/kg, with concentrations of 25.0, 30.7, and 30.9 mg/kg. These samples were over-excavated and one confirmation sample with a concentration of arsenic less than laboratory detection limits was collected. Arsenic-impacted soil is no longer found in the Lower Yard.

3.2 Light Nonaqueous Phase Liquid

Prior to the 2001 Interim Action, there were six main areas of LNAPL beneath the Lower Yard These areas were the four areas of the 2001 excavations (excavation areas A through D), plus the southwest Lower Yard property boundary and the asphalt warehouse area, south of the detention basins, and in the central Lower Yard (MFA 2004c).

From 1988 to June 2001, approximately 9,500 gallons of LNAPL were recovered as part of Interim Action product recovery activities, as discussed in Section 2.7.1. During the 2001 Interim Action, an additional estimated 2,500 gallons of product were removed from the excavation areas (MFA 2002). LNAPL has never been observed seeping into the tidal basin or Willow Creek, and LNAPL has never been detected in the offsite monitoring wells.

In September 2006, prior to the 2007/2008 excavation, SLR conducted a groundwater sampling event at the Lower Yard (SLR 2006). Four distinct areas of LNAPL were interpreted to be present at this time. These areas were in Excavation A (adjacent to the tidal basin), southeast of Excavation B (in the central Lower Yard), Excavation D in the west/northwestern area (south of DB-2), and the central portion of the Lower Yard between DB-1 and lower Unoco Road. Dissolved-phase impacts were not found in the southwest or southeast Lower Yard, or north of DB-1 (SLR 2007a).

Since the 2007/2008 Interim Action excavation activities, LNAPL on groundwater has been present in only two areas. One observance of LNAPL in well MW-129R at a thickness of 0.01 foot was observed in February 2009, but has not been observed since. LNAPL on groundwater has also been present in the DB-2 area in three wells (MW-510, P-12 and P-13). Monitoring well MW-510 and piezometers P-12 and P-13 are located 15 feet apart in the DB-2 area. Monitoring well MW-510 has had measurable amounts of LNAPL present during nine sampling events since October 2009, with thicknesses ranging from 0.01 to 0.13 foot. Piezometer P-12 has had measurable amounts of LNAPL present during five of the past 11 sampling events, with thicknesses ranging from 0.01 to 0.09 foot. Piezometer P-13 has had measurable amounts of LNAPL present during the past 11 gauging events, from September 2011 to September 2013, with thicknesses ranging from 0.01 foot to 1.25 feet. LNAPL in monitoring well MW-510, piezometer P-12, and piezometer P-13 is black in color, has a high viscosity, and is difficult to recover with a bailer.

3.3 Groundwater Quality

The conceptual site model (CSM) presented in the IAWP (SLR 2007a) concluded that groundwater beneath the Site discharges to surface water and sediment in Willow Creek. As a result, the IAWP (SLR 2007a) establishes groundwater CULs based on the protection of surface water. According to the AO, the groundwater CULs are required to be met at the POC monitoring wells, which are located along the downgradient perimeter of the Site, where groundwater discharges to surface water. Data collected from the interior monitoring well locations are not used for compliance; rather, the dissolved concentration data collected at interior monitoring well locations are used to evaluate groundwater concentration trends at the Site and overall plume stability.

In accordance with the AO, groundwater monitoring was initiated and is ongoing following completion of the 2007/2008 Interim Action activities. Groundwater flow paths were established within the interior of the Lower Yard and each groundwater flow path consisted of seven monitoring wells (an upgradient well, three source area wells, and three downgradient wells). POC wells were established at the point where groundwater discharges to surface water within the monitoring well network, located along the downgradient perimeter of the Site. Seventeen POC wells were originally established in the IAWP (SLR 2007a); currently, 23 POC wells are present onsite.

The locations of the wells inside the three groundwater flow paths were based on the presence of LNAPL on groundwater prior to remedial activities. Prior to the 2007/2008 Interim Action remedial excavations, the groundwater flow paths fit the established model of upgradient, source area, and downgradient wells. However, as a result of the 2007/2008 Interim Action, remedial excavations extended beyond the mapped flow path areas, and the resulting monitoring well arrangement was no longer suitable for use with Ecology's Natural Attenuation Analysis Tool Package A, as originally intended. As a result of the source removal, the flow paths previously defined did not contain monitoring wells that could provide upgradient and downgradient water quality data in relation to specific source areas, and were no longer applicable for a spatial evaluation of natural attenuation away from the source, as required for use with Ecology's Natural Attenuation Analysis Tool Package A. This change in the CSM rendered the previous sampling schedule and monitoring program obsolete with respect to the planned data evaluation, and necessitated revisions to the monitoring program that were reviewed and approved by Ecology in December 2009. However, the current monitoring well network is sufficient to monitor and evaluate the status of the overall dissolved-phase plume; the stability of the Site plume is being evaluated on a well-by-well basis, and the monitoring program needed to support this analysis was revised accordingly. Currently, groundwater sampling events are conducted quarterly, with POC wells sampled during first and third quarter events, and all Site wells (POC and interior wells) sampled during second and fourth quarter events.

The following sections describe the current groundwater conditions in the Lower Yard.

3.3.1 Petroleum Hydrocarbons

A Site-wide groundwater sampling event was completed in June 2001, before the 2001 Interim Action was conducted. TPH was present in the shallow groundwater throughout most of the western, northwestern, and central parts of the Lower Yard, and in localized areas beneath the southwestern, northern, eastern, and southeastern parts of the Lower Yard. In general, the areas of impacted groundwater beneath the Lower Yard coincided with historical facility operations (e.g., asphalt plant and fuel storage and distribution areas).

Site-wide groundwater sampling events were conducted in February and August 2004 (i.e., after the 2003 Interim Action). The area of TPH-impacted groundwater in 2004 is similar to the impacted area in June 2001. Based on the results of the 2001 and 2003 Interim Actions, the TPH concentrations in August 2004 in wells located near Excavation B, the southwest Lower Yard, and DB-1 excavations were typically less than the concentrations in June 2001. Due to the continued presence of LNAPL in Excavations A and D, elevated TPH concentrations in groundwater remained in the vicinity of Excavations A, C, and D. Groundwater analytical results from the August, 2004 sampling event indicated that samples collected from 13 Site wells, outside of the LNAPL areas, contained dissolved concentrations of TPH exceeding the Site-specific CULs at that time (SLR 2004a).

In September 2006, prior to the 2007/2008 excavation, SLR conducted a groundwater sampling event at the Lower Yard (SLR 2006). Four distinct areas of LNAPL were interpreted to be present at this time. These areas were in the 2001 Excavation A area (adjacent to the tidal basin), southeast of Excavation B (in the central Lower Yard), Excavation D in the west/northwestern area (south of DB-2) and in the central portion of the Lower Yard between DB-1 and lower Unoco Road. Dissolved-phase impacts were not found in the southwest or southeast Lower Yard, or north of DB-1 (SLR 2007). Dissolved concentrations of TPH greater than Site-specific CULs were detected in six wells outside of the LNAPL areas, during 2006 groundwater sampling event (SLR 2006). Approximate concentration contours of TPH from this time are shown on Figure 3-1.

Compared to groundwater conditions prior to Interim Action work in the Lower Yard (2001), groundwater has displayed a marked decrease in areas of LNAPL and a marked decrease in dissolved-phase TPH across the Site. Geochemical parameters monitored across the Site indicate that an environment that is conducive to anaerobic biodegradation of petroleum hydrocarbons is present and that biodegradation is likely ongoing at the Site. As of June 2013, two wells (MW-525 and MW-526) contained concentrations of dissolved-phase hydrocarbons exceeding sample-specific CULs during the past four sampling events (since September 2012). One well (MW-510) contained LNAPL during the past four monitoring events. Maximum TPH concentrations in these samples were 1,182 µg/L (MW-526) and 23,416 µg/L (MW-525). During the December 2012, and March and June 2013 sampling events, MW-510 did not contain LNAPL and groundwater samples were collected. The maximum concentration of dissolved TPH in MW-510 during these events was 1,759 µg/L.

Well MW-510 is a POC well in a downgradient area of the Lower Yard. However, the newly installed monitoring well (MW-529) located approximately 20 feet downgradient of MW-510 has not contained dissolved concentrations of TPH greater than laboratory detection limits since its installation in June 2012, suggesting that Site groundwater is not impacting surface water at this location.

Wells MW-525 and MW-526 are interior monitoring wells installed along the WSDOT stormwater line in soils that had not been disturbed during prior excavation activities. The monitoring wells downgradient of MW-525 (MW-104 and MW-20R) and MW-526 (MW-101 and MW-512 through MW-518) have not exceeded the TPH CULs since March 2012. These wells are located approximately 47 feet to 300 feet downgradient of MW-525 and MW-526 (MW-512 and MW-518, respectively).

Although recent (post 2012) groundwater analytical data indicates petroleum hydrocarbon concentrations are elevated in wells MW-525 and MW-526, there are no new releases or source materials in this area. These wells were installed in known impacted soils that were not excavated during previous Interim Actions. The source of the elevated dissolved phase TPH concentrations within the soil originated from operation of the terminal from 1920 to 1993. Since the completion of Interim Action excavations, groundwater has had five to six years to transport dissolved phase TPH from the WSDOT stormwater line to POC wells. Groundwater concentrations, as discussed above, have shown a marked decrease in TPH over the last five to six years, which suggests that the impacted soils adjacent to the WSDOT stormwater line are not impacting groundwater at the POC.

3.3.2 Benzene

In June 2001 (before the 2001 Interim Action), dissolved-phase benzene concentrations were detected in shallow groundwater in localized areas in the western, southwestern, northwestern, central, and eastern parts of the Lower Yard (MFA 2004c). Benzene was not detected in the northern and southeastern parts of the Lower Yard. Outside of the LNAPL areas, benzene concentrations greater than 20 µg/L were present in the western part of the Lower Yard (near the northeastern former truck loading rack) and in the southwestern part of the Lower Yard (MFA 2004c).

After 2003 Interim Action excavation activities, the August 2004 groundwater sampling results indicated that benzene concentrations decreased in the vicinities of Excavations B and C and in the southwest Lower Yard. Due to the continued presence of LNAPL after excavation was completed, elevated benzene concentrations remained in groundwater near Excavations A and D. In August 2004, areas outside of the LNAPL areas contained dissolved benzene concentrations greater than 20 µg/L in four monitoring wells, in the vicinity of Excavation A and in a localized area of the southwestern Lower Yard (SLR 2004a).

After completion of the 2007/2008 Interim Action excavation activities, and since the implementation of the current groundwater monitoring program in October 2008, dissolved-phase benzene concentrations have exceeded the Site CUL of 51 µg/L in two monitoring wells. POC monitoring well MW-20R, near Point Edwards storm drain, exceeded the CUL in February 2009, with a concentration of 55 µg/L. Monitoring well MW-525 in the central Lower Yard, an interior monitoring well, has contained a maximum benzene concentration of 5,900 µg/L since its installation in June 2012.

3.3.3 Carcinogenic Polycyclic Aromatic Hydrocarbons

Prior to the 2001 Interim Action excavations, dissolved-phase cPAHs were detected in one groundwater sample collected from one well (MW-8) in the Lower Yard. The sample from MW-8 contained an estimated concentration of 0.933 µg/L (MFA 2004c). Chrysene was also likely present in the LNAPL areas.

Groundwater sampling results from August 2004 showed that dissolved-phase cPAHs were detected in a groundwater sample collected from one well (MW-13U) in the Lower Yard. The sample from MW-13U, which is near the former garage, contained a chrysene concentration of 0.0135 µg/L. Chrysene was also likely present in the remaining LNAPL areas (MFA 2004c).

Since the implementation of the current groundwater monitoring program in October 2008, nine samples have exceeded the Site-specific CUL for cPAHs of 0.018 µg/L. However, eight of nine samples contained concentrations less than laboratory detection limits, but exceeded CULs due to raised detection limits. One sample collected from well MW-510 contained a concentration of 0.07807 µg/L in December 2012, exceeding the Site CUL.

3.4 Surface Water

During the RI and the SRI investigations, and the 2003 assessment, and subsequent to the 2003 assessment, surface water samples (SW-1 through SW-4 and SW-1A through SW-4) were collected from four locations in Willow Creek and the tidal basin in April 1996; September 2001; October 2003; and May, July, and August 2004 (MFA 2004c). The April 1996 samples were collected during a storm event. In April 1996, the samples from Willow Creek and the tidal basin did not contain GRO, DRO, or HO concentrations greater than laboratory detection limits. The samples (SW-3 and SW-4) collected downstream from the Lower Yard stormwater outfalls contained toluene, ethylbenzene, total xylenes, and/or pyrene concentrations of up to 1 µg/L (MFA 2001b). The upstream (background) surface water sample (SW-1) collected near the fish hatchery contained detectable concentrations of cPAH compounds ranging from 0.017 to 1.1 µg/L. Arsenic, chromium, copper, lead, and zinc were detected in almost all of the samples, although the detections were estimated values due to the low concentrations (MFA 2004c).

During the 2001 and 2003 sampling events, GRO, DRO, HO, and BTEX constituents were not detected in the surface water samples collected from Willow Creek or the tidal basin (MFA 2003b). PAHs and metals were not analyzed in the 2001 samples. In 2003, samples SW-1, SW-3, and SW-4 contained detectable concentrations of PAH compounds (including cPAHs) that ranged from 0.030 to 0.066 µg/L (MFA 2004b). Samples SW-3 and SW-4 contained total copper and total lead concentrations that ranged from 12 to 19 µg/L; however, the dissolved copper and dissolved lead concentrations ranged up to only 1 µg/L (MFA 2004b).

One additional surface water sampling event was conducted in 2004 to determine the source of the arsenic concentrations detected in 1996 at downstream sample locations SW-3 and SW-4. Using an analysis procedure to reduce interference from the brackish water of the sample, the analytical results showed that dissolved arsenic concentrations ranged from 1.4 to 2.1 µg/L, and that the arsenic concentrations reflected the upstream concentrations that flow into the site area (SLR 2004b).

3.5 Sediment

In 1996, 15 sediment samples (US-01 through US-15) were collected from Willow Creek and the tidal basin, and two sediment samples were collected from offsite control locations. The samples were tested for conventionals (e.g., grain size and total organic carbon) and bioassay testing. The bioassay testing results identified that the sediment in Willow Creek produced effects on amphipod (*Eohaustarius estuaris*) survival, bivalve (*Mytilus edulis*) larvae survival and development, and juvenile polychaete (*Neanthes arenaceodentata*) development (MFA 2004c).

In 2003, 16 sediment samples were collected (US-1 through US-15 locations and one additional sample location US-16, located between locations US-14 and US-15).

These samples were analyzed using a suite of chemical analyses and bulk chemistry analyses. Elevated GRO and DRO concentrations were detected in 10 samples and elevated HO concentrations were detected in 13 samples. The greatest GRO concentration (59.1 mg/kg) was detected near the terminal's stormwater outfall #002 (sample US-07).The highest DRO and HO concentrations (1,470 and 5,480 mg/kg), respectively, were detected in the sample collected downgradient (northwest) of the former asphalt plant (sample US-04). PAH compounds (including cPAHs) were also detected in several samples. VOCs and chlorinated hydrocarbons were not detected in any of the samples (MFA 2004b). Polychlorinated biphenyls (PCBs) were detected at a total concentration of 0.484 mg/kg (without normalization to organic carbon content) in sample US-07 collected near stormwater outfall #002 (MFA 2004b). Metals (arsenic, copper, zinc, lead, chromium, mercury, and silver) were detected in all of the samples with the highest concentration observed in the upstream sample location US-16. Due to elevated TPH concentrations, bioassay toxicity testing was conducted on sediment samples from six locations. The results of the sediment toxicity testing showed that the toxicity at two sample stations located near the Lower Yard outfalls into Willow Creek adjacent to the OWS and DB-2 (US-05 and US-07) exceeded cleanup screening levels (CSLs).The sediment toxicity at the upstream (background) station adjacent to the southeast Lower Yard (US-15) prevented use of this station as a reference station for two of the three bioassay test species.

The 2007/2008 Interim Action included the removal of sediment that failed bioassay tests due to discharges at outfall locations made during facility operations (at sample locations US-05 and US-07). After the Interim Action, three sediment samples were collected from Willow Creek on July 30, 2012, to assess sediment toxicity conditions near 2003 sediment sampling location US-15, as described in the Final CSM (ARCADIS 2013a). Chemical analytical results of the sediment samples were evaluated to determine if bioassays should be performed on the samples. This determination was made by comparing the results to the Sediment Management Standards (SMS; Chapter 173-204 Washington Administrative Code [WAC]) Sediment Quality Standards (SQSs) and CSLs. Based on the evaluation of the data, which showed that all results for the 2012 sediment samples were below the SMS SQS and the CSL or lowest apparent effects threshold (LAET), ARCADIS suggested that bioassay testing was not necessary. On August 9, 2012, Ecology concurred that bioassay testing was not needed and that no further cleanup of Willow Creek is required unless Willow Creek subsequently becomes contaminated by impacts currently remaining onsite (ARCADIS 2013a).

3.6 Air Quality

During the 2007/2008 Interim Action excavation activities and all subsequent drilling, sampling, and investigation activities, continuous air monitoring was conducted. Air monitoring consisted of utilizing a calibrated PID to measure VOCs in the air. VOC measurements were collected in the workers' breathing zone, in open atmosphere conditions. Sustained concentrations of VOCs in the air exceeded 5 parts per million (ppm), for a minimum of 2 minutes, only two times during remedial excavation activities, and zero times during subsequent drilling, sampling, and investigation activities. In general, from 2007 to 2013, VOC concentrations in the air at the site have been <1 ppm.

Continuous air monitoring at the Site has indicated that vapors from petroleum hydrocarbons have not adversely impacted air quality and demonstrates that there is no significant potential for migration of VOCs to the air from impacted soil and groundwater.

4. Conceptual Site Model

This section synthesizes the data collected during previous investigations and Interim Actions into a CSM of contaminant occurrence, movement, and potential exposures. The CSM is a tool used to develop CULs and remedial alternatives. The text presented in this section is also provided in the Final CSM (ARCADIS 2013a).

4.1 Source Characterization

As discussed in Section 2.2, the Lower Yard was only used by Unocal for office purposes after 1991. Based on the results of the previous investigations, there are no continuing sources of hazardous substance releases at the terminal. The historical primary sources of contamination in the Lower Yard are the former asphalt plant and the former fuel storage and distribution operations (aboveground tanks and piping, truck loading racks, and railroad loading rack).

Petroleum hydrocarbons (GRO, DRO, and HO) were likely released from the former asphalt plant and fuel storage and distribution activities. Petroleum-impacted materials from offsite sources were also stockpiled and stored in the southeastern Lower Yard. Metals impacts were traced to the use of metals-impacted sandblast grit, used during sandblasting of aboveground tanks and piping. Off-specification asphalt from the asphalt plant was likely disposed of in DB-1 (EMCON 1994).

4.2 Remaining Impacts

Extensive investigation and remediation has been conducted at the Site as described in Sections 2.6, 2.7, and 2.8. As the result of Interim Action excavation activities and confirmation sampling, multiple Site investigations, and groundwater monitoring activities, each area of the Lower Yard containing soil, groundwater, or sediment with concentrations of Site IHSs greater than applicable CULs is believed to have been fully delineated. Each area containing soil, groundwater, or sediment impacts is discussed below. Areas of the Lower Yard with remaining impacts are shown on Figures 4-1 through 4-3.

4.2.1 Soil

4.2.1.1 Washington State Department of Transportation Stormwater Line

The WSDOT stormwater line runs across the Lower Yard, along lower Unoco Road and out to Puget Sound. During the 2007/2008 Interim Action excavation activities, impacted soil was encountered adjacent to the WSDOT stormwater line. Five soil samples collected on the excavation sidewalls adjacent to the WSDOT stormwater line in the south-central portion of the Site contained concentrations exceeding Site CULs and/or RELs (ARCADIS 2009). These soil samples were located directly north of the WSDOT stormwater line at depths between 4 and 6 feet bgs with concentrations of TPH ranging from 3,060 to 15,700 mg/kg. One of these samples exceeded the CUL for cPAHs (0.14 mg/kg), with a concentration of 0.159 mg/kg. Soil along the WSDOT stormwater line, including those with CUL/REL exceedances, was unable to be excavated without compromising the integrity of the line. Polyethylene sheeting was left in place to demarcate the excavation limits adjacent to the WSDOT stormwater line. The sheeting extends from ground surface to approximately 6 feet bgs (7.5 feet amsl) and is located along lower Unoco Road as shown on Figure 2-1 (ARCADIS 2009).

In 2008, 14 soil borings were installed along the south and southwest sides of the WSDOT stormwater line. Soil samples from five of these borings adjacent to the WSDOT stormwater line contained concentrations of IHSs that exceeded Site RELs and/or CULs. The locations of these borings are to the south and southwest of the WSDOT stormwater line, at the end of upper and lower Unoco Road, and in the area between the WSDOT stormwater line and monitoring well MW-143. Soil samples containing IHS concentrations exceeding Site CULs and/or RELs were collected between 4 and 8 feet bgs in this area, with TPH concentrations ranging from 3,720 to 16,900 mg/kg (ARCADIS 2010b).

In 2012, four monitoring wells were installed adjacent to the WSDOT stormwater line. Soil samples collected during the installation of two of the monitoring wells exceeded Site CULs and/or RELs at depths of 6 and 7 feet bgs, with concentrations of TPH ranging from 10,540 to 17,850 mg/kg. Soil samples collected from these wells at greater depths did not contain concentrations exceeding Site CULs and/or RELs, as discussed in Section 2.8.3. Both of these monitoring wells were installed in an area of known remaining soil impacts left in place during 2007/2008 excavation activities and verified during 2008 Site investigation activities.

In total, there are 11 sample locations in two distinct areas adjacent to the WSDOT stormwater line (to the north and south/southwest), that contain soil with concentrations of IHSs greater than Site CULs and/or RELs. The depths of these remaining impacts occur between 4 and 8 feet bgs. The impacted soil is adjacent to the WSDOT stormwater line and covers an area of approximately 0.31 acre, of the 22 total acres of the Lower Yard. The areas of limited remaining impacts are shown on Figures 4-1 through 4-3.

4.2.1.2 Detention Basin No.2 Area

In 2011, soil investigation activities were conducted in the unexcavated areas surrounding DB-2, including the installation of 17 soil borings and eight piezometers. LNAPL was encountered in eight of the soil borings, located south of DB-2, along the northern-most 2007/2008 Interim Action excavation area, surrounding monitoring well MW-510, and in one location north of DB-2 and adjacent to the southwest corner of DB-1. LNAPL was encountered in these borings at depths from 7 to 12 feet bgs (ARCADIS 2012a).

Soil samples containing concentrations of IHSs exceeding Site CULs and/or RELs were collected south of DB-2, along the northern-most 2007/2008 Interim Action excavation area, surrounding monitoring well MW-510, adjacent to the southwest corner of DB-1, on the berm separating DB-1 and DB-2, and in one location on the bank of Willow Creek at a depth of 0.5 to 1 foot bgs. Soil containing concentrations of IHSs exceeding CULs and/or RELs was encountered in 11 of the 17 soil borings, from depths ranging from 4 to 14 feet bgs with concentrations ranging from 4,413 to 220,400 mg/kg. The area surrounding DB-2, where impacted soil was encountered, covers approximately 0.43 acre of the 22 total acres of the Lower Yard. Boring locations from the DB-2 investigation area are shown on Figure 2-14.

4.2.1.3 Monitoring Well MW-129R, Southwest Lower Yard, and Southeast Lower Yard

Isolated soil samples from three locations exceeded Site CULs and/or RELs for TPH and/or cPAHs:

- During the installation of monitoring well MW-129R, one soil sample was collected at a depth of 7 feet bgs that contained a concentration of TPH at 3,010 mg/kg.
- During Phase I of the 2007/2008 Interim Action, one soil sample from the southwest Lower Yard (sample EX-B18-VV-1-6SW) had a TPH concentration of 4,980 mg/kg at a depth of 6 feet bgs.
- During Phase II of the 2007/2008 Interim Action, one soil sample from the southeast Lower Yard (sample EX-BI-F-44-4) had a cPAH concentration of 0.212 mg/kg at a depth of 4 feet bgs.
-

4.2.2 Groundwater

The CSM presented in the IAWP (SLR 2007a) concluded that groundwater beneath the Site discharges to the surface water and sediment in Willow Creek. As a result, the IAWP (SLR 2007a) established groundwater CULs based on the protection of surface water. According to the AO, the groundwater CULs are required to be met only at the POC monitoring wells, which are located along the downgradient perimeter of the Site where groundwater discharges to surface water. Data collected from the interior monitoring well locations are not used for compliance; rather, the dissolved concentration data collected at interior monitoring well locations are used to evaluate groundwater concentration trends at the Site and overall plume stability.

4.2.2.1 Groundwater Concentration Trends

As of September 2013, 23 POC groundwater monitoring wells are sampled quarterly and 29 interior monitoring wells are sampled semiannually. Two POC wells (MW-529 and MW-530) and 10 interior monitoring wells (MW-126, MW-13U, MW-134X, MW-203, MW-525 through MW-528, MW-531, and MW-532) have only been sampled since the June 2012 event. The most recent groundwater monitoring event that included all POC and interior wells took place in June 2013. Monitoring wells MW-510, MW-525, and MW-526 were the only wells that contained concentrations of dissolved petroleum hydrocarbon constituents that exceeded CULs, with TPH concentrations of 3,630, 5,984, and 1,216 µg/L, respectively. Well MW-525 also contained a benzene concentration of 980 µg/L. September 2013 groundwater sampling analytical results are presented on Figure 2-11.

TPH is calculated by summing the concentrations of GRO, DRO, and HO; where concentrations do not exceed method reporting limits, one-half of the reporting limit is used to calculate TPH. The CUL for TPH in groundwater is calculated based on the relative proportions of GRO, DRO, and HO, and thus differs at each monitoring location and with each monitoring event, as described in Section 5.3.2.

Dissolved concentrations of TPH in groundwater at the 23 POC monitoring wells are summarized below:

- None of the 23 POC monitoring wells (except MW-510, which has contained LNAPL) have exceeded the sample-specific TPH CUL since March 2012.

- Six POC monitoring wells have never contained concentrations of TPH greater than sample-specific CULs since the beginning of the monitoring period in October 2008.

- POC monitoring well MW-529, located on the bank of Willow Creek directly adjacent to MW-510, has not contained TPH concentrations greater than laboratory detection limits since its installation in July 2012.

- From October 2009 to September 2012, monitoring well MW-510 was sampled once (June 2011) and contained a TPH concentration of 15,300 µg/L. Samples were collected from MW-510 from December 2012 to September 2013, with a maximum TPH concentration of 3,630 µg/L (September 2013).

- Benzene has not been detected at concentrations greater than the Site-specific CUL of 51 µg/L in samples collected from any POC wells since February 2009 (MW-20R with a concentration of 55 µg/L).

- cPAHs have not been detected at concentrations greater than the Site-specific CUL of 0.018 µg/L in samples collected from any POC wells since December 2012 (MW-510 with a concentration of 0.07817 µg/L).

Dissolved concentrations of TPH in groundwater at the 29 interior monitoring wells are summarized below:

- Concentrations of TPH have not exceeded the sample-specific CUL in any interior monitoring wells (except MW-525 and MW-526) since June 2011 (MW-143 with a concentration of 1,745 µg/L).

- Fifteen of the 29 interior monitoring wells have never exceeded the sample-specific TPH CUL since the beginning of the monitoring period in October 2008.

- Monitoring well MW-525 has contained concentrations of TPH exceeding the sample-specific CUL in the all of the three sampling events since its installation in June 2012, with a maximum concentration of 23,416 µg/L in December 2012.

- Monitoring well MW-526 has contained concentrations of TPH exceeding the sample-specific CUL during two of the three sampling events since its installation in June 2012, with a maximum concentration of 1,216 µg/L in June 2013.

- Since the beginning of the monitoring period in October 2008, benzene has been detected in one interior monitoring well (MW-525), with a maximum concentration of 5,900 µg/L in December 2012.

- cPAHs have not been detected at concentrations greater than the Site-specific CUL of 0.018 µg/L in samples collected from any interior monitoring wells since the beginning of the monitoring period in October 2008.

4.2.2.1.1 Light Nonaqueous Phase Liquid.

LNAPL has been effectively delineated and is currently present at three locations in the DB-2 area in the Lower Yard. Piezometers P-12, P-13, and P-15 contain measurable amounts (>0.01 foot) of LNAPL, and are located within 100 feet of one another. From October 2009 to September 2012, LNAPL was present in measurable amounts in well MW-510. LNAPL has not been detected in MW-510 in measurable amounts from December 2012 to the present, during which time absorbent socks were placed in the well between sampling events.

LNAPL was present in piezometer P-12 in September 2011, June and September 2012, and June and September 2013. LNAPL was present in piezometer P-13 from September 2011 to the present, and in piezometer P-15 in March and June 2013. Piezometers P-12, P-13, and P-15 were installed in August 2011.

LNAPL in piezometers P-12, P-13, and P-15 is black in color, has a high viscosity, and is difficult to recover with a bailer. During each monitoring event, an oil/water interface probe is used to measure depth to LNAPL and depth to water. Bailers are used to confirm the presence of LNAPL after each groundwater measurement in piezometers P-12, P-13, and P-15. In an attempt to recover LNAPL, absorbent socks have been installed in well MW-510 between monitoring events since March 2011.

4.3 Fate and Transport of Contaminants

Petroleum components in soil can exist in four different phases: adsorbed to soil particles, dissolved in soil pore water, as vapors in soil pore air, and as LNAPL or residual product in the soil pore spaces.

As rain falls on the ground surface and infiltrates the subsurface, residual contaminants in surface soil dissolve in the rainwater and percolate through the subsurface soil. Some of the contaminants remain in the subsurface soil, in the phases listed previously, and some eventually reach the groundwater. Portions of the volatile components of petroleum in soil and groundwater could volatilize into the soil pore spaces and move upward to ambient and indoor air.

Petroleum contaminants in groundwater can exist in three phases: dissolved phase, LNAPL, and adsorbed to the soil particles in the aquifer. LNAPL refers to the fact that the petroleum is less dense than water, so it remains near the top of the aquifer. Groundwater beneath the southeastern, eastern, and northwestern portions of the Lower Yard flows toward Willow Creek; groundwater beneath the southwestern Lower Yard flows toward Puget Sound; and groundwater beneath the central and north-central areas flows toward DB-1.

4.4 Potential Receptors

Potential human and ecological receptors are described below.

4.4.1 Human Receptors

The Lower Yard is currently vacant; however, current human receptors that might be exposed to surface water in Willow Creek are limited to the unlikely occurrence of a trespasser, environmental consultants, and subcontractors. In order for trespassers to come into contact with surface water from Willow Creek, they would need to enter the Site without authorization through either the Lower Yard, or across Edmonds Marsh or the BNSF rail line. The unlikely trespasser and current environmental consultants and subcontractors may be exposed to surface water in Willow Creek.

The Lower Yard may be developed in the future. Potential future human receptors include construction workers exposed during redevelopment activities, as well as potential residents or commercial workers.

4.4.2 Ecological Receptors

The Lower Yard was a former industrial Site that has recently been subject to intensive remedial activity, including excavation, backfilling, and grading. Except for recent overgrowth of native and invasive vegetation, limited vegetation is present, except a border of mature trees along the eastern perimeter of the Site. In addition, the eastern, northeastern, and northwestern parts of the Lower Yard are adjacent to Willow

Creek, a tidally influenced creek feeding into Puget Sound. Based on this information, potential ecological receptor groups include plants, soil, aquatic invertebrates (e.g., earthworms and benthic invertebrates), terrestrial mammals, birds, and potentially small forage fish.

4.5 Potential Exposures

4.5.1 Exposures to Human Receptors

4.5.1.1 Current Exposures

The human receptors currently present at the Lower Yard are limited to trespassers and onsite environmental consultants and subcontractors. The Site-specific CULs and RELs established in the IAWP (SLR 2007a) are based on standard Method B CULs for direct contact. The Method B CULs for direct contact are designed to protect residents from daily exposure, and assume daily exposure of children present at the Lower Yard, 365 days a year, for 6 years. Because children are more highly exposed on a body weight basis than adults, the soil CULs and RELs are adequately protective of adult onsite environmental consultants and subcontractors. Currently, public access to Willow Creek is not allowed, and exposure to the public is limited to trespassers. As discussed in Section 4.4.1, exposure to the public is very unlikely due to the restricted access to Willow Creek, and even in contact with surface water in Willow Creek the exposure to COCs is limited. The Method B surface water CULs established for the Site are designed to protect people eating contaminated seafood, which is considered a more significant exposure route than incidental contact. Furthermore, because petroleum hydrocarbons are not expected to enter the aquatic food chain, ingestion of fish or other aquatic biota (e.g., crayfish) is not considered a complete exposure pathway. Environmental consultants and subcontractors currently working at the Site are further protected from exposures by personal protective equipment and limited duration of exposure.

Inhalation of windblown dust is not explicitly addressed in Method B CULs, but they are sufficiently protective of that pathway considering that windblown dust is considered a limited exposure pathway for the Site IHSs.

Due to the Lower Yard's proximity to Puget Sound, groundwater at the Site contains salinity levels making it unsuitable for ingestion or as a potable water source; therefore, ingestion is not a potential exposure route.

4.5.1.2 Potential Future Exposures

The Lower Yard may be redeveloped in the future. If that occurs, construction workers may be exposed to Site soil and LNAPL via incidental ingestion, dermal contact, and inhalation of dust for short periods while excavating, trenching, or conducting other construction activities in the vicinity of DB-2 and the WSDOT stormwater line. Future commercial workers and residents may be exposed to soil via incidental ingestion, dermal contact, and inhalation of dust while working in buildings onsite. However, as stated above, the Site-specific CULs and RELs established in the IAWP (SLR 2007a) are based on standard Method B CULs for direct contact. The Method B CULs for direct contact are designed to protect residents from daily exposure, and assume daily exposure of children present at the Lower Yard, 365 days a year, for 6 years. Because children are more highly exposed on a body weight basis than adults, the soil CULs and RELs are adequately protective of adult construction workers. Also, if the Site is redeveloped, commercial workers and residents are not expected to be exposed to surface and subsurface soil because the surface will be covered by buildings and pavement.

Inhalation of windblown dust is not explicitly addressed in Method B CULs, but they are sufficiently protective of that pathway considering that windblown dust is considered a limited exposure pathway for the Site IHSs.

If people use Willow Creek recreationally in the future, they could come into direct contact with surface water, and they could potentially eat contaminated fish or shellfish. As stated above, Method B surface water CULs are designated to protect people eating contaminated seafood. Although, again, Method B surface water CULs do not implicitly address direct contact with surface water, ingestion of seafood is considered a more significant exposure route.

Due to the Lower Yard's proximity to Puget Sound, groundwater at the Site contains salinity levels making it unsuitable for ingestion or as a potable water source; therefore, ingestion is not a potential exposure route.

A human exposure pathways diagram is provided on Figure 4-4. Soil RELs and CULs that have been used to date are believed protective for current and future exposure scenarios (ARCADIS 2013b).

4.5.2 Exposures to Ecological Receptors

Ecological receptors onsite and in the surrounding environment can be directly or indirectly exposed to remaining impacts if a complete exposure pathway exists. A potential exposure pathway is considered complete if it contains the following five elements:

- Constituent source
- Release mechanism to the environment
- Transport medium
- Receptor contact at the exposure point

- Exposure route

Important features that must be considered when evaluating exposure pathway completeness include:

- Chemical concentrations in different media and their respective locations
- Physical and chemical properties of the COCs
- Locations of habitats and other environmentally sensitive areas

As noted above, the remaining limited impacts at the Site are limited to subsurface soil in two discrete areas of the Site, with elevated concentrations present only at depths greater than 4 feet bgs. Subsurface soil at this depth does not represent a complete exposure pathway because they are below the area in which most biological activity occurs. Therefore, no complete exposure pathways associated with soil were identified.

Similarly, direct exposure to groundwater represents an incomplete exposure pathway, unless the groundwater directly discharges to surface water. Site groundwater may discharge to the surface water of Willow Creek; therefore, aquatic receptors such as fish and water column invertebrates may be directly exposed to surface water via ingestion and direct contact/uptake. Method B surface water CULs are protective of aquatic receptors living in Willow Creek. Furthermore, direct contact with surface water to upper-trophic-level wildlife through ingestion is not likely to occur given the brackish nature of the stream. Also, the tidal nature of Willow Creek and the stormwater inputs to the creek will result in significant exchange (i.e., mixing) between discharging groundwater, tidal water, and stormwater. Depending on the net flow in this mixing zone, groundwater seeping into Willow Creek will be quickly mixed with other water in the creek, reducing the concentration in the discharging groundwater and therefore further decreasing the exposure. As previously noted, sediment analytical results from Willow Creek indicate that the sediment in Willow Creek does not contain contaminants in excess of the SMS SQS, and most POC wells directly adjacent to Willow Creek currently comply with surface water CULs. Based on this information, exposure to surface water is considered the only potentially complete pathway for ecological receptors, albeit a minimal exposure risk.

5. Cleanup Standards

A cleanup standard consists of the following three elements [WAC 173-340-700(3)]:

1. CUL, the concentration that must be met to protect human health and the environment.
2. POC, the location where the CUL must be achieved.

3. Other regulatory requirements commonly referred to as applicable or relevant and appropriate requirements (ARARs) that apply to the site because of the type of action or the location of the site and are included in Appendix D.

The cleanup standards developed for and used during Interim Action work are documented in the IAWP (SLR 2007), which is provided as Exhibit B to AO 4460. The cleanup standards were developed using an MTCA Method B approach and included the use of RELs as part of the Interim Action soil removal. The CULs, RELs, and POCs are discussed in this section.

5.1 Indicator Hazardous Substances

IHSs are the chemicals expected to account for most of the risks at a site, and cleanup standards must be developed for each IHS in each medium. The IHSs for sediment, surface water, groundwater, and soil were developed in accordance with WAC 173-340-703, as documented in the IAWP (SLR 2007a).

The IAWP (SLR 2007a) identifies four IHSs in the Lower Yard based on the history and previous investigations conducted at the Site. The following IHSs for soil were developed based on direct contact and leaching pathways: TPH (the sum of GRO, DRO, and HO); benzene; cPAHs adjusted for toxicity; and arsenic (direct contact only).

Groundwater IHSs were also developed to protect surface water and sediment in Willow Creek. Arsenic was eliminated as a groundwater/surface water IHS because arsenic concentrations in groundwater were determined to be caused by geochemical conditions associated with naturally occurring organic carbon sources in the soil beneath the Lower Yard, and arsenic concentrations in surface water samples collected in Willow Creek reflected background concentrations (SLR 2007a).

5.1.1 Sediment

Sediment chemistry data were compared with SMS Chapter 173-204 WAC to identify IHSs for sediment. Prior to the 2007/2008 Interim Action, the only contaminant known to be present at a concentration greater than the SMS was total PCBs at one sample location (US-07), which was located near the terminal’s stormwater outfall #002. Because of the presence of petroleum hydrocarbons in sediment and the possibility of a sediment-to-surface water pathway, several additional chemicals or compound groups were designated as tentative IHSs (TPH, PAHs, and metals) (SLR 2007a).

According to the SMS, sites with sediment that exceed numeric chemical criteria may go through confirmatory biological testing. In 2003, biological testing of sediment samples was conducted at the Site to identify areas of sediment toxicity to help delineate the extent of sediment removal. Sediment samples were collected from 16 locations (US-01 through US-16) in all areas of Willow Creek. These samples were analyzed using a suite of chemical and bulk chemistry analyses. Due to elevated TPH concentrations, bioassay toxicity testing was conducted on sediment samples from six of the locations. The results showed that the toxicity at two sample stations located near the Lower Yard outfalls into Willow Creek adjacent to the OWS and DB-2 (US-05 and US-07) exceeded CSLs, and the sediment toxicity at the upstream (background) station adjacent to the southeast Lower Yard (US-15) prevented use of this station as a reference station for two of the three bioassay test species. Based on 2003 sediment sample data, IHSs were not identified for sediment and sediment CULs were not established for Willow Creek (SLR 2007a). The 2007/2008 Interim Action included the removal of sediment that failed bioassay tests due to discharges at outfall locations made during facility operations (at stations US-05 and US-07).

Three sediment samples were collected from Willow Creek on July 30, 2012, to assess sediment toxicity conditions in the vicinity of 2003 sediment sampling location US-15, as described in the Final CSM (ARCADIS 2013a). Chemical analytical results of the sediment samples were evaluated to determine if bioassays should be performed on the samples. This determination was made by comparing the results to the SMS Chapter 173-204 WAC SQSs and CSLs. Based on an evaluation of the data, which showed that all results for the 2012 sediment samples were below the SMS SQS and the CSL or LAET, ARCADIS suggested that bioassay testing was not necessary. On August 9, 2012, Ecology concurred that bioassay testing was not needed and that no further cleanup of Willow Creek is required unless Willow Creek subsequently becomes contaminated by impacts currently remaining onsite (ARCADIS 2013a).

5.1.2 Surface Water and Groundwater

The groundwater beneath the Site is considered nonpotable. AO 4460, Exhibit B, and Section 5.4.1 of this report discusses this determination. The endpoint for groundwater is protection of Willow Creek, a tidally influenced stream, and Puget Sound.

The endpoint for groundwater CULs is protection of surface water; therefore, a combined list of groundwater/ surface water IHSs was developed (see AO 4460, Exhibit B, §5.1). TPH, benzene, chrysene, lead, zinc, arsenic and copper were screened as potential IHSs. Concentrations of arsenic, copper, lead, and zinc in the surface water of Willow Creek were compared against screening levels to determine if the metals should be retained as surface water IHSs. The samples collected in April 1996 and October 2003 did not contain dissolved copper, lead, and/or zinc concentrations above their screening levels. These results support eliminating copper, lead, and zinc as surface water IHSs. The arsenic concentrations in all of the October 2003 samples were above the screening level; therefore, arsenic was retained for further analysis. Additional evaluation of the sampling results indicated that arsenic concentrations in the samples reflect the upstream concentrations that flow into the Site (background conditions), and that groundwater beneath the Lower Yard is not increasing the arsenic concentrations in the Willow Creek. On this basis, arsenic was eliminated as an IHS for surface water.

The final list of surface water and groundwater IHSs is as follows:

- TPH (sum of GRO, DRO, and HO concentrations)
- Benzene
- Toxicity-adjusted total cPAHs [sum of benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene concentrations that are adjusted using toxicity equivalency factors to represent a total benzo(a)pyrene concentration]. (The toxicity equivalency factors published in CLARC Version 3.1 [Ecology 2001] are used to make the adjustments.)

5.1.3 Soil

The IAWP (SLR 2007a) identifies IHSs for the following four endpoints considered for soil: terrestrial ecological evaluation (TEE), direct human contact (incidental ingestion), leaching to groundwater, and residual saturation.

For the TEE and residual saturation concentrations (Csat), GRO, DRO, HO, benzene, chrysene, and arsenic were considered potential IHSs. Because residual saturation is relevant only to organic chemicals that are liquid at ambient soil temperatures, arsenic was eliminated as an IHS for residual saturation. In addition, cPAHs, which exist as needles and platelets at ambient soil temperatures, were also eliminated as IHSs for residual saturation. The final soil IHSs for the TEE and residual saturation are:

- TPH constituents (GRO, DRO, and HO)
- Benzene
- CPAHs (TEE only)
- Arsenic (TEE only)

For RELs and CULs based on direct human contact and for evaluating the leaching pathway, GRO, DRO, HO, benzene, and cPAHs were considered in combination so that one TPH REL could be developed. A separate soil REL for benzene and a separate CUL for toxicity-adjusted total cPAHs were also developed to comply with MTCA Method B risk target for individual carcinogens ($1x10^{-6}$) [WAC 173-340-705(2)(c)(ii)]. Arsenic was evaluated for direct contact, but not for leaching because arsenic is not an IHS for groundwater or surface water. The final soil IHSs for direct contact and the leaching pathway are:

- TPH (sum of GRO, DRO, and HO concentrations)
- Benzene
- Toxicity-adjusted total cPAHs [sum of benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene concentrations that are adjusted using toxicity equivalency factors to represent a total benzo(a)pyrene concentration]. (The toxicity equivalency factors published in CLARC Version 3.1 [Ecology 2001] are used to make the adjustments.)
- Arsenic (direct contact only)

5.1.4 Surface Water Screening for Metals

Concentrations of metals observed in the surface water of Willow Creek were compared against screening levels and background concentrations to determine if the metals should be retained as surface water IHSs. Four metals (arsenic, copper, lead, and zinc) were reviewed. Copper, lead, and zinc were eliminated as IHSs on the basis of comparisons with screening levels I) and arsenic was eliminated as an IHS on the basis of comparisons with background concentrations (SLR 2007a).

5.2 Sediment Cleanup Standards

Sediment cleanup was based on bioassay data, as discussed in Section 3.5. After the 2007/2008 Interim Action, Ecology concurred that the cleanup of Willow Creek is complete (ARCADIS 2013a) as discussed in Section 3.5.

5.3 Surface Water Cleanup Standards

5.3.1 Endpoints for Cleanup Levels

Method B surface water CULs are endpoints for surface and groundwater at the Lower Yard [WAC 173-340-730(3)(b)]:

- Washington State Water Quality Standards (WQSs) (Chapter 173-201A WAC) for marine water
- National Recommended Water Quality Criteria (NRWQC) for marine organisms and humans ingesting seafood
- National Toxics Rule related to human health [40 CFR 131.36(c)(14)]

- For hazardous substances for which sufficiently protective, health-based criteria or standards have not been established under applicable state and federal standards, MTCA Method B equation values are used for surface water.

Willow Creek is tidally influenced and is not a source of drinking water. The CULs applicable to the Site include the WQS and NRWQC based upon use for aquatic organisms and human exposure based upon ingestion of aquatic organisms (SLR 2007a, ARCADIS 2013a), the National Toxics Rule (NTR), and MTCA Method B levels for TPH.

5.3.2 Cleanup Levels

The surface water CULs are presented in **Table 5-1** and represent the lowest of the WQS (WAC 173-201A-240), NRWQC, and NTR (40 CFR 131.36). The most stringent CUL for benzene and cPAHs are the NRWQC human health (organisms only). The NRWQC human health (organisms only) for benzene (51 µg/L) is associated with a cancer risk of 2×10^{-6}, and the NRWQC for cPAHs (0.018 µg/L) is associated with a cancer risk of 6×10^{-7}. Under MTCA, standards are considered sufficiently protective if the cancer risk for those standards is less than 1×10^{-5}. Therefore, the NRWQC for benzene and cPAHs are appropriate surface water CULs [WAC 173-340-730(5)(b)].

WQSs and NRWQC are not established for TPH mixtures. MTCA allows the use of Method A groundwater CULs (WAC 173-340-900, Table 720-1) to calculate surface water CULs for petroleum mixtures [WAC 173-340-730(3)(b)(iii)(C)].

MTCA Method A CULs for TPH were derived by setting a hazard index (HI) of 1 for all three TPH constituents (DRO, GRO, and HO) and adjusting the compositions of each TPH constituent for each sample, on an individual basis. The CUL ranges from 500 to 800 µg/L, depending upon the fraction composition of the sample. The CUL calculation is as follows:

Total TPH CUL = 1/ (%GRO/800+%DRO/500+%HO/500)

Where:

Total TPH CUL = Overall CUL adjusted for HI=1
%GRO = Sample-specific percentage of GRO in groundwater, expressed as a decimal
800 = Method A groundwater CUL for GRO (µg/L)
%DRO = Sample-specific percentage of DRO in groundwater, expressed as a decimal
500 = Method A groundwater CUL for DRO and HO (µg/L)
%HO = Sample-specific percentage of HO in groundwater, expressed as a decimal

The surface water CULs are presented in Table 5-1.

Table 5-1. Surface Water and Groundwater Cleanup Levels

Indicator Hazardous Substance	Surface Water and Groundwater Cleanup Level (µg/L)
Total TPH	-[1]
Benzene[2]	18
Total cPAHs[2,3]	0.14

Notes:

[1] Method A (WAC 173-340-900, Table 720-1); total TPH calculated on a sample-specific basis. The CUL will fall between 500 and 800 µg/L, depending upon the sample's composition.

[2] NRWQC for human-health (organisms only) (USEPA 2012). NRWQC. http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm#hhtable. Accessed on March 10, 2013.

[3] Total cPAHs adjusted for toxicity based on WAC 173-340-708(8).

5.3.3 Surface Water Points of Compliance

The POCs for surface water CULs are the point or points where hazardous substances are released to surface water [WAC 173-340-730(6)]. These POCs are monitored by 23 compliance monitoring wells along the downgradient (western, northwestern, northeastern, and eastern) perimeter of the Lower Yard. POC monitoring wells are located from the southwestern corner to the northern corner of DB-1, to the southeastern corner of the Lower Yard. Surface water and groundwater CULs are required to be met at POC monitoring well locations. The Lower Yard POC monitoring wells are listed below:

LM-2	MW-8R	MW-20R	MW-101	MW-104	MW-108
MW-109	MW-129R	MW-135	MW-136	MW-139R	MW-147
MW-149R	MW-150	MW-500	MW-501	MW-510	MW-518
MW-522	MW-523	MW-524	MW-529	MW-530	

5.4 Groundwater Cleanup Standards

5.4.1 Endpoints for Cleanup Levels

Groundwater beneath the Lower Yard has been determined to be nonpotable groundwater (ARCADIS 2013a, SLR 2007a). As such, the endpoint for CULs is based upon a groundwater to surface water interface. The groundwater beneath the Lower Yard is hydraulically connected to Puget Sound. MTCA allows groundwater that is hydraulically connected to marine surface water to be classified as nonpotable if the following five criteria can be met [WAC 173-340-720(2)(d)]:

- Groundwater does not serve as a current source of drinking water.
- Ecology determines that it is unlikely that the hazardous substances will be transported from the contaminated groundwater to groundwater that is or could be a source of drinking water.
- There are known or projected points of entry of the groundwater into the surface water.
- Surface water is not classified as a suitable domestic water supply source under Chapter 173-201A WAC.
- Groundwater is sufficiently hydraulically connected to the surface water that it is not practicable to use the groundwater as a drinking water source.

There are no drinking water supply wells located at the Lower Yard or between the Lower Yard and Puget Sound (SLR 2007a). The IAWP (SLR 2007a) determined that it is unlikely that the hazardous substances at the Lower Yard will be transported to an aquifer that could be used for drinking water (SLR 2007a). Groundwater monitoring results demonstrate that the general direction of groundwater flow beneath the eastern part of the Lower Yard is toward Willow Creek, which discharges into Puget Sound, and the general direction of groundwater flow beneath the western part of the Lower Yard is toward Willow Creek and Puget Sound (ARCADIS 2013a). Tidal response studies and salinity concentrations in the groundwater have shown that there is a hydraulic connection between the groundwater beneath the Lower Yard and the surface water in Willow Creek (directly connected to Puget Sound) (ARCADIS 2013a). Therefore, groundwater beneath the Lower Yard is hydraulically connected to Puget Sound, a marine water, which is not suitable for domestic water supply.

Based upon the above, the groundwater beneath the Lower Yard is nonpotable under WAC 173-340-720(2). The endpoint for groundwater is protection of surface water in Willow Creek and Puget Sound.

5.4.2 Cleanup Levels

The endpoint for groundwater is protection of surface water; therefore, the surface water CULs presented in Section 5.3.2 establishes the groundwater CULs for the Lower Yard.

5.4.3 Groundwater Point of Compliance

Previous Interim Actions consisting of excavation of impacted soil in various areas of the Site have demonstrated that groundwater CULs can be met in a reasonable restoration timeframe within those areas. However, in areas of the Site where it is not practicable to remediate soil (e.g., adjacent to the WSDOT stormwater line [MW-525]), groundwater is not anticipated to meet CULs within a reasonable restoration timeframe. Therefore, a conditional POC will be established at the Site boundary under WAC 173-340-720(8)(c). Groundwater monitoring wells located at the Site boundary will be used for compliance monitoring. The compliance monitoring wells and POC boundary are shown on Figure 5-1.

5.5 Soil Cleanup Standards

Method B soil CULs are endpoints for the Lower Yard [WAC 173-340-740(3)(b)]. Six possible endpoints must be considered for soil:

1. TEE
2. Direct human contact (incidental ingestion)
3. Leaching to groundwater
4. Residual saturation
5. Inhalation of soil vapors
6. Dermal contact with soil

Previous soil RELs for the direct contact/dermal contact and leaching to groundwater pathways were calculated using a prior version of Ecology's Workbook to calculate CULs for a petroleum mixture (MTCATPH11). A revised version of Ecology's Workbook for calculating CULs for a petroleum mixture (MTCATPH11.1) was released by Ecology in December 2007, subsequent to the submittal of the IAWP (SLR 2007a).

The calculation formulas used for the revised Workbook MTCATPH11.1 are exactly the same as those used in the previous Workbook MTCATPH11. However, several changes were made to the table of physical and chemical properties and the toxicological information for several petroleum fractions and individual hazardous substances, which affect the calculation results (Washington State Department of Ecology 2007).

CULs protective of the direct contact/dermal contact and leaching to groundwater pathways were recalculated using the revised Workbook MTCATPH11.1 (Washington State Department of Ecology 2007) and are presented in Section 5.5.2. The remaining endpoints are also discussed below. The final soil CULs and RELs and POCs for soil are summarized in Sections 5.5.2 and 5.5.3, respectively.

5.5.1 Terrestrial Ecological Evaluation for Soil

In 2007, SLR conducted a TEE evaluation in accordance with MTCA (WAC 173-304-7490 to -7493) for the Lower Yard (SLR 2007b). The site-specific TEE calculated ecological indicator concentrations of 5,000 mg/kg for GRO, 6,000 mg/kg for DRO, 12 mg/kg for cPAHs [benzo(a)pyrene used as surrogate], and 7 mg/kg for arsenic in unsaturated soil [WAC 173-340-7493(2)(a)(i)].

The arsenic CUL of 7 mg/kg is lower than arsenic soil background concentration in the state of Washington (WAC 173-340-900, Table 740-1, footnote b), which is 20 mg/kg. Hence the TEE CUL for arsenic is 20 mg/kg. No table values exist for HO and benzene. These ecological-based concentrations are greater than or equal to the soil CULs used for the Interim Action, based on direct human contact with soil.

The TEE performed by SLR in 2007 was reviewed to assess whether or not the information used in the evaluation was outdated or required updating. This review consisted of comparing site-specific data to the TEE exclusion criteria in WAC 173-340-4791(1) and evaluating the information used in the site-specific TEE performed by SLR in 2007 under WAC 173-340-7491(2), including information obtained from the following sources:

- Edmonds Crossing Final EIS (CH2M HILL 2001)
- Washington Department of Fish and Wildlife (WDFW) Priority Habitat and Species database
- Washington State Department of Natural Resources' Natural Heritage Information System

The information obtained from the sources listed above and the rationale used to establish the ecological indicator concentrations in the 2007 TEE was re-evaluated and determined to still be applicable to the Site. Therefore, the ecological indicator concentrations established during the 2007 TEE are still applicable to the Site. The 2007 TEE is included as Appendix E.

5.5.2 Direct Human Contact Soil Pathway

Soil CULs for direct human contact were developed in accordance with MTCA Method B, WAC 173-340-740(3)(b)(iii), Equations 740-2 and 740-3, and Ecology's MTCASGL10 spreadsheet (for benzene, toxicity-adjusted total cPAHs [benzo(a)pyrene equivalents], and arsenic) (SLR 2007b) and Ecology's MTCATPH11.1 spreadsheet for petroleum mixtures. No changes were made to the default exposure assumptions in any of the equations. The option for inclusion of dermal contact was not considered, as presented in Section 5.5.7.

Based upon the results of these calculations, the Lower Yard TPH CUL is 2,775 mg/kg. This CUL was calculated based upon the median of the 14 fractionated samples collected during the 2003 assessment and Interim Action (SLR 2007b). The CULs for the direct contact pathway for benzene and cPAHs are based upon MTCA Method B direct contact [WAC 173-340-740(3)(b)(iii)(B)] and for arsenic are adjusted to background [WAC 173-340-740-(5)(c)]. These CULs are 18 mg/kg for benzene, 0.14 mg/kg for toxicity-adjusted total cPAHs, and 0.67 mg/kg for arsenic. The direct soil contact values are presented in Table 5-2. The MTCATPH11.1 Worksheet for Soil Data Entry and Calculation and Summary of Results for the 14 fractionated samples are presented as Appendix F.

Table 5-2. Soil Cleanup and Remediation Levels

Indicator Hazardous Substance	Soil Cleanup Level (mg/kg)
Total TPH[1]	2,775
Benzene[1]	18
Total cPAHs[1,2]	0.14
Arsenic[3]	20

Notes:

[1] Proposed soil CUL based on soil direct contact pathway and proposed soil REL based on soil leaching pathway.
[2]Total cPAHs adjusted for toxicity based on WAC 173-340-708(8).
[3] Based on natural background concentrations [WAC 173-340-740(5)(c)].

5.5.3 Soil Points of Compliance

Soil IHS concentrations protective of direct contact and TEE for soil in the Lower Yard will be met within the standard soil POC, which is within 15 feet of the ground surface. Soil CULs appear to be protective of the residual saturation pathway throughout the saturated and unsaturated zones.

5.5.4 Soil Leaching Pathway

To evaluate the leaching to groundwater pathway for TPH, the revised Workbook MTCATPH11.1 uses the three and four-phase partitioning models described in WAC 173-340-747 to calculate a CUL protective of potable groundwater. However, because groundwater beneath the site is considered nonpotable, a soil CUL protective of surface water quality is applicable. The revised Workbook MTCATPH11.1 includes a feature that will calculate a soil CUL that is protective of surface water quality by entering a target TPH groundwater concentration.

Using the results of the 14 fractionated samples discussed in Section 5.5.2 and a target TPH groundwater concentration of 561.3 µg/L (the average surface water CUL at the Site) (561.3 µg/L), the revised Workbook

MTCATPH11.1 calculated a median value of “100% NAPL” (Appendix F). This indicates that the TPH soil CUL exceeds the theoretical maximum TPH that would be reached if all of the available air space in the porous medium is filled with petroleum product. When “100% NAPL” is calculated as the leaching pathway CUL, the revised Workbook MTCATPH11.1 states that “soil-to-groundwater is not a critical pathway” (Ecology 2007).

Therefore, to demonstrate compliance with WAC 173-340-740(3)(b)(iii)(A), an empirical demonstration will be used to show that soil concentrations will not cause an exceedance of groundwater CULs. As defined under WAC 173-340-747(9), the following conditions are required for the empirical demonstration:

- The measured groundwater concentration is less than or equal to the applicable groundwater CUL established under WAC 173-340-720.

- The measured soil concentration will not cause an exceedance of the applicable groundwater CUL established under WAC 173-340-720 at any time in the future. Specifically, it must be demonstrated that a sufficient amount of time has elapsed for migration of hazardous substances from soil into groundwater to occur and that the characteristics of the Site (e.g., depth to groundwater and infiltration) are representative of future Site conditions. This demonstration may also include a measurement or calculation of the attenuating capacity of soil between the source of the hazardous substance and the groundwater table using Site-specific data.

Compliance monitoring will assess whether the empirical demonstration has been successful. If after a reasonable restoration time frame, the empirical demonstration has not been made, the compliance monitoring plan will require additional active remedial measures.

5.5.5 Soil Residual Saturation

When a NAPL, such as petroleum hydrocarbons, is released to soil, some of the liquid will dissolve in the soil pore water, some will adsorb to the soil particles, some will vaporize in the soil pore air, and some will be held by capillary force in liquid form (NAPL) in the soil pore spaces. The threshold concentration at which NAPL becomes continuous in the soil pore space is called the Csat. At concentrations just below Csat, the NAPL exists in small, isolated blebs. The concentration at which the isolated NAPL blebs become connected to form streamers is called residual saturation. At concentrations below residual saturation, the isolated blebs are relatively immobile. At concentrations above residual saturation, the NAPL streamers can migrate downward under the force of gravity, and the NAPL can reach groundwater if a sufficient volume is present.

The IAWP (SLR 2007a) evaluated soil residual saturation, considering default residual Csat values of 1,000 mg/kg for GRO and 2,000 mg/kg for DRO from MTCA Table 747-5. Data for additional soil types (Ecology

2001, p. 343) indicate that residual Csat values for silt to fine sand (the predominant soil type in the unsaturated zone) can range as high as 9,643 mg/kg for GRO and 22,857 mg/kg for DRO. Residual Csat values for fine to medium sand (the predominant soil type in the saturated zone) can range as high as 5,625 mg/kg for GRO and 13,333 mg/kg for DRO. The IAWP (SLR 2007a) did not use residual saturation to establish soil RELs/CULs.

An empirical demonstration may be used to show that NAPL in soil is not impacting groundwater, if the following three criteria can be met [WAC 173-340-747(10)(c)]:

- NAPL is not accumulating on or in groundwater.
- Soil contamination has been present sufficiently long for NAPL to reach groundwater.
- Site conditions will not change in the future to promote NAPL migration.

LNAPL is no longer present onsite, except in the area of and perhaps beneath DB-2, where soil impacts remain above TPH soil RELs (i.e., adjacent to DB-2) based on an evaluation of remaining soil impacts and associated LNAPL. Because LNAPL is not present where the soil RELs were met, the soil RELs appear to be protective of groundwater and appear to be appropriate CULs for the residual saturation pathway. Ongoing groundwater monitoring will continue to assess the presence or absence of LNAPL in the monitoring wells and piezometers. For the purposes of developing this FS, the direct contact TPH concentration will be assumed to be less than Csat.

5.5.6 Soil Vapor Pathway

WAC 173-340-740(3)(b)(iii)(C) identifies conditions that trigger whether or not an evaluation of the soil to vapor pathway will be required. These conditions include:

- For GRO, whenever the TPH concentration is significantly higher than a concentration derived for protection of groundwater for drinking water beneficial use under WAC 173-340-747(6) using the default assumptions.
- For DRO, whenever the TPH concentration is greater than 10,000 mg/kg.
- For other VOCs, including petroleum components, whenever the concentration is significantly higher than a concentration derived for protection of groundwater for drinking water beneficial use under WAC 173-340-747(4).

DRO concentrations in Site soil have been detected above 10,000 mg/kg. Additionally, GRO and VOCs have been detected in Site soil at concentrations higher than concentrations derived for protection of groundwater for drinking water beneficial use, which under MTCA requires further evaluation of the soil to vapor pathway.

WAC 173-340-740(3)(c)(iv)(B) lists the methods available under MTCA to evaluate whether or not soil CULs are protective of the indoor or ambient air. These methods include:

- Measuring site-specific soil vapor concentrations and demonstrating that they would not exceed air CULs established in WAC 173-340-750.

- Measuring ambient air concentrations and/or indoor air vapor concentrations throughout buildings, using methods approved by Ecology, demonstrating that air does not exceed CULs established under WAC 173-340-750.

- Use of modeling methods approved by Ecology to demonstrate that the air cleanup standards established under WAC 173-340-750 will not be exceeded.

- Other methods approved by Ecology demonstrating that the air cleanup standards established under WAC 173-340-750 will not be exceeded.

Soil vapor data collected from soil vapor probes VP-1, VP-2 and VP-3 were compared to Ecology Method B soil gas screening levels calculated from indoor air CULs. Soil vapor data collected during this sampling event exceeded the Method B screening levels for benzene, naphthalene and TPH (specific aliphatic and aromatic carbon ranges). However, due to source zone removal from proposed further remedial action, the environmental covenant and the current zoning restrictions at the site, the vapor intrusion exposure pathway is considered incomplete.

As discussed in Section 5.1.3, the final soil IHSs include TPH (sum of GRO, DRO, and HO concentrations), benzene, toxicity-adjusted total cPAHs, and arsenic. Of the final soil IHSs, benzene is the only substance considered to be sufficiently volatile and toxic to pose a potential threat to indoor air quality via the vapor intrusion pathway, with an established groundwater screening level protective of indoor air of 2.4 µg/L (Ecology 2009).

- In 2012, benzene concentrations in groundwater exceeded the screening level considered to be protective of indoor air in two monitoring wells (MW-20R [28 µg/L] and MW-525 [5,900 µg/L]).

- In 2013, concentrations of aliphatic and aromatic carbon ranges and benzene exceeded the screening levels considered to be protective of indoor air in three vapor probe locations.

5.5.7 Soil Dermal Contact Pathway

Dermal contact with the IHSs must be evaluated if changes have been made to MTCA Method B direct contact equations, WAC 173-340-740, Tables 740-1 and 740-2 [WAC 173-340-740(3)(c)(iii)]. No changes were made to the equations for calculating CULs.

5.6 Summary of Soil and Groundwater Cleanup Levels

Water and soil CULs are summarized in Tables 5-1 and 5-2. The soil CULs of 2,775 mg/kg for TPH, 18 mg/kg for benzene, and 0.14 mg/kg for total cPAHs are based on direct contact. The soil CUL of 20 mg/kg for arsenic is based on the natural background concentration.

The groundwater CULs are based on protection of surface water, using a weighted average of the Method A groundwater CULs for GRO, DRO, and HO, and considering the composition of the TPH in the groundwater beneath the Lower Yard. The groundwater CULs (51 µg/L for benzene and 0.018 µg/L for total cPAHs) are based on the protection of surface water and consider the human consumption of aquatic animals. Arsenic is not an IHS for groundwater, so there is no groundwater CUL for arsenic.

5.7 Other Potentially Applicable Requirements

MTCA requires that all cleanup actions comply with applicable state and federal laws (WAC 173-340-710). MTCA defines applicable state and federal laws to include “legally applicable requirements” and “relevant and appropriate requirements.” Appendix D describes all other potentially applicable requirements and permits required to ensure compliance with WAC 173-340-710. The laws and regulations cited in Appendix D pertain to nonhazardous waste only as neither “hazardous waste” exists at the site, nor generation, handling, and treatment/disposal are anticipated as part of remedial action. Appendix D does not refer to State Dangerous Waste regulations (WAC 173-304) or Resource Conservation and Recovery Act Subtitle C regulations (40 CFR 260-268), which control the management and disposal of hazardous waste.

6. Development of Remedial Alternatives

Potential treatment technologies were developed to define the actions that may be taken, either individually or in combination, to achieve the CULs.

As described in Section 4.2, the remaining impacts to soil and groundwater are limited to the following areas (Figures 4-1 through 4-3):

- WSDOT stormwater line: Eleven sample locations in soils along the WSDOT stormwater line, that had not been disturbed during prior excavation activities, contain soil with concentrations of IHSs greater than Site CULs and/or RELs. Nine of these sample locations are under the construction easement placed by WSDOT to restrict the present /future activities within 25 feet on each side of the WSDOT stormwater line (Figure 7-1a)

- DB-2 area: Free-phase and/or residual LNAPL was encountered.

- Isolated soil samples from three locations exceeded Site CULs and/or RELs for TPH and/or cPAHs:

    - Monitoring well MW-129R: One soil sample collected at a depth of 7 feet bgs contained a TPH concentration of 3,010 mg/kg. This is an isolated exceedance surrounded by soil and groundwater with no impacts observed (Figure 4-3). The soil concentration observed at this location exceeds the Site TPH REL by a minimal amount (235 mg/kg) and the groundwater sampled from monitoring well MW-129R has been in compliance for 6 consecutive quarters indicating that the soil impacts observed at this location are protective of soil leaching pathway.

    - Excavation side wall sample EX-B18-VV-1-6SW: An excavation side wall soil sample collected at a depth of 6 feet bgs contained a TPH concentration of 4,980 mg/kg. This sample location lies on the property boundary with BNSF railroad. This is an isolated exceedance surrounded by soil and groundwater with no impacts observed (Figure 4-3).

    - Excavation side wall sample EX-BI-F-44-4: Soil sample collected at a depth of 4 feet bgs contained a cPAH concentration of 0.212 mg/kg. This is an isolated exceedance surrounded by soil and groundwater with no impacts observed (Figure 4-3). Based on the available data, this data point is determined to be statistically insignificant for further remediation.

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The above listed three soil exceedances are isolated. Monitoring wells in the immediate vicinity of these locations, show no groundwater impacts indicating that these isolated soil exceedances are protective of soil leaching pathway. The Site is zoned MP2 which does not allow for residential dwellings on the ground floor, limiting the risk of the vapor intrusion pathway. Based on the statistical data analysis, these isolated soil exceedances are considered statistically insignificant and are not considered in the development of remedial alternatives for the Site.

The discussion below identifies the potentially applicable technologies which will address remaining impacts in the vicinity of WSDOT stormwater line and DB-2. These technologies are consistent with Washington Administrative Code (WAC) 173-340-350(8)(b) Screening of Alternatives and were derived from the Federal Remediation Technologies Roundtable's Remediation Technologies Screening Matrix (U.S. Army Corps of Engineers 2002; www.frtr.gov) and the project team's professional experience. Per Ecology's request, potential remedial technologies for the Site include:

- Environmental covenants
- MNA
- Excavation with groundwater MNA
- In-situ solidification
- Enhanced bio-oxidation
- Surfactant flushing
- Groundwater containment system using groundwater extraction wells
- Groundwater containment system using groundwater collection trench
- LNAPL barrier trench with reactive core mat
- Funnel and gate system with in-situ remediation
- Funnel and gate system with groundwater extraction

ARCADIS performed an initial screening of the technical implementability of each technology type to eliminate less viable technologies before performing a more rigorous screening and evaluation process. Technical implementability refers to the ability of a remedial action or process to meet a cleanup goal or level. The initial screening also eliminates those technologies or process options that are not applicable based on the site COCs and site-specific characteristics. As a result, remedial technologies that cannot be effectively implemented were eliminated from further consideration.

The potential remedial technologies and preliminary screening are described in Table 6-1. Technologies that were eliminated from further consideration on the basis of effectiveness and implementability are shaded in the tables for clarity.

6.1 Description of Remedial Technologies

This section summarizes the remedial technologies presented in Table 6-1 that were developed and evaluated for the Lower Yard.

6.1.1 Remedial Technology 1: Environmental Covenants

An administrative control, such as environmental covenants, may be an effective means of managing exposure to site contaminants. Environmental covenants alone would not meet the minimum requirements of WAC 173-340-360, but may be used to supplement other technologies.

An environmental covenant is a type of restrictive covenant, and per WAC 173-340-440 (9), the restrictive covenant would (where required):

- Prohibit activities at the Site that may interfere with a cleanup action, operation and maintenance, monitoring, or other measures necessary to assure the integrity of the cleanup action and continued protection of human health and the environment.

- Prohibit activities that may result in the release of a hazardous substance that was contained as part of the cleanup action.

- Require notice to Ecology of the owner's intent to convey any interest in the Site. No conveyance of title, easement, lease, or other interest in the Site would be consummated by the owner without adequate and complete provision for the continued operation, maintenance, and monitoring of the cleanup action, and for continued compliance with this requirement.

- Require the owner to restrict leases to uses and activities consistent with the restrictive covenant and notify all lessees of the restrictions on the use of the Site.

- Require the owner to include in any instrument conveying any interest in any portion of the Site, notice of the restrictive covenant.

- Require notice and approval by Ecology of any proposal to use the Site in a manner that is inconsistent with the restrictive covenant. If Ecology, after public notice and comment approves the proposed change, the restrictive covenant would be amended to reflect the change.

- Grant Ecology and its designated representatives the right to enter the Site at reasonable times to evaluate compliance with the cleanup action plan and other required plans, including the right to take samples, inspect any remedial actions taken at the Site, and inspect records.

This technology does not involve the implementation of active remedial activities to remove, treat, or contain COCs at the Site and is not a stand-alone technology. Minimal long term maintenance will be required. Table 6-1 presents a preliminary evaluation of the effectiveness and implementability associated with Remedial Technology 1: Environmental Covenants. This remedial technology can be used to supplement the technology selected as a preferred alternative.

6.1.2 Remedial Technology 2: Groundwater Monitored Natural Attenuation

MNA is defined as the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a timeframe that is reasonable compared to that offered by other, more active methods. The natural attenuation processes at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act to reduce the mass, toxicity, mobility, volume, or concentration of COCs in groundwater. These in-situ processes include diffusion, dilution, sorption, biodegradation, volatilization, and chemical biological stabilization, transformation, or destruction of COCs.

Natural attenuation processes are typically occurring at all sites, but to varying degrees of effectiveness. Depending on the types and concentrations of contaminants present, physical, chemical, and biological characteristics of the soil and groundwater.

This technology does not involve the implementation of active remedial activities to remove, treat, or contain COCs at the site. Under this alternative, natural attenuation processes would reduce chemical concentrations through time. Compliance monitoring would be performed to assess whether the natural attenuation processes are occurring at a sufficient rate to achieve compliance within the restoration timeframe identified in the Cleanup Action Plan. Contingency plans would be included in the compliance monitoring plan and would require additional cleanup if the restoration timeframe will not be met.

Table 6-1 presents a preliminary evaluation of the effectiveness and implementability associated with Remedial Technology 2: MNA. This technology is not acceptable as a stand-alone alternative because treatment would not be addressed within a reasonable timeframe. However, this technology is retained for detailed analysis for use in conjunction with other technologies in establishing remedial alternatives.

6.1.3 Remedial Technology 3: Excavation with Groundwater Monitored Natural Attenuation

Excavation is an effective way to meet CULs because contaminants would be physically removed from the Site. This technology has been used extensively at the Lower Yard and in areas unencumbered by facility infrastructure has been both implementable and effective at removing impacted soil and reducing dissolved-phase petroleum hydrocarbon concentrations in groundwater to below CULs or within one order of magnitude of CULs.

This technology could be used to address soil surrounding DB-2 to remove measureable LNAPL detected in monitoring well MW-510 and residual LNAPL remaining in soil. Excavation could also be used to physically remove soil surrounding the WSDOT stormwater line, although doing so may be impractical due to the risk of compromising the structural integrity of the line.

Water ingress into the excavation must be evaluated and managed when excavation occurs beneath the groundwater table. If excavating beneath the water table with freestanding water is not feasible due to project conditions (when workers are required to enter the excavation), dewatering would be used. Dewatering is the removal of freestanding water from excavations using submersible "dewatering" pumps, centrifugal ("trash") pumps, or application of vacuum to adjacent well points.

Dewatering and shoring would likely be required for excavation at the Site. Excavation can be implemented with minimal exposure of workers to soil and airborne contaminants through the use of personal protective equipment and proper health and safety planning such as the use of dust suppression measures. Table 6-1 presents a preliminary evaluation of the effectiveness and implementability associated with Remedial Technology 3: Excavation with Groundwater MNA. This technology was retained for further consideration.

6.1.4 Remedial Technology 4: In-Situ Solidification

In-situ solidification (ISS) provides long-term protection of human health and the environment through physical contaminant sequestering. This technology involves mixing binding agents (typically Portland cement) into the soil. The resulting mixture of soil and binding agent encapsulates the wastes and forms a low-permeability solid. ISS has been used as an environmental remediation tool since the 1980s and can be effectively implemented to encapsulate VOCs and PCBs.

In addition to the encapsulating effect of ISS, the addition of binding agents can improve the engineering strength properties of the soil. Once the treated soil has cured, it would act as a physical barrier between the ground surface and the soil beneath the treated monolith.

For remediation mixing depths less than 20 feet bgs, conventional backhoes and excavators are the simplest and most common method used to mix the binding agents into the soil. This technology was retained for further consideration.

6.1.5 Remedial Technology 5: Enhanced Bio-Oxidation

Engineered anaerobic bio-oxidation (ABOx) applications entail delivery of soluble electron acceptors other than oxygen to petroleum hydrocarbon release sites to stimulate biodegradation. A review of biogeochemical data from multiple petroleum hydrocarbon release sites demonstrates that groundwater conditions are predominantly anaerobic based on the availability of petroleum hydrocarbon impacts and background electron acceptors (e.g., nitrate, ferric iron, and sulfate). In many instances, the abundance of background sulfate and favorable reaction yield (i.e., mass of petroleum hydrocarbons degraded per mass of sulfate used) allows ABOx via sulfate reduction to serve as the dominant terminal electron accepting process and can account for a majority of the natural biodegradation capacity (Wiedemeier et al. 1999).

This technology includes installation of approximately 15 injection wells with approximately 40-foot centers within the unexcavated footprint surrounding DB-2 and monitoring well MW-510. Magnesium sulfate and sodium nitrate would be injected into the subsurface semiannually for approximately 5 years to enhance ABOx. Groundwater monitoring would be performed to evaluate changes in biogeochemical data and VOC concentrations in groundwater.

ABOx is an approach that is typically reserved for sites where dissolved-phase concentrations remain in groundwater where petroleum hydrocarbons source material has been depleted or remediated. ABOx injections would not address residual LNAPL in vadose zone soil. Additionally, injection rates may be slow based on site-specific groundwater flux calculations.

Remedial Technology 5: Enhanced Bio-Oxidation was eliminated from further consideration because it does not remove or treat LNAPL and would have to be coupled with excavation to meet terms of the AO. Table 6-1 presents the evaluation of the effectiveness and implementability associated with this remedial technology.

6.1.6 Remedial Technology 6: Surfactant Flushing

Surfactant injection and subsequent extraction has been successfully used as an alternative soil and groundwater remediation solution at LNAPL-impacted sites in recent years. Surfactant reduces surface tension between LNAPL and groundwater, creating micelles to more readily remove LNAPL with vacuum extraction. Other advantages of surfactant injection include increased biodegradation following LNAPL removal (Paria 2008). Several studies indicate a temporary increase in the solubility of LNAPL and an increased dissolution of molecules in the aqueous phase, which increases the bioavailability to microorganisms.

This technology consists of the addition of surfactants into the subsurface to enhance LNAPL recoverability and its removal. A 4 percent bio-surfactant solution would be gravity fed into injection locations selected in the vicinity of DB-2. A mobile vacuum event would remove a minimum of three times the injected volume at each injection location and injected wells would be monitored to determine the frequency and extent of recurring measurable LNAPL. Two piezometers would be installed: one downgradient and one crossgradient from the estimated LNAPL boundary to monitor and address potential LNAPL migration during treatment. Table 6-1 presents the evaluation of the effectiveness and implementability associated with Remedial Technology 6: Surfactant Flushing.

Surfactant flushing was eliminated from further consideration because the technology would be difficult to implement. Injection rates would be slow based on site-specific groundwater flux calculations, causing a slower remediation timeframe. Downgradient monitoring would be difficult to implement because Willow Creek is located adjacent and downgradient (<25 feet) from the remaining LNAPL impacts. This technology would not address remaining impacts in soil and would have to be coupled with excavation to meet direct contact CULs and terms of the AO.

6.1.7 Remedial Technology 7: Groundwater Containment System Using Groundwater Extraction Wells

This technology consists of extracting contaminated groundwater through extraction wells and treating extracted groundwater at the surface using a variety of methods (e.g., oil/water separators, air strippers, filters, and granular activated carbon) prior to discharge. The groundwater extraction wells would be installed at the downgradient site boundary to contain COCs and control plume migration offsite. The system would be designed to allow for expansion. Based on preliminary flux data and groundwater modeling, approximately six wells would be installed downgradient from MW-510. Groundwater modeling data indicate that extraction wells spaced on approximately 40 foot centers would provide an adequate capture zone encompassing the DB-2 area (Appendix G). Wells would be advanced to a depth of approximately 15 to 20 feet bgs (maximum historical excavation depth) at a combined average pumping rate of approximately 3 to 5 gallons per minute (gpm).

This technology is effective in controlling offsite migration of COCs and LNAPL to the adjacent surface water body. LNAPL and groundwater would be extracted and treated prior to discharge to a product recovery tank or stormwater/sanitary sewer line. This strategy would be coupled with MNA and environmental covenants to meet direct contact CULs and terms of the AO, and to address remaining petroleum hydrocarbon-related impacts left in place in the vicinity of the WSDOT stormwater line. Table 6-1 presents a preliminary evaluation of the effectiveness and implementability associated with this remedial technology. Remedial Technology 7 was retained for further consideration.

6.1.8 Remedial Technology 8: Groundwater Containment System Using Groundwater Extraction Trench

This remedial technology is similar to Remedial Technology 7. However, for this remedial technology, a series of groundwater extraction sumps within a groundwater interceptor trench with high permeability backfill would be installed. The trench would be excavated along the northeast and northwest boundary of DB-2 to approximately 15 feet bgs. The layout of the extraction trench along the northern boundary of DB-2 is based on groundwater modeling data. Modeling data estimates that a pumping rate of approximately 4 to 7 gpm would provide an adequate groundwater capture zone encompassing the DB-2 area (Appendix G).

This technology would be effective in controlling offsite migration of COCs and LNAPL to the adjacent surface water body. LNAPL and groundwater would be extracted and treated prior to discharge to a product recovery tank or stormwater/sanitary sewer line. Environmental covenants would be required to meet direct contact CULs and terms of the AO, and to address remaining petroleum-related hydrocarbons in soil left in place in the vicinity of the WSDOT stormwater line. Table 6-1 presents a preliminary evaluation of the effectiveness and implementability associated with this remedial technology. Remedial Technology 8 was retained for further consideration.

6.1.9 Remedial Technology 9: LNAPL Barrier Trench with Reactive Core Mat

This technology includes construction of a barrier trench constructed downgradient from DB-2 to stop offsite migration of LNAPL. The LNAPL barrier trench would be constructed with a reactive core mat to essentially lock LNAPL in place and ensure that no offsite migration occurs. When LNAPL comes into contact with the reactive organoclay mat, it eventually becomes an impenetrable barrier. The organoclay mat would allow groundwater to flow through the barrier in areas where LNAPL is not present. However, where LNAPL is present, the barrier would essentially become an impermeable wall. Several LNAPL collection sumps will be installed within the trench to passively remove LNAPL through manual bailing or pumping.

The barrier would prevent horizontal LNAPL discharge to the adjacent surface water; however, because this technology does not include source removal, LNAPL would remain in place through time. Table 6-1 presents the evaluation of the effectiveness and implementability associated with this. Remedial Technology 9 was eliminated from further consideration because it is does not meet compliance requirements. Additionally, this technology does not meet terms of the AO.

6.1.10 Remedial Technology 10: Funnel and Gate System with In-Situ Remediation

This technology consists of low hydraulic conductivity cut-off walls that may be constructed of sheet piling or organoclay mats with gaps that contain in-situ remediation zones where air sparge wells target the plume. The cut-off walls (the funnel) would modify flow patterns so that groundwater flows primarily toward the higher permeability gates, where a series of sparge wells would treat the groundwater plume through volatilization and aerobic degradation. The remediated groundwater would then flow through the downgradient side of the gate.

The funnel and gate system would function to isolate LNAPL and the dissolved-phase plume in groundwater and effectively funnel the plumes through an in-situ remediation zone. Site-specific conditions would not allow for an adequately sized in-situ reactive zone within and downgradient from the gate. The highly weathered nature of the LNAPL onsite is not amenable to a volatilization remediation strategy leading to potential offsite migration of the LNAPL.

Based on overall construction costs and the measured groundwater flux, a series of groundwater extraction wells would provide adequate control of the groundwater plume at substantially less cost than the funnel and gate design with in-situ remediation. Thus, this technology would not be effective for site conditions. Table 6-1 presents the evaluation of the effectiveness and implementability associated with this remedial technology. Remedial Technology 10 was eliminated from further consideration because of the limited downgradient area available for an effective in-situ remediation zone, the ineffectiveness of the technology to remove LNAPL observed in soil near DB-2, and the technology would have to be coupled with excavation to meet the terms of the AO.

6.1.11 Remedial Technology 11: Funnel and Gate System with Groundwater Extraction

This technology would consist of permeable sorptive walls constructed with an organoclay mat. The organoclay in the permeable sorptive walls (the funnel) would adsorb LNAPL until it reaches adsorption capacity. The remediated groundwater would then flow through the downgradient side of the gate where any remaining dissolved-phase hydrocarbons or LNAPL would be extracted and treated ex-situ.

The funnel and gate system would function to isolate LNAPL and dissolved-phase plumes in groundwater and effectively funnel the plumes toward the extraction zone. In some cases where groundwater flux at site boundary conditions is high, the funnel and gate system would allow for greater control of plume migration. Based on pumping test data, this technology would not likely be effective due to the limited groundwater flux across the site boundary caused by the dampening tidal effects and recharge from Willow Creek. Based on overall construction costs and the measured flux, a series of groundwater extraction wells would provide adequate control of the groundwater plume at substantially less cost than the funnel and gate design.

Table 6-1 presents the evaluation of the effectiveness and implementability associated with this remedial technology. The funnel and gate with permeable sorptive walls technology was eliminated from further consideration because would not be effective and would not remove LNAPL observed in soil near DB-2.

6.2 Summary of Remedial Alternatives

Remedial technologies that passed initial screening were selected as remedial alternatives for further analysis under MTCA requirements. The selected five remedial alternatives include:

- Alternative 1: Excavation and MNA with Environmental Covenants

- Alternative 2: Groundwater Containment System Using Groundwater Extraction Wells, and Environmental Covenants

- Alternative 3: Groundwater Containment System Using Groundwater Extraction Trench, and Environmental Covenants

- Alternative 4: Excavation with MNA

- Alternative 5: Excavation with MNA and ISS with Environmental Covenants

These remedial alternatives are evaluated in Section 7.

7. Evaluation of Remedial Alternatives

This section evaluates the proposed remedial alternatives in the context of the requirements of MTCA. Requirements are defined based on WAC 173-340-360 and include the following considerations:

- Threshold requirements
- Compliance with cleanup standards
- Compliance monitoring
- Use of permanent solutions to the maximum extent possible
- Disproportionate cost analysis
- Restoration timeframe

Alternatives are also evaluated based on expectations for cleanup action alternatives as defined in WAC 173-340-370. The selected five alternatives are ranked highest (being the best) to lowest (being the worst) scores are presented in Table 7-1.

It is assumed impacted soil in the southern portion of Site near the WSDOT stormwater line will remain in place for implementation of Alternatives 1, 2, 3, and 5. In evaluating these alternatives, it is presumed that an environmental covenant would be completed for this area. Based on available groundwater data, remaining petroleum hydrocarbon-related impacts in soil near the WSDOT stormwater line have not impacted downgradient POC or interior monitoring wells (Section 3.3.1), indicating that the leaching to groundwater pathway is not complete (Section 3.3). Since the leaching to groundwater pathway is not complete, an environmental covenant is an effective way to protect against the remaining potential exposure pathways (direct contact and soil vapor intrusion).

Alternative 4 includes excavation of impacted soil in the vicinity of DB-2 and the WSDOT stormwater line; therefore, an environmental covenant will not be needed. Excavation of soils near the WSDOT stormwater line was not previously evaluated in the Draft Feasibility Study Technology Screening Report (ARCADIS 2013c); however in a letter dated January 14, 2013, WSDOT presented an assessment of pipe integrity and recommendations for soil removal (WSDOT 2013). Based on this letter, Ecology recommended that this technology be evaluated. The letter recommended; dewatering, accurately locating the stormwater line and mechanical excavation within 3 feet of the line, followed by final excavation to the line itself via vacuum excavation or less mechanical means such as shovels. Alternative 4 uses WSDOT's recommended approach and incorporates the more specific engineering and geotechnical considerations necessary for its implementation. Some of the engineering and geotechnical considerations used for development of this alternative are dewatering design and groundwater cutoff with shoring walls, excavation shoring for worker protection, as well as, protection of the bluff between the Site and Point Edwards to the south, and consideration of the WSDOT stormwater line design life (approximately 60 years for corrugated metal pipe [NCSPA, 2010]).

7.1 Threshold Requirements

Cleanup actions are subject to the threshold requirements set forth in WAC 173-340-360 (2)(a). Under the threshold requirements, the cleanup action will:

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

For cleanup actions that meet the threshold requirements, the selected action will:

- Use permanent solutions to the maximum extent practicable
- Provide for a reasonable restoration timeframe
- Consider public concerns

7.2 Protect Human Health and the Environment and Comply with Cleanup Standards

The alternatives evaluated below protect human health and the environment through compliance with either the agreed-upon cleanup standards for groundwater and soil, or implementation of institutional controls through environmental covenants.

7.2.1 Alternative 1: Excavation and Monitored Natural Attenuation with Environmental Covenants

In Alternative 1, impacted soil and LNAPL in the area of DB-2 would be excavated, removed from the Site, and transported to an appropriate waste disposal facility. The proposed area of excavation is shown on Figure 7-1 and includes soil around and in the vicinity of MW-510. It is anticipated that removal of the impacted soil would meet applicable CULs, and that removal of impacted soil and MNA will eventually remediate groundwater to below CULs. Currently MW-529, which is installed downgradient of the proposed excavation area, has demonstrated compliance with its respective groundwater CULs since its installation. Previous excavation work at the Site has demonstrated that removal of impacted soil has resulted in a decrease in dissolved-phase concentrations in the area. Groundwater modeling data indicate that groundwater flux at POC compliance well MW-510 stems from upgradient soil and groundwater conditions observed in the vicinity of DB-2. Removal of LNAPL-saturated soil from the DB-2 area coupled with MNA will reduce COC concentrations. Environmental covenants will be used to protect human health and the environment in the WSDOT stormwater line area, and long-term groundwater monitoring as part of an MNA program will be implemented to comply with cleanup standards, and to address remaining petroleum hydrocarbon-related impacts in soil near the WSDOT stormwater line. Impacted soil near the WSDOT stormwater line will remain in place under an environmental covenant. The environmental covenant would be used in an area already covered by the construction easement signed in October 1971 by the Washington State's Attorney General's Office and Unocal.

The construction easement covers an area extending 25 feet from the center line of the WSDOT stormwater line, running the length of the Unocal property. Current WSDOT construction easement and remaining soil impacts in the vicinity of the WSDOT stormwater line are shown on Figure 7-1a.

The environmental covenant proposed in this alternative will help:

- Protect against direct contact with impacted soil adjacent to the stormwater line.
- Provide a framework that would allow for subsurface work in the area adjacent to the stormwater line to occur in a manner protective of human health and the environment.
- Address subsurface use in the impacted area adjacent to the stormwater line, and help guide above ground construction activities (i.e. installation of vapor barriers, etc.), should there be desire in the future to build a structure over the storm drain.

The environmental covenant will require minimal long term maintenance. Historical groundwater data indicate that remaining petroleum-related hydrocarbons in soil do not impact groundwater concentrations in POC wells (Figure 4-2). The combined elements of Alternative 1 would be protective of human health and the environment.

7.2.2 Alternative 2: Groundwater Containment System Using Groundwater Extraction Wells, and Environmental Covenants

In Alternative 2, a groundwater containment system using groundwater extraction wells would be installed along the downgradient property boundary northwest of DB-2 to recover and treat groundwater that contains hydrocarbon concentrations greater than the CULs. Based on groundwater modeling, extraction wells containing pumps will be installed on approximately 40-foot centers. The layout and capture radius of influence based on groundwater modeling is shown on Figure 7-2. Environmental covenants will be used to protect human health and the environment in the WSDOT stormwater line area, MNA will be used to comply with cleanup standards, and to address remaining petroleum hydrocarbon-related impacts near the WSDOT stormwater line.

As discussed earlier in Section 7.2.1, a construction easement covers an area extending 25 feet from the center line of the WSDOT stormwater line, running the length of the Unocal property.

The environmental covenant proposed in this alternative will help:

- Protect against direct contact with impacted soil near the stormwater line.
- Provide a framework that would allow for subsurface work in the area adjacent to the stormwater line to occur in a manner protective of human health and the environment.
- Address subsurface use in the impacted area adjacent to the stormwater line, and help guide above ground construction activities (i.e. installation of vapor barriers, etc.), should there be desire in the future to build a structure over the storm drain.

The environmental covenant will require minimal long term maintenance; however, a groundwater extraction system requires long term maintenance. The combined elements of Alternative 2 would be protective of human health and the environment through time.

7.2.3 Alternative 3: Groundwater Containment System Using Groundwater Extraction Trench, and Environmental Covenants

In Alternative 3, a groundwater containment system using a groundwater extraction trench would be installed downgradient of DB-2 and southwest of DB-1. This technology is similar to Alternative 2; however, in lieu of a series of groundwater extraction wells, a groundwater interceptor trench with high-permeability backfill would be installed. The trench would be excavated downgradient from DB-2 to approximately 15 feet bgs. A series of groundwater collection sumps would be placed within the trench to extract groundwater and contain the groundwater plume onsite. Based on groundwater modeling, the trench would be installed along the northeast and northwest boundaries of DB-2 to provide an adequate capture zone encompassing DB-2.

A Site plan of the trench is provided on Figure 7-3. Environmental covenants will be used to protect human health and the environment in the WSDOT stormwater line area, MNA will be used to comply with cleanup standards, and to address remaining petroleum hydrocarbon-related impacts near the WSDOT stormwater line.

As discussed earlier in Section 7.2.1, a construction easement covers an area extending 25 feet from the center line of the WSDOT stormwater line, running the length of the Unocal property.

The environmental covenant proposed in this alternative will help:

- Protect against direct contact with impacted soil near the stormwater line.
- Provide a framework that would allow for subsurface work in the area adjacent to the stormwater line to occur in a manner protective of human health and the environment.
- Address subsurface use in the impacted area adjacent to the stormwater line, and help guide above ground construction activities (i.e. installation of vapor barriers, etc.), should there be desire in the future to build a structure over the storm drain.

The environmental covenant will require minimal long term maintenance. The combined elements of Alternative 3 would be protective of human health and the environment through time.

7.2.4 Alternative 4: Excavation with Monitored Natural Attenuation

In Alternative 4, impacted soil in the area of DB-2 and adjacent to the WSDOT stormwater line will be excavated and disposed of at an appropriate waste disposal facility. The removal of impacted soil is expected to meet applicable CULs. It is expected that the removal of impacted soil and MNA will remediate groundwater to below CULs. Previous excavation work at the Site has shown that removal of impacted soil has resulted in a decrease in dissolved-phase hydrocarbon concentrations in the area. Since impacted soils will be removed under this alternative, it is expected that an environmental covenant would not be needed. Alternative 4 would be protective of human health and the environment.

7.2.5 Alternative 5: Excavation with Monitored Natural Attenuation and In-Situ Solidification with Environmental Covenants

In Alternative 5, impacted soil in DB-2 would be excavated and disposed of at an appropriate waste disposal facility, and impacted soil near the WSDOT stormwater line will be treated using ISS. Under this remedial alternative, the top 1 foot of soil above and adjacent to the stormwater line will be excavated and disposed of. Soil from 1 foot to 5 feet bgs will be mixed with a binding agent and left in place, which will bulk approximately to the ground surface. The mixture produces a hardened surface that prevents surface water infiltration, therefore closing the soil leaching to groundwater pathway. Soil deeper than 5 feet bgs in this area would remain in place. The removal of impacted soil in the area of DB-2 coupled with MNA will remediate groundwater to below CULs. Previous excavation work at the site has shown that removal of impacted soil has resulted in a decrease in dissolved-phase hydrocarbon concentrations in the area.

Institutional controls and groundwater monitoring are also components of Alternative 5. Impacted soil near the WSDOT stormwater line will remain in place under an environmental covenant. As discussed earlier in Section 7.2.1, a construction easement is already in place 25 feet from the center line of the WSDOT stormwater line.

The environmental covenant proposed in this alternative will help:

- Protect against direct contact with impacted soil near the stormwater line.
- Provide a framework that would allow for subsurface work in the area adjacent to the stormwater line to occur in a manner protective of human health and the environment.
- Address subsurface use in the impacted area adjacent to the stormwater line, and help guide above ground construction activities (i.e. installation of vapor barriers, etc.), should there be desire in the future to build a structure over the storm drain.

The environmental covenant will require minimal long term maintenance. Historical groundwater data indicate that remaining petroleum-related hydrocarbons in soil near the WSDOT stormwater line do not impact dissolved-phase COC concentrations in POC wells. The combined elements of Alternative 5 would be protective of human health and the environment through time.

7.3 Comply with Applicable State and Federal Laws

As discussed in the Draft CULs and Remediation Levels Report (ARCADIS 2013b), the selected RELs and CULs are consistent with MTCA. Additionally, numerous state and federal laws will apply to each proposed alternative related to environmental protection, health and safety, transportation, and disposal. Each of the proposed alternatives can be implemented in compliance with these laws.

7.4 Provide for Compliance Monitoring

All five alternatives include compliance monitoring as required by WAC 173-340-410 and 173-340-720 through 173-340-760. Compliance monitoring will consist of protection, performance, and confirmation monitoring to determine the short- and long-term safety and effectiveness of the alternative that is implemented, as summarized below:

- Protection monitoring is used to confirm that human health and the environment are adequately protected during construction, operation, and maintenance periods.

- Performance monitoring confirms that the cleanup action has attained cleanup standards or other performance standards, including those outlined in any permits. For each alternative, performance monitoring will include programs designed to: assess rates of natural attenuation, and/or provide data necessary to confirm that LNAPL migration is not continuing in areas with soil TPH concentrations exceeding residual saturation.

- Confirmation monitoring verifies the long-term effectiveness of the remedial action.

7.5 Use Permanent Solutions to the Maximum Extent Practicable

MTCA states that when selecting an alternative, preference will be given to “permanent solutions to the maximum extent practicable.” “Permanent” is defined in WAC 173-340- 200 as a cleanup action in which the cleanup standards of WAC 173-340-700 through 173-340-760 are met without further action being required at the site being cleaned up, or at any other site involved with the cleanup action, other than the approved disposal of any residue from the treatment of hazardous substances. Evaluating the “maximum extent practicable” for each alternative requires the application of a disproportionate cost analysis as described below.

7.6 Disproportionate Cost Analysis

The disproportionate cost analysis involves comparing the costs and benefits of alternatives and selecting the alternative whose incremental costs are not disproportionate to the incremental benefits. As outlined in WAC 173-340-360(3)(e), costs are determined to be disproportionate to benefits if the incremental cost of a more expensive alternative compared to a lower cost alternative exceeds the incremental degree of benefits achieved by the more expensive alternative. The evaluation criteria for the disproportionate cost analysis are specified in WAC 173-340-360(3)(f), and include protectiveness, permanence, cost, long-term effectiveness, management of short-term risks, technical and administrative implement ability, and consideration of public concerns.

Per WAC 173-340-360(3)(e), the most practicable permanent solution evaluated in the FS will be the baseline cleanup action alternative against which the other cleanup action alternatives are compared. On this basis, Alternative 1 is the baseline alternative for this analysis. Alternative 1 was selected as the baseline alternative because it is implementable, has proven to be successful in reducing dissolved-phase concentrations and removing LNAPL, and is a permanent solution to the extent practicable. Alternative 1 was chosen as the baseline comparison alternative instead of Alternative 4 due to the cost, risk, and implementability issues associated with dewatering and excavating in the WSDOT stormwater line excavation area. Table 7-1 summarizes the comparative analysis. Each alternative was given a relative rating between 1 and 5 (1 being best, 5 being worst). The basis for each rating is provided below.

7.6.1 Protectiveness

With proper implementation, all five alternatives are adequately protective of human health and the environment during implementation and after the remedial action has been completed. MTCA describes protectiveness as the overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, time required to reduce risk at the facility and attain cleanup standards, onsite and offsite risks resulting from implementing the alternative, and improvement of the overall environmental quality (Ecology 2007).

Due to the excavation of soil containing concentrations above the CULs, Alternatives 1, 4, and 5 are determined to be more protective than Alternatives 2 and 3. Due to the extent of excavation, Alternative 4 is more protective than Alternatives 1 and 5. Alternative 5 ranks higher than Alternative 1 because ISS will create a surface barrier where impacted soil remains.

It is expected that Alternatives 1, 4, and 5 will reach groundwater CULs at POC wells through removal of impacted soil and LNAPL, and MNA. For Alternatives 2 and 3, groundwater CULs will be met at POC wells through a pump and treat system.

Based on the degree of protectiveness, the following alternatives are ranked from highest to lowest:

- *Highest: Alternative 4*. This is the most protective alternative based on the complete removal of soil with COC concentrations above CULs.

- *Medium: Alternative 5 and Alternative 1*. These alternatives are less protective compared to Alternative 4 because some soil with COC concentrations above CULs would remain in place. Environmental covenants would be required for any soil left in place with COC concentrations above CULs.

- *Lowest: Alternative 2 and Alternative 3*. These alternatives are the least protective because onsite dissolved-phase groundwater COC concentrations, soil COC concentrations, and potentially non-mobile LNAPL may remain in-place. Protectiveness would be addressed through environmental covenants.

7.6.2 Permanence

Permanence refers to the degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances, including the adequacy of the alternative in destroying the hazardous substances, reduction or elimination of hazardous substance releases and sources of releases, degree of irreversibility of waste treatment process, and characteristics and quantity of treatment residuals generated (Ecology 2007).

Alternatives 1, 4, and 5 provide the greatest degree of permanence, with the removal of impacted soil and LNAPL, compared to Alternatives 2 and 3. Based on previous excavation activities at the site, it has been shown that the removal of impacted soil and LNAPL, along with MNA, will cause a decrease in dissolved-phase COC concentrations in the area. It is expected that groundwater compliance will be met through MNA. Because Alternative 4 removes the greatest quantity of impacted soil, it is expected to have the shortest remediation duration. Alternative 5 ranks higher than Alternative 1 because ISS will create a surface barrier where impacted soil remains.

Alternatives 2 and 3 only address potentially mobile LNAPL from groundwater. It is expected that groundwater compliance will be met through MNA, but will take longer to achieve compared to Alternative 1. Alternative 2 was rated lower compared to Alternatives 1 and 3 because impacted soil will remain onsite and groundwater compliance will be met through pump and treat through time.

Based on the degree of permanence, the following alternatives are ranked from highest to lowest:

- *Highest: Alternative 4*. This is the most permanent alternative based on the complete removal of soil with COC concentrations above CULs. Environmental covenants would not be required.

- *Medium: Alternative 5 and Alternative 1*. These are less permanent alternatives compared to Alternative 4 because some soil with COC concentrations above CULs would remain in place. Environmental covenants would be required for any soil left in place with COC concentrations above CULs.

- *Lowest: Alternative 3 and Alternative 2*. These alternatives are the least permanent because onsite dissolved-phase groundwater COC concentrations, soil COC concentrations, and potentially non-mobile LNAPL would remain in place. Protectiveness would be addressed through environmental covenants.

7.6.3 Cost

Cost refers to the cost of implementing the alternative, including construction, net present value of any long-term costs, and agency oversight costs that are cost recoverable. Long-term costs include operation and maintenance, monitoring, equipment replacement costs, and the cost of maintaining institutional controls (Ecology 2007).

Order of magnitude costs were developed for all five alternatives. The significant assumptions made to develop the cost estimates for the five alternatives are listed below. Alternative 1 is the least expensive alternative based on the excavation of known impacts in the area of DB-2. The area is shown on Figure 7-1. The cost analysis is based on approximately 3,000 to 5,800 CYs of material to be excavated and transported to an appropriate waste disposal facility. Long-term costs include continued groundwater monitoring at the Site coupled with an environmental covenant placed on the WSDOT stormwater line.

Costs associated with this alternative are the lowest compared to the other alternatives. The cost for Alternative 1 is estimated to range from approximately $1,001,000 to $2,336,000. A cost estimate for this alternative is summarized in Table 7-2.

Alternative 2 is the third least expensive alternative and assumes a groundwater extraction system with six extraction wells installed on 40-foot centers. Wells will be advanced to a depth of approximately 15 to 20 feet bgs (maximum historical excavation depth) at pumping rates of approximately 3 to 5 gpm. Installation costs for the groundwater extraction system include drilling, well construction, soil disposal, conveyance piping, and trenching. System costs include electrical connections, system controls, system building, and groundwater pumping and treatment equipment. Long-term costs include 10 years of continued site-wide groundwater monitoring, utility costs, and operation and maintenance of the treatment system. The estimated cost for Alternative 2 ranges from approximately $2,548,000 to $3,796,000. A cost estimate for this alternative is summarized in Table 7-3.

Alternative 3 is the fourth least expensive alternative and assumes the installation of an approximately 280-foot groundwater extraction trench. Installation costs for the groundwater extraction trench system include specialized trenching equipment, soil disposal, permeable backfill, and conveyance piping. System costs include electrical connections, system controls, system building, and groundwater pumping and treatment equipment. Long-term costs include 10 years of continued site-wide groundwater monitoring, utility costs, and operation and maintenance of the treatment system. The estimated cost for Alternative 3 ranges from approximately $2,834,000 to $4,225,000. A cost estimate for this alternative is summarized in Table 7-4.

Alternative 4 is the most expensive alternative based on the excavation of known impacts in the area of DB-2 and near the WSDOT stormwater line. The area is shown on Figure 7-4**.** Costs associated with this alternative include the excavation costs from Alternative 1 in addition to excavation activities near the WSDOT stormwater line. Soil analytical results in the vicinity of the WSDOT stormwater line indicate that excavations would extend to approximately 8 or 9 feet bgs. In order to create a reasonable estimate for the FS, and based on previous experiences at the Site, it was estimated that excavations would extend approximately 10 to 15 feet bgs. It is estimated that approximately 7,990 cy of material will be excavated and transported to an appropriate waste disposal facility. Excavation near the WSDOT stormwater line will require shoring and dewatering. Long-term costs include continued groundwater monitoring at the Site. The cost for implementing Alternative 4 is estimated to range from approximately $5,462,000 to $8,615,000. The majority of costs associated with this remedial alternative stem from shoring and dewatering requirements near the WSDOT stormwater line. Of the $5,462,000 to $8,615,000 approximate cost for Alternative 4, $4,524,000 to $6,344,000 of the total cost is associated with the WSDOT stormwater line. A cost estimate for this alternative is summarized in Table 7-5.

Alternative 5 is the second least expensive alternative based on the excavation of known impacts in the area of DB-2 and implementing ISS for impacts near the WSDOT stormwater line. The area is shown on Figure

7-5. To complete ISS activities near the WSDOT stormwater line, it is estimated that approximately 710 cy of material will be excavated, mixed with a binding agent, and used as backfill. Long-term costs include continued groundwater monitoring at the Site. It is assumed that costs for excavation of impacted soil near DB-2 will cost the same as Alternative 1. Long-term costs include continued groundwater monitoring and implementing an environmental covenant at the Site. The total cost of Alternative 5 is estimated to be approximately $1,631,000 to $3,309,000. A cost estimate for this alternative is summarized in Table 7-6.

A comparison of cost for Alternatives 1 through Alternative 5 is listed below in Table 7-7.

Table 7-7. Cost Comparison of Remedial Alternatives

Remedial Alternative No.	Remedial Alternative	Total Lower Cost ($)	Total Upper Cost ($)
1	Excavation and MNA with Environmental Covenants	$1,001,000	$2,366,000
2	Groundwater Containment System Using Groundwater Extraction Wells, and Environmental Covenants	$2,548,000	$3,796,000
3	Groundwater Containment System Using Groundwater Extraction Trench, and Environmental Covenants	$2,834,000	$4,225,000
4	Excavation with Monitored Natural Attenuation	$5,462,000	$8,615,000
5	Excavation with Monitored Natural Attenuation and In-Situ Solidification with Environmental Covenants	$1,631,000	$3,309,000

Based on the degree of cost, the following alternatives are ranked from highest (least expensive) to lowest (most expensive):

- *Highest: Alternative 1*. This is the least expensive alternative. Implementation of this remedial alternative involves DB-2 excavation, environmental covenants, and MNA.

- *Medium: Alternative 5, Alternative 2, and Alternative 3*. These alternatives are more expensive to implement than Alternative, but less expensive than Alternative 4.

- Lowest: Alternative 4. This is the most expensive alternative and includes excavation of DB-2 and the WSDOT stormwater line. The cost of this alternative is significantly higher due to the extensive dewatering and shoring required for the WSDOT stormwater line.

7.6.4 Long-Term Effectiveness

The following criteria will be considered when evaluating the long-term effectiveness of each alternative:

- Degree of certainty that the alternative will be successful.
- How reliable the alternative will be while the hazardous substances remain onsite and exceed CULs.
- Magnitude of residual risk associated with the alternative.
- Effectiveness of controls that are in place to manage treatment residues or remaining wastes.

MTCA provides guidance for determining long-term effectiveness, as presented below (in descending order [Ecology 2007]):

1. Destruction or detoxification
2. Immobilization or solidification
3. Onsite or offsite disposal at an appropriate waste disposal facility
4. Onsite isolation or containment with attendant engineering controls
5. Institutional controls and monitoring

Alternative 4 offers the highest degree of long-term effectiveness because this alternative removes the largest amount of impacted soil and LNAPL from the Site, thereby providing the greatest reduction in residual risk. It is expected that groundwater impacts will also be eliminated by removal of the source area and by MNA through time. Regular groundwater monitoring events will be used to minimize any additional residual risk.

Alternatives 1 and 5 are also expected to offer a high degree of long-term effectiveness because these alternatives remove impacted soil near DB-2. Impacted soil near the storm drain will remain in place; however, based on available groundwater data, it appears that impacts in the area have not affected downgradient interior monitoring or POC wells (as discussed in Section 3.3.1). Alternative 5 ranks higher than Alternative 1 because ISS will provide a surface barrier to prevent surface water infiltration, which would reduce the migration of impacts from soil to groundwater through leaching if that were occurring. Alternative 3 offers the second lowest degree of long-term effectiveness because residual risk at the site is reduced by removing LNAPL from groundwater. Impacted groundwater in the area will be treated through the reactive core mat while LNAPL will be collected using passive bailers or pumps. Alternative 2 offers the least amount of long-term effectiveness. The groundwater pump and treat system offers a method for containing and treating impacted groundwater; however, impacted soil and non-mobile LNAPL may remain onsite and institutional controls will be used to reduce residual risks.

Based on the degree of long-term effectiveness, the following alternatives are ranked from highest to lowest:

- *Highest: Alternative 4*. This alternative offers the highest degree of long-term effectiveness based on complete removal of soil with COC concentrations above CULs. Environmental covenants would not be required for this alternative and groundwater compliance sampling would only be required for a short duration.

- *Medium: Alternative 5 and Alternative 1*. These alternatives provide a high degree of long-term effectiveness but given MTCA's preference for disposal over containment, these alternatives were ranked lower than Alternative 4 because some soil with COC concentrations above CULs would remain in place. Environmental covenants would be required for any soil left in place with COC concentrations above CULs.

- *Lowest: Alternative 3 and Alternative 2*. These alternatives are the least effective over the long term because onsite dissolved-phase groundwater COC concentrations, soil COC concentrations, and non-mobile LNAPL may remain in place and protectiveness would be addressed through environmental covenants.

7.6.5 Management of Short-Term Risks

Management of short-term risks relates to the risk to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures to control the risk (Ecology 2007).

Alternative 1 has the third lowest short-term risk. Removal of approximately 3,000 to 5,800 cy of excavated material for transport and offsite disposal involves considerable short-term risk. The excavation of DB-2 to below the groundwater table will also pose short-term risk to construction workers, and potential releases to surface water through flooding or mismanagement of groundwater. Onsite decontamination procedures must be implemented to reduce short-term risk to site workers and the public.

Alternative 2 has the lowest volume of soil and groundwater removed during remedial system construction and implementation. Only a minimal amount of soil associated with drilling and conveyance piping and trenching will be removed and disposed of offsite. During system operation, minimal short-term risk will be associated with groundwater extraction and treatment. Based on the short-term risks, Alternative 2 has the highest rating with the lowest short-term risk.

Alternative 3 has the second lowest short-term risk. Excavated soil associated with trenching activities will be removed from the site and transported to a disposal facility. During system operation, minimal short-term risk will be associated with groundwater extraction and treatment.

Alternative 4 has the highest short-term risk. Since the majority of the WSDOT stormwater line is located below the water table, potential risks involve floating of the WSDOT stormwater line once the weight of the soil and groundwater is relieved from the top of the line. Floating of the line could result in injury or death to workers caused by crushing or engulfment by heaving sands. Floating the line could also result in the discharge of potentially impacted groundwater to Puget Sound as it may enter the ruptured line and flows through the remaining open line toward Puget Sound. Assuming the WSDOT stormwater line does not float, a substantial risk to Site workers must be controlled through shoring and dewatering of the WSDOT stormwater line. The sheet pile design for this alternative is conservative, taking into account the worst case scenario where soil is removed to a depth of 10 to 15 feet bgs. In order to protect against the geotechnical concerns of slope stability of the land area between the Site and Point Edwards, larger, deeper sheets were utilized. The type and length of sheet piles required for cutting off groundwater, and protecting against slope failure in this area are not conventional, are expensive, and may require severing the WSDOT stormwater line during installation. Significant engineering design will be required to ensure that the shoring and dewatering infrastructure is sufficient for implementation. Once sheet piles are installed, the dewatering system will potentially handle more than 1 million gallons of water prior to treatment and discharge to the stormwater system, averaging approximately 86,000 gallons per day, which exceeds general construction NPDES permits by 60,000 gallons per day. This alternative is the only alternative that would require workers to enter an excavation to remove soils by manual means. Furthermore the excavation activities themselves could rupture the line. If not properly controlled, this rupture could allow impacted groundwater to enter the stormwater line and eventually discharge to Puget Sound. To control these risks, certain measures may need to be taken. For example, the segment of the WSDOT stormwater line running through the Unocal property may need to be isolated in order to seal the line from both ends to ensure impacted groundwater does not enter the line, potentially discharging to Puget Sound, and keep Puget Sound from flowing up the line and entering the excavation. Additionally, it may be necessary to build and maintain, a stormwater diversion system to route stormwater around the construction site during excavation activities.

This activity offers greater short term risk in terms of direct contact with Site contaminants and workers safety through injury from engulfment from heaving sands, crushing from floating of the stormwater line. In addition, this alternative involves removing and transporting and additional 7,990 cy (or approximately 400 truck and trailer loads) of soil to an offsite waste disposal facility.

Alternative 5 has the second highest short-term risk. In addition to the removal of approximately 3,000 to 5,800 cy of soil for transportation and offsite disposal, impacted soil will be excavated and mixed in situ surrounding the WSDOT stormwater line. The in-situ mixing activities pose a moderate short-term risk and will require onsite decontamination.

Based on the management of short-term risks, the following alternatives are ranked from highest (lowest short-term risk) to lowest (highest short-term risk):

- *Highest (lowest short-term risk): Alternative 2:* This alternative has the lowest volume of soil and groundwater removed during remedial system construction and implementation and offers the highest degree of management of short term risk.

- *Medium: Alternative 3, Alternative 1, and Alternative 5:* These alternatives include moderate volumes of soil and groundwater to be removed and/or handled during remedial implementation and offer medium degree of management of short term risk.

- *Lowest (highest short-term risk): Alternative 4:* This alternative includes activities which could potentially rupture or float the WSDOT stormwater line, produce exorbitant amount of dewatering water, and put Site workers in direct contact with Site contaminants and at risk of being crushed or engulfed, offers lowest degree of management of short term risk.

7.6.6 Technical and Administrative Implementability

Technical and administrative implementability relates to the ability of the alternative to be implemented including whether the alternative is technically possible, availability of necessary off-site facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity, monitoring requirements, access for construction operations and monitoring, and integration with existing facility operations and other current or potential remedial actions (Ecology 2007).

All five alternatives require long-term groundwater monitoring; therefore, rating the technical and administrative implementability was based the amount of work required to install and operate the alternative.

Alternative 1 is the most implementable in terms of technical and administrative complexities. Soil removal has occurred at the Site and has been shown to reduce groundwater COCs to below CULs. The excavation of DB-2 can be accomplished without extensive dewatering or shoring, and minimal long-term maintenance is only required for the environmental covenant.

Alternative 2 is the second most implementable in terms of technical and administrative complexities. Pump and treat remediation systems have a history of effective implementation at many remediation sites. The operation and maintenance of the remediation equipment reduces the overall rating of implementability and increases the administrative complexity compared to Alternative 1.

Alternative 3 is the fourth most implementable in terms of technical and administrative complexities. Pump and treat systems using an interceptor trench have a history of effective implementation at remediation sites. However, the installation of the trench coupled with backfill material placement increases the technical implementation of this remedial alternative compared to Alternative 2. In addition, operation and maintenance of the remediation equipment reduces the overall rating of implementability and increases the administrative complexity.

Alternative 4 is the least implementable in terms of technical and administrative complexities. The issues that created the highest short-term risk for Alternative 4, as described in detail in Section 7.6.5, also make this alternative the least implementable. Since the majority of the WSDOT stormwater line is located below the water table, extensive dewatering and sheet piling would be required to implement this alternative. The sheet pile design for this alternative is conservative, taking into account the worst case scenario where soil is removed to a depth of 10 to 15 feet bgs. In order to protect against the geotechnical concerns of slope stability of the land area between the Site and Point Edwards, larger, deeper sheets were utilized. The type and length of sheet piles required for cutting off groundwater, and protecting against slope failure in this area are not conventional, are expensive, and may require severing the WSDOT stormwater line during installation. Significant engineering design will be required to ensure that the shoring and dewatering infrastructure is sufficient for implementation. Once sheet piles are installed, the dewatering system will potentially handle more than 1 million gallons of water prior to treatment and discharge to the stormwater system, averaging approximately 86,000 gallons per day, which exceeds general construction NPDES permits by 60,000 gallons per day. This alternative is the only alternative that would require workers to enter an excavation to remove soils by manual means. Furthermore the excavation activities themselves could rupture the line. If not properly controlled, this rupture could allow impacted groundwater to enter the stormwater line and eventually discharge to Puget Sound. To control these risks, certain measures may need to be taken. For example, the segment of the WSDOT stormwater line running through the Unocal property may need to be isolated in order to seal the line from both ends to ensure impacted groundwater does not enter the line, potentially discharging to Puget Sound, and keep Puget Sound from flowing up the line and entering the excavation. Additionally, it may be necessary to build and maintain, a stormwater diversion system to route stormwater around the construction site during excavation activities. In addition, this alternative involves removing and transporting approximately 8,000 cy of soil to an offsite disposal facility.

Alternative 5 is the third most implementable in terms of technical and administrative complexities. Technical complexities involved in ISS of soil above the WSDOT stormwater line are related to specialized mixing equipment and field verification. However, during implementation of this technology, extensive dewatering and shoring will not be required. This alternative would result in long-term administrative and implementability issues. ISS would provide more permanent protection against direct contact with impacted soil and limit the potential vapor intrusion risk, but would result in a semi-permanent barrier above an aging stormwater line. If the WSDOT stormwater line was in need of repair, this stabilized soil would offer a barrier to unearthing the pipe. ISS offers the same protection as environmental covenants, but results in a long-term impediment to accessing the stormwater infrastructure.

Based on the extent and complexity of earthwork and construction activities, the technical and administrative implementability of each alternative is ranked below from highest to lowest:

- *Highest: Alternative 1.* This alternative is the most implementable and offers the highest degree of technical and administrative implementability.

- *Medium: Alternative 3, Alternative 2, and Alternative 5.* Operation and maintenance of remediation equipment or implementation of the specialized technology in these alternatives offer medium degree of technical and administrative implementability.

- *Lowest: Alternative 4.* This alternative includes extensive dewatering and shoring and offers lowest degree of technical and administrative implementability.

7.6.7 Public Concerns

Public concerns, if any, will be identified through the public participation steps planned by Ecology for this project.

7.6.8 Disproportionate Cost Analysis Preliminary Summary

Based on the qualitative and quantitative assessment discussed in Section 7.6 and presented in Figure 7-1, Remedial Alternative 1 offers the best solution for the criteria considered: protectiveness, permanence, long-term effectiveness, management of short-term risks, and technical and administrative implementability. Remedial Alternative 1 has an average qualitative score of 2.5 (1 being the best, 5 being the worst) which was the lowest (best) of the 5 alternatives. Remedial Alternative 1 offers the median level of benefit in most criteria, but when compared to the similar levels of benefit versus the cost to implement it presents the best solution. For example, when comparing the cost of Remedial Alternative 4, and the area in which it covers, to the cost of the remedial efforts conducted to date over the remaining 22 acre Site, it is approximately 19 times more expensive per acre, or represents approximately 1 percent of the land mass for 20 to 30 percent of the total remedial cost for the Lower Yard. When considering that other remedial alternatives (Alternatives 1, 2, 3, and 5) offer an equal level benefit at a lower cost, it outweighs the benefit of permanence. WAC 173-340-360 states that the comparison of benefits and costs are not just quantitative but qualitative as well. Ecology has the discretion to favor or disfavor qualitative benefits, but where two or more alternatives offer equal benefits, the department shall select the less costly alternative. Alternative 1 offers an equal level of benefits for a lower cost.

7.7 Provide for a Reasonable Restoration Timeframe

WAC 173-340-360(4) contains guidance for evaluating reasonable restoration timeframes. Preference is given for alternatives that can be implemented in a shorter period of time if other factors such as permanence and costs are equal. Relative restoration timeframes are discussed below. A precise analysis to project expected restoration timeframes for the five alternatives would require site-specific bench and/or pilot studies.

Alternative 1 is expected to have a short restoration timeframe (1 to 3 years) because it is expected that the removal of impacted soil and MNA will remediate groundwater to below CULs. Previous excavation work at the Site has shown that removal of impacted soil in the area of DB2 will result in a rapid decrease of dissolved-phase COC concentrations in the area. Impacted soil near the storm drain will remain in place; however, historical groundwater data indicate that the remaining COC concentrations in soil near the storm drain line do not impact downgradient interior monitoring or POC wells (as discussed in Section 3.3.1). An environmental covenant would be put in place to protect human health and environment against any residual risks associated with soil contamination adjacent to the storm drain.

Alternative 2 is expected to have long restoration timeframe (15-20 years) because the groundwater pump and treat system may not directly address residual petroleum hydrocarbon-related soil impacts. Protection of human health and the environment against risks associated with soil contaminants will be achieved through groundwater containment and environmental covenants.

Alternative 3 is expected to have a long restoration timeframe (15 to 20 years) because the trench recovery system may not directly address residual petroleum hydrocarbon-related soil impacts. Protection of human health and the environment against risks associated with soil contaminants will be achieved through groundwater containment.

Alternative 4 is expected to have a short restoration timeframe (1 to 3 years) because the removal of petroleum hydrocarbon-related impacts to soil coupled with MNA will remediate groundwater to below CULs. Previous excavation work at the Site has shown that removal of impacted soil has resulted in a decrease in dissolved-phase COC concentrations in the area. As of the date of this FS Report, POC wells (except MW-510) have been in compliance with their respective CULs for six consecutive events.

Alternative 5 is expected to have a short restoration timeframe (1 to 3 years) because it is expected that the removal of impacted soil and implementation of ISS coupled with MNA will remediate groundwater to below CULs. Previous excavation work at the Site has shown that removal of impacted soil has resulted in a decrease in dissolved-phase COC concentrations in the area. Impacted soil near the storm drain will remain in place; however, based on available groundwater data, it appears that impacts in the area have not affected downgradient interior monitoring or POC wells (as discussed in Section 3.3.1). An environmental covenant would be put in place to protect human health and environment against any residual risks associated with soil contamination adjacent to the storm drain

7.8 Consider Community Concerns

Ecology has addressed community concerns throughout the history of this project. Ecology will consider additional issues or concerns as part of the cleanup action selection process, per WAC 173-340-600. Public comments on the project and this FS Report will be solicited from the community during the formal comment period, following Ecology input. Common community concerns include noise and traffic, short- and long-term risks, and timeframe of any proposed cleanup actions.

7.9 Expectations for Cleanup Action Alternatives

WAC 173-340-370 outlines Ecology’s expectations for the development of alternatives and the selection of cleanup actions.

Each of the Expectation Criteria is described in more detail below:

7.9.1 Waste/Hazardous Substances Treatment

Ecology expects that treatment technologies will be used for sites that contain liquid wastes, areas impacted with high concentrations of hazardous substances, highly mobile materials, and/or discrete areas of hazardous substances (Ecology 2007).

For Alternative 1, 4, and 5 impacted soils and LNAPL will be excavated and removed from the Site and transported to an appropriate waste disposal facility. Groundwater pumped as part of the excavation dewatering strategy will be treated onsite and disposed of under a NPDES permit.

For Alternative 2, only minimal volumes of soil related to system trenching and extraction well installation will be removed from the Site. Groundwater and LNAPL collected from the pump and treat system will be sent to an onsite treatment system, where LNAPL will be recovered, stored, and eventually disposed of at an appropriate waste disposal facility. Treated groundwater will be discharged to DB-2 or Willow Creek under a NPDES permit or to a sanitary sewer under an appropriate discharge permit.

7.9.2 For Alternative 3, impacted soil and LNAPL excavated during trenching activities will be removed from the Site and transported to an appropriate waste disposal facility. The trench will contain five groundwater/ LNAPL recovery sumps. Groundwater and LNAPL will be collected from the trench and sent to an onsite system for treatment, where LNAPL will be recovered, stored, and eventually disposed of at an appropriate waste disposal facility. Treated groundwater will be discharged to DB-2 or Willow Creek under a NPDES permit or to a sanitary sewer under the appropriate discharge permit.Minimization of Long-Term Management at Small Sites

Ecology expects to minimize the need for long-term management of contaminated materials at sites containing small volumes of hazardous substances by destroying, detoxifying, and/or removing these substances to concentrations below CULs (Ecology 2007).

This expectation does not apply to this Site, due to the large size of the Site.

7.9.3 Use of Engineering Controls at Large Sites

Per WAC 173-340-37(3), Ecology recognizes the need to use engineering controls, such as containment, for sites or portions of sites that contain large volumes of materials with relatively low levels of hazardous substances where treatment is impracticable.

Alternative 1 proposes to remove impacted soil and LNAPL through excavation near DB-2. Following the implementation of this alternative, the need for engineering controls will be minimal. Previous excavation work at the Site has shown that removal of impacted soil has resulted in a decrease in dissolved-phase COC concentrations in the area. Regular groundwater monitoring events will continue under this alternative to monitor compliance at POC wells. An environmental covenant will be put in place to protect human health and environment against any residual risks associated with soil contamination adjacent to the storm drain. Based on available groundwater data, impacts in the area have not affected downgradient interior monitoring or POC wells (as discussed in Section 3.3.1).

Alternative 2 proposes to use groundwater containment to control the migration of hazardous substances. Groundwater and LNAPL collected from the pump and treat system will be sent to an onsite system for treatment, where LNAPL will be recovered, stored, and eventually disposed of at an appropriate waste disposal facility. Treated groundwater will be discharged to DB-2 or Willow Creek. Regular groundwater monitoring events will continue under this alternative to monitor compliance at POC wells.

Alternative 3 proposes to use groundwater containment to control the migration of hazardous substances through a groundwater collection trench. Groundwater and LNAPL will be removed from the collection trench through a series of collection sumps and sent to the onsite treatment system. Treated groundwater will be discharged to the appropriately permitted discharge location (DB-2 or Willow Creek). Regular groundwater monitoring events will continue under this alternative to monitor compliance at POC wells.

Alternative 4 proposes to remove impacted soil and LNAPL through excavation near DB-2 and the WSDOT stormwater line. Following the implementation of this alternative, the need for engineering controls will be minimal. Previous excavation work at the Site has shown that removal of impacted soil has resulted in a decrease in dissolved-phase COC concentrations in the area. Regular groundwater monitoring events will continue under this alternative to monitor compliance at POC wells. Under Alternative 4, petroleum hydrocarbon-related impacts to soil will be removed in the vicinity of the WSDOT stormwater line and DB-2.

Alternative 5 proposes to remove impacted soil and LNAPL through excavation near DB-2 and to implement ISS near the WSDOT stormwater line. Following the implementation of this alternative, the need for engineering controls will be minimal. Previous excavation work at the Site has shown that removal of impacted soil has resulted in a decrease of dissolved-phase COC concentrations in the area. ISS will minimize surface water infiltration, which will decrease the possibility of offsite migration; however, based on available groundwater data, it appears that impacts adjacent to the WSDOT stormwater line have not affected downgradient interior monitoring or POC wells (as discussed in Section 3.3.1). Regular groundwater monitoring events will continue under this alternative to monitor compliance at POC wells. An environmental covenant will be put in place protect human health and environment against any residual risks associated with soil contamination adjacent to the storm drain.

7.9.4 Minimize Stormwater Contamination and Offsite Migration

To minimize the potential for migration of hazardous substances, Ecology expects that active measures will be taken to prevent precipitation and subsequent runoff from coming into contact with impacted soil and waste materials. When such measures are impracticable, such as during active cleanup, Ecology expects that site runoff will be contained and treated prior to release from the Site (Ecology 2007).

For all alternatives, during excavation and construction activities, standard engineering controls and construction techniques will be applied to avoid stormwater contamination and offsite migration. This will be addressed through standard best practices for runoff control.

For Alternative 1, following excavation, it is expected that removal of impacted soil and LNAPL in the area of DB-2 will reduce the risk of offsite migration due to stormwater infiltration. Previous excavation work at the Site has shown that removal of impacted soil has resulted in a decrease in dissolved-phase COC concentrations in the area. Impacted soil adjacent to the WSDOT stormwater line will remain in place; however, based on available groundwater data, it appears that impacts adjacent to the WSDOT stormwater line have not affected downgradient interior monitoring or POC wells (as discussed in Section 3.3.1). Regular groundwater monitoring events will continue under this alternative.

Alternative 2 and 3 propose to use groundwater containment to control the migration of hazardous substances. Groundwater and LNAPL collected from the pump and treat system will be sent to an onsite system for treatment. In the system, LNAPL will be recovered, stored, and eventually disposed of at an appropriate waste disposal facility. Treated groundwater will be discharged to DB-2 or Willow Creek. Regular groundwater monitoring events will continue under this alternative to monitor compliance at POC wells.

For Alternative 4, following excavation, it is expected that removal of impacted soil and LNAPL in the area of DB-2 and adjacent to the WSDOT stormwater line will reduce the risk of offsite migration due to stormwater infiltration. This alternative, however, offers the highest potential of short-term risk to discharge contaminated water to surface water. If the stormwater line were to float or split during construction, a direct conduit to Puget Sound would be available through the remaining open stormwater line, or as overland flow. Also, the calculated dewatering volumes would result in a surplus of dewatering water that must be stored onsite and treated for discharge. Regular groundwater monitoring events will continue under this alternative.

Alternative 5 proposes to remove impacted soil and LNAPL through excavation near DB-2 and to implement ISS near the WSDOT stormwater line. It is expected that the removal of impacted soil and LNAPL in the area of DB-2 will reduce the risk of offsite migration due to stormwater infiltration. Previous excavation work at the Site has shown that removal of impacted soil has resulted in a decrease in dissolved-phase COC concentrations in the area. It is expected that ISS will minimize surface water infiltration, which will decrease the possibility of offsite migration. It should be noted; however, based on available groundwater data, it appears that impacts adjacent to the WSDOT stormwater line have not affected downgradient interior monitoring or POC wells (as discussed in Section 3.3.1). Regular groundwater monitoring events will continue under this alternative to monitor compliance at POC wells.

7.9.5 Minimize Direct Contact and Migration by Consolidating Hazardous Substances

When hazardous substances remain onsite at concentrations that exceed CULs, Ecology expects those hazardous substances will be consolidated to the maximum extent practicable where needed to minimize the potential for direct contact and migration of hazardous substances (Ecology 2007).

Large volumes of impacted soil, product, and groundwater have been removed through prior Interim Actions. Additional soil, product, and groundwater will be removed as part of all remedial alternatives.

Under Alternative 1, remaining impacted soil will be limited to an area adjacent to the WSDOT stormwater line; therefore, consolidation will not be necessary. An environmental covenant will be put in place to minimize the potential of direct contact should future earthwork activities occur in this area.

Under Alternatives 2 and 3, impacted soil will remain in the areas of DB-2 and the WSDOT stormwater line. However, groundwater containment will be used to control offsite migration; therefore, consolidation will not be necessary. Groundwater will be collected and treated onsite. An environmental covenant will be put in place to minimize the potential of direct contact should future earthwork activities occur in these areas.

Under Alternative 4, all impacted soil will be removed from the area of DB-2 and the WSDOT stormwater line; therefore, consolidation will not be necessary.

Under Alternative 5, the only remaining impacted soil will be in the area adjacent to the WSDOT stormwater line; therefore, consolidation will not be necessary. An environmental covenant will be put in place to minimize the potential of direct contact during future earthwork activities in this area.

7.9.6 Avoid Surface Water Contamination through Control of Runoff and Control of Groundwater Discharge or Migration

Ecology expects that for facilities adjacent to a surface water body, active measures will be taken to prevent or minimize releases to surface water via surface runoff and groundwater discharges in excess of CULs. Ecology expects that dilution will not be the sole method for demonstrating compliance with cleanup standards in these instances (Ecology 2007).

All the alternatives protect against surface water contamination through the control of runoff since IHSs are generally not present at the surface of the Site. Surface water runoff is further controlled by the stormwater infrastructure and DB-1 and DB-2.

Under Alternative 1, releases to surface water through groundwater discharge are not expected because removal of impacted soil and LNAPL in the area of DB-2, along with MNA, will decrease dissolved-phase COC concentrations and eliminate the soil to groundwater leaching pathway. Based on available groundwater data, it appears that impacts adjacent to the WSDOT stormwater line have not affected downgradient interior monitoring or POC wells (as discussed in Section 3.3.1). Regular groundwater monitoring events will continue under this alternative to monitor compliance at POC wells.

Under Alternatives 2 and 3, groundwater containment will be used to control offsite groundwater migration to surface water. Regular groundwater monitoring events will continue under this alternative to monitor compliance at POC wells. Groundwater will be treated with the onsite remediation system prior to discharge to the stormwater system under a NPDES permit, or to the sanitary sewer under appropriate Ecology permits.

Under Alternative 4, releases to surface water through groundwater discharge are not expected because removal of impacted soil and LNAPL in the area of DB-2 and adjacent to the WSDOT stormwater line, along with MNA, will decrease dissolved-phase COC concentrations and eliminate the soil to groundwater leaching pathway. Based on available groundwater data, it appears that impacts adjacent to the WSDOT stormwater line have not affected downgradient interior monitoring or POC wells (as discussed in Section 3.3.1). Regular groundwater monitoring events will continue under this alternative to monitor compliance at POC wells.

Under Alternative 5, releases to surface water through groundwater discharge are not expected because removal of impacted soil and LNAPL in the area of DB-2, along with MNA, will decrease dissolved-phase COC concentrations and eliminate the soil to groundwater leaching pathway. Based on available groundwater data, it appears that impacts adjacent to the WSDOT stormwater line have not affected downgradient interior monitoring or POC wells (as discussed in Section 3.3.1). Regular groundwater monitoring events will continue under this alternative to monitor compliance at POC wells.

7.9.7 Use of Natural Attenuation

Ecology (2007) expects that natural attenuation of hazardous substances may be appropriate at sites where:

- Source control has been conducted to the maximum extent practicable.
- Impacts that remain onsite during the restoration timeframe do not pose an unacceptable threat to human health or the environment.
- Site data show that natural biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the site.
- Appropriate monitoring requirements are conducted to ensure that the natural attenuation process is taking place and that human health and the environment are protected.

Analytical and biogeochemical data indicate that natural attenuation is occurring at the Site and is a component of all the alternatives. Regular groundwater monitoring events would continue under each alternative and will be designed, in part, to evaluate the ongoing rate of natural attenuation throughout the remedial action period.

Selected cleanup actions will not result in significantly greater overall threat to human health and the environment compared to other alternatives.

All of the alternatives are designed to minimize threats to human health and the environment, both during initial remedial actions and during the operation and maintenance/groundwater monitoring period.

7.10 Implementation

Together with current and available construction and scientific accepted practices, a calibrated groundwater flow model for the Site (Appendix G) was used to evaluate the selected five potential remediation scenarios To accomplish this, internal boundary conditions such as extraction wells, high hydraulic conductivity zones, or vertical flow barriers were added to the Site groundwater flow model (Appendix G) as necessary to simulate each alternative. After the internal boundary conditions were added, the Site groundwater flow model (Appendix G) was run at steady-state conditions to estimate average flow rates and predict resulting changes in groundwater flow patterns. External boundary conditions were also modified during evaluation of the potential remedial alternatives to predict potential groundwater flow rates and patterns that may occur under high tide conditions and extreme rainfall events. High tides were simulated by raising the assigned constant head elevation by 5 feet. The extreme rainfall event incorporated both a high tide condition and a doubling of assigned recharge rates.

To evaluate the effectiveness of the hydraulic containment alternatives (i.e., Alternatives 2 and 3), the Site groundwater flow model (Appendix G) was used to estimate the extent of the capture zone resulting from hypothetical groundwater extraction. A “capture zone” is defined as the spatial area that contributes groundwater to the pumping system; in other words, a capture zone is an area of hydraulic containment. The objective of these simulations was to adjust the locations of the simulated extraction wells or interceptor trenches, and to adjust the simulated groundwater extraction rates until the shape of the predicted capture zone fully encompassed the target remediation area.

For the soil excavation area alternatives (i.e., Alternatives 1, 4, and 5), the Site groundwater flow model (Appendix G) was used to estimate the construction dewatering rates that would be required during remediation.

The following subsections describe the evaluation of these potential remediation scenarios.

7.10.1 Remedial Alternative 1 – Excavation and Monitored Natural Attenuation with Environmental Covenants

Remedial Alternative 1 involves excavating remaining impacts below the water table nearDB-2 from the approximate area shown on Figure 7-1 using conventional soil excavation and construction dewatering equipment. As shown, it is theoretically possible to excavate the remaining impacts near DB-1 and DB-2 using a construction dewatering strategy that would require an average pumping rate of approximately 10 gpm. High tide or short-duration rainfall events may result in the need for excavation dewatering at an average rate of 23 gpm. Extensive shoring and sheet pile installation are not required for this remedial strategy. However, it is anticipated that a Joint Aquatic Resources Permit Application (JARPA) and accompanying Hydraulic Project Approval (HPA) through the USACE and the WDFW would be required. During excavation of soil near DB-2, Willow Creek would be coffer damned to prevent unplanned discharges to the creek and Puget Sound. Based on the groundwater model (Appendix G), standard best practices for dewatering using suction pumps or submersible pumps could be used. This approach was successfully implemented during previous soil excavations performed onsite.

This scenario is based on the following assumptions and limitations:

- The total depth of the construction dewatering system would need to be approximately 15 to 20 feet bgs.
- The intake portion of the construction dewatering system would need to extend to an elevation of approximately 0.25 foot mean sea level (msl) or lower (i.e., drain elevation).
- Faster dewatering rates during the initial phase of excavation may be required.
- The potential exists for pumping-induced saltwater intrusion to further degrade groundwater quality.

7.10.2 Remedial Alternative 2 – Groundwater Containment System Using Groundwater Extraction Wells, and Environmental Covenants

Remedial Alternative 2 involves hydraulic containment of remaining impacts near DB-2, as shown on Figure 7-2, using a series of six groundwater extraction wells. A conceptual layout of the six groundwater extraction wells and the resulting predicted capture zone is also shown on Figure 7-2. As shown, it is theoretically possible to hydraulically contain the remaining impacts near DB-1 and DB-2 using groundwater extraction wells pumping at a long-term average combined rate of approximately 3 to 5 gpm, which would include both high-tide conditions and short-duration rainfall events. The layout of the wells and the pumping footprint differs slightly from Alternative 3 to minimize well interference and ensure an adequate capture zone. The theoretical groundwater pumping rate would be verified through additional pilot testing. The theoretical groundwater pumping rate would be verified through additional pilot testing using a smaller section of interceptor trench. The 3 to 5 gpm total would require a groundwater treatment system that would include an OWS, air stripper, and series of granular activated carbon vessels. These system components would be designed to handle more than 5 gpm and would operate for 24 hours per day. System controls and automatic shutoff alarms would ensure that untreated groundwater will not discharge into Willow Creek. Based on the overall pumping rates and system components, a smaller overall system treatment capacity would be required for Alternative 2 compared to Alternative 3.

This scenario is based on the following assumptions and limitations:

- Extraction wells would need to be installed to total depths of approximately 15 to 20 feet bgs.

- The intake portion of the extraction wells would need to extend to an elevation of approximately 0.25 foot msl or lower (i.e., drain elevation).
- Extraction wells are 100% efficient.
- The potential exists for pumping-induced saltwater intrusion to further degrade groundwater quality.

7.10.3 Remedial Alternative 3 – Groundwater Containment System Using Groundwater Extraction Trench, and Environmental Covenants

Remedial Alternative 3 involves hydraulic containment of remaining impacts near DB-2 as shown on Figure 7-3 using a groundwater interceptor trench. A conceptual layout of the groundwater interceptor trench and the resulting predicted capture zone is also shown on Figure 7-3. As shown, it is theoretically possible to hydraulically contain the remaining impacts near DB-1 and DB-2 using a groundwater interceptor trench pumping at a long-term average rate of approximately 4 to 7 gpm, which would include both high-tide conditions and short-duration rainfall events. The location and layout of the trench requires a higher overall extraction rate compared to the groundwater extraction system using extraction wells. The layout of the trench, running along the northeast and northwest boundaries of DB-2, will minimize the likelihood of saltwater intrusion. The theoretical groundwater pumping rate would be verified through additional pilot testing using a smaller section of interceptor trench. The 4 to 7 gpm total would require a groundwater treatment system that would include an OWS, airstripper, and series of granular activated carbon vessels. These system components would be designed to handle more than 7 gpm and would operate for 24 hours per day. System controls and automatic shutoff alarms would ensure that untreated groundwater will not discharge into Willow Creek. Based on the greater volume of water to be treated from Alternative 3, system components would need to be sized to handle a larger total volume of water. This will in turn increase overall system costs compared to Alternative 2.

This scenario is based on the following assumptions and limitations:

- The interceptor trench would be installed to a total depth of approximately 15 to 20 feet bgs.
- The intake portion of the interceptor trench would need to extend to an elevation of approximately 0.25 foot msl or lower (i.e., drain elevation).
- The backfill of the interceptor trench would need to have a hydraulic conductivity of 1,000 feet per day.
- The potential exists for pumping-induced saltwater intrusion to further degrade groundwater quality.

7.10.4 Remedial Alternative 4 – Excavation with Monitored Natural Attenuation

Remedial Alternative 4 involves soil excavation in both the DB-2 and WSDOT stormwater line areas. Excavation in each of these areas is described in the following sections.

7.10.4.1 Soil Excavation Near DB-2

Remedial Alternative 4 involves excavating remaining impacts below the water table near DB-2 from the approximate area shown on Figure 7-4 using conventional soil excavation and construction dewatering equipment. As shown, it is theoretically possible to excavate the remaining impacts near DB-2 using a construction dewatering strategy that would require an average pumping rate of approximately 10 gpm. High-tide or short-duration rainfall events may result in the need for excavation dewatering at an average rate of 23 gpm. Again, it is anticipated that a JARPA and accompanying HPA through the USACE and the WDFW would be required. During excavation of soil near DB-2, Willow Creek would be coffer damned to prevent unplanned discharges to the creek and Puget Sound.

This scenario is based on the following assumptions and limitations:

- The total depth of the construction dewatering system would need to be approximately 15 to 20 feet bgs.
- The intake portion of the construction dewatering system would need to extend to an elevation of approximately 0.25 foot msl or lower (i.e., drain elevation).
- Faster dewatering rates during the initial phase of excavation may be required.
- The potential exists for pumping-induced saltwater intrusion to further degrade groundwater quality.

7.10.4.2 Soil Excavation Adjacent to the WSDOT Stormwater Line

In addition to the dewatering required for excavation of DB-2, Alternative 4 involves excavating the remaining impacts below the water table adjacent to the WSDOT stormwater line from the approximate area shown on Figure 7-4. In order to protect against the geotechnical concerns of slope stability of the land area between the Site and Point Edwards, unconventional, larger, deeper sheets were utilized, as well as conventional soil excavation equipment, and robust construction dewatering equipment. As described throughout the Section 7 and the subsequent subsections, it is theoretically possible to excavate the remaining impacts adjacent to the WSDOT stormwater line using sheet pile walls and a construction dewatering strategy that would require an average pumping rate of approximately 60 gpm. High-tide or short-duration rainfall events may result in the need for excavation dewatering at an average rate of 75 gpm. . During initial start-up, dewatering rates may be as high as 120 to 240 gpm until a steady state is achieved.

The excavation dewatering treatment system would require system components to handle a large volume of water (upwards of 80,000 to 300,000 gallons per day) through a series of flocculation tanks, settling tanks, and filtration prior to discharge to either DB-1 or Willow Creek. Considering typical flocculation and settling tanks hold approximately 21,000 gallons of water, it may take up to 15 tanks to store dewatering water daily.The large volumes of water and the discharge rate of more than 75 gpm increases the technical difficulty of excavation implementation compared to the other alternatives.

This scenario is based on the following assumptions and limitations:

- The total depth of the construction dewatering system would need to be approximately 30 feet bgs.
- The intake portion of the construction dewatering system would need to extend to an elevation of approximately -15 feet msl or lower (i.e., drain elevation).
- The excavation may encounter fill materials, beach deposits, and marsh deposits, and would terminate at the top of the Whidbey Formation.
- The hydraulic conductivity of the sheet pile walls is 0.003 foot per day.
- Faster dewatering rates during the initial phase of excavation may be required.
- The potential exists for pumping-induced saltwater intrusion to further degrade groundwater quality.

Excavation of the soil adjacent to the WSDOT stormwater line offers many additional logistic concerns. Sheet piling of the excavation area would be required, as stated above, to effectively dewater the excavation area.

7.10.5 Remedial Alternative 5: Excavation with Monitored Natural Attenuation and In-Situ Solidification with Environmental Covenants

Remedial Alternative 5 involves excavating the remaining impacts below the water table near DB-2 from the approximate area shown on Figure 7-5 using conventional soil excavation and construction dewatering equipment. As shown, it is theoretically possible to excavate the remaining impacts near DB-2 using a construction dewatering strategy that would require an average pumping rate of approximately 10 gpm. High-tide or short-duration rainfall events may result in the need for excavation dewatering at an average rate of 23 gpm. Construction of the ISS would not require extensive dewatering surrounding the WSDOT stormwater line.

This scenario is based on the following assumptions and limitations:

- The total depth of the construction dewatering system would need to be approximately 15 to 20 feet bgs.

- The intake portion of the construction dewatering system would need to extend to an elevation of approximately 0.25 foot msl or lower (i.e., drain elevation).

- Faster dewatering rates during the initial phase of excavation may be required.

- The potential exists for pumping-induced saltwater intrusion to further degrade groundwater quality near the DB-2 area.

8. Recommended Remedial Alternative

Based on minimum requirements for cleanup action alternatives as described by WAC 173-340-360 and the expectations for cleanup action alternatives as described by WAC 173-340-370, Remedial Alternatives 1, 4, and 5 provide more permanent solutions. Although Remedial Alternative 4 provides a more permanent solution compared to Remedial Alternatives 1 and 5, severe risks and complexities are associated with the technical implementation. The land area of WSDOT stormwater line impacts represents approximately 0.31 acre of the 22-acre Site. The total remediation cost for 0.31 acre is estimated to range between $4,524,000 and $6,344,000. This cost associated with the WSDOT stormwater line when compared to total costs of remedial efforts at the Site represents approximately 20 to 30 percent of the cost for 1 percent of land area, which makes the alternative impracticable and outweighs the benefit of permanence.

Remedial Alternative 5 offers a combination of permanence and protectiveness. Although it addresses direct contact and vapor intrusion concerns associated with contamination under the WSDOT stormwater line, it will create a concrete cap above the WSDOT stormwater line in the area of impacted soil adjacent to the line, making the line less accessible for repairs or any other emergency access to the line in the area if needed in the future.

Remedial Alternative 1 involves excavation of DB-2 coupled with an environmental covenant on the impacted soil adjacent to the WSDOT stormwater line. This alternative provides a permanent solution to the maximum extent practicable. It is reasonable to implement and has been proven effective at the Site in past. The soil excavation conducted onsite in the past has brought the groundwater in compliance for six quarters or more in all POC monitoring wells except one (MW-510), indicating that soil excavation has been successful as a remedy at this Site. This alternative will provide remediation and restoration within a shorter timeframe. Environmental covenants will help to protect human health and environment against any residual risks associated with soil contamination adjacent to the storm drain. Currently, groundwater downgradient of the WSDOT stormwater line is in compliance with groundwater CULs (as discussed in Section 3.3.1), indicating that the leaching to groundwater pathway is already protective and does not require further remediation to achieve CULs.

Based on the disproportionate cost analysis performed, Alternative 1 uses permanent solutions to the maximum extent practicable. The removal of impacted soil and LNAPL through excavation of the DB-2 area coupled with environmental covenant on the WSDOT stormwater line offers a high degree of protectiveness, permanence, and effectiveness. Addressing the soil impacts adjacent to the WSDOT stormwater line through excavation requires extensive dewatering and shoring. The additional costs associated with these activities ranges from $4,524,000 to $6,344,000 and represent a disproportionate cost to benefit ratio.

Remedial Alternative 1 offers an optimum balance of cleanup goals, regulatory requirements, restoration timeframes, protectiveness, management of public concerns, implementation, and certainty of success along with a relatively low cost to benefit ratio, and therefore recommend this alternative as the preferred alternative.

9. References

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Tables

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Table 2-1
Site Investigations and Remedial Actions Chronology
Chevron Environmental Management Company
Draft Feasibility Study Report
Former Unocal Edmonds Bulk Fuel Terminal
Edmonds, Washington

Year	Activity	Details	Contaminated Soils Removed (tons)	LNAPL Removed (gal)	Focus Site Area	Report	Author
1986	Phase 1 Site Assessment – GeoEngineers (1986)	• Soil, groundwater, and sediment sampling in the Lower Yard. • LNAPL detected in 10 of 27 wells. Thickness ranged from trace to 3.18 feet. Three separate LNAPL plumes were defined. • Depths to groundwater varied from 3 to 8 feet bgs. • Approximately 20,000 gallons of recoverable product are reported to be in the vicinity of the tidal basin.			Lower Yard	Background History Report Unocal Edmonds Bulk Fuel Terminal	Maul, Foster, and Alongi
1987-1991	Product Recovery Project – GeoEngineers (1987, 1988, 1989, 1991)	• Two product recovery systems installed, to the southeast of the tidal basin, and northwest of the facility oil/water separators. • Systems consist of recovery sumps and trenches with perforated drains. • Between May 1988 and September 1990, a total of approximately 7,500 gallons was recovered from RW-1. • RW-2 was never activated, but it is estimated that 1,000 gallons of recoverable petroleum product are located in the former RW-2 area.		7,500	Lower Yard	Background History Report Unocal Edmonds Bulk Fuel Terminal	Maul, Foster, and Alongi
1988	Subsurface Contamination Study, Upland Fuel Tank Area – GeoEngineers (1988)	• Subsurface contamination study to determine conditions within a portion of the Upper Yard. • Consisted of six soil borings, 12 hand auger borings, and installation of groundwater and vapor monitoring wells. • TPH in soil varied from non-detect (ND) to 12,000 milligrams per kilogram (mg/kg), consisting of primarily heavy end hydrocarbons. • Groundwater concentrations were ND for benzene, toluene, ethylbenzene and xylene (BTEX) except for one well with elevated benzene concentrations.			Upper Yard	Background History Report Unocal Edmonds Bulk Fuel Terminal	Maul, Foster, and Alongi
1988	Phase 1 Site Assessment, Detention Basin No. 1 – GeoEngineers (1988)	• Phase 1 assessment of DB-1, surface water, soil and tar samples collected for analysis. • TPH concentrations of the lake sediments and tar exceeded 100,000 mg/kg, ethylbenzene ranged from ND to 3.9 mg/kg, and total xylenes varied from 2 to over 1,000 mg/kg. • No volatile or semivolatile organic compounds were detected in water samples analyzed. TPH concentrations ranged from 560 to 930 µg/L.			Detention Basin No.1	Background History Report Unocal Edmonds Bulk Fuel Terminal	Maul, Foster, and Alongi

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Table 2-1
Site Investigations and Remedial Actions Chronology
Chevron Environmental Management Company
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Former Unocal Edmonds Bulk Fuel Terminal
Edmonds, Washington

Year	Activity	Details	Contaminated Soils Removed (tons)	LNAPL Removed (gal)	Focus Site Area	Report	Author
1989	Phase 2 Site Assessment, Detention Basin No. 1 – GeoEngineers (1989)	• Investigation to determine the possibility of contamination of groundwater by DB-1. • Installed three new monitoring wells and drilled exploratory borings along the northwest margin of the original limits of DB-1. • TPH in soil ranged from 65 to 360 mg/kg, TPH in groundwater varied from 0.84 to 1.8 milligrams per liter (mg/L). Benzene ranged from ND to 110 micrograms per liter (µg/L).			Detention Basin No.1	Background History Report Unocal Edmonds Bulk Fuel Terminal	Maul, Foster, and Alongi
1989	Site Contamination Assessment, Waste Soil Stockpile Area – GeoEngineers (1989)	• Purpose of the study was to evaluate the waste soil stockpile area (southeast Lower Yard) for subsurface contamination. • Five hand auger borings and one groundwater monitoring well installed. • Soil in stockpile was from the Unocal Station No. 5353 from 1980, and from Unocal Station No. 6211 from 1987. • TPH in soil varied from 510 to 6,300 mg/kg. TPH immediately below or adjacent to the stockpile ranged from ND to 100 mg/kg. The highest benzene concentration was 110 µg/kg.			Lower Yard	Background History Report Unocal Edmonds Bulk Fuel Terminal	Maul, Foster, and Alongi
1990	Site Contamination Study, Marine Diesel Spill – GeoEngineers (1990)	• On May 5, 1990, approximately 350 gallons of marine diesel fuel spilled in the Lower Yard. • Ten soil samples were analyzed for TPH, results ranged from 9 to 14,000 mg/kg. The highest concentrations were found beneath the aboveground pipe racks. Contamination was noted up to 2 to 3 feet bgs, and estimated to be about 100 cubic yards.			Lower Yard	Background History Report Unocal Edmonds Bulk Fuel Terminal	Maul, Foster, and Alongi
1990	Site Contamination Assessment, Lower Yard – GeoEngineers (1990)	• Purpose was to determine the extent of soil contamination due to past releases. • Excavated and collecting soil samples from 25 test pits for TPH and BTEX, and evaluated ongoing landfarming activities. • Soil samples collected in 23 of 25 test pits between 6 and 8 feet bgs. • Benzene concentrations ranged from ND to 3 mg/kg, toluene from ND to 17 mg/kg, ethylbenzene from ND to 43 mg/kg, and total xylenes from ND to 310 mg/kg. TPH varied from 12 to 16,000 mg/kg, TPH-G from ND to 2,800 mg/kg, and TPH-D from ND to 23,000 mg/kg. • Landfarming efforts reduced TPH levels from 2,600 mg/kg to less than 200 mg/kg.			Lower Yard	Background History Report Unocal Edmonds Bulk Fuel Terminal	Maul, Foster, and Alongi

Table 2-1
Site Investigations and Remedial Actions Chronology
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Year	Activity	Details	Contaminated Soils Removed (tons)	LNAPL Removed (gal)	Focus Site Area	Report	Author
1991	Supplemental Subsurface Contamination Assessment, Upper Yard – GeoEngineers (1991)	• Purpose was to explore subsurface conditions in the eastern portion of the Upper Yard and the BNSF property north of the Lower Yard. • Excavated four test pits, drilled five borings in the eastern portion of the Upper Yard, installed groundwater monitoring wells in each Upper Yard boring, installed 15 hand auger borings throughout the Upper Yard, and installed three borings and groundwater monitoring wells in the BNSF right-of-way. • BTEX components in soil were detected in two of 20 samples. Benzene was not detected in any sample. TPH-G varied from 7 to 2,700 mg/kg, TPH-D ranged from 90 to 19,000 mg/kg, and TPH varied from ND to 30,000 mg/kg. • BTEX components were detected at very low levels in groundwater; TPH-G and TPH-D were ND.			Upper Yard	Background History Report Unocal Edmonds Bulk Fuel Terminal	Maul, Foster, and Alongi
1991	Harbor Square Phase 1 Site Assessment – Landau Associates (1991)	• This assessment was conducted for the Port of Edmonds to assess the nature and extent of potential contamination at a portion of the Port's Harbor Square property. • Identified a report in Ecology files documenting a leaking 2,000 gallon UST on the BNSF property ~700 feet north of Harbor Square (which was removed in 1990). TPH in soil surrounding the tank ranged from ND to 64,000 mg/kg. • Four soil borings were completed. TPH in soil varied from 2,000 to 4,400 mg/kg, and TPH ranged from ND to 7,900 mg/kg. • The Phase 1 indicated that the source was most likely from the Unocal terminal and the railroad spur on the west side of the Site.			Harbor Square	Background History Report Unocal Edmonds Bulk Fuel Terminal	Maul, Foster, and Alongi
1991	Harbor Square Phase 2 Site Assessment – Landau Associates (1991)	• This assessment was conducted for the Port of Edmonds to assess the nature and extent of potential contamination at a portion of the Port's Harbor Square property. • Drilled and sampled five soil borings, and installed five monitoring wells. • TPH in soil ranged from 14 to 110,000 mg/kg, PAHs in soil ranged from 2.9 to 680 mg/kg. • It was reported that up to 4 feet of soil was encountered at one location that was saturated with a viscous tar-like substance. • All groundwater results were ND.			Harbor Square	Background History Report Unocal Edmonds Bulk Fuel Terminal	Maul, Foster, and Alongi

Table 2-1
Site Investigations and Remedial Actions Chronology
Chevron Environmental Management Company
Draft Feasibility Study Report
Former Unocal Edmonds Bulk Fuel Terminal
Edmonds, Washington

Year	Activity	Details	Contaminated Soils Removed (tons)	LNAPL Removed (gal)	Focus Site Area	Report	Author
1992	Preliminary Remedial Investigation – EMCON (1992)	• Focused on evaluating the aerial extent of LNAPL plumes. Six soil borings were completed, four of which were completed as groundwater monitoring wells. • TPH-G in soil ranged from ND to 2.7 mg/kg, TPH-D in soil ranged from ND to 2,670 mg/kg, and TPH-O ranged from ND to 2,250 mg/kg. Benzene was not detected in any soil sample. • TPH-G in groundwater ranged from ND to 15 mg/L, TPH-D ranged from ND to 4.96 mg/L, benzene was detected from ND to 0.585 mg/L.			Lower Yard	Background History Report Unocal Edmonds Bulk Fuel Terminal	Maul, Foster, and Alongi
1992-2000	Free Petroleum Product Recovery Operations - EMCON (1994-1998), MFA (1999-2000)	• Four monitoring wells redeveloped, and Welex Environmental, Inc., Hydro-Skimmer units installed in each well for passive recovery of phase-separated petroleum hydrocarbons. • Two of the Hydro-Skimmer units were removed after it was determined that the product was too viscous to pass through the units' filters. • Between December 1992 and September 1993, monitoring wells containing phase separated hydrocarbons were hand-bailed, and the Hydro-Skimmer units were drained, on a biweekly basis. An estimated 100 gallons of petroleum product were recovered by this action. • During 1994, 22 gallons of petroleum product were removed from monitoring wells by hand-bailing. • Starting in 1995, product was pumped on a weekly or biweekly basis from monitoring wells and from Recovery well RW-1 using a peristaltic pump. • 718 gallons of petroleum product were recovered in 1995; 491 gallons were recovered in 1996; 223 gallons were recovered in 1997; 136 gallons were recovered in 1998; and 111 gallons were recovered in 1999. • In 2000, more effective product pumping methods were employed at recovery well RW-1 and 169 gallons of petroleum products were recovered (including 85 gallons from RW-1).		1,970	Lower Yard	1998 Interim Product Recovery Operations Report 2000 Interim Product Recovery Operations Report	EMCON Maul, Foster, and Alongi
1994	UST Decommissioning	• Two Lower Yard and three Upper Yard USTs were decommissioned. • Petroleum hydrocarbon products were detected above MTCA Method A cleanup levels, at two of the tank excavations and in one of the product line trenches.			Upper and Lower Yard	Underground Storage Tank Decommissioning, 1995	EMCON

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Year	Activity	Details	Contaminated Soils Removed (tons)	LNAPL Removed (gal)	Focus Site Area	Report	Author
1996	Remedial Investigation Report	• This RI was performed between October 1994 and August 1996. Field investigation included 31 surface soil samples, 120 shallow soil borings, installation of 39 additional monitoring wells and nine piezometers, 17 basin sediment/soil samples, three test pits, and four trenches. Four quarters of groundwater monitoring were collected, seven monthly rounds of water levels were measured, one round of surface water and storm water samples, and aquifer characterization tests. • LNAPL was found in six Lower Yard plumes. Approximately 8,600 gallons of LNAPL were recovered (1996) and it was estimated that 5,200 gallons of LNAPL remained. LNAPL consisted of TPH-G, TPH-D, and TPH-O. Field observations indicated that much of the LNAPL may have been heavy end hydrocarbons. LNAPL migration rates were estimated to be less than six feet per year. • Dissolved phase hydrocarbons were primarily found near LNAPL plumes, and in areas with LNAPL trapped in the vadose zone. • Zinc was present at elevated levels in groundwater along the perimeter of the Site. • High concentrations of petroleum hydrocarbons in soil were primarily found near LNAPL plumes and in areas with LNAPL trapped in the vadose zone. High concentrations of petroleum hydrocarbons were also found in soil within DB- 1. • Elevated metals concentrations were found in surface soil in areas of sand blast grit and paint chips, but not found in significant concentrations in subsurface soil. • Petroleum-related compounds were detected in onsite stormwater, but at low levels. The highest metal and PAH concentrations were found in surface water upgradient of the Terminal. • Sediment samples passed all criteria for bioassay testing. Limited toxic effects were exhibited in bioassay testing. • Four different vegetation communities were found at the Terminal, but the habitat value was deemed low to moderate.		8,600	Lower Yard	Draft Remedial Investigation Report, 1998	EMCON

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Year	Activity	Details	Contaminated Soils Removed (tons)	LNAPL Removed (gal)	Focus Site Area	Report	Author
2001	Interim Action	• Consisted of the removal of LNAPL saturated soils from four areas of the Lower Yard. • Excavations were left open for weeks to allow floating LNAPL to be recovered. • 10,763 tons of soil was shipped offsite, 76,237 gallons of product, water, and associated solids were removed from the excavations (including an estimated 2,524 gallons of petroleum product).	10,763	2,524	Lower Yard	Lower Yard Interim Action As-Built Report, 2002	Maul, Foster, and Alongi
2001	Interim Action	• Demolition, removal of ASTs, piping and process structures, excavation and removal of 98,000 tons of impacted soil.	98,000		Upper Yard	Interim Action Report, 2003	Maul, Foster, and Alongi
2003	Supplemental Remedial Investigation – MFA (2003)	• Offsite contamination at the Port of Edmonds South Marina property was investigated. Borings were completed in South Admiral Way. • The highest concentration of DRO was ~2,100 mg/kg, the highest concentration found on the South Marina property is in excess of 20,000 mg/kg. It was determined that the petroleum impacts on the South Marina property were not due to migration from the Terminal. Samples from test pits excavated along the SW Lower Yard contained concentrations of DRO at ~13,000 mg/kg but were ~350 feet from the South Marina Property. • The highest concentrations of TPH in soil were found in the far eastern corner of the Lower Yard, in DB-1, and in the central portion of the Lower Yard. • Groundwater conditions were similar to prior years. • Surface water samples from Willows Creek did not contain concentrations of TPH. • It was determined that it was not likely that TPH was migrating offsite from the Terminal.			Lower Yard	Supplemental Remedial Investigation Report, 2003	Maul, Foster, and Alongi
2003	Interim Action	• Excavation of Detention Basin No.1, the Southwestern Lower Yard, Metals Area 3, and the stormdrain line area. • A total of 39,130 tons of soil were removed. • A total of 1,861,520 gallons of groundwater were extracted from the excavation and effectively treated on site before being discharged into Detention Basin Number 2.	39,130	1,861,520 (Groundwater removed and treated)	Lower Yard	Lower Yard Interim Action As-Built Report, 2004	Maul, Foster, and Alongi
2007	Phase I - Interim Action	• Bulk of soil excavation, 108,000 tons removed and approx. 9,700 gallons of LNAPL recovered.	108,000	9,700	Lower Yard	Phase I As-Built Report, 2007	ARCADIS
2008	Additional Site Assessment	• Soil boring installation, soil sample collection along WSDOT line and other areas of concern in the Lower Yard.			Lower Yard, WSDOT line	2008 Additional Site Investigation and Groundwater Monitoring Report, 2010	ARCADIS

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Table 2-1
Site Investigations and Remedial Actions Chronology
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Year	Activity	Details	Contaminated Soils Removed (tons)	LNAPL Removed (gal)	Focus Site Area	Report	Author
2008	Phase II - Interim Action	• Sediments removal, remaining soil excavation. 14,825 tons of soil removed, 131 gallons of LNAPL and 2,000 tons of sediment from Willow Creek.	16,825	131	Lower Yard	Phase II As-Built Report, 2008	ARCADIS
2008	Post-excavation Groundwater Monitoring Program Begins	• Post-excavation groundwater monitoring program begins, POC wells established.			Lower Yard	Reported Annually	ARCADIS
2011	Soil Investigation, Tidal Study, Hydraulic Conductivity Testing	• DB-2 soil and LNAPL investigation, piezometer installation, site-wide tidal study, site-wide hydraulic conductivity testing.			Lower Yard, Willow Creek	Final 2011 Site Investigation Completion Report, 2012	ARCADIS
2012	Monitoring Well Installation, soil sampling, sediment sampling	• Installed monitoring wells MW-525 to MW-532, collected confirmation sediment samples from Willow Creek.			Lower Yard, Willow Creek	Final Conceptual Site Model, 2012	ARCADIS

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Table 2-5
Soil Vapor Analytical Results
Chevron Environmental Management Company
Draft Feasibility Study Report
Former Unocal Edmonds Bulk Fuel Terminal
Edmonds, Washington

Sample ID	Sample Depth (ft bgs)	Sample Date	Analytical Method	Dilution Factor	Benzene	Naphthalene	Σ(C5-C6AL)+(>C6-C8AL)	Σ(>C8-C10AL)+(>C10-C12AL)	Σ(C8-C10AR)+(>C10-C12AR)	Oxygen	Methane	Carbon Dioxide	Helium
Analysis Method (units)					TO-15 GC/MS (μg/m³)					ASTM D-1946 (%)			
VP-1	5	10/09/13[2]	TO-17	4	>530,000 SJ	9,700 J	NA	NA	NA	5.0	>5.0	2.62	6.4[4]
		11/21/13	TO-15	108	**710,000**	**ND<11,000**	**35,000,000**	**6,600,000**	**34,000**	2.6	29	11	ND<0.11
VP-2	5	10/09/13[2]	TO-15	1	940	40	5,900	4,300	2,300	1.8	2.0	8.0	ND<0.11
		10/09/13[2]	TO-17	22.4	310	ND<230	NA	NA	NA	4.8	1.7	1.92	0.19[4]
		11/21/13	TO-15	9.04	**340**	**ND<95**	**33,700**	**36,000**	1,200	1.6	2.6	12	ND<0.11
(DUP)				8.48	**300**	**ND<89**	**27,800**	**25,000**	1,000	4.0	2.3	10	ND<0.11
VP-3	5	10/09/2013[2]	TO-17	1.00	190	8.5	NA	NA	NA	5.4	>5.0	2.1	4.5[4]
		11/21/13	TO-15	21.0	**46**	**ND<220**	**529,000**	**305,000**	**ND<3,600**	1.3	23	11	ND<0.10
Field Blank	NA	10/09/2013[2]	TO-17	1.00	ND<21	ND<1.7	NA	NA	NA	NA	NA	NA	NA
Equipment Blank	NA	10/09/2013[2]	TO-15	2.33	31	<6.1	170	300	110[3]	0.79	0.0015	ND<0.023	ND<0.12
Equipment Blank	NA	11/21/13	TO-15	2.10	ND<0.67	ND<5.5	ND<154	ND<270	ND<220	2.5	ND<0.00021	ND<0.021	ND<0.10
DOE Method B Soil Gas Screening Levels for Shallow Soil Gas[1]					**3.2**	**14**	**27,000**	**1,400**	**1,800**	**NA**	**NA**	**NA**	**NA**

NOTES:
Concentrations are in micrograms per cubic meter (μg/m³).
Highlighted cells indicate detected concentrations above the Ecology Method B Screening Level.
Greyed data was collected during the October 2013 sampling event and was not used for data evaluation.
Fixed gas data for TO-17 samples was collected in the field.
DUP = Duplicate sample
[1]Sub-slab or shallow soil gas screening level just beneath a building or less than 15 feet bgs.
[2]Equipment blank results indicate potential contamination of sampling equipment. Data collected during this sampling event are considered questionable.
[3]Value reported is the concentration detected above the laboratory reporting limit for the summed total.
[4]Methane causes interference with helium detector and these readings are indicative of methane. To prove the readings were methane interference, the concentration of helium inside the shroud was more than doubled, to 50%; however, a corresponding increase in the helium was not observed.
J = Estimated value due to bias in the Continuous Calibration Value (CCV)
S = Saturated peak; data reported as estimated
<ND = Non-detect, Value listed is laboratory reporting limit.
ft bgs = feet below ground surface
NA = Not applicable.

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Table 6-1
Remedial Alternatives Screening
Chevron Environmental Management Company
Draft Feasibility Study Report
Former Unocal Edmonds Bulk Fuel Terminal
Edmonds, Washington

Potential Remedial Technology	Description	Effectiveness	Implementability	Retained (yes/no)	Comments
Environmental Covenant	Environmental covenant is an administrative control which will limit the future uses of the site and therefore limit exposure.	An Environmental covenant does not involve the implementation of active remedial activities and will not remove or treat contaminated soils or LNAPL in the DB-2 area.	This technology is implementable at the Site in supplement with a primary active remedial alternative.	Yes	Does not meet all requirements of AO.
Groundwater Monitored Natural Attenuation	Natural attenuation includes a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater.	Natural attenuation is occurring in the groundwater beneath the lower yard; however, natural attenuation does not meet requirements for restoration within a reasonable timeframe; thus is not effective as a stand-alone technology. When combined with another alternative, compliance monitoring will have continue to demonstrate that natural attenuation is occurring at the predicted rate. Cleanup contingency plans may have to be prepared if expected MNA rate is not obtained.	This technology is implementable at the Site in supplement with a primary remedial alternative.	Yes	Does not meet all requirements of AO.
Excavation with Groundwater MNA	Excavation includes the physical removal of impacted soil and LNAPL from the Site.	Effective at removing impacted soils and reducing dissolved-phase petroleum hydrocarbons. Extensive excavation has been completed at the site and is an effective way to meet cleanup levels because contaminants are physically removed from the Site.	This technology will help meet direct contact CULs in soil and groundwater CULs at the POC boundary. Excavation is implementable at the Site. Approximately 146,000 tons of material have been removed from the Site successfully.	Yes	Preferred alternative outlined in AO to remediate observed LNAPL.
In-Situ Solidification	In-situ solidification (ISS) involves mixing binding agents (typically Portland cement) into the soil to provide physical sequestration of contaminants and a physical barrier between the ground surface and the soil beneath the treated monolith.	Effective at providing a physical barrier between the ground surface and soils beneath the treated monolith. This barrier can also minimize surface water infiltration which will stop migration of contaminants from soil to groundwater through leaching. Does not directly treat impacted soils or LNAPL.	This technology is implementable at the Site in supplement with a primary remedial alternative.	Yes	Technology will need to be coupled with excavation to meet the requirements of AO

Table 6-1
Remedial Alternatives Screening
Chevron Environmental Management Company
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Enhanced Bio-Oxidation	Electron acceptors are injected into the subsurface to promote a reducing environment, which enhances anaerobic bio-oxidation (ABOx) of contaminants.	The technology is generally less effective on the predominant contaminant at the lower yard (fuel hydrocarbons) and may require several injections to see reduction in LNAPL and dissolved phase. ABOx injections will not address residual LNAPL in vadose zone soils.	This technology has low implementability because the volume of contaminated soil at the lower yard is likely too low for chemical reduction/oxidation to be implementable on a cost-effective basis.	No	Technology will need to be coupled with excavation to meet the requirements of AO.
Surfactant Flushing	Clean water and surfactant is injected into the subsurface to mobilize contaminants in-situ for subsequent recovery.	Surfactant flushing can be effective in the reduction of organic- and inorganic- contaminant levels within the saturated zone, but may not be effective in addressing LNAPL impacted soil in the vadose zone.	Technology and downgradient monitoring would be difficult to implement as Willow Creek is located adjacent downgradient (<25 feet) of the remaining LNAPL impacts.	No	Does not address remaining impacts in soil and will have to be coupled with excavation to meet direct contact CULs and terms of the AO.
Groundwater Containment System using Groundwater Extraction Wells	The groundwater extraction wells would be installed downgradient of DB-2 in order to contain COC concentrations and control plume migration off site. Extracted LNAPL and groundwater would be treated prior to discharge to a product recovery tank or stormwater sanitary sewer line.	This technology will act as a barrier to offsite migration of LNAPL and dissolved phase COCs.	This technology is implementable at the Site.	Yes	This technology does not address non-mobile LNAPL in soils upgradient of the extraction radius of influence and will have to be coupled with excavation to meet direct contact CULs and terms of the AO.
Groundwater Containment System using Groundwater Extraction Trench	A Groundwater interceptor trench with high permeability backfill would be installed downgradient of DB-2 in order to contain COC concentrations and control plume migration off site. There would be a series of collection sumps within the trench to extract groundwater. Extracted LNAPL and groundwater would be treated prior to discharge to a product recovery tank or stormwater/ sanitary sewer line.	This technology will act as a barrier to offsite migration of LNAPL and dissolved phase COCs.	This technology is potentially implementable at the Site.	Yes	This technology does not address non-mobile LNAPL in soils upgradient of the extraction radius of influence and will have to be coupled with excavation to meet direct contact CULs and terms of the AO.
LNAPL Barrier Trench with Reactive Core Mat	The LNAPL barrier trench would be constructed with a reactive core mat to essentially lock LNAPL in place and ensure no offsite migration occurs. When LNAPL comes into contact with the reactive organoclay mat, it eventually becomes an impenetrable barrier.	This technology may be effective in preventing migration of contaminants or LNAPL, however is not effective as a long-term solution because it does not treat LNAPL or upgradient groundwater contaminants.	This technology is not potentially implementable at the Site.	No	Does not meet all requirements of AO.

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Funnel and Gate with in-situ Remediation	Install a funnel and gate system to direct groundwater movement toward the extraction system.	This technology is likely not effective due to the limited net groundwater movement because of dampening tidal effects and recharge from Willow Creek. Additionally, there is limited downgradient area for adequate installation of the in-situ reactive zone consisting of sparge wells. Additionally, this technology is not adaptable to changing conditions and does not treat LNAPL within a reasonable restoration timeframe.	This technology is not implementable at the Site.	No	Does not meet requirements of AO.
Funnel and Gate with Groundwater Extraction.	Install a reactive barrier to allow groundwater outside of extraction influence to pass through and remove contaminants.	This technology is likely not effective due to the limited net groundwater movement because of dampening tidal effects and recharge from Willow Creek. Additionally, this technology is not adaptable to changing conditions and does not treat LNAPL within a reasonable restoration timeframe.	This technology is not implementable at the Site.	No	Does not meet requirements of AO.

Notes:
Shading indicates that the process option was eliminated during the initial screening stage.
ABOx = Anaerobic Bio-Oxidation
AO = Agreed Order
COC = Constituent of Concern
CUL = Cleanup Level
DB-2 = Detention Basin No. 2
LNAPL = Light Nonaqueous Phase Liquid
POC = Point of Compliance

Table 7-1
Remedial Alternatives Evaluation
Chevron Environmental Management Company
Draft Feasibility Study Report
Former Unocal Edmonds Bulk Fuel Terminal
Edmonds, Washington

Alternatives		**Remedial Alternative 1**	**Remedial Alternative 2**	**Remedial Alternative 3**	**Remedial Alternative 4**	**Remedial Alternative 5**
Dispropostionate Cost Analysis Parameter		**Excavation + MNA**	**Groundwater Containment Using Extraction Wells**	**Groundwater Containment Using Groundwater Extraction Trench**	**Excavation of DB-2 and WSDOT Storm Drain Line**	**Excavation of DB-2 and ISS (Near WSDOT Storm Drain Line)**
Protectiveness	*Overall protectiveness of human health and the environment*	3	5	4	1	2
Permanence	*The degree to which the alternative permanently reduces the toxicity, mobility or volume of hazardous substances*	3	5	4	1	2
Cost	*The cost to implement the alternative*	1	3	4	5	2
Effectiveness over the long term	*The degree of certainty of success, the reliability of the alternative, the magnitude of residual risk, and the effectiveness of controls*	3	5	4	1	2
Management of short-term risks	*The risk to human health and environment associated with construction and implementation of the alternatives*	3	1	2	5	4
Technical and administrative implementability	*Technical feasibility of the alternative and administrative requirements*	2	1	3	5	4
Consideration of public concerns	*Whether the community has concerns regarding the alternative and, if so, the extent to which the alternative addresses those concerns.*	Not rated - see note 1				
	Average Score	**2.5**	**3.3**	**3.5**	**3.0**	**2.7**

Notes:
1) Public concerns, if any, will be identified through the public participation steps planned by Ecology for this project.
Remedial alternatives were ranked from 1 to 5: 1 being best and 5 being worst.
MNA - Monitored Natural Attenuation
ISS - In-situ Solidification
WSDOT - Washington State Department of Transportation
DB-2 - Detention Basin Number 2
EC - Environmental Covenant

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Table 7-2
Cost Estimate for Remedial Alternative 1:
Excavation and MNA with Environmental Covenants
Draft Feasibility Study Report
Former Unocal Edmonds Bulk Fuel Terminal
Edmonds, Washington

Task Description	Quantity	Units	Unit Lower Cost ($)	Unit Upper Cost ($)	Total Lower Cost ($)	Total Upper Cost ($)	Assumptions / Descriptions
Pre-Design Costs							
Surveying - Establish Control Points, Base Mapping, As-builts, Etc	1	Lump Sum	$2,000	$3,000	$2,000	$3,000	
Engineering Design		Lump Sum	$10,000	$15,000	$19,000	$28,500	
Remediation Activities							
Mobilization/Demobilization	1	Lump Sum	$50,000	$100,000	$50,000	$100,000	
Excavation Work	3,000-5,800	Cubic Yards	$10	$15	$30,000	$86,730	Lower cost based on anticipated minimum excavation of DB-2 and upper cost based on the assumption that DB2 was built on top of the former Slops pond and complete removal of DB-2 and replacement assumed.
Lab (soil)	50-60	Sample	$572	$572	$28,600	$34,320	
Lab (water)	6	Sample	$950	$950	$5,700	$5,700	
Excavation Water Mangement	1	Lump Sum	$10,000	$15,000	$10,000	$15,000	
Material Handling - Impacted Soils	3,000-5,800	Cubic Yards	$7	$11	$21,000	$63,602	
Material Stockpile Area & Management	1	Lump Sum	$10,000	$15,000	$10,000	$15,000	
Truck Loading Area	1	Lump Sum	$5,000	$7,500	$5,000	$7,500	
Odor/Dust Control System & Material	1	Month	$5,000	$7,500	$5,000	$7,500	
Transportation and Off-Site Disposal							
- Hazardous Soil	0	Tons	$250	$375	$0	$0	
- Non-Hazardous Soil	4,500-8,700	Tons	$60	$90	$270,000	$780,570	
Air Monitoring	1	Lump Sum	$8,000	$12,000	$8,000	$12,000	
Excavation Restoration Activities							
Furnish Backfill	4,500-8,700	Ton	$15	$20	$67,500	$173,460	
Placement & Compaction of Backfill	3,000-5,800	CY	$6	$10	$18,000	$57,820	
Management							
Project Management (8% of Overall Costs)	1	Lump Sum	$43,984	$111,256	$43,984	$111,256	
Construction Oversight and Health & Safety (12% of Construction Costs)	1	Lump Sum	$63,456	$163,104	$63,456	$163,104	
Groundwater Monitored Natural Attenuation	1	Lump Sum	$80,000	$100,000	$80,000	$100,000	
Environmental Covenant on WSDOT Stormwater Line	1	Lump Sum	$30,000	$50,000	$30,000	$50,000	

Complete Remedial Alternative 1 Subtotal Cost	**$770,000**	**$1,820,000**
Contingency (30%)	**$231,000**	**$546,000**
Complete Remedial Alternative 1 Cost	**$1,001,000**	**$2,366,000**

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Table 7-3
Cost Estimate for Remedial Alternative 2:
Groundwater Containment System Using Extraction Wells
Draft Feasibility Study Report
Former Unocal Edmonds Bulk Fuel Terminal
Edmonds, Washington

Task Description	Quantity	Units	Unit Lower Cost ($)	Unit Upper Cost ($)	Total Lower Cost ($)	Total Upper Cost ($)	Assumptions / Descriptions
Pre-Design Costs							
Surveying - Establish Control Points, Base Mapping,	1	Lump Sum	$2,000	$3,000	$2,000	$3,000	Assume Survey for Well Locations
Pilot Testing	1	Lump Sum	$40,000	$60,000	$40,000	$60,000	Pilot Testing with one well and additional Peizometers - includes Pilot Test Designa and Implementation
System Design Costs							
System Design	1	Lump Sum	$25,000	$37,500	$25,000	$37,500	Includes Post Pilot testing system design
Permitting and Fees	1	Lump Sum	$15,000	$22,500	$15,000	$22,500	Includes permitting fees for PSCAA, Construction and NPDES
Remediation Activities							
Mobilization/Demobilization (5% of Construction Costs, Excludes T&D Costs)	1	Lump Sum	$21,900	$32,850	$21,900	$32,850	
Soil Disposal	40	Cubic Yards	$10	$15	$400	$600	Assume 40 yds for trenching and Well spoils
Well Installation	6	Wells	$6,000	$9,000	$36,000	$54,000	6 wells based on Groundwater Modeling
Trenching/Piping Installation	1	Lump sum	$115,000	$172,500	$115,000	$172,500	Assumes 300 feet of trenching with indivicual piping for each well. Piping includes Air delivery, water and shutoff
Discharge Piping	1	LS	$10,000	$15,000	$10,000	$15,000	Discharge piping includes connection to stormwater discharge and associated trenching and piping
System Electrical Installation	1	Lump sum	$25,000	$37,500	$25,000	$37,500	Electrical installation includes new power drop to site
Remediation Equipment	1	LS	$250,000	$375,000	$250,000	$375,000	Remediation equipment includes 10 X 20 building, oumps, treatment train, system controls
Operation & Maintenance							
Routine Operation	10	years	$72,000	$108,000	$720,000	$1,080,000	Based on bi-monthly site visits for parameter readings
Maintenance Costs	10	years	$15,000	$22,500	$150,000	$225,000	Based on two carbon changeouts per year along with oil changes, filters and contingency costs.
Utilities	10	years	$24,000	$36,000	$240,000	$360,000	Based on $2000 per month in electrical utilites
Groundwater Monitoring and Sampling	10	years	$8,000	$10,000	$80,000	$100,000	Annual Sampling and reporting
Management							
Project Management (8% of Overall Costs)	1	Lump Sum	$138,424	$206,036	$138,424	$206,036	
Construction Oversight and Health & Safety (12% of Construction Costs)	1	Lump Sum	$54,996	$82,494	$54,996	$82,494	
Environmental Covenant	1	Lump Sum	$30,000	$50,000	$30,000	$50,000	

Complete System Install Subtotal Cost	**$1,960,000**	**$2,920,000**
Contingency (30%)	**$588,000**	**$876,000**
Complete Excavation Cost	**$2,548,000**	**$3,796,000**

DRAFT

Table 7-4
Cost Estimate for Remedial Alternative 3:
Groundwater Containment System Using Groundwater Extraction Trench
Draft Feasibility Study
Former Unocal Edmonds Bulk Fuel Terminal
Edmonds, Washington

Task Description	Quantity	Units	Unit Lower Cost ($)	Unit Upper Cost ($)	Total Lower Cost ($)	Total Upper Cost ($)	Assumptions / Descriptions
Pre-Design Costs							
Surveying - Establish Control Points, Base Mapping,	1	Lump Sum	$2,000	$3,000	$2,000	$3,000	Assume Survey for Well Locations
Pilot Testing	1	Lump Sum	$70,000	$105,000	$70,000	$105,000	Pilot Testing with trench section and additional peizometers - includes Pilot Test Design and Implementation
System Design Costs							
System Design	1	Lump Sum	$30,000	$45,000	$30,000	$45,000	Additional costs above well extraction system include trench design
Permitting and Fees	1	Lump Sum	$10,000	$15,000	$10,000	$15,000	
Remediation Activities							
Mobilization/Demobilization (5% of Construction Costs, Excludes T&D Costs)	1	Lump Sum	$29,400	$44,100	$29,400	$44,100	
Soil Disposal	250	Cubic Yards	$10	$15	$2,500	$3,750	250 yds of soil for trench at 280 feet X 4 feet X 20 feet
Trenching Equipment	5	Days	$20,000	$30,000	$100,000	$150,000	Trenching Equipment at $20,000 per day assume 5 days for install
Trenching One Pass	280	LF	$250	$375	$70,000	$105,000	Trenching costs per lineal foot
Trenching/Piping Installation	1	Lump sum	$100,000	$150,000	$100,000	$150,000	Includes additional conveyance piping and trenching
Discharge Piping	1	LS	$10,000	$15,000	$10,000	$15,000	Discharge piping includes connection to stormwater discharge and associated trenching and piping
System Electrical Installation	1	Lump sum	$25,000	$37,500	$25,000	$37,500	
Remediation Equipment	1	LS	$280,000	$420,000	$280,000	$420,000	System will require Larger treatment train to handle 7 GPM
Operation & Maintenance							
Routine Operation	10	years	$72,000	$108,000	$720,000	$1,080,000	Based on bi-monthly site visits for parameter readings
Maintenance Costs	10	years	$15,000	$22,500	$150,000	$225,000	Based on two carbon changeouts per year along with oil changes, filters and contingency costs.
Utilities	10	years	$24,000	$36,000	$240,000	$360,000	Based on $2000 per month in electrical utilites
Groundwater Monitoring and Sampling	10	years	$8,000	$10,000	$80,000	$100,000	Annual Sampling and reporting
Management							
Project Management (8% of Overall Costs)	1	Lump Sum	$153,512	$228,668	$153,512	$228,668	
Construction Oversight and Health & Safety (12% of Construction Costs)	1	Lump Sum	$74,028	$111,042	$74,028	$111,042	
Environmental Covenant	1	Lump Sum	$30,000	$50,000	$30,000	$50,000	

Complete System Install Subtotal Cost	**$2,180,000**	**$3,250,000**
Contingency (30%)	**$654,000**	**$975,000**
Complete Trenching Install Cost	**$2,834,000**	**$4,225,000**

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Table 7-5
Cost Estimate for Remedial Alternative 4:
Excavation with MNA
Draft Feasibility Study Report
Former Unocal Edmonds Bulk Fuel Terminal
Edmonds, Washington

Task Description	Quantity	Units	Unit Lower Cost ($)	Unit Upper Cost ($)	Total Lower Cost ($)	Total Upper Cost ($)	Assumptions / Descriptions
DB-2 Excavation Costs							
Pre-Design Costs							
Surveying - Establish Control Points, Base Mapping, As-builts, Etc	1	Lump Sum	$2,000	$3,000	$2,000	$3,000	
Engineering Design		Lump Sum	$10,000	$15,000	$19,000	$28,500	
Remediation Activities							
Mobilization/Demobilization	1	Lump Sum	$50,000	$100,000	$50,000	$100,000	
Excavation Work	3,000-5,800	Cubic Yards	$10	$15	$30,000	$86,730	Lower cost based on anticipated minimum excavation of DB-2 and upper cost based on the assumption that DB2 was built on top of the former Slops pond and complete removal of DB-2 and replacement assumed.
Lab (soil)	50-60	Sample	$572	$572	$28,600	$34,320	
Lab (water)	6	Sample	$950	$950	$5,700	$5,700	
Excavation Water Mangement	1	Lump Sum	$10,000	$15,000	$10,000	$15,000	
Material Handling - Impacted Soils	3,000-5,800	Cubic Yards	$7	$11	$21,000	$63,602	
Material Stockpile Area & Management	1	Lump Sum	$10,000	$15,000	$10,000	$15,000	
Truck Loading Area	1	Lump Sum	$5,000	$7,500	$5,000	$7,500	
Odor/Dust Control System & Material	1	Month	$5,000	$7,500	$5,000	$7,500	
Transportation and Off-Site Disposal							
- Hazardous Soil	0	Tons	$250	$375	$0	$0	
- Non-Hazardous Soil	4,500-8,700	Tons	$60	$90	$270,000	$780,570	
Air Monitoring	1	Lump Sum	$8,000	$12,000	$8,000	$12,000	
Excavation Restoration Activities							
Furnish Backfill	4,500-8,700	Ton	$15	$20	$67,500	$173,460	
Placement & Compaction of Backfill	3,000-5,800	CY	$6	$10	$18,000	$57,820	
Management							
Project Management (8% of Overall Costs)	1	Lump Sum	$43,984	$111,256	$43,984	$111,256	
Construction Oversight and Health & Safety (12% of Construction Costs)	1	Lump Sum	$63,456	$163,104	$63,456	$163,104	
				DB-2 Excavation Subtotal Cost	**$660,000**	**$1,670,000**	
				Contingency (30%)	**$198,000**	**$501,000**	
				DB-2 Excavation Cost	**$858,000**	**$2,171,000**	
WSDOT Stormwater Line Excavation Costs							
Pre-Design Costs							
Surveying - Establish Control Points, Base Mapping, As-builts, Etc	1	Lump Sum	$2,000	$3,000	$2,000	$3,000	
Geotechnical Investigation	1	Lump Sum	$30,000	$45,000	$30,000	$45,000	Assume 3 MR borings to 50 feet bgs and index property testing.
Sheetpile Design	1	Lump Sum	$30,000	$45,000	$30,000	$45,000	Design 2 sheet sections, provide drawings and specs to team
Remediation Activities							
Mobilization/Demobilization	1	Lump Sum	$50,000	$100,000	$50,000	$100,000	
Excavation Work	7990	Cubic Yards	$10	$15	$79,900	$119,850	
15 Foot Excavation Shoring Materials (Drive Extract, Salvage (43 Foot Depth)	281	Tons	$1,900	$2,200	$533,828	$618,116	From RSMeans
10 Foot Excavation Shoring Materials (Drive Extract, Salvage (29 Foot Depth)	168	Tons	$2,300	$2,800	$386,193	$470,148	From RSMeans + extra for light sheets and higher wieght to labor cost
Water Tight Sealant (sheets sealed to 20 ft bgs)	8600	LF	$3	$5	$25,800	$38,700	
Geotechnical Monitoring	1	Month	$10,000	$20,000	$10,000	$20,000	
Excavation Dewatering -Set up of Water Treatment System	1	Lump Sum	$15,000	$22,500	$15,000	$22,500	Approximate
Excavation Dewatering - Operation of Water Treatment System	1,728,000	Gallons	$0.40	$1	$691,200	$1,036,800	Assumes 60 gpm for 20 continuous days.
Material Handling - Impacted Soils	7990	Cubic Yards	$7	$11	$55,930	$83,895	Material Handling - Relocation and temporary stockpile for subsequent load-out. Double Handling of soils.
Material Stockpile Area & Management	1	Lump Sum	$10,000	$15,000	$10,000	$15,000	
Truck Loading Area	1	Lump Sum	$5,000	$7,500	$5,000	$7,500	
Odor/Dust Control System & Material	1	Month	$5,000	$7,500	$5,000	$7,500	Assumes equipment will be kept on standby for dust/odor control due to existing active facility/tenants
Transportation and Off-Site Disposal							
- Hazardous Soil	0	Tons	$250	$375	$0	$0	
- Non-Hazardous Soil	11985	Tons	$60	$90	$719,100	$1,078,650	
Air Monitoring	1	Lump Sum	$8,000	$12,000	$8,000	$12,000	Assumes air monitoring will be performed as part of work for H&S and active facility/tenants (Provided by Team)
Excavation Restoration Activities							
Pipe Replacement	1	Lump Sum	$20,000	$30,000	$20,000	$30,000	Approximate
Furnish Backfill	11,985	Ton	$15	$20	$179,775	$239,700	
Placement & Compaction of Backfill	7,990	CY	$6	$10	$47,940	$79,900	From RSMeans
Management							
Project Management (8% of Overall Costs)	1	Lump Sum	$232,373	$325,861	$232,373	$325,861	
Construction Oversight and Health & Safety (12% of Construction Costs)	1	Lump Sum	$341,120	$477,631	$341,120	$477,631	
				WSDOT Stormwater Line Excavation Subtotal Cost	**$3,480,000**	**$4,880,000**	
				Contingency (30%)	**$1,044,000**	**$1,464,000**	
				WSDOT Stormwater Line Excavation Cost	**$4,524,000**	**$6,344,000**	
Groundwater Monitored Natural Attenuation	1	Lump Sum	$80,000	$100,000	$80,000	$100,000	

Complete Excavation and MNA Cost $5,462,000 $8,615,000

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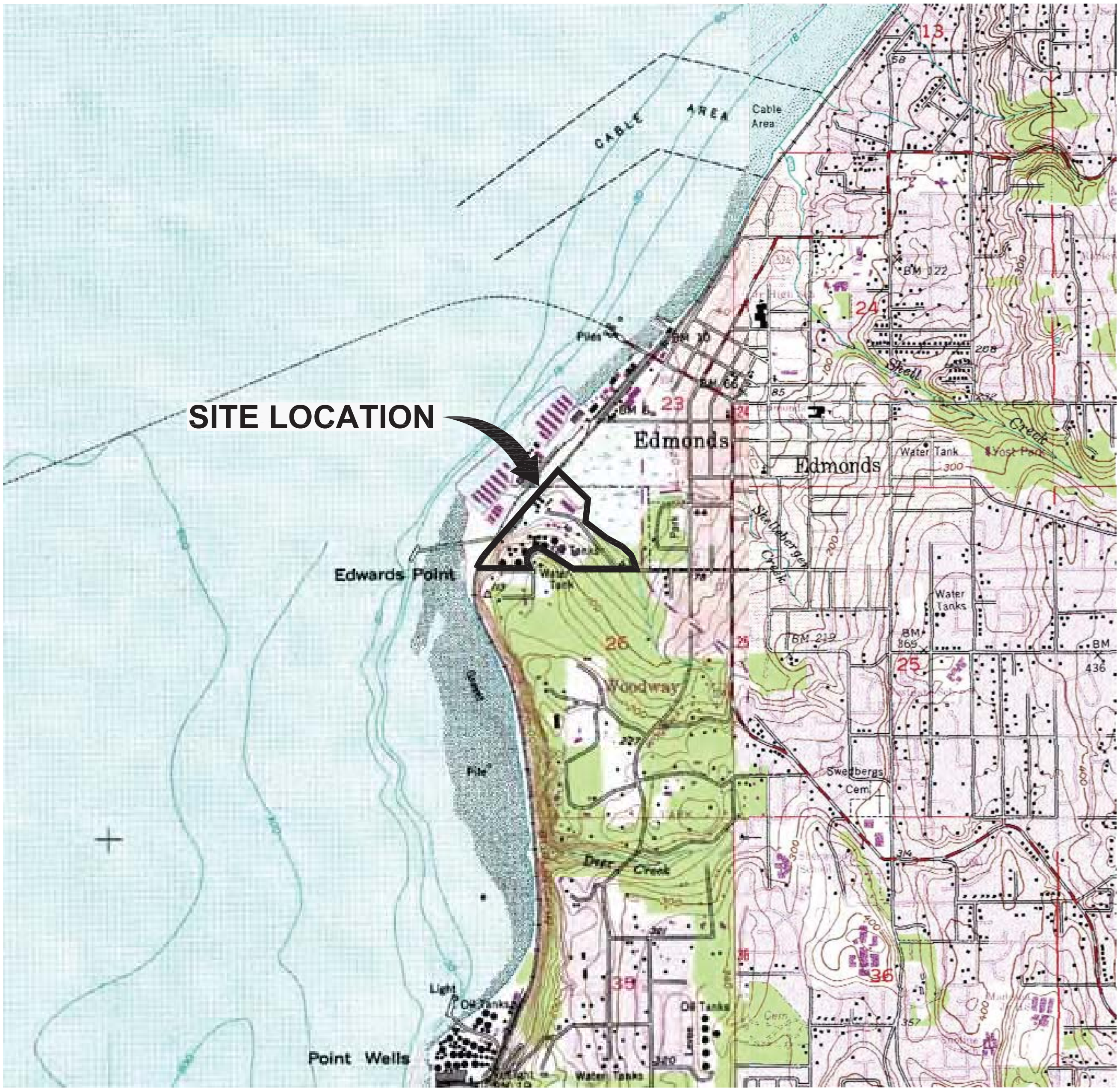
Table 7-6
Cost Est. for Remedial Alt. 5: Excavation with MNA and In-Situ Solidification with Environmental Covenants
Draft Feasibility Study
Former Unocal Edmonds Bulk Fuel Terminal
Edmonds, Washington

Task Description	Quantity	Units	Unit Lower Cost ($)	Unit Upper Cost ($)	Total Lower Cost ($)	Total Upper Cost ($)	Assumptions / Descriptions
DB-2 Excavation Costs							
Pre-Design Costs							
Surveying - Establish Control Points, Base Mapping, As-builts, Etc	1	Lump Sum	$2,000	$3,000	$2,000	$3,000	
Engineering Design		Lump Sum	$10,000	$15,000	$19,000	$28,500	
Remediation Activities							
Mobilization/Demobilization	1	Lump Sum	$50,000	$100,000	$50,000	$100,000	
Excavation Work	3,000-5,800	Cubic Yards	$10	$15	$30,000	$86,730	Lower cost based on anticipated minimum excavation of DB-2 and upper cost based on the assumption that DB2 was built on top of the former Slops pond and complete removal of DB-2 and replacement assumed.
Lab (soil)	50-60	Sample	$572	$572	$28,600	$34,320	
Lab (water)	6	Sample	$950	$950	$5,700	$5,700	
Excavation Water Mangement	1	Lump Sum	$10,000	$15,000	$10,000	$15,000	
Material Handling - Impacted Soils	3,000-5,800	Cubic Yards	$7	$11	$21,000	$63,602	
Material Stockpile Area & Management	1	Lump Sum	$10,000	$15,000	$10,000	$15,000	
Truck Loading Area	1	Lump Sum	$5,000	$7,500	$5,000	$7,500	
Odor/Dust Control System & Material	1	Month	$5,000	$7,500	$5,000	$7,500	
Transportation and Off-Site Disposal							
- Hazardous Soil	0	Tons	$250	$375	$0	$0	
- Non-Hazardous Soil	4,500-8,700	Tons	$60	$90	$270,000	$780,570	
Air Monitoring	1	Lump Sum	$8,000	$12,000	$8,000	$12,000	
Excavation Restoration Activities							
Furnish Backfill	4,500-8,700	Ton	$15	$20	$67,500	$173,460	
Placement & Compaction of Backfill	3,000-5,800	CY	$6	$10	$18,000	$57,820	
Management							
Project Management (8% of Overall Costs)	1	Lump Sum	$43,984	$111,256	$43,984	$111,256	
Construction Oversight and Health & Safety (12% of Construction Costs)	1	Lump Sum	$63,456	$163,104	$63,456	$163,104	
				DB-2 Excavation Subtotal Cost	**$660,000**	**$1,670,000**	
				Contingency (30%)	**$198,000**	**$501,000**	
				DB-2 Excavation Cost	**$858,000**	**$2,171,000**	
WSDOT Pipe ISS Costs							
Pre-Design Costs							
Surveying - Establish Control Points, Base Mapping, As-builts, Etc	1	Lump Sum	$2,000	$3,000	$2,000	$3,000	
Geotechnical Investigation	1	Lump Sum	$5,000	$7,500	$5,000	$7,500	
ISS Design	1	Lump Sum	$10,000	$15,000	$10,000	$15,000	
Remediation Activities							
Mobilization/Demobilization	1	Lump Sum	$13,000	$19,500	$13,000	$19,500	5% of labor
Excavation Work	710	Cubic Yards	$10	$15	$7,100	$10,650	Assumed top foot would be removed, then the ISS would bulk into that space, no ISS spoil excavation needed
Material Handling - Impacted Soils	710	Cubic Yards	$7	$11	$4,970	$7,455	
Mobilization/Demobilization & Setup of the ISSS Batch Mixing Plant	1	Lump Sum	$100,000	$150,000	$100,000	$150,000	
In-Situ Soil Mixing - Excavator Mixing (1-5 feet depth interval)	2840	Lump Sum	$50	$75	$142,000	$213,000	
Water Supply	1	Lump Sum	$20,000	$30,000	$20,000	$30,000	
Portland Cement (5%)	213	Tons	$120	$180	$25,560	$38,340	
Performance Monitoring (1 Per 300 Cubic Yards)	10	Each	$1,500	$2,250	$15,000	$22,500	
Odor/Dust Control System & Material	1	Month	$5,000	$7,500	$5,000	$7,500	
Transportation and Off-Site Disposal							
- Hazardous Soil	0	Tons	$250	$375	$0	$0	
- Non-Hazardous Soil	1065	Tons	$60	$90	$63,900	$95,850	
Air Monitoring	1	Lump Sum	$8,000	$12,000	$8,000	$12,000	
Management							
Project Management (8% of Overall Costs)	1	Lump Sum	$33,722	$50,584	$33,722	$50,584	
Construction Oversight and Health & Safety (12% of Construction Costs)	1	Lump Sum	$48,544	$72,815	$48,544	$72,815	
				WSDOT Pipe ISS Subtotal Cost	**$510,000**	**$760,000**	
				Contingency (30%)	**$153,000**	**$228,000**	
				WSDOT Pipe ISS Cost	**$663,000**	**$988,000**	
Groundwater Monitored Natural Attenuation	1	Lump Sum	$80,000	$100,000	$80,000	$100,000	
Environmental Covenant	1	Lump Sum	$30,000	$50,000	$30,000	$50,000	

Complete Excavation, ISS, MNA, and Environmental Covenant Cost $1,631,000 $3,309,000

ARCADIS

Figures



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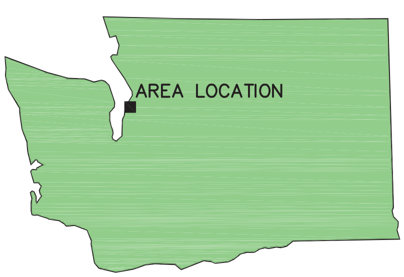
Approximate Scale: 1"=0.5 Miles



CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

SITE LOCATION MAP

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FIGURE
1-1

CITY:SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM/ TM: R. ANDRESEN TR: D. RASAR LYR:(OPT)ON=*;OFF=REF
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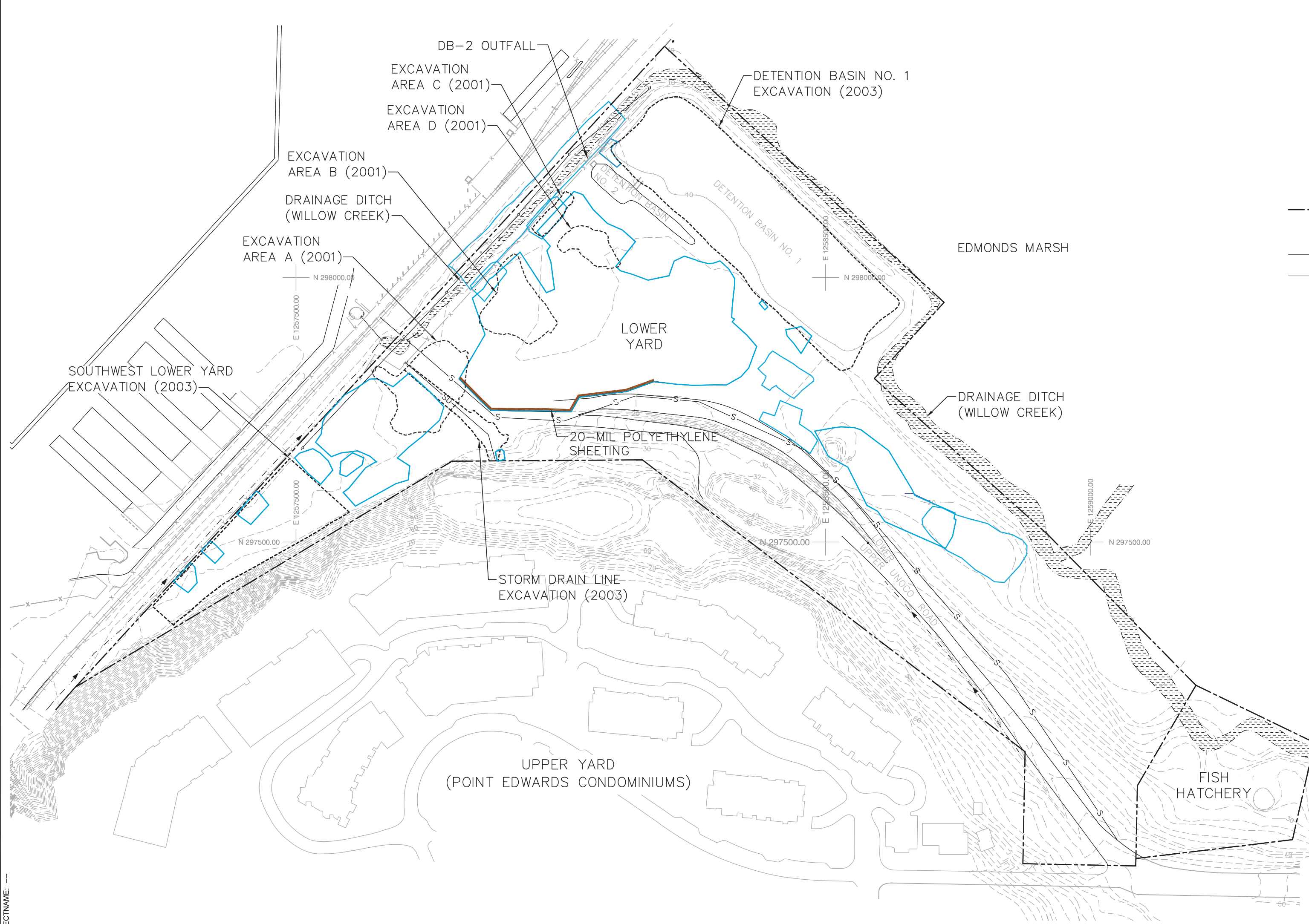

LEGEND:

- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- LOWER YARD PROPERTY BOUNDARY
- 2007/2008 EXCAVATION BOUNDARIES
- S — WSDOT STORM DRAIN LINE
- SD — POINT EDWARDS STORM DRAIN LINE

NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I OF THE 2007/2008 EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
   VERTICAL DATUM: N.A.V.D. 88
   UNITS: U.S. SURVEY FEET
   HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 200' 400'
GRAPHIC SCALE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

SITE LAYOUT

ARCADIS

FIGURE
2-1

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
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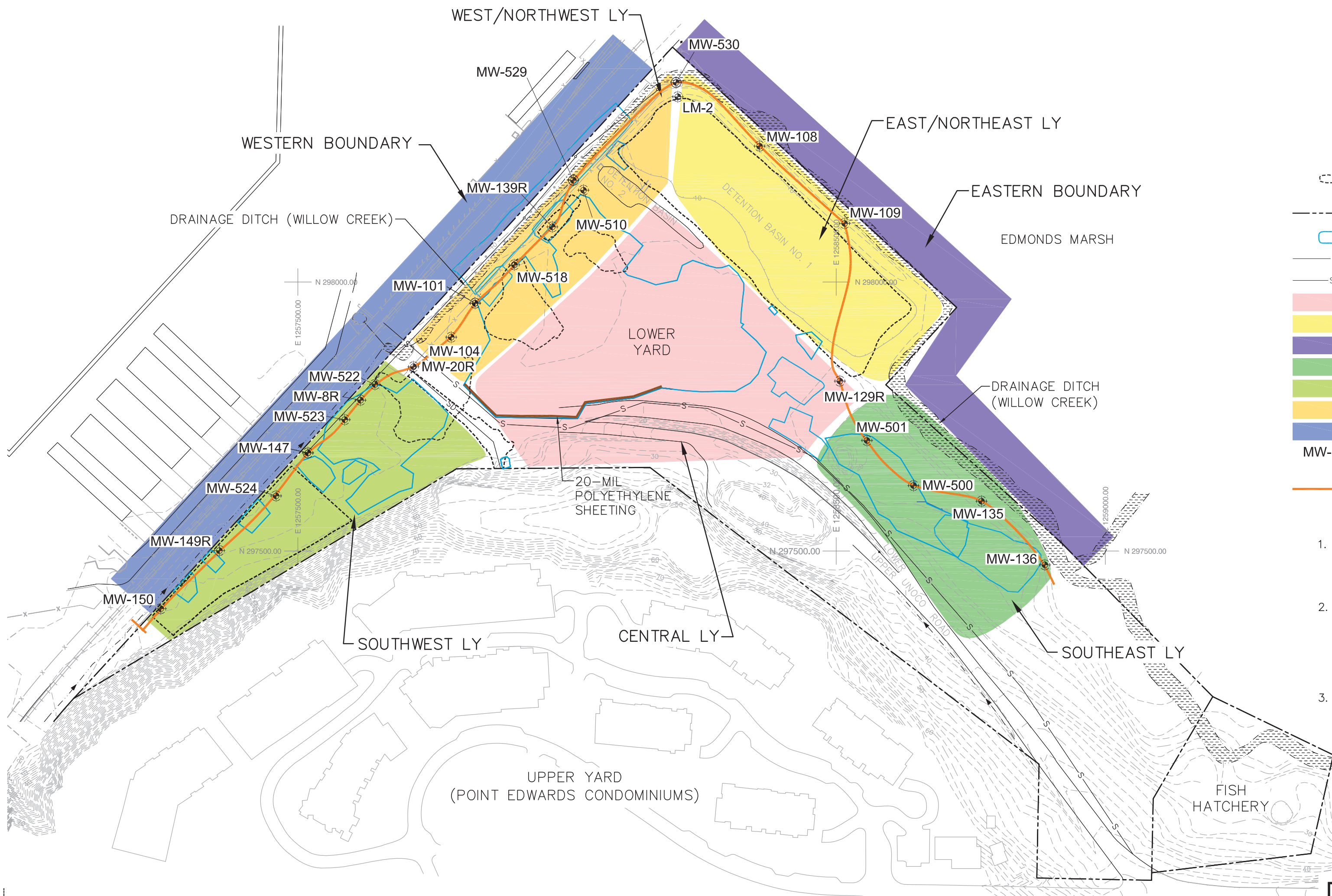

LEGEND:

- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- LOWER YARD PROPERTY BOUNDARY
- 2007/2008 EXCAVATION BOUNDARIES
- S — WSDOT STORM DRAIN LINE
- SD — POINT EDWARDS STORM DRAIN LINE
- CENTRAL LY
- EAST/NORTHEAST LY
- EASTERN BOUNDARY
- SOUTHEAST LY
- SOUTHWEST LY
- WEST/NORTHWEST LY
- WESTERN BOUNDARY
- MW-529 SURFACE WATER COMPLIANCE MONITORING WELL LOCATION INSTALLED JUNE 2012
- POINT OF COMPLIANCE BOUNDARY

NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
VERTICAL DATUM: N.A.V.D. 88
UNITS: U.S. SURVEY FEET
HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 200' 400'
GRAPHIC SCALE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

AREAS OF THE LOWER YARD MAP

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FIGURE
2-2

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
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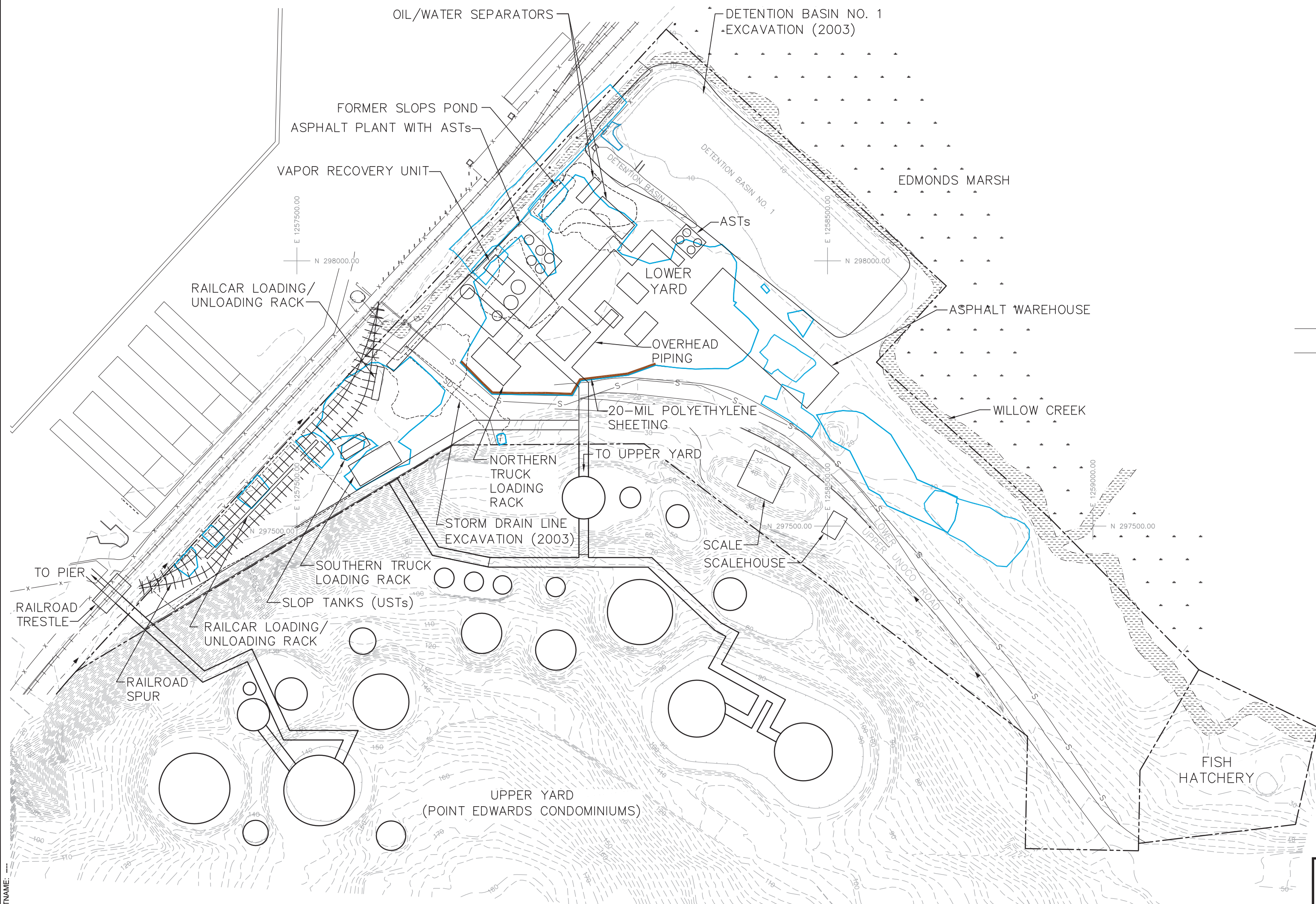

LEGEND:

- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- 2007/2008 EXCAVATION BOUNDARIES
- WSDOT STORM DRAIN LINE
- POINT EDWARDS STORM DRAIN LINE
- HISTORIC FEATURE

NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98). VERTICAL DATUM: N.A.V.D. 88 UNITS: U.S. SURVEY FEET HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 200' 400'

GRAPHIC SCALE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

HISTORIC FACILITIES LOCATION MAP

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FIGURE
2-3

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF* (FRZ)
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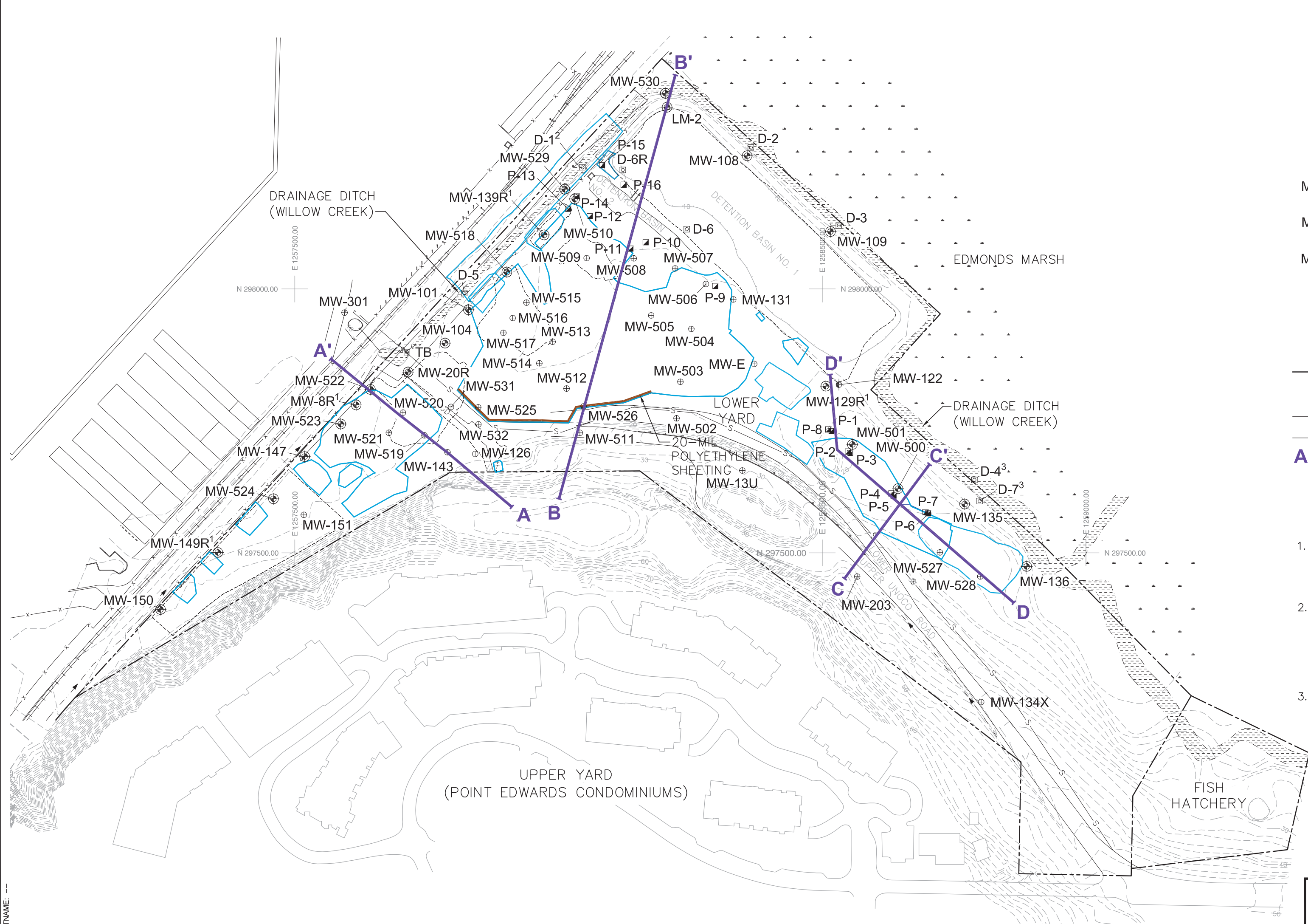

LEGEND:

- MW-203 ⊕ INTERIOR MONITORING WELL LOCATION AND DESIGNATION
- MW-122 DEEP MONITORING WELL LOCATION AND DESIGNATION
- MW-109 SURFACE WATER POINT OF COMPLIANCE MONITORING WELL LOCATION
- P-11 PIEZOMETER
- D-1 STAFF GAUGE
- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- LOWER YARD PROPERTY BOUNDARY
- 2007/2008 EXCAVATION BOUNDARIES
- S WSDOT STORM DRAIN LINE
- SD POINT EDWARDS STORM DRAIN LINE
- A — A' CROSS SECTION LOCATIONS

NOTES:

1. 20–MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
VERTICAL DATUM: N.A.V.D. 88
UNITS: U.S. SURVEY FEET
HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 200' 400'
GRAPHIC SCALE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

CROSS SECTION LOCATION MAP

ARCADIS

FIGURE
2-4

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362G04.dwg LAYOUT: 2-4 SAVED: 12/17/2013 1:08 PM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: OCE TDS600 SV1F.CTB PLOTTED: 12/17/2013 1:08 PM BY: LISTER, PAUL
XREFS: IMAGES: PROJECTNAME: ---
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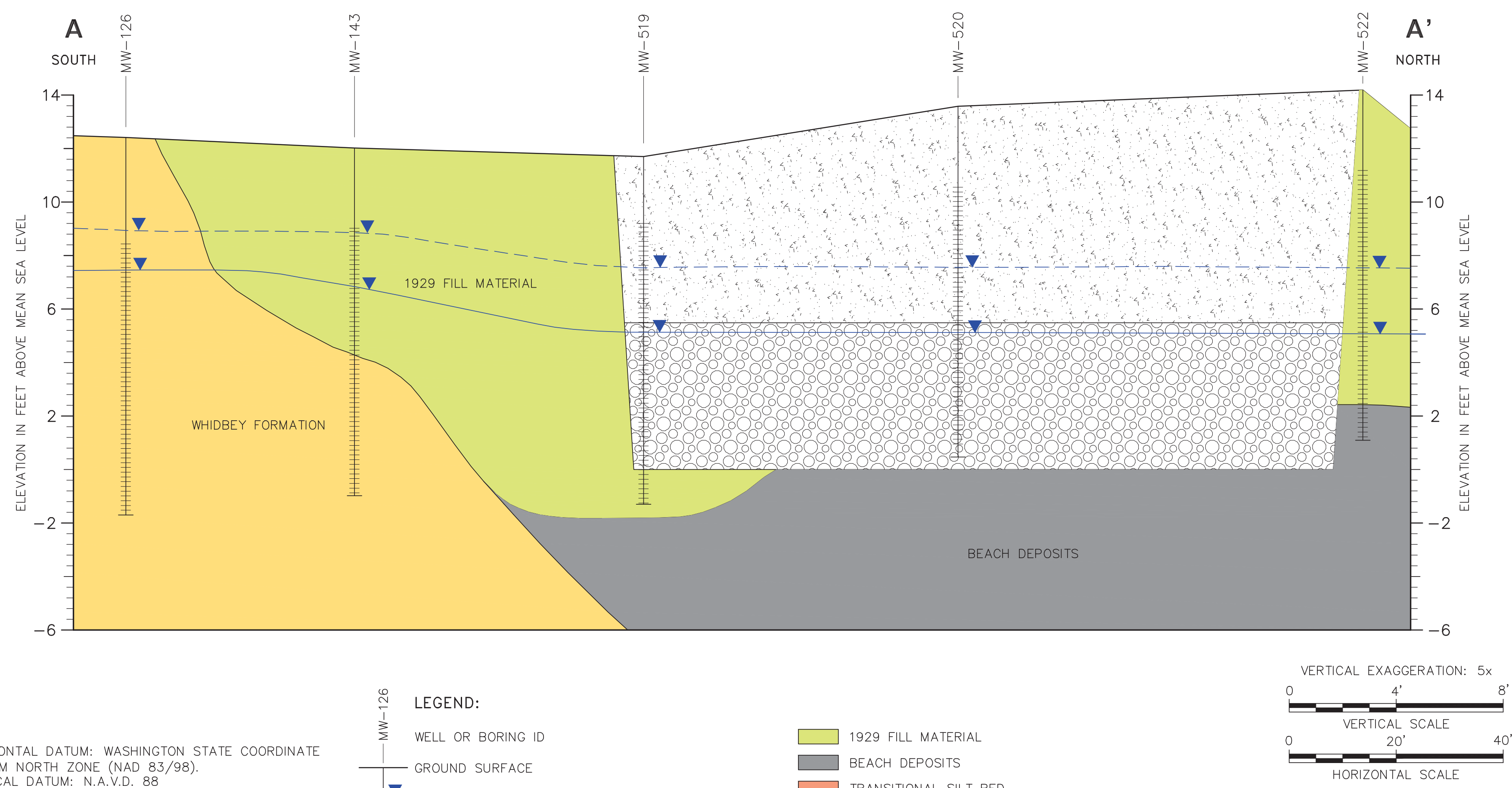
45362X02
45362X03



NOTES:

- HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
- VERTICAL DATUM: N.A.V.D. 88
- UNITS: U.S. SURVEY FEET
- HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).

LEGEND:

MW-126 WELL OR BORING ID
GROUND SURFACE
HISTORIC HIGH WATER LEVEL
HISTORIC LOW WATER LEVEL
LITHOLOGIC CONTACT (DASHED WHERE INFERRED)
SCREENED INTERVAL
BOTTOM OF BORING

1929 FILL MATERIAL
BEACH DEPOSITS
TRANSITIONAL SILT BED
WHIDBEY FORMATION
MARSH DEPOSITS
2007/2008 FILL (GRAVEL)
2007/2008 FILL (SILT, SAND AND GRAVEL)
(35' SE)=OFFSET DISTANCE FROM CROSS SECTION PROFILE

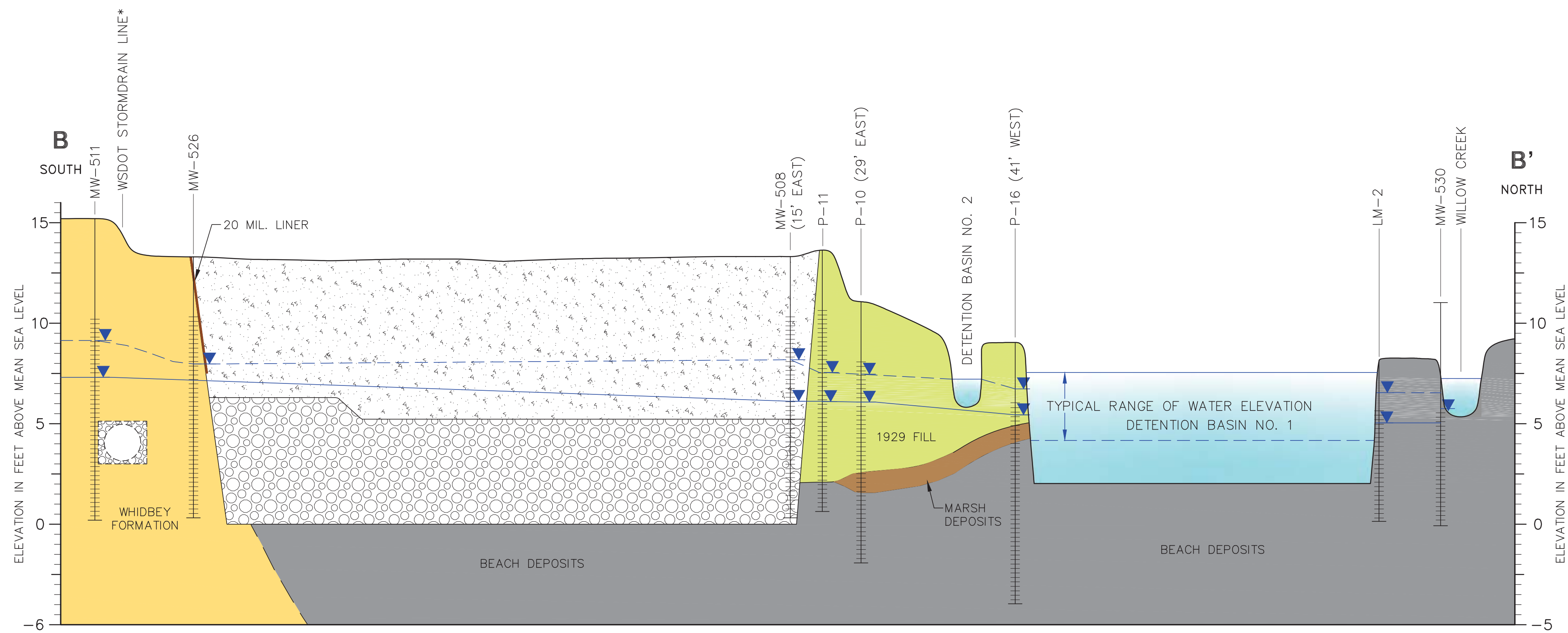
CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

LOWER YARD
GEOLOGIC CROSS SECTION A-A'

ARCADIS

FIGURE
2-5

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362V05.dwg LAYOUT: 2-5 SAVED: 11/19/2013 11:18 AM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: OCE TDS600 SV1F.CTB PLOTTED: 12/3/2013 10:09 AM BY: LISTER, PAUL
XREFS: IMAGES: PROJECTNAME: ---
45362XDL



NOTES:

1. WSDOT STORMDRAIN LINE LOCATION IS APPROXIMATE AND DRAWN TO A NON EXAGGERATED SCALE FOR CLARITY.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
VERTICAL DATUM: N.A.V.D. 88
UNITS: U.S. SURVEY FEET
HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).

LEGEND:

- MW-511 — WELL OR BORING ID
- GROUND SURFACE
- HISTORIC HIGH WATER LEVEL
- HISTORIC LOW WATER LEVEL
- LITHOLOGIC CONTACT (DASHED WHERE INFERRED)
- SCREENED INTERVAL
- BOTTOM OF BORING
- 1929 FILL MATERIAL
- BEACH DEPOSITS
- WHIDBEY FORMATION
- MARSH DEPOSITS
- 2007/2008 FILL (GRAVEL)
- 2007/2008 FILL (SILT, SAND AND GRAVEL)
- (29' E)=OFFSET DISTANCE FROM CROSS SECTION PROFILE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

LOWER YARD
GEOLOGIC CROSS SECTION B-B'

ARCADIS

FIGURE
2-6

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362V06.dwg LAYOUT: 2-6 SAVED: 11/19/2013 11:19 AM ACADVER: 18.1S (LMS TECH) PAGESETUP: --- PLOTSTYLETABLE: OCE TDS600 SV1F.CTB PLOTTED: 12/3/2013 10:09 AM BY: LISTER, PAUL
XREFS: IMAGES: PROJECTNAME: ---
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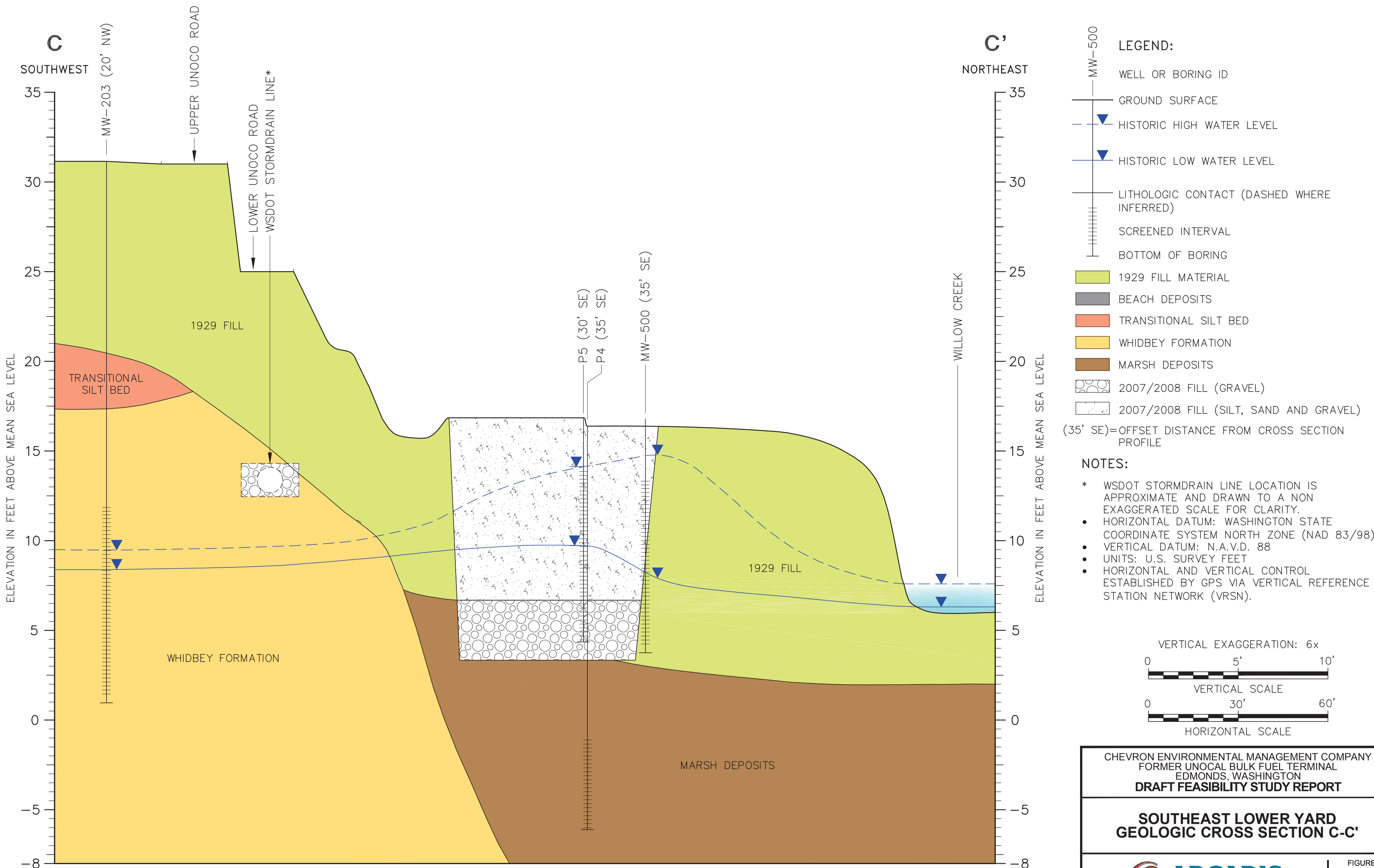
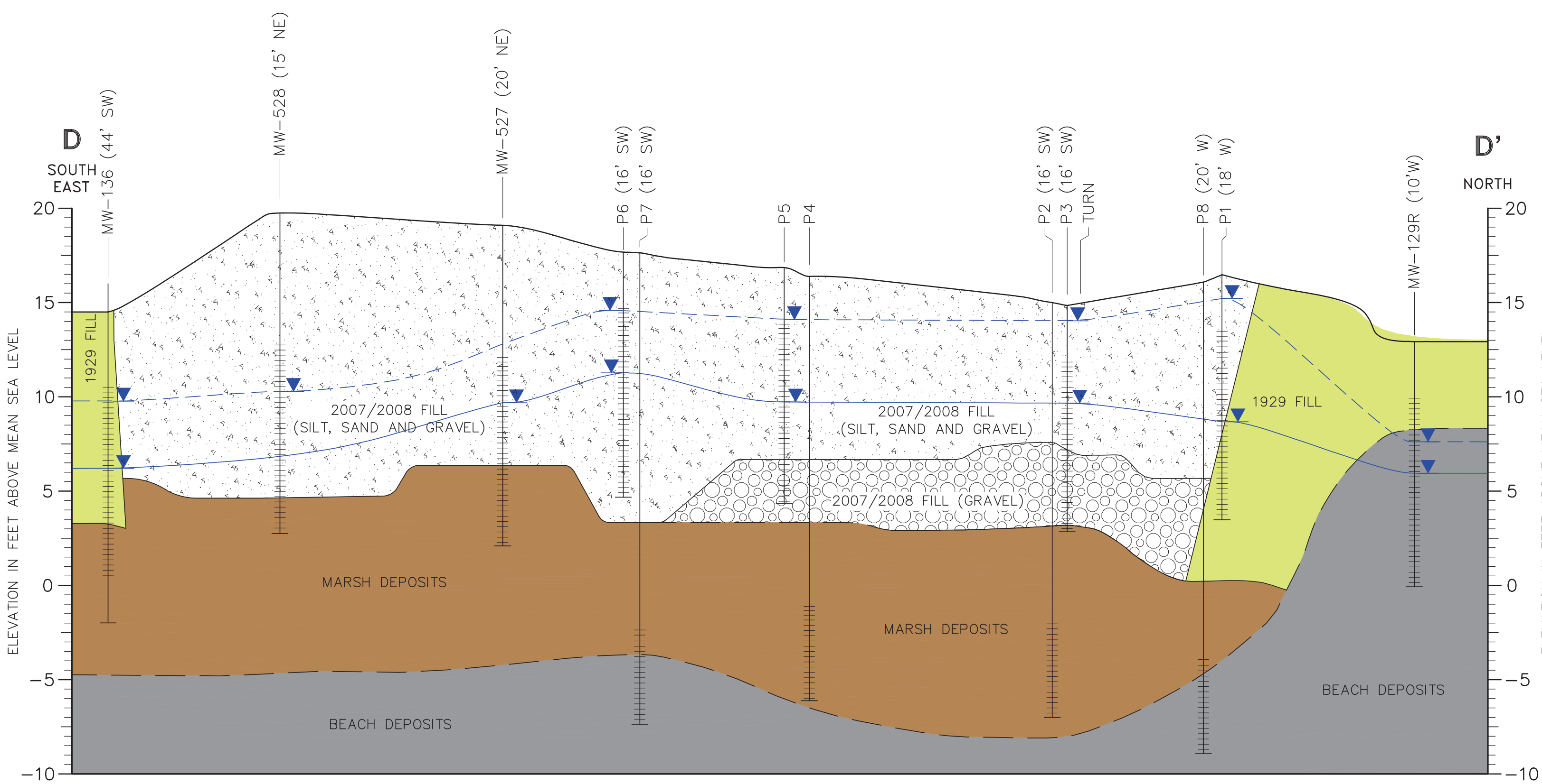


CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

SOUTHEAST LOWER YARD
GEOLOGIC CROSS SECTION C-C'

ARCADIS

FIGURE
2-7



LEGEND:

- MW-136 WELL OR BORING ID
- GROUND SURFACE
- HISTORIC HIGH WATER LEVEL
- HISTORIC LOW WATER LEVEL
- LITHOLOGIC CONTACT (DASHED WHERE INFERRED)
- SCREENED INTERVAL
- BOTTOM OF BORING
- 1929 FILL MATERIAL
- BEACH DEPOSITS
- TRANSITIONAL SILT BED
- WHIDBEY FORMATION
- MARSH DEPOSITS
- 2007/2008 FILL (GRAVEL)
- 2007/2008 FILL (SILT, SAND AND GRAVEL)
- (20' W)= OFFSET DISTANCE FROM CROSS SECTION PROFILE

NOTES:

1. CROSS SECTION DEPICTS SOIL CHARACTERISTICS OF EXCAVATION SIDE WALLS. EXCAVATIONS REACHED TOTAL DEPTHS OF 15 FT. BGS. (<0 FEET AMSI).
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98). VERTICAL DATUM: N.A.V.D. 88 UNITS: U.S. SURVEY FEET HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).

VERTICAL EXAGGERATION: 8x

0 6.25' 12.5'
VERTICAL SCALE

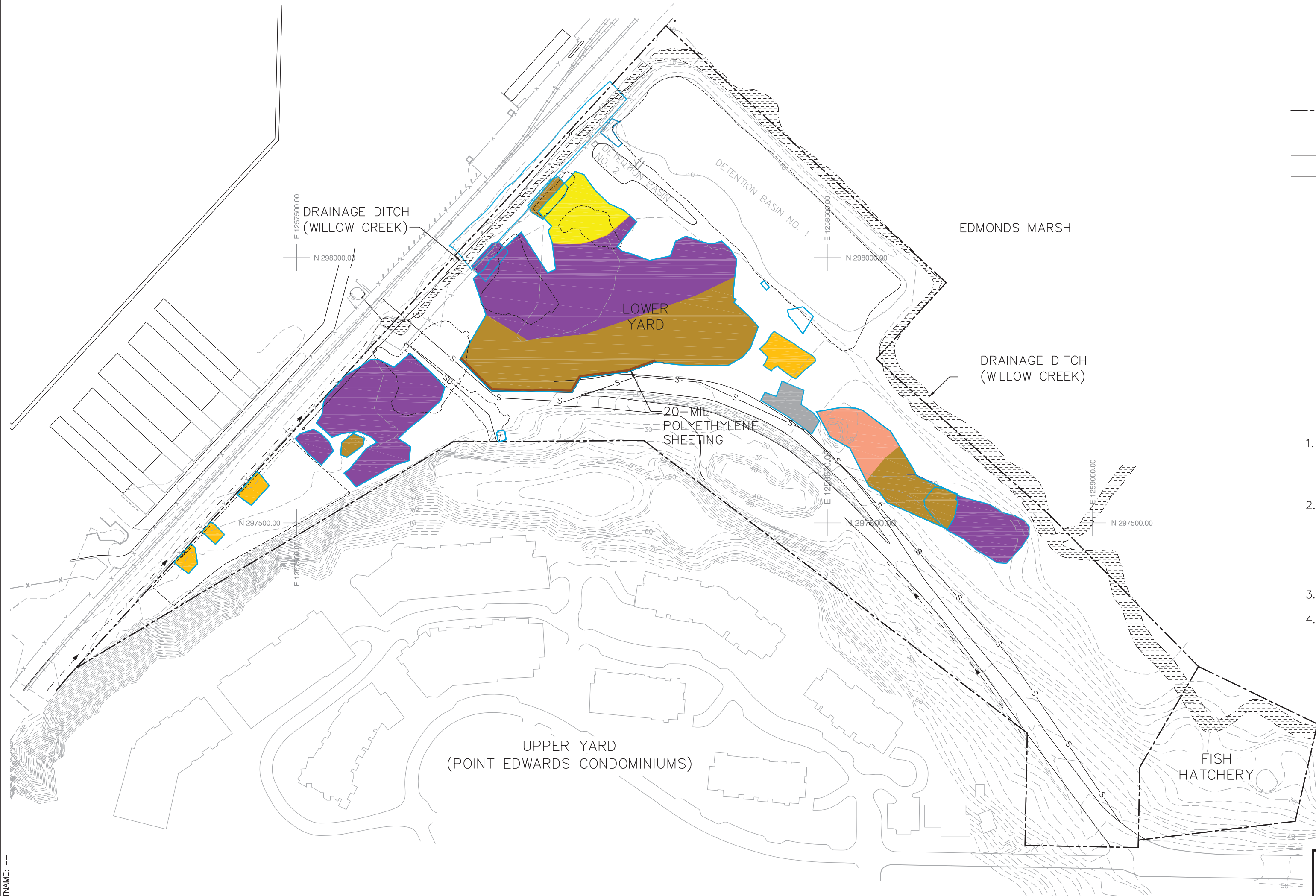
0 50' 100'
HORIZONTAL SCALE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

SOUTHEAST LOWER YARD
GEOLOGIC CROSS SECTION D-D'

ARCADIS

FIGURE
2-8



LEGEND:

- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- LOWER YARD PROPERTY BOUNDARY
- 2007/2008 EXCAVATION BOUNDARIES
- WSDOT STORM DRAIN LINE
- POINT EDWARDS STORM DRAIN LINE

TOP OF GRAVEL BACKFILL ELEVATION:

- 2 – 3 FT AMSL
- 4 – 5 FT AMSL
- 5 – 6 FT AMSL
- 6 – 7 FT AMSL
- 7 – 8 FT AMSL
- 9 – 11 FT AMSL

NOTES:

1. 20–MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
   VERTICAL DATUM: N.A.V.D. 88
   UNITS: U.S. SURVEY FEET
   HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. FT AMSL = FEET ABOVE MEAN SEA LEVEL.
4. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 200' 400'
GRAPHIC SCALE

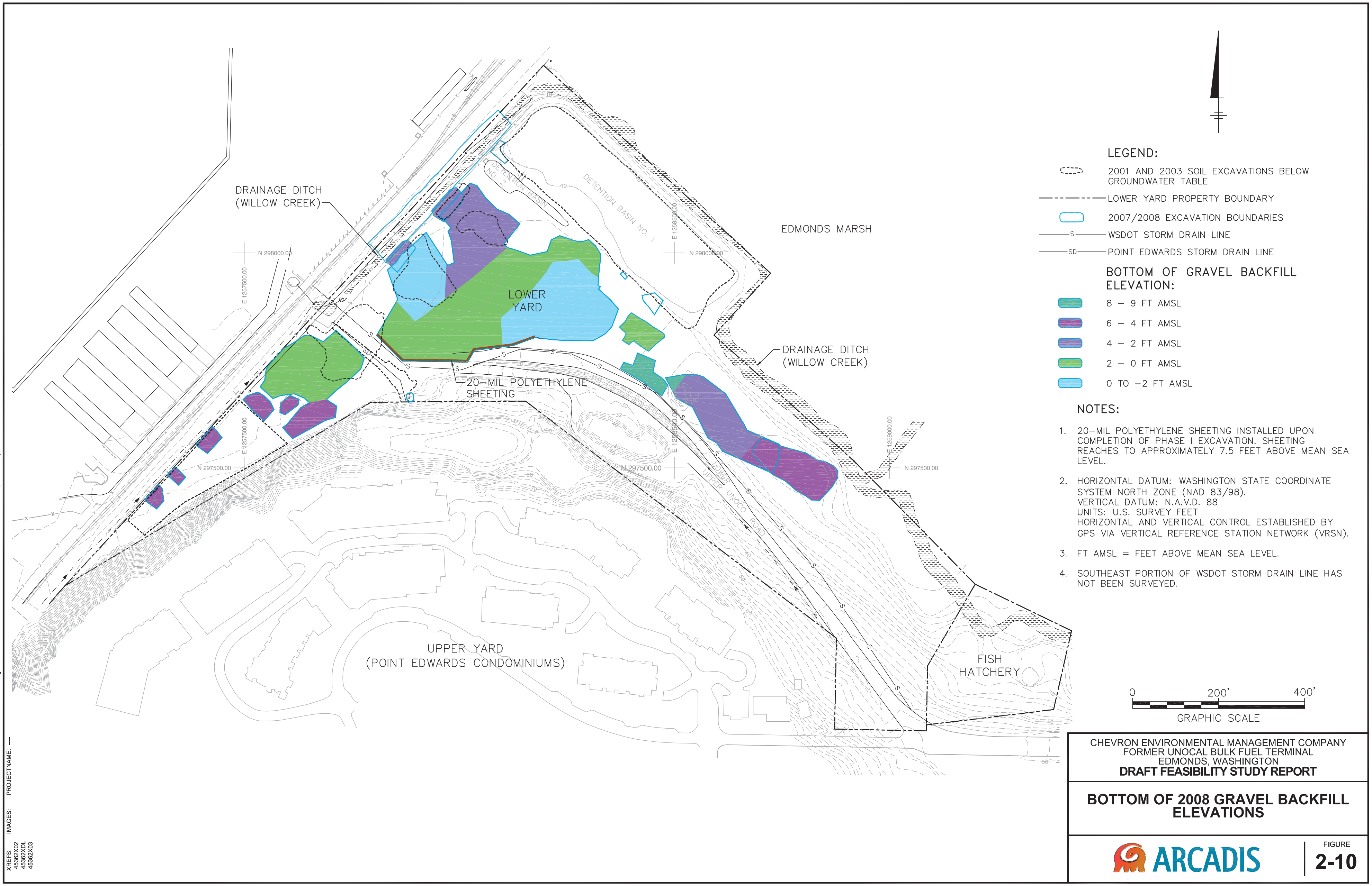
CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

TOP OF 2008 GRAVEL BACKFILL ELEVATIONS

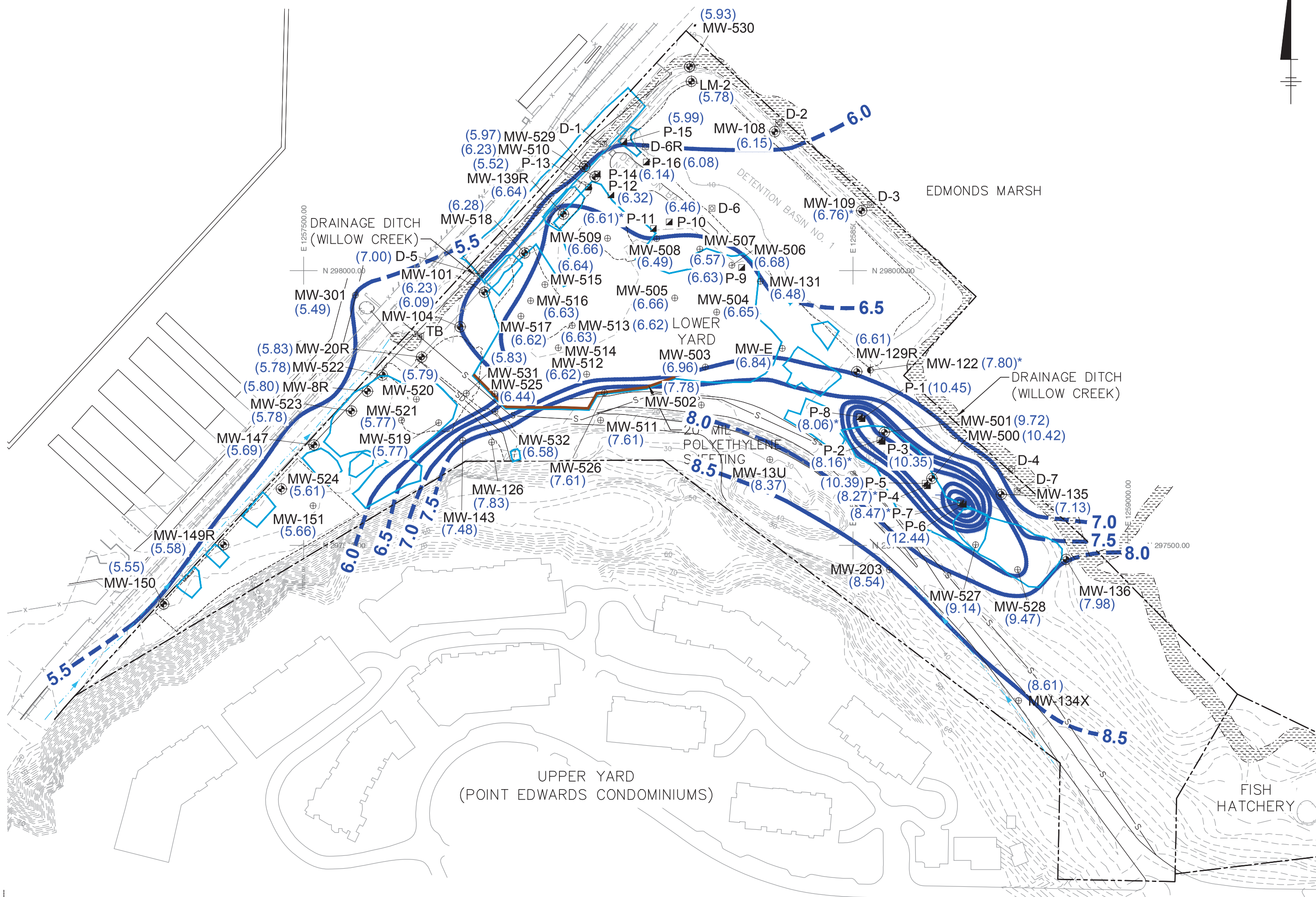
ARCADIS

FIGURE
2-9

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362B02.dwg LAYOUT: 2-9 SAVED: 12/17/2013 12:50 PM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: OCE TDS600 SV1F.CTB PLOTTED: 12/17/2013 12:51 PM BY: LISTER, PAUL
XREFS: 45362X02 45362XDL 45362X03 IMAGES: PROJECTNAME: ---



DRAINAGE DITCH (WILLOW CREEK)
EDMONDS MARSH
DETENTION BASIN NO. 1
DETENTION BASIN NO. 2
LOWER YARD
20-MIL POLYETHYLENE SHEETING
DRAINAGE DITCH (WILLOW CREEK)
UPPER UNOCO ROAD
UPPER YARD (POINT EDWARDS CONDOMINIUMS)
FISH HATCHERY
N 298000.00
N 297500.00
E 1257500.00
E 1258500.00
E 1259000.00
LEGEND:
2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
LOWER YARD PROPERTY BOUNDARY
2007/2008 EXCAVATION BOUNDARIES
WSDOT STORM DRAIN LINE
POINT EDWARDS STORM DRAIN LINE
BOTTOM OF GRAVEL BACKFILL ELEVATION:
8 – 9 FT AMSL
6 – 4 FT AMSL
4 – 2 FT AMSL
2 – 0 FT AMSL
0 TO –2 FT AMSL
NOTES:
1. 20–MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98). VERTICAL DATUM: N.A.V.D. 88 UNITS: U.S. SURVEY FEET HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. FT AMSL = FEET ABOVE MEAN SEA LEVEL.
4. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.
0 200' 400'
GRAPHIC SCALE
CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT
BOTTOM OF 2008 GRAVEL BACKFILL ELEVATIONS
ARCADIS
FIGURE 2-10
CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362B21.dwg LAYOUT: 2-10 SAVED: 12/17/2013 1:01 PM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: OCE TDS600 SV1F.CTB PLOTTED: 12/17/2013 1:02 PM BY: LISTER, PAUL
XREFS: 45362X02 45362XDL 45362X03 IMAGES: PROJECTNAME: ---



LEGEND:

MW-203 ⊕	INTERIOR MONITORING WELL LOCATION AND DESIGNATION
MW-122	DEEP MONITORING WELL LOCATION AND DESIGNATION
MW-109	SURFACE WATER POINT OF COMPLIANCE MONITORING WELL LOCATION
P-11	PIEZOMETER
D-1	STAFF GAUGE
	2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
	LOWER YARD PROPERTY BOUNDARY
	2007/2008 EXCAVATION BOUNDARIES
—S—	WSDOT STORM DRAIN LINE
—SD—	POINT EDWARDS STORM DRAIN LINE
7.5	GROUNDWATER ELEVATION CONTOUR (DASHED WHERE INFERRED)
(9.72)	GROUNDWATER ELEVATION
(8.16)*	GROUNDWATER ELEVATION NOT USED IN CONTOURING

NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98). VERTICAL DATUM: N.A.V.D. 88 UNITS: U.S. SURVEY FEET HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 200' 400'
GRAPHIC SCALE

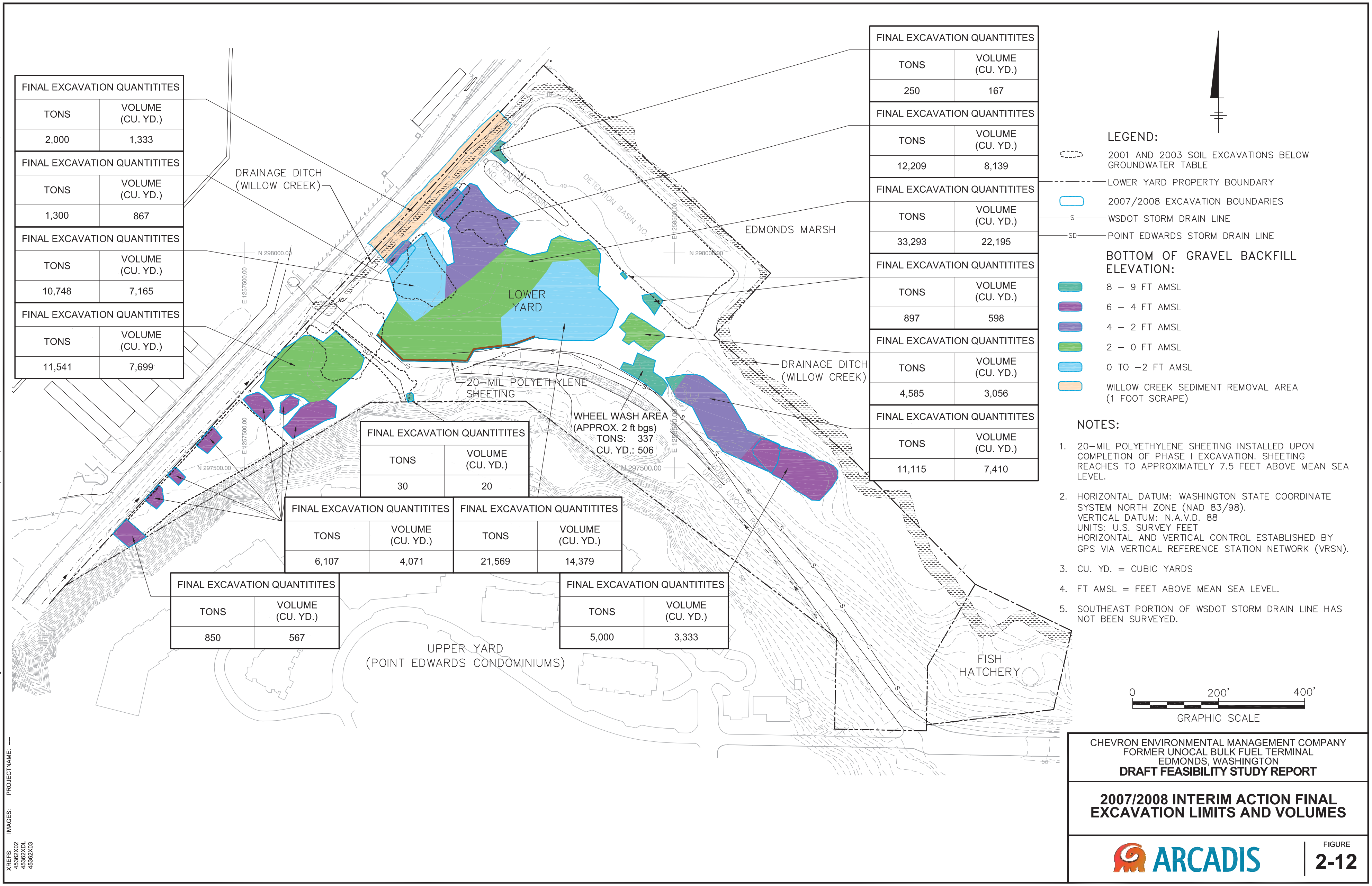
CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

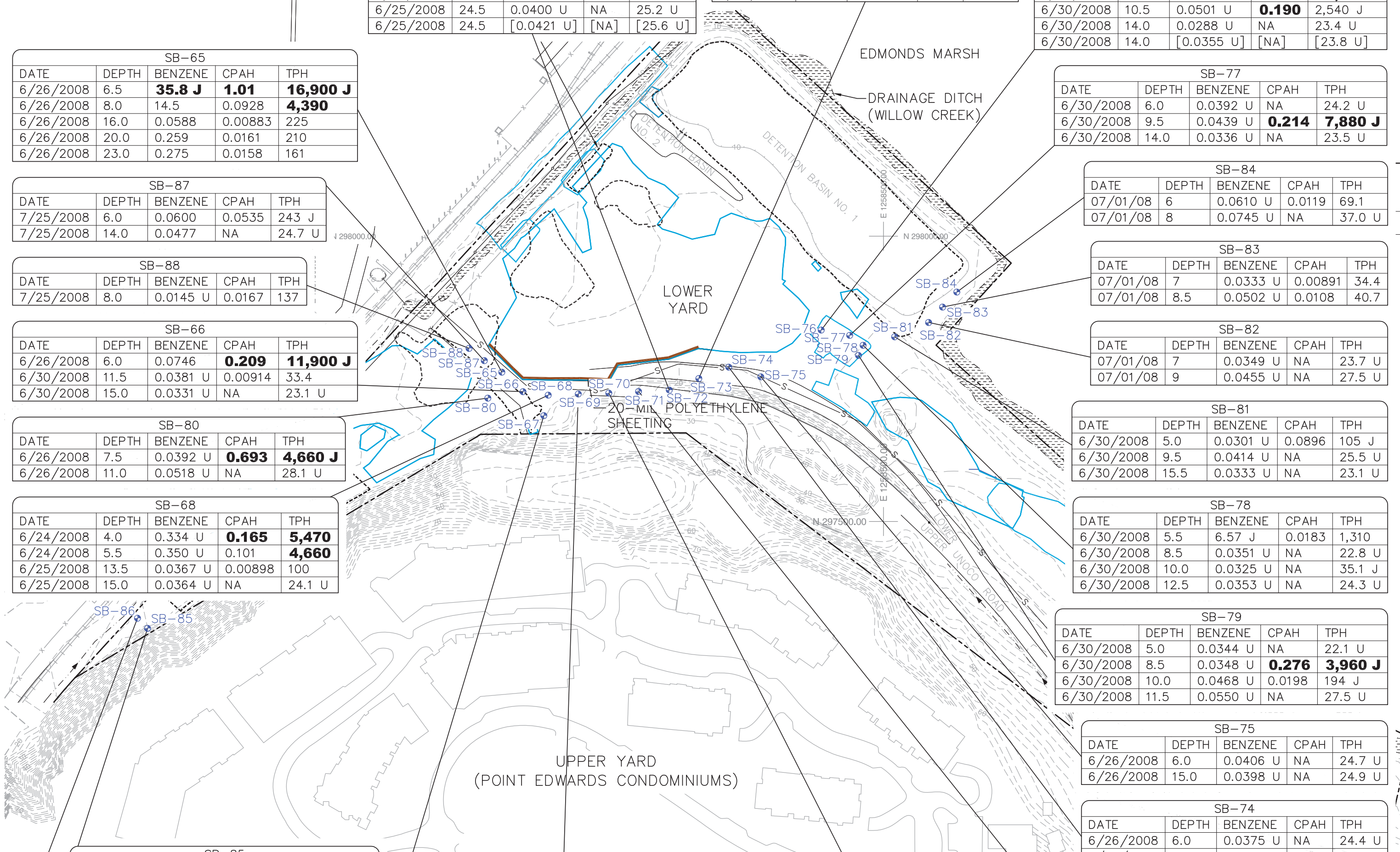
THIRD QUARTER, 2013 GROUNDWATER ELEVATIONS AND CONTOURS - SEPTEMBER 23, 2013

ARCADIS

FIGURE
2-11

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362W02.dwg LAYOUT: 2-11 SAVED: 12/17/2013 1:09 PM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: OCE TDS600 SV1F.CTB PLOTTED: 12/17/2013 1:10 PM BY: LISTER, PAUL
XREFS: 45362x02 45362x03 45362XDL IMAGES: PROJECTNAME: ----


FINAL EXCAVATION QUANTITITES
TONS 2,000 VOLUME (CU. YD.) 1,333
FINAL EXCAVATION QUANTITITES
TONS 1,300 VOLUME (CU. YD.) 867
FINAL EXCAVATION QUANTITITES
TONS 10,748 VOLUME (CU. YD.) 7,165
FINAL EXCAVATION QUANTITITES
TONS 11,541 VOLUME (CU. YD.) 7,699
FINAL EXCAVATION QUANTITITES
TONS 250 VOLUME (CU. YD.) 167
FINAL EXCAVATION QUANTITITES
TONS 12,209 VOLUME (CU. YD.) 8,139
FINAL EXCAVATION QUANTITITES
TONS 33,293 VOLUME (CU. YD.) 22,195
FINAL EXCAVATION QUANTITITES
TONS 897 VOLUME (CU. YD.) 598
FINAL EXCAVATION QUANTITITES
TONS 4,585 VOLUME (CU. YD.) 3,056
FINAL EXCAVATION QUANTITITES
TONS 11,115 VOLUME (CU. YD.) 7,410
FINAL EXCAVATION QUANTITITES
TONS 30 VOLUME (CU. YD.) 20
FINAL EXCAVATION QUANTITITES
TONS 6,107 VOLUME (CU. YD.) 4,071
FINAL EXCAVATION QUANTITITES
TONS 21,569 VOLUME (CU. YD.) 14,379
FINAL EXCAVATION QUANTITITES
TONS 850 VOLUME (CU. YD.) 567
FINAL EXCAVATION QUANTITITES
TONS 5,000 VOLUME (CU. YD.) 3,333
DRAINAGE DITCH (WILLOW CREEK)
EDMONDS MARSH
LOWER YARD
20-MIL POLYETHYLENE SHEETING
WHEEL WASH AREA (APPROX. 2 ft bgs) TONS: 337 CU. YD.: 506
DETENTION BASIN NO. 2
UPPER YARD (POINT EDWARDS CONDOMINIUMS)
FISH HATCHERY
N 298000.00
N 297500.00
E 1257500.00
E 1258000.00
LEGEND:
2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
LOWER YARD PROPERTY BOUNDARY
2007/2008 EXCAVATION BOUNDARIES
WSDOT STORM DRAIN LINE
POINT EDWARDS STORM DRAIN LINE
BOTTOM OF GRAVEL BACKFILL ELEVATION:
8 – 9 FT AMSL
6 – 4 FT AMSL
4 – 2 FT AMSL
2 – 0 FT AMSL
0 TO –2 FT AMSL
WILLOW CREEK SEDIMENT REMOVAL AREA (1 FOOT SCRAPE)
NOTES:
1. 20–MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98). VERTICAL DATUM: N.A.V.D. 88 UNITS: U.S. SURVEY FEET HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. CU. YD. = CUBIC YARDS
4. FT AMSL = FEET ABOVE MEAN SEA LEVEL.
5. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.
0 200' 400'
GRAPHIC SCALE
CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT
2007/2008 INTERIM ACTION FINAL EXCAVATION LIMITS AND VOLUMES
ARCADIS
FIGURE 2-12



LEGEND:

- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- LOWER YARD PROPERTY BOUNDARY
- 2007/2008 EXCAVATION BOUNDARIES
- S — WSDOT STORM DRAIN LINE
- SD — POINT EDWARDS STORM DRAIN LINE
- SOIL BORING/HAND AUGER LOCATION
- CPAH — CARCINOGENIC POLYNUCLEAR AROMATIC HYDROCARBONS, ADJUSTED FOR TOXICITY
- TPH — TOTAL PETROLEUM HYDROCARBONS
- [ ] — VALUES SHOWN IN BRACKETS INDICATE DUPLICATE RESULTS
- NA — INDICATES ANALYSIS NOT CONDUCTED
- U — THE COMPOUND WAS ANALYZED FOR BUT NOT DETECTED. THE ASSOCIATED VALUE IS THE COMPOUND QUANTITATION LIMIT
- J — INDICATES AN ESTIMATED VALUE
- ALL DATA REPORTED AS MILLIGRAMS PER KILOGRAMS (mg/kg)
- SAMPLE DEPTHS REPORTED AS FEET BELOW GROUND SURFACE (ft bgs)
- BOLDED DATA INDICATES CONCENTRATIONS GREATER THAN APPLICABLE SITE CULs/RELs

NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I OF THE 2007/2008 EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
VERTICAL DATUM: N.A.V.D. 88
UNITS: U.S. SURVEY FEET
HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

GRAPHIC SCALE: 0 — 200' — 400'

SB-72

DATE	DEPTH	BENZENE	CPAH	TPH
6/25/2008	6.5	0.0371 U	NA	23.6 U
6/25/2008	15.5	0.0348 U	NA	24.0 U
6/25/2008	24.5	0.0400 U	NA	25.2 U
6/25/2008	24.5	[0.0421 U]	[NA]	[25.6 U]

SB-73

DATE	DEPTH	BENZENE	CPAH	TPH
6/26/2008	6.0	0.0445 U	NA	26.5 U
6/26/2008	15.0	0.0369 U	NA	24.1 U

SB-76

DATE	DEPTH	BENZENE	CPAH	TPH
6/30/2008	4.5	0.0389 U	NA	29.1
6/30/2008	9.0	0.0436 U	**0.198**	**17,100 J**
6/30/2008	10.5	0.0501 U	**0.190**	2,540 J
6/30/2008	14.0	0.0288 U	NA	23.4 U
6/30/2008	14.0	[0.0355 U]	[NA]	[23.8 U]

SB-65

DATE	DEPTH	BENZENE	CPAH	TPH
6/26/2008	6.5	**35.8 J**	**1.01**	**16,900 J**
6/26/2008	8.0	14.5	0.0928	**4,390**
6/26/2008	16.0	0.0588	0.00883	225
6/26/2008	20.0	0.259	0.0161	210
6/26/2008	23.0	0.275	0.0158	161

SB-87

DATE	DEPTH	BENZENE	CPAH	TPH
7/25/2008	6.0	0.0600	0.0535	243 J
7/25/2008	14.0	0.0477	NA	24.7 U

SB-88

DATE	DEPTH	BENZENE	CPAH	TPH
7/25/2008	8.0	0.0145 U	0.0167	137

SB-66

DATE	DEPTH	BENZENE	CPAH	TPH
6/26/2008	6.0	0.0746	**0.209**	**11,900 J**
6/30/2008	11.5	0.0381 U	0.00914	33.4
6/30/2008	15.0	0.0331 U	NA	23.1 U

SB-80

DATE	DEPTH	BENZENE	CPAH	TPH
6/26/2008	7.5	0.0392 U	**0.693**	**4,660 J**
6/26/2008	11.0	0.0518 U	NA	28.1 U

SB-68

DATE	DEPTH	BENZENE	CPAH	TPH
6/24/2008	4.0	0.334 U	**0.165**	**5,470**
6/24/2008	5.5	0.350 U	0.101	**4,660**
6/25/2008	13.5	0.0367 U	0.00898	100
6/25/2008	15.0	0.0364 U	NA	24.1 U

SB-77

DATE	DEPTH	BENZENE	CPAH	TPH
6/30/2008	6.0	0.0392 U	NA	24.2 U
6/30/2008	9.5	0.0439 U	**0.214**	**7,880 J**
6/30/2008	14.0	0.0336 U	NA	23.5 U

SB-84

DATE	DEPTH	BENZENE	CPAH	TPH
07/01/08	6	0.0610 U	0.0119	69.1
07/01/08	8	0.0745 U	NA	37.0 U

SB-83

DATE	DEPTH	BENZENE	CPAH	TPH
07/01/08	7	0.0333 U	0.00891	34.4
07/01/08	8.5	0.0502 U	0.0108	40.7

SB-82

DATE	DEPTH	BENZENE	CPAH	TPH
07/01/08	7	0.0349 U	NA	23.7 U
07/01/08	9	0.0455 U	NA	27.5 U

SB-81

DATE	DEPTH	BENZENE	CPAH	TPH
6/30/2008	5.0	0.0301 U	0.0896	105 J
6/30/2008	9.5	0.0414 U	NA	25.5 U
6/30/2008	15.5	0.0333 U	NA	23.1 U

SB-78

DATE	DEPTH	BENZENE	CPAH	TPH
6/30/2008	5.5	6.57 J	0.0183	1,310
6/30/2008	8.5	0.0351 U	NA	22.8 U
6/30/2008	10.0	0.0325 U	NA	35.1 J
6/30/2008	12.5	0.0353 U	NA	24.3 U

SB-79

DATE	DEPTH	BENZENE	CPAH	TPH
6/30/2008	5.0	0.0344 U	NA	22.1 U
6/30/2008	8.5	0.0348 U	**0.276**	**3,960 J**
6/30/2008	10.0	0.0468 U	0.0198	194 J
6/30/2008	11.5	0.0550 U	NA	27.5 U

SB-75

DATE	DEPTH	BENZENE	CPAH	TPH
6/26/2008	6.0	0.0406 U	NA	24.7 U
6/26/2008	15.0	0.0398 U	NA	24.9 U

SB-74

DATE	DEPTH	BENZENE	CPAH	TPH
6/26/2008	6.0	0.0375 U	NA	24.4 U
6/26/2008	15.0	0.0380 U	NA	24.5 U

SB-71

DATE	DEPTH	BENZENE	CPAH	TPH
6/25/2008	8.0	0.0368 U	NA	23.6 U
6/25/2008	15.5	0.0363 U	0.00876	50.9
6/25/2008	24.0	0.0366 U	NA	23.7 U

SB-85

DATE	DEPTH	BENZENE	CPAH	TPH
7/02/2008	5.5	0.0357 U	0.0225	92.5
7/02/2008	7.5	0.114 U	NA	214 J

SB-86

DATE	DEPTH	BENZENE	CPAH	TPH
7/02/2008	4.5	0.0324 U	0.0182	112 J
7/02/2008	6.5	0.0513 U	NA	29.1 U

SB-67

DATE	DEPTH	BENZENE	CPAH	TPH
6/24/2008	5.5	0.0398 U	NA	24.1 U

SB-69

DATE	DEPTH	BENZENE	CPAH	TPH
6/26/2008	6.0	0.149 J	**0.236**	**3,720**
6/26/2008	12.0	0.0385 U	NA	24.0 U
6/26/2008	15.0	0.0393 U	NA	24.1 U
6/26/2008	15.0	[0.0384 U]	NA	[32.6]

SB-70

DATE	DEPTH	BENZENE	CPAH	TPH
6/24/2008	6.0	0.0371 U	NA	22.1 U
6/24/2008	7.0	0.0369 U	NA	23.2 U
6/25/2008	12.5	0.0366 U	NA	23.4 U
6/25/2008	20.5	0.0340 U	NA	23.4 U

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

2008 SITE INVESTIGATION SAMPLE LOCATIONS AND ANALYTICAL RESULTS

ARCADIS

FIGURE **2-13**

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ) PAGESETUP: --- PLOTSTYLETABLE: OCE TDS600 SV1F.CTB PLOTTED: 12/17/2013 11:53 AM BY: LISTER, PAUL
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362C06.dwg LAYOUT: 2-13 SAVED: 12/3/2013 10:02 AM ACADVER: 18.1S (LMS TECH)
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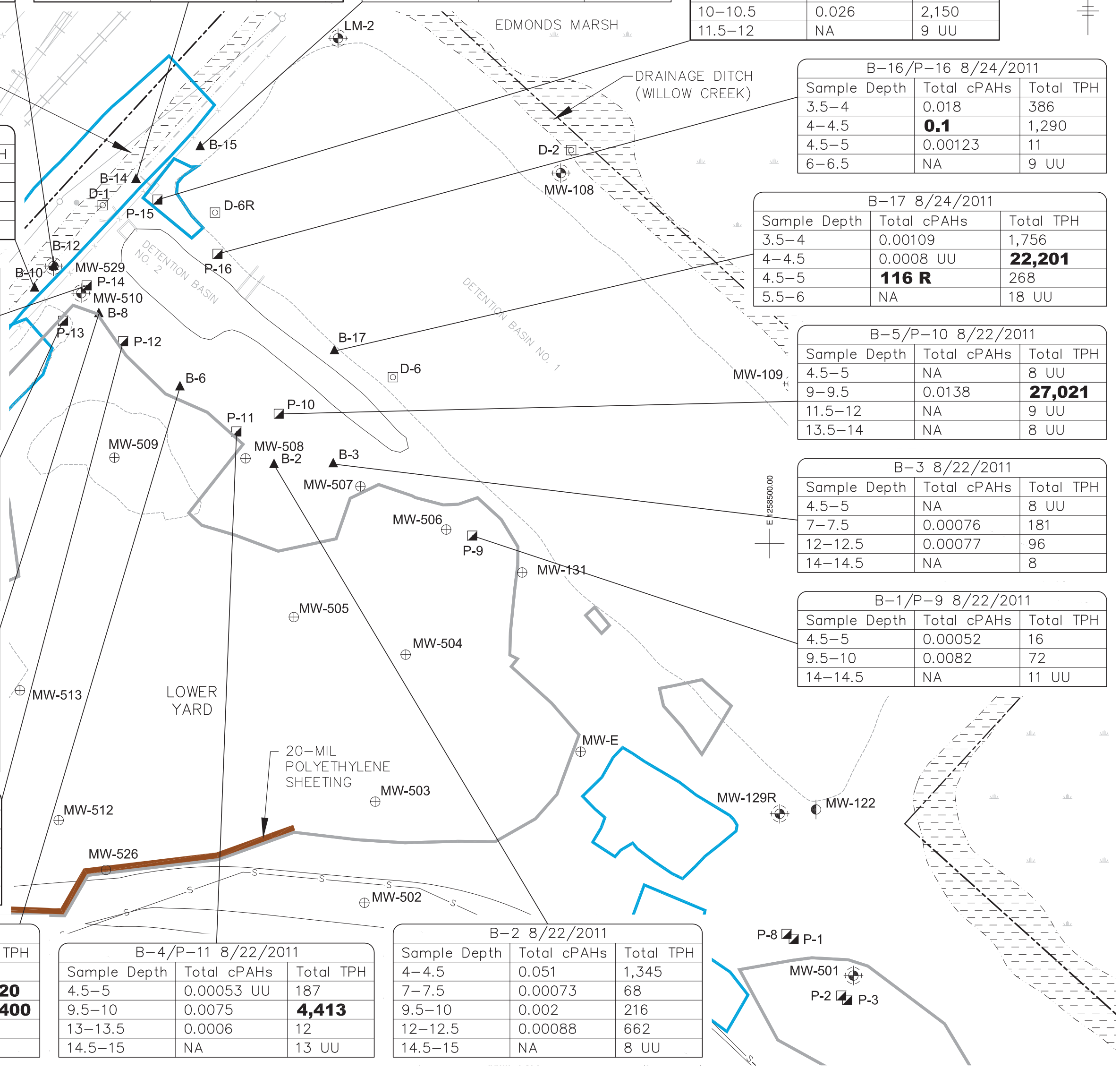


B-12 8/24/2011		
Sample Depth	Total cPAHs	Total TPH
0.5–1	0.0117	299
1–1.5	0.00072 UU	254
2.5–3	0.079	248
3.5–4	0.00063	33

B-14 8/25/2011		
Sample Depth	Total cPAHs	Total TPH
0.5–1	0.029	155
1.5–2	NA	6 UU
2.5–3	NA	24 UU
3.5–4	0.0009	98

B-15 8/23/2011		
Sample Depth	Total cPAHs	Total TPH
4.5–5	0.0005	22
6.5–7	NA	20
8.5–9	0.0008	63
11–11.5	NA	16 UU

B-13/P-15 8/23/2011		
Sample Depth	Total cPAHs	Total TPH
4.5–5	0.0046	81
6–6.5	0.036	368
7–7.5	0.054 R	**15,900**
9–9.5	NA	9 UU
10–10.5	0.026	2,150
11.5–12	NA	9 UU

B-10 8/25/2011		
Sample Depth	Total cPAHs	Total TPH
0.5–1	**0.2**	758
1.5–2	0.018	86
2.5–3	0.00068 UU	37
3.5–4	0.00072	57

B-16/P-16 8/24/2011		
Sample Depth	Total cPAHs	Total TPH
3.5–4	0.018	386
4–4.5	**0.1**	1,290
4.5–5	0.00123	11
6–6.5	NA	9 UU

B-17 8/24/2011		
Sample Depth	Total cPAHs	Total TPH
3.5–4	0.00109	1,756
4–4.5	0.0008 UU	**22,201**
4.5–5	**116 R**	268
5.5–6	NA	18 UU

B-11/P-14 8/23/2011		
Sample Depth	Total cPAHs	Total TPH
4.5–5	**0.24**	1,011
7.5–8	0.012	**35,240**
8.5–9	0.012	53
9.5–10	**1.6 T**	12
10–10.5	**3.4**	**37,150**
11–11.5	0.01	461
13.5–14	NA	8 UU

B-5/P-10 8/22/2011		
Sample Depth	Total cPAHs	Total TPH
4.5–5	NA	8 UU
9–9.5	0.0138	**27,021**
11.5–12	NA	9 UU
13.5–14	NA	8 UU

B-9/P-13 8/23/2011		
Sample Depth	Total cPAHs	Total TPH
4.5–5	NA	29
8.5–9	**0.29**	**20,970**
9.5–10	0.0024	30
10.5–11	0.025	921
11–11.5	**0.15 T**	**16,250**
12.5–13	0.00065	15

B-3 8/22/2011		
Sample Depth	Total cPAHs	Total TPH
4.5–5	NA	8 UU
7–7.5	0.00076	181
12–12.5	0.00077	96
14–14.5	NA	8

B-8 8/23/2011		
Sample Depth	Total cPAHs	Total TPH
4.5–5	0.114	**16,500**
7.5–8	0.077	**9,360**
9.5–10	**0.5 T**	**75,730**
11–11.5	0.09	**8,200**
13.5–14	**0.1**	55
14.5–15	NA	8 UU

B-1/P-9 8/22/2011		
Sample Depth	Total cPAHs	Total TPH
4.5–5	0.00052	16
9.5–10	0.0082	72
14–14.5	NA	11 UU

B-7/P-12 8/22/2011		
Sample Depth	Total cPAHs	Total TPH
4.5–5	0.071	700
8–8.5	**2.8 T**	**111,400**
9.5–10	0.037 T	**5,947**
14–14.5	NA	8 UU

B-6 8/22/2011		
Sample Depth	Total cPAHs	Total TPH
4.5–5	0.09	970
7–7.5	**0.36**	**21,620**
9–9.5	**3.2 T**	**220,400**
11–11.5	0.012	317
13–13.5	NA	8 UU

B-4/P-11 8/22/2011		
Sample Depth	Total cPAHs	Total TPH
4.5–5	0.00053 UU	187
9.5–10	0.0075	**4,413**
13–13.5	0.0006	12
14.5–15	NA	13 UU

B-2 8/22/2011		
Sample Depth	Total cPAHs	Total TPH
4–4.5	0.051	1,345
7–7.5	0.00073	68
9.5–10	0.002	216
12–12.5	0.00088	662
14.5–15	NA	8 UU

LEGEND:

MW-203 — INTERIOR MONITORING WELL LOCATION AND DESIGNATION
MW-122 — DEEP MONITORING WELL LOCATION AND DESIGNATION
MW-109 — SURFACE WATER POINT OF COMPLIANCE MONITORING WELL LOCATION
P-11 — PIEZOMETER
D-1 — STAFF GAUGE
2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
LOWER YARD PROPERTY BOUNDARY
2007/2008 EXCAVATION BOUNDARIES
S — WSDOT STORM DRAIN LINE
SD — POINT EDWARDS STORM DRAIN LINE

LOCATION ID SAMPLE DATE		
Sample Depth	Total cPAHs	Total TPH
Depth in feet below ground surface	Total carcinogenic polynuclear aromatic hydrocarbons (mg/kg)	Total petroleum hydrocarbons (mg/kg)

UU – THE CONSTITUENTS MAKING UP THE TOTAL ARE ALL NON-DETECTS
T – REPORTING LIMITS WERE RAISED DUE TO INTERFERENCE FROM THE SAMPLE MATRIX
R – THE GC/MS SEMIVOLATILE INTERNAL STANDARD PEAK AREAS WERE OUTSIDE OF THE QC LIMITS FOR BOTH THE INITIAL INJECTION AND THE RE-INJECTION
NA – ANALYSIS NOT CONDUCTED
mg/kg – MILLIGRAMS PER KILOGRAM
BOLD CONCENTRATIONS REPRESENT EXCEEDANCE OF SITE CLEAN-UP LEVELS

NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98). VERTICAL DATUM: N.A.V.D. 88. UNITS: U.S. SURVEY FEET. HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 80' 160'
GRAPHIC SCALE

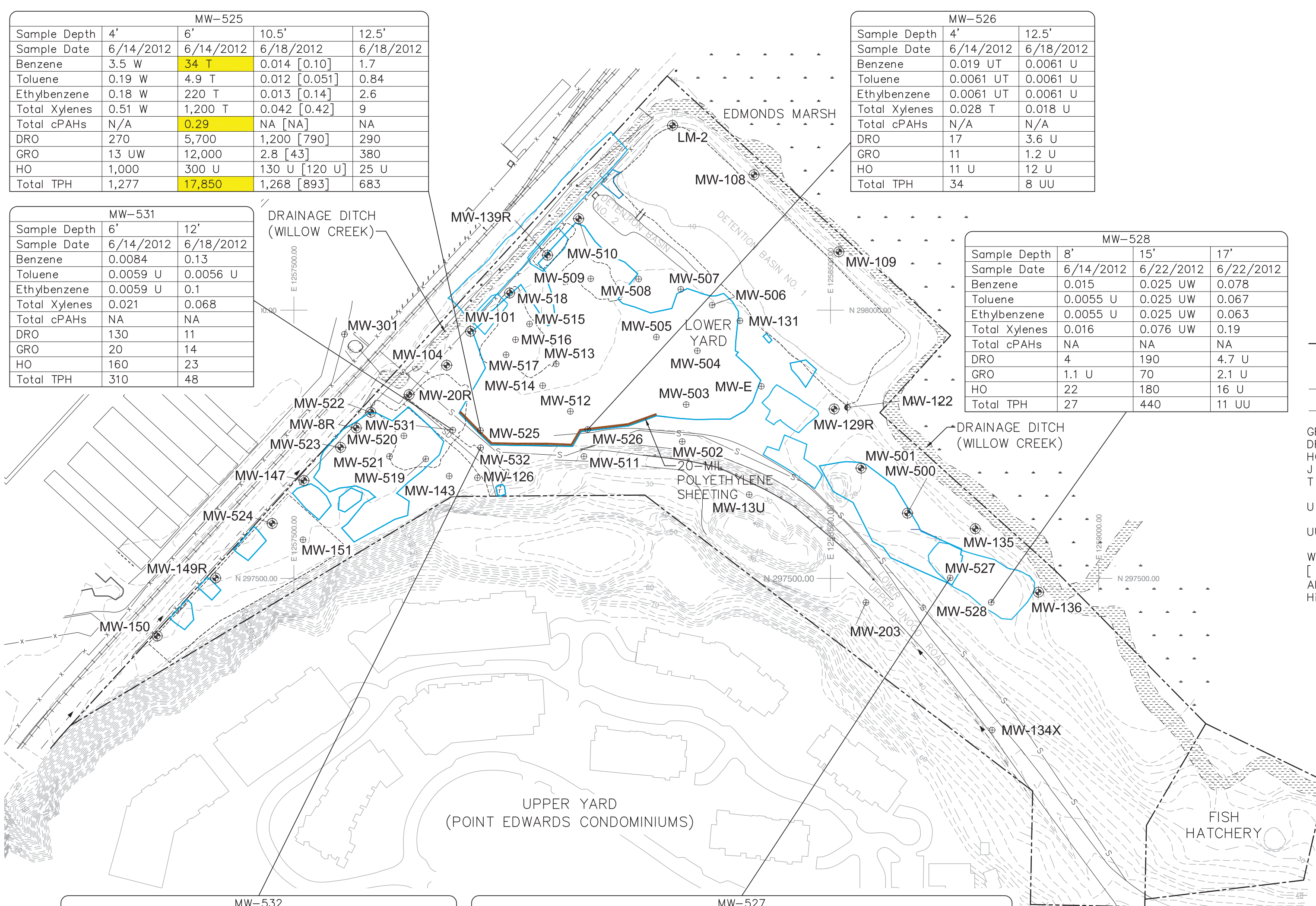
CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

2011 SITE INVESTIGATION SOIL SAMPLE LOCATIONS AND ANALYTICAL RESULTS

ARCADIS

FIGURE
2-14

CITY: SYRACUSE, NY DIV/GROUP: ENV/IM DB: PS LD: PIC: PM: TM: TR: LYR: ON=*;OFF=*REF*
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362C01.dwg LAYOUT: 2-14 SAVED: 11/20/2013 10:25 AM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 11/20/2013 PLOTTER: PAUL
XREFS: 45362X01 45362X02 45362XDL 45362X03 IMAGES: PROJECTNAME: ---



MW-525				
Sample Depth	4'	6'	10.5'	12.5'
Sample Date	6/14/2012	6/14/2012	6/18/2012	6/18/2012
Benzene	3.5 W	34 T	0.014 [0.10]	1.7
Toluene	0.19 W	4.9 T	0.012 [0.051]	0.84
Ethylbenzene	0.18 W	220 T	0.013 [0.14]	2.6
Total Xylenes	0.51 W	1,200 T	0.042 [0.42]	9
Total cPAHs	N/A	0.29	NA [NA]	NA
DRO	270	5,700	1,200 [790]	290
GRO	13 UW	12,000	2.8 [43]	380
HO	1,000	300 U	130 U [120 U]	25 U
Total TPH	1,277	17,850	1,268 [893]	683

MW-531		
Sample Depth	6'	12'
Sample Date	6/14/2012	6/18/2012
Benzene	0.0084	0.13
Toluene	0.0059 U	0.0056 U
Ethylbenzene	0.0059 U	0.1
Total Xylenes	0.021	0.068
Total cPAHs	NA	NA
DRO	130	11
GRO	20	14
HO	160	23
Total TPH	310	48

MW-526		
Sample Depth	4'	12.5'
Sample Date	6/14/2012	6/18/2012
Benzene	0.019 UT	0.0061 U
Toluene	0.0061 UT	0.0061 U
Ethylbenzene	0.0061 UT	0.0061 U
Total Xylenes	0.028 T	0.018 U
Total cPAHs	N/A	N/A
DRO	17	3.6 U
GRO	11	1.2 U
HO	11 U	12 U
Total TPH	34	8 UU

MW-528			
Sample Depth	8'	15'	17'
Sample Date	6/14/2012	6/22/2012	6/22/2012
Benzene	0.015	0.025 UW	0.078
Toluene	0.0055 U	0.025 UW	0.067
Ethylbenzene	0.0055 U	0.025 UW	0.063
Total Xylenes	0.016	0.076 UW	0.19
Total cPAHs	NA	NA	NA
DRO	4	190	4.7 U
GRO	1.1 U	70	2.1 U
HO	22	180	16 U
Total TPH	27	440	11 UU

MW-532				
Sample Depth	6'	7'	10'	13.5'
Sample Date	6/18/2012	6/18/2012	6/18/2012	6/18/2012
Benzene	0.084 U	0.16 UT	0.0079 U	0.0066 U
Toluene	0.084 U	0.11 T	0.0079 U	0.0066 U
Ethylbenzene	0.084 U	0.026 UT	0.0079 U	0.0066 U
Total Xylenes	0.25 U	0.026 UT	0.024 U	0.02
Total cPAHs	NA	0.04	NA	NA
DRO	800	5,000	4.4 U	760
GRO	17 UW	340	1.6 U	1.3 U
HO	690	5,200	15 U	920
Total TPH	1,499	10,540	11 UU	1,681

MW-527					
Sample Depth	8'	9'	12'	13.5'	17'
Sample Date	6/14/2012	6/22/2012	6/22/2012	6/22/2012	6/22/2012
Benzene	0.02	0.053 UW	0.11 UW	0.11 UW	0.068 UW [0.070 UW]
Toluene	0.0061 U	0.053 UW	0.11 UW	0.11 UW	0.068 UW [0.070 UW]
Ethylbenzene	0.0061 U	0.053 UW	0.11 UW	0.11 UW	0.068 UW [0.070 UW]
Total Xylenes	0.018 U	0.16 UW	0.32 UW	0.32 UW	0.20 UW [0.21 UW]
Total cPAHs	NA	NA	NA	NA	NA [NA]
DRO	170	240	220	990	3.8 U [3.9 U]
GRO	2.4	11 UW	96	21 UW	14 UW [14 UW]
HO	180	390	400	620	13 U [13 U]
Total TPH	352	636	716	1,621	15 UU [15 UU]

LEGEND:

- MW-203 ⊕ INTERIOR MONITORING WELL LOCATION AND DESIGNATION
- MW-122 DEEP MONITORING WELL LOCATION AND DESIGNATION
- MW-109 SURFACE WATER POINT OF COMPLIANCE MONITORING WELL LOCATION
- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- LOWER YARD PROPERTY BOUNDARY
- 2007/2008 EXCAVATION BOUNDARIES
- —S— WSDOT STORM DRAIN LINE
- —SD— POINT EDWARDS STORM DRAIN LINE

GRO = Total petroleum hydrocarbons in the gasoline range
DRO = Total petroleum hydrocarbons in the diesel range
HO = Total petroleum hydrocarbons in the heavy oil range
J = an estimated value.
T = Reporting limits were raised due to interference from the sample matrix.
U = The compound was analyzed for but not detected. The associated value is the compound quantitation limit.
UU = The constituents making up the total are all Non-detects.
W = Reporting limits were raised due to sample foaming.
[ ] = Duplicate results are shown in brackets
All results are micrograms per kilogram (mg/kg).
Highlighted values exceed remediation or cleanup levels.

NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98). VERTICAL DATUM: N.A.V.D. 88 UNITS: U.S. SURVEY FEET HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

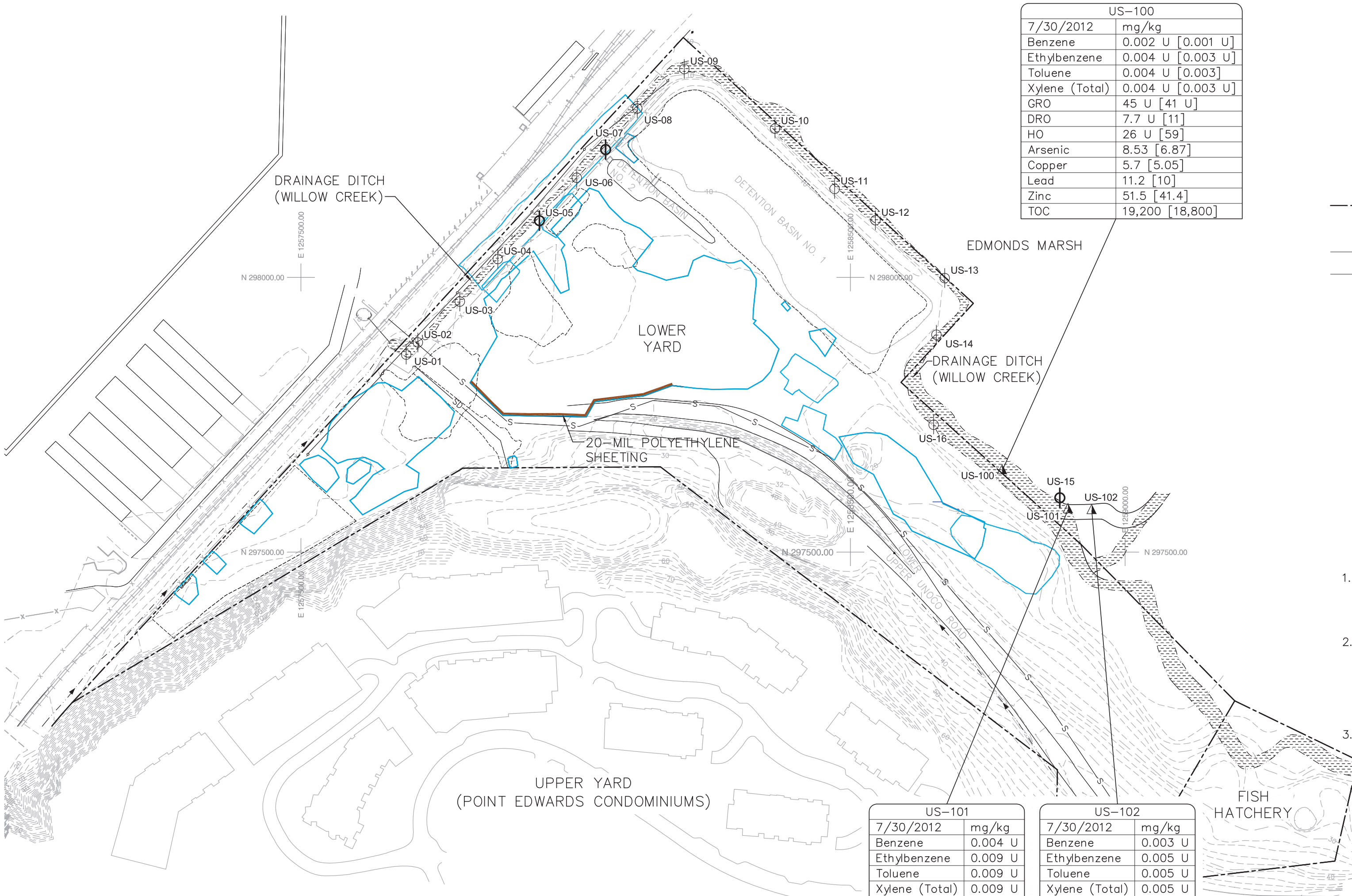
CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

2012 SOIL SAMPLE LOCATIONS AND ANALYTICAL RESULTS

ARCADIS

FIGURE
2-15

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362C08.dwg LAYOUT: 2-15 SAVED: 12/3/2013 10:03 AM ACADVER: 18.1S (LMS TECH) PAGESETUP: --- PLOTSTYLETABLE: OCE TDS600 SV1F.CTB PLOTTED: 12/17/2013 1:05 PM BY: LISTER, PAUL
XREFS: 45362XDL 45362X02 45362X03 IMAGES: PROJECTNAME: ---



US-100	
7/30/2012	mg/kg
Benzene	0.002 U [0.001 U]
Ethylbenzene	0.004 U [0.003 U]
Toluene	0.004 U [0.003]
Xylene (Total)	0.004 U [0.003 U]
GRO	45 U [41 U]
DRO	7.7 U [11]
HO	26 U [59]
Arsenic	8.53 [6.87]
Copper	5.7 [5.05]
Lead	11.2 [10]
Zinc	51.5 [41.4]
TOC	19,200 [18,800]

US-101	
7/30/2012	mg/kg
Benzene	0.004 U
Ethylbenzene	0.009 U
Toluene	0.009 U
Xylene (Total)	0.009 U
GRO	140 U
DRO	29
HO	170
Arsenic	29.1
Copper	43.6
Lead	107
Zinc	319
TOC	64,700

US-102	
7/30/2012	mg/kg
Benzene	0.003 U
Ethylbenzene	0.005 U
Toluene	0.005 U
Xylene (Total)	0.005 U
GRO	100 U
DRO	17
HO	110
Arsenic	20.2
Copper	21.6
Lead	60.6
Zinc	144
TOC	65,200

LEGEND:

- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- LOWER YARD PROPERTY BOUNDARY
- 2007/2008 EXCAVATION BOUNDARIES
- S — WSDOT STORM DRAIN LINE
- SD — POINT EDWARDS STORM DRAIN LINE
- SEDIMENT SAMPLE LOCATIONS (2003)
- SEDIMENT SAMPLE LOCATIONS (2012)
- BOLDED SEDIMENT SAMPLE LOCATIONS INDICATE FAILED BIOASSAY TESTING IN 2003.

GRO = Total petroleum hydrocarbons in the gasoline range
DRO = Total petroleum hydrocarbons in the diesel range
HO = Total petroleum hydrocarbons in the heavy oil range
TOC = Total Organic Carbon
U = Indicates the value was below the Method Detection Limit.
[ ] = Duplicate results are shown in brackets

NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
   VERTICAL DATUM: N.A.V.D. 88
   UNITS: U.S. SURVEY FEET
   HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 200' 400'
GRAPHIC SCALE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

SEDIMENT SAMPLING LOCATIONS AND 2012 ANALYTICAL RESULTS

ARCADIS

FIGURE
2-16

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF* (FRZ)
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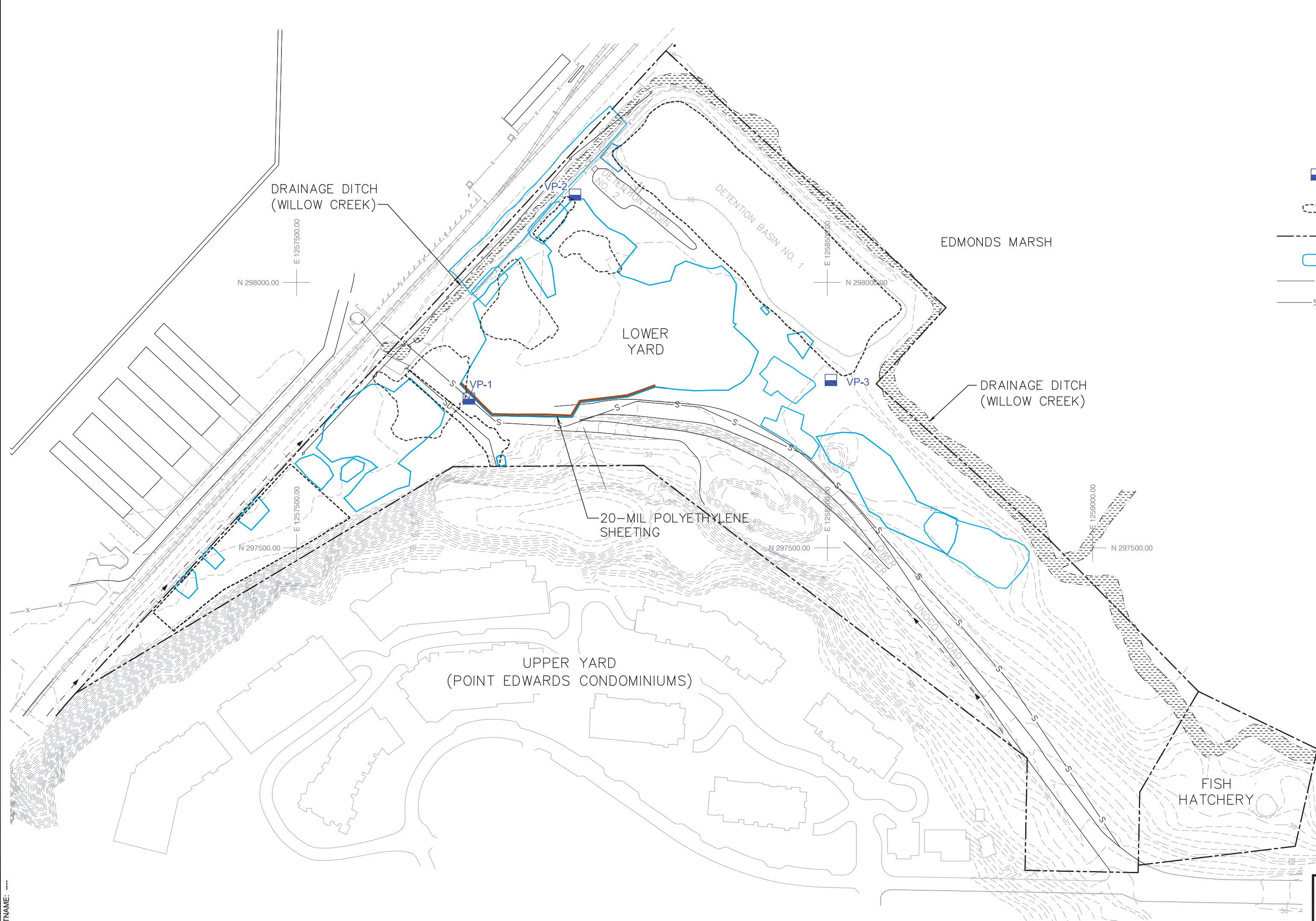
XREFS: IMAGES: PROJECTNAME: ---
45362X02
45362XDL
45362X03



LEGEND:

- SOIL VAPOR PROBE/SAMPLING LOCATION
- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- LOWER YARD PROPERTY BOUNDARY
- 2007/2008 EXCAVATION BOUNDARIES
- S — WSDOT STORM DRAIN LINE
- SD — POINT EDWARDS STORM DRAIN LINE

NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98). VERTICAL DATUM: N.A.V.D. 88
UNITS: U.S. SURVEY FEET
HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 200' 400'
GRAPHIC SCALE

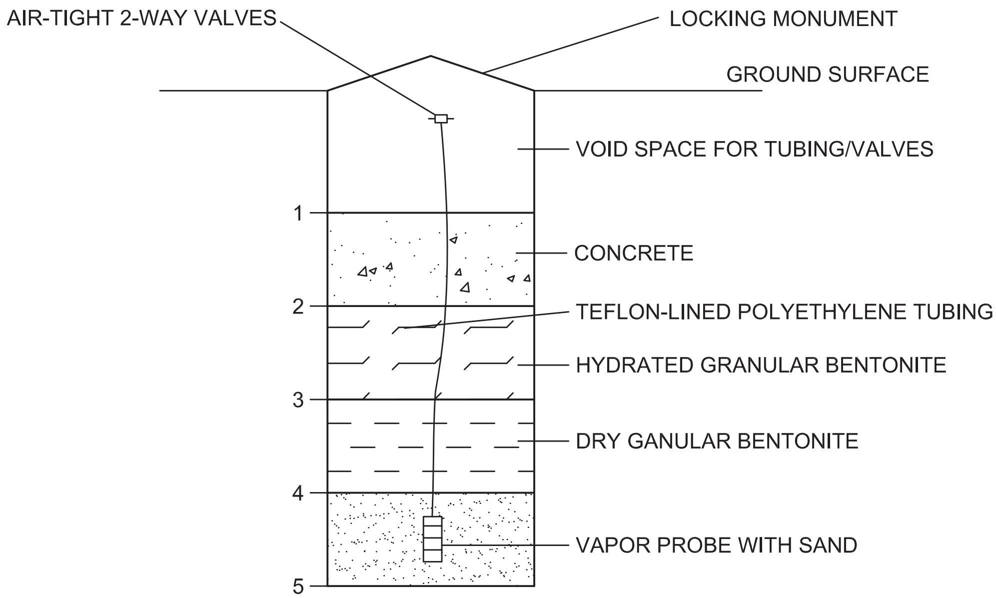
CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

SOIL VAPOR SAMPLING LOCATIONS

ARCADIS

FIGURE
2-17

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362B13.dwg LAYOUT: 2-17 SAVED: 12/17/2013 11:51 AM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: OCE TDS600 SV1F.CTB PLOTTED: 12/17/2013 11:51 AM BY: LISTER, PAUL
XREFS: 45362X02 45362XDL 45362X03 IMAGES: PROJECTNAME: ---



NOT TO SCALE

NOTE:

VAPOR PROBE IS CONSTRUCTED WITH A 6-INCH, 0.375-INCH OUTER DIAMETER STAINLESS STEEL SOIL VAPOR SCREEN.

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

SOIL VAPOR PROBE SCHEMATIC DIAGRAM

ARCADIS

FIGURE
2-18

CITY: (PETALUMA, CA), SYRACUSE, NY DIV/GROUP: ENV/REM-W/IM-DV DB: (J. HARRIS), P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362T01.dwg LAYOUT: 2-18 SAVED: 12/3/2013 10:06 AM ACADVER: 18.1S (LMS TECH) PAGESETUP: SETUP1 PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 12/3/2013 10:07 AM BY: LISTER, PAUL
XREFS: IMAGES: PROJECTNAME: ---

LEGEND:

- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- LOWER YARD PROPERTY BOUNDARY
- 2007/2008 EXCAVATION BOUNDARIES
- WSDOT STORM DRAIN LINE
- POINT EDWARDS STORM DRAIN LINE
- >500 μg/L
- >700 μg/L
- >900 μg/L
- LIGHT NONAQUEOUS PHASE LIQUID (LNAPL)

NOTES:

1. μg/L = MICROGRAMS PER LITER.
2. TOTAL TPH CONCENTRATIONS BASED ON SEPTEMBER 2006 SAMPLING EVENT RESULTS.
3. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
4. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98). VERTICAL DATUM: N.A.V.D. 88 UNITS: U.S. SURVEY FEET HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
5. SOUTEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 200' 400'
GRAPHIC SCALE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

PRE-REMEDIATION DISSOLVED TOTAL PETROLEUM HYDROCARBON CONCENTRATION AND LNAPL MAP (2006)

ARCADIS

FIGURE
3-1

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362C10.dwg LAYOUT: 3-1 SAVED: 12/3/2013 10:04 AM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: OCE TDS600 SV1F.CTB PLOTTED: 12/17/2013 1:07 PM BY: LISTER, PAUL
XREFS: IMAGES: PROJECTNAME: ---
45362X02
45362XDL
45362X03

LEGEND:

- ESTIMATED LNAPL BOUNDARY
- SOIL SAMPLE COLLECTION LOCATION WITH CONCENTRATIONS OF TOTAL TPH AND / OR CPAHs NOT EXCEEDING APPLICABLE SITE CULs AND / OR RELs.
- SOIL SAMPLE COLLECTION LOCATION WITH CONCENTRATIONS OF TOTAL TPH AND/OR CPAHS EXCEEDING APPLICABLE SITE CULs AND/OR RELs.
- AREA WITH REMAINING SOIL IMPACTS EXCEEDING SITE CULs AND/OR RELs

TPH	TOTAL PETROLEUM HYDROCARBONS
CPAH	CARCINOGENIC POLYNUCLEAR AROMATIC HYDROCARBONS
B	BENZENE
mg/kg	MILLIGRAMS PER KILOGRAM
J	INDICATES AN ESTIMATED VALUE

- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- LOWER YARD PROPERTY BOUNDARY
- 2007/2008 EXCAVATION BOUNDARIES
- S — WSDOT STORM DRAIN LINE
- SD — POINT EDWARDS STORM DRAIN LINE

NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
   VERTICAL DATUM: N.A.V.D. 88
   UNITS: U.S. SURVEY FEET
   HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 200' 400'
GRAPHIC SCALE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

LOWER YARD REMAINING SOIL IMPACTS MAP

ARCADIS

FIGURE
4-1

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
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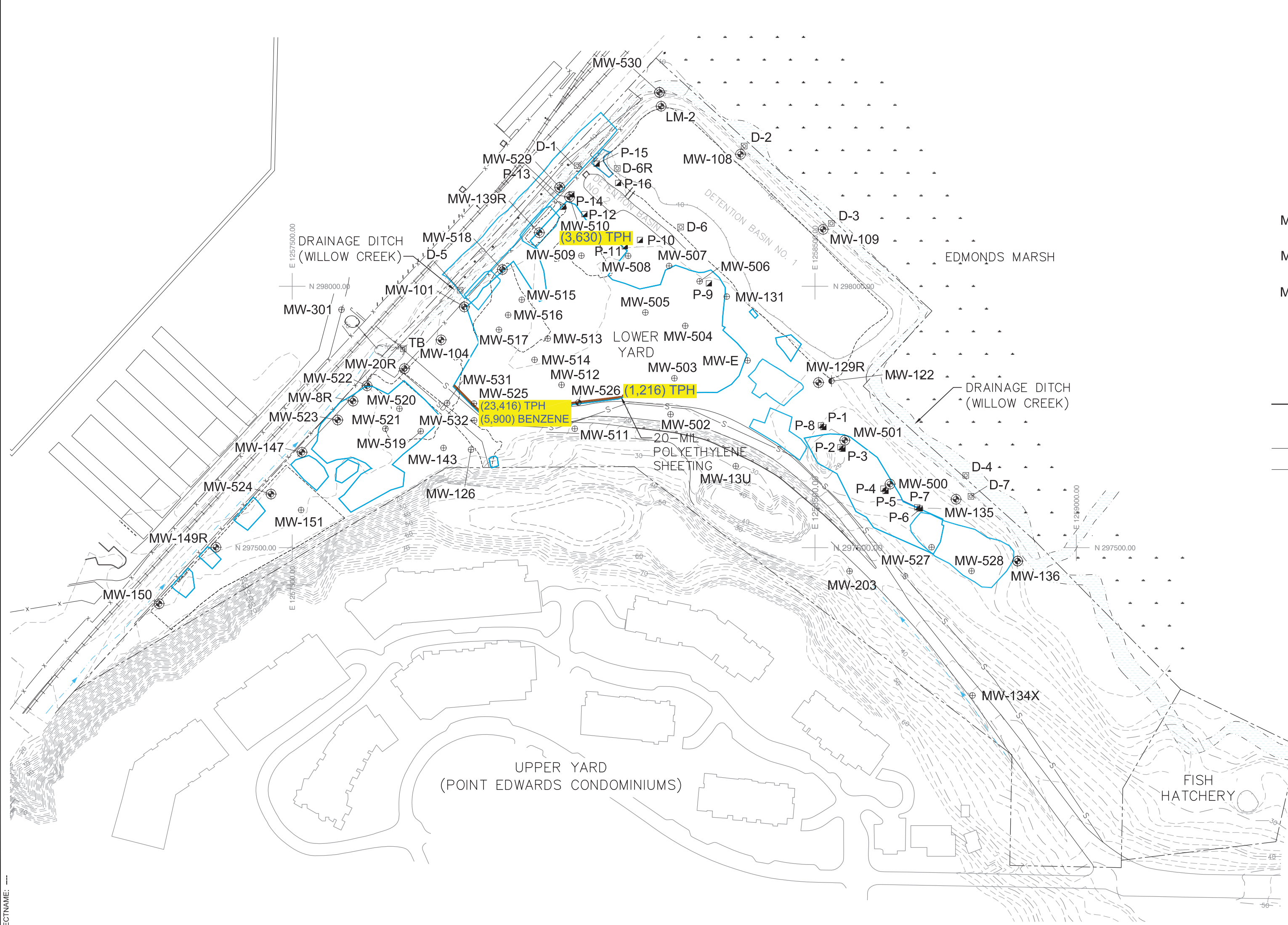
XREFS: IMAGES: PROJECTNAME: ---
45362X02
45362XDL
45362X03



LEGEND:

MW-203 ⊕	INTERIOR MONITORING WELL LOCATION AND DESIGNATION
MW-122	DEEP MONITORING WELL LOCATION AND DESIGNATION
MW-109	SURFACE WATER POINT OF COMPLIANCE MONITORING WELL LOCATION
P-11	PIEZOMETER
D-1	STAFF GAUGE
	2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
	LOWER YARD PROPERTY BOUNDARY
	2007/2008 EXCAVATION BOUNDARIES
—S—	WSDOT STORM DRAIN LINE
—SD—	POINT EDWARDS STORM DRAIN LINE
TPH	TOTAL PETROLEUM HYDROCARBONS

NOTES:

1. 20–MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HIGHLIGHTED NUMBERS ARE MAXIMUM CONCENTRATIONS OF TOTAL TPH IN MICROGRAMS PER LITER (ug/L) IN ALL WELLS THAT EXCEEDED GROUNDWATER CULs WITHIN THE PAST FOUR MONITORING EVENTS (DECEMBER 2012 TO SEPTEMBER 2013).
3. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
VERTICAL DATUM: N.A.V.D. 88
UNITS: U.S. SURVEY FEET
HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
4. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 200' 400'
GRAPHIC SCALE

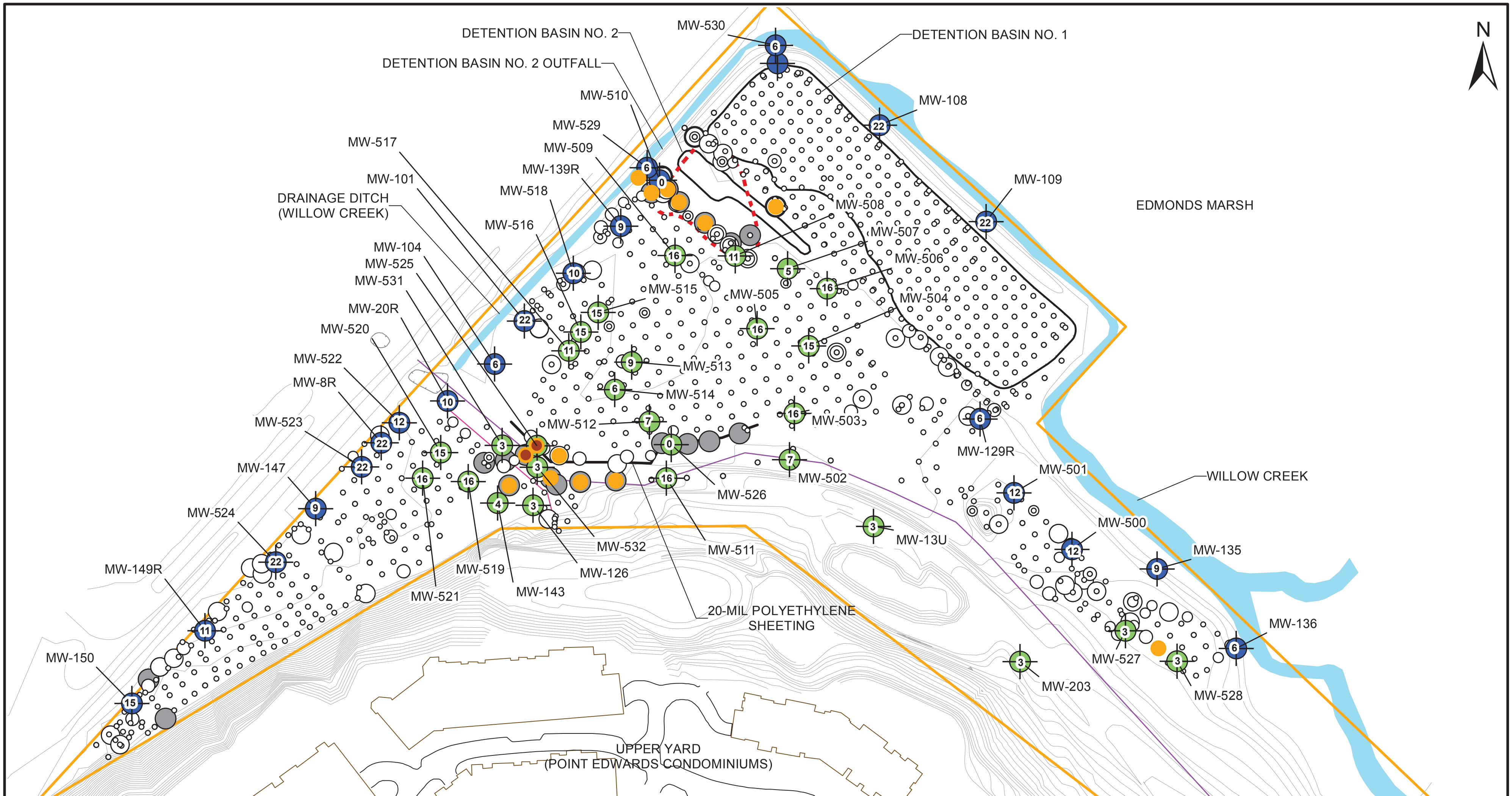
CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

LOWER YARD REMAINING GROUNDWATER IMPACTS MAP

ARCADIS

FIGURE
4-2

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362B11.dwg LAYOUT: 4-2 SAVED: 12/3/2013 9:51 AM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: OCE TDS600 SV1F.CTB PLOTTED: 12/17/2013 12:55 PM BY: LISTER, PAUL
XREFS: 45362XDL 45362X02 45362X03 IMAGES: PROJECTNAME: ---



LEGEND

POINT OF COMPLIANCE WELL AND NUMBER OF CONSECUTIVE SAMPLING ROUNDS SHOWING CONCENTRATIONS OF TPH LESS THAN PROPOSED GW CULS

INTERIOR WELL AND NUMBER OF CONSECUTIVE SAMPLING ROUNDS SHOWING CONCENTRATIONS OF TPH LESS THAN PROPOSED GW CULS

SOIL TPH CONCENTRATION <250 mg/kg

SOIL TPH CONCENTRATION OF 250 - 500 mg/kg

SOIL TPH CONCENTRATION OF 500 - 1,000 mg/kg

SOIL TPH CONCENTRATION OF 1,000 - 2,775 mg/kg

SOIL TPH CONCENTRATION > 2,775 mg/kg

SOIL BENZENE CONCENTRATION > CUL (18mg/kg)

SOIL cPAHs CONCENTRATION > CUL (0.14 mg/kg)

WSDOT STORM DRAIN LINE

POINT EDWARDS STORM DRAIN LINE

LOWER YARD PROPERTY BOUNDARY

ESTIMATED LNAPL BOUNDARY

NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

TPH - TOTAL PETROLEUM HYDROCARBONS
MG/KG - MILLIGRAMS PER KILOGRAM

0 140 280
SCALE IN FEET

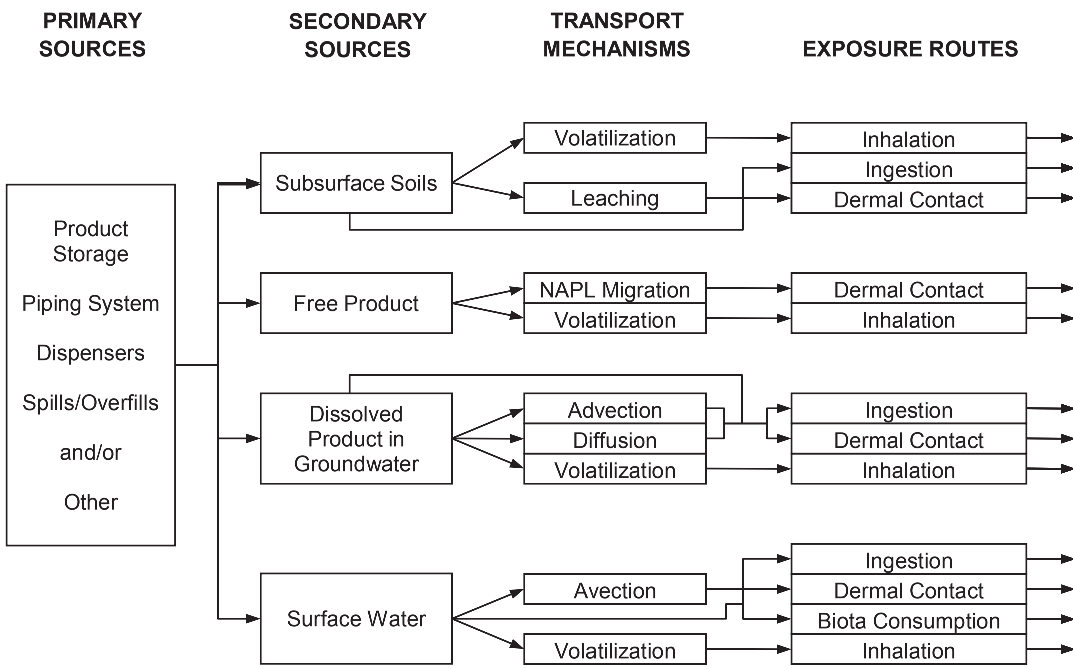
CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY

SITE SOIL AND GROUNDWATER REMEDIATION STATUS - SEPTEMBER 2013

ARCADIS

FIGURE
4-3

CITY:HIGHLANDS RANCH, CO DIV/GROUP:(ENV/GIS) DB: B GRIFFITH
Path: Z:\GISPROJECTS_ENV\Chevron_Edmonds\MXD\CurrentSiteSoilGWRemStatus.mxd Date: 12/18/2013 Time: 12:53:37 PM



Exposure Route	POTENTIAL RECEPTORS						
	Residential	Commercial	Trespassers		Construction & Excavation	Aquatic Biota	
	Future	Future	Current	Future	Future	Current	Future
Inhalation	-	-	-	-	P	-	-
Ingestion	P	P	-	-	P	-	-
Dermal Contact	P	P	-	-	P	-	-
Dermal Contact	-	-	-	-	P	-	-
Inhalation	-	-	-	-	P	-	-
Ingestion	-	-	-	-	P	-	-
Dermal Contact	-	-	-	-	P	-	-
Inhalation	U	P	-	-	P	-	-
Ingestion	U	U	U	U	-	P	P
Dermal Contact	U	U	U	U	-	P	P
Biota Consumption	-	-	-	-	-	-	-
Inhalation	-	-	-	-	-	-	-

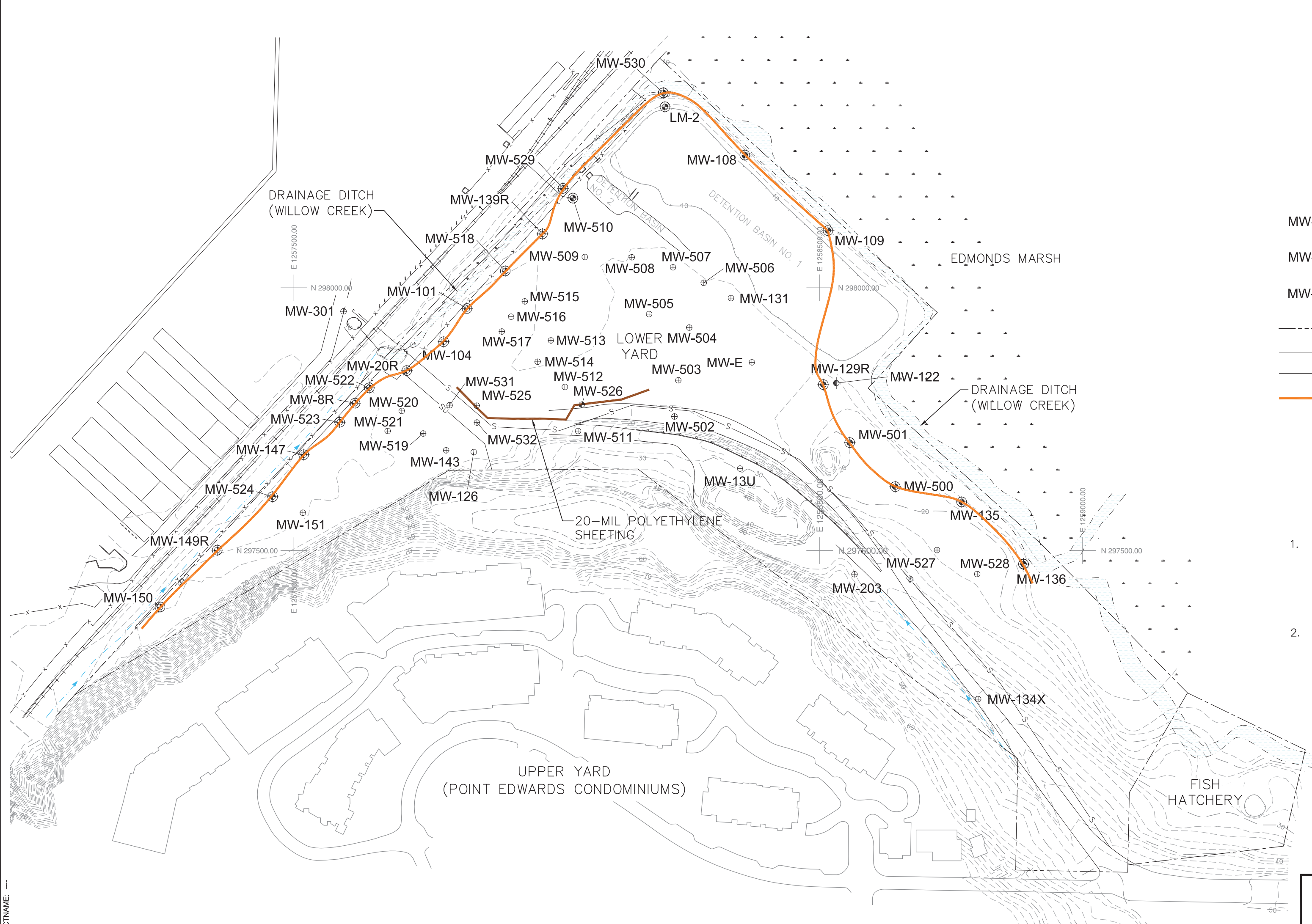
Notes:
- - = There is no exposure by this route
- **U** = Unlikey source of exposure
- **P** = This route is a potential source of exposure

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

CONCEPTUAL SITE MODEL
HUMAN EXPOSURE PATHWAYS

ARCADIS

FIGURE
4-4



LEGEND:

- MW-203 ⊕ INTERIOR MONITORING WELL LOCATION AND DESIGNATION
- MW-122 DEEP MONITORING WELL LOCATION AND DESIGNATION
- MW-109 SURFACE WATER POINT OF COMPLIANCE MONITORING WELL LOCATION
- LOWER YARD PROPERTY BOUNDARY
- S WSDOT STORM DRAIN LINE
- SD POINT EDWARDS STORM DRAIN LINE
- POINT OF COMPLIANCE BOUNDARY

NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98). VERTICAL DATUM: N.A.V.D. 88 UNITS: U.S. SURVEY FEET HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
2. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 200' 400'
GRAPHIC SCALE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

POINT OF COMPLIANCE WELL LOCATIONS AND BOUNDARY LINE

ARCADIS

FIGURE **5-1**

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-W/IM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
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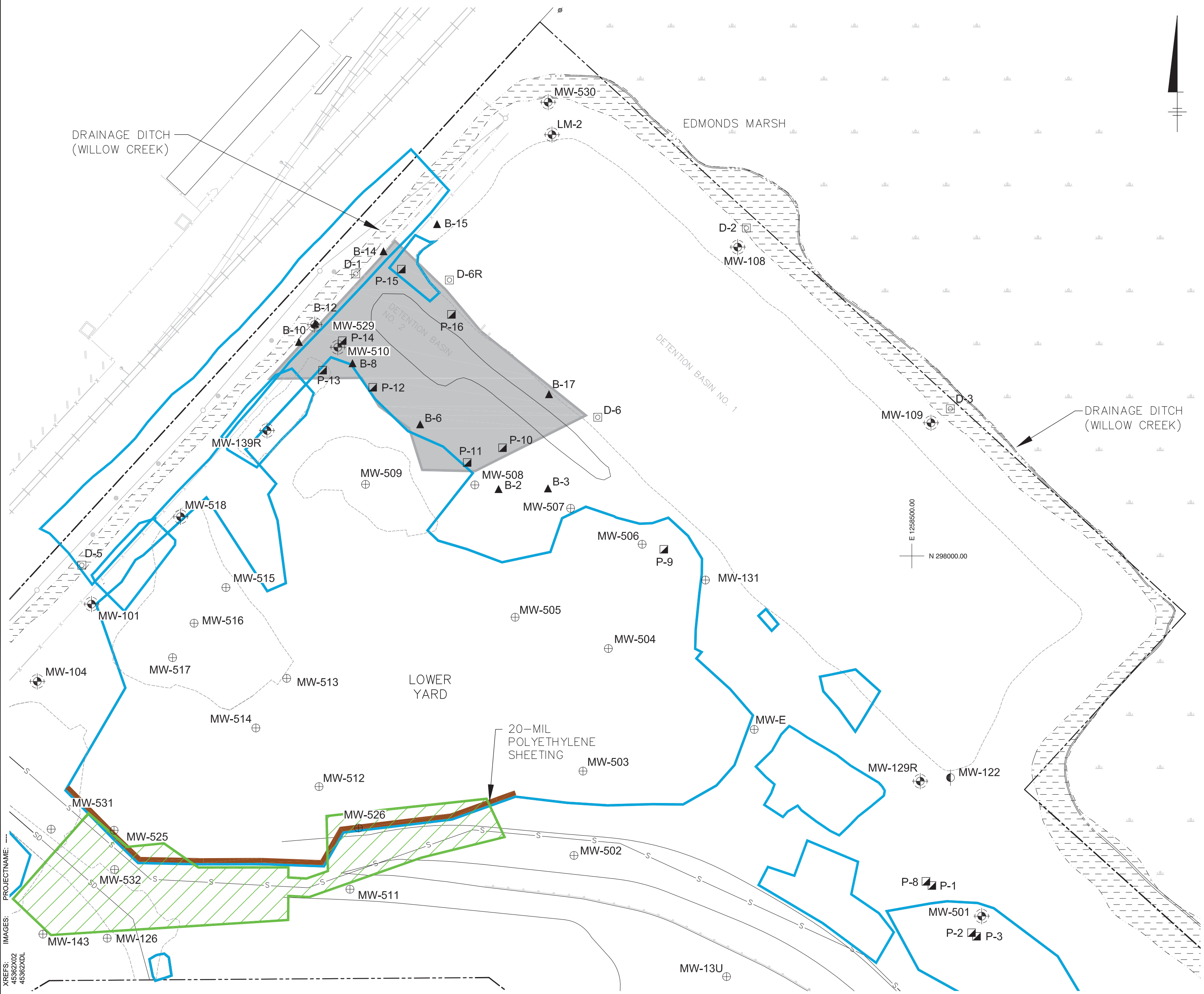
XREFS: 45362XDL 45362X02 45362X03 IMAGES: PROJECTNAME: ---



LEGEND:

- MW-203 ⊕ INTERIOR MONITORING WELL LOCATION AND DESIGNATION
- MW-122 DEEP MONITORING WELL LOCATION AND DESIGNATION
- MW-109 SURFACE WATER POINT OF COMPLIANCE MONITORING WELL LOCATION
- P-11 PIEZOMETER
- D-1 STAFF GAUGE
- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- 2007/2008 EXCAVATION BOUNDARIES
- LOWER YARD PROPERTY BOUNDARY
- S — WSDOT STORM DRAIN LINE
- SD — POINT EDWARDS STORM DRAIN LINE
- ▲ SOIL BORING
- EXCAVATION BOUNDARY
- ENVIRONMENTAL COVENANT AREA

NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
   VERTICAL DATUM: N.A.V.D. 88
   UNITS: U.S. SURVEY FEET
   HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

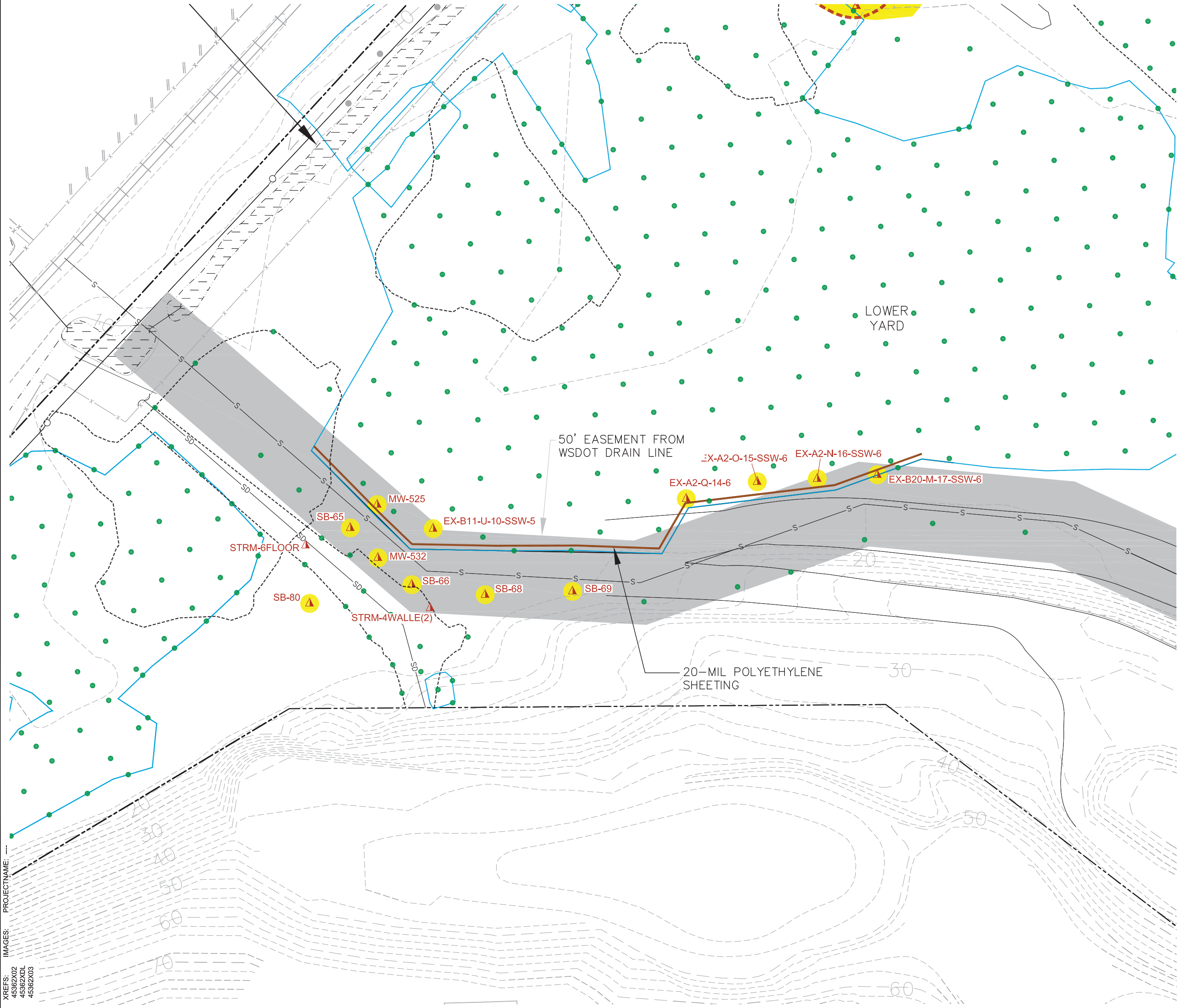
0 80' 160'
GRAPHIC SCALE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

REMEDIAL ALTERNATIVE 1: EXCAVATION AND MNA WITH ENVIRONMENTAL COVENANTS

ARCADIS

FIGURE
7-1



LEGEND:

	ESTIMATED LNAPL BOUNDARY
	SOIL SAMPLE COLLECTION LOCATION WITH CONCENTRATIONS OF TOTAL TPH AND / OR CPAHs NOT EXCEEDING APPLICABLE SITE CULs AND / OR RELs.
	SOIL SAMPLE COLLECTION LOCATION WITH CONCENTRATIONS OF TOTAL TPH AND/OR CPAHS EXCEEDING APPLICABLE SITE CULs AND/OR RELs.
	AREA WITH REMAINING SOIL IMPACTS EXCEEDING SITE CULs AND/OR RELs
TPH	TOTAL PETROLEUM HYDROCARBONS
CPAH	CARCINOGENIC POLYNUCLEAR AROMATIC HYDROCARBONS
B	BENZENE
mg/kg	MILLIGRAMS PER KILOGRAM
J	INDICATES AN ESTIMATED VALUE
	2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
	LOWER YARD PROPERTY BOUNDARY
	2007/2008 EXCAVATION BOUNDARIES
S	WSDOT STORM DRAIN LINE
SD	POINT EDWARDS STORM DRAIN LINE

NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
VERTICAL DATUM: N.A.V.D. 88
UNITS: U.S. SURVEY FEET
HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 60' 120'
GRAPHIC SCALE

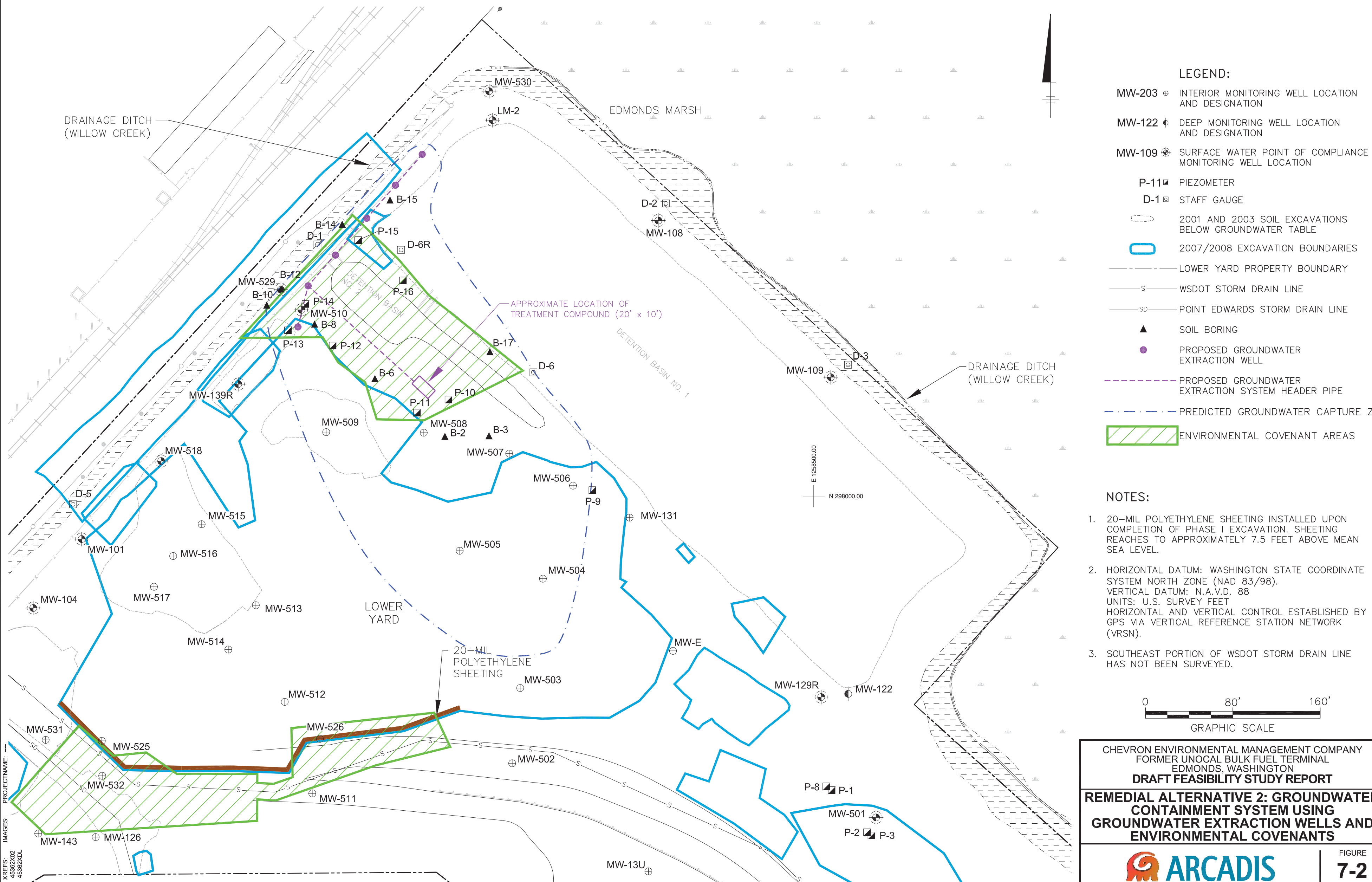
CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

CURRENT WSDOT CONSTRUCTION EASEMENT

ARCADIS

FIGURE
7-1a

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362B29.dwg LAYOUT: 7-1A SAVED: 12/3/2013 8:56 AM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: OCE TDS600 SV1F.CTB PLOTTED: 12/3/2013 8:56 AM BY: LISTER, PAUL
XREFS: 45362X02 45362XDL 45362X03 IMAGES: PROJECTNAME: ----



NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
   VERTICAL DATUM: N.A.V.D. 88
   UNITS: U.S. SURVEY FEET
   HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON

DRAFT FEASIBILITY STUDY REPORT

REMEDIAL ALTERNATIVE 2: GROUNDWATER CONTAINMENT SYSTEM USING GROUNDWATER EXTRACTION WELLS AND ENVIRONMENTAL COVENANTS

ARCADIS

FIGURE
7-2

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362B25.dwg LAYOUT: 7-2 SAVED: 12/20/2013 8:29 AM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: OCE TDS600 SV1F.CTB PLOTTED: 12/20/2013 8:29 AM BY: LISTER, PAUL
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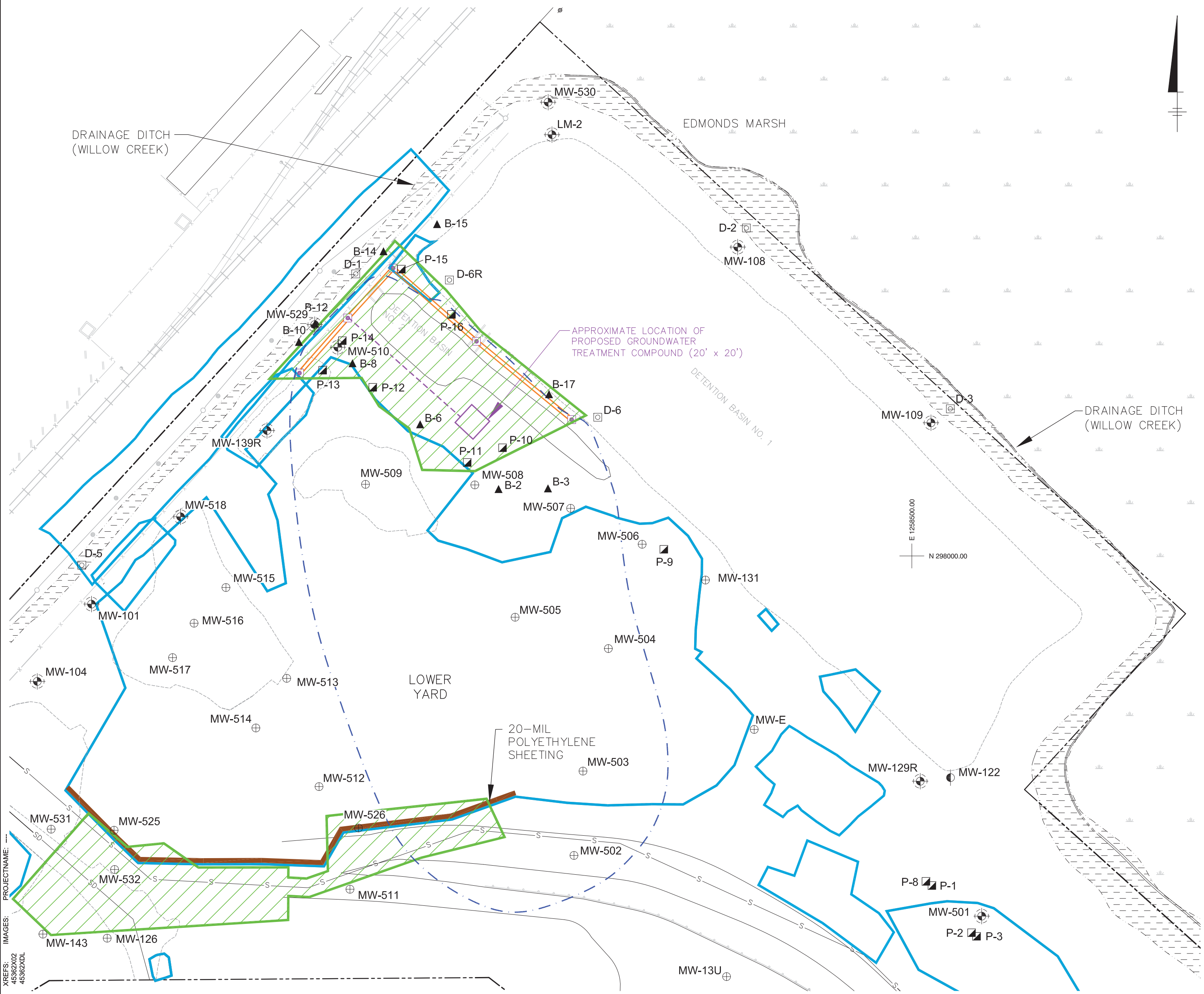

LEGEND:

- MW-203 ⊕ INTERIOR MONITORING WELL LOCATION AND DESIGNATION
- MW-122 DEEP MONITORING WELL LOCATION AND DESIGNATION
- MW-109 SURFACE WATER POINT OF COMPLIANCE MONITORING WELL LOCATION
- P-11 PIEZOMETER
- D-1 STAFF GAUGE
- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- 2007/2008 EXCAVATION BOUNDARIES
- LOWER YARD PROPERTY BOUNDARY
- S — WSDOT STORM DRAIN LINE
- SD — POINT EDWARDS STORM DRAIN LINE
- ▲ SOIL BORING
- PROPOSED GROUNDWATER EXTRACTION SUMP
- PROPOSED GROUNDWATER EXTRACTION SYSTEM HEADER PIPE
- PROPOSED GROUNDWATER CONTAINMENT TRENCH
- PREDICTED GROUNDWATER CAPTURE ZO
- ENVIRONMENTAL COVENANT AREAS

NOTES:

1. 20–MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
   VERTICAL DATUM: N.A.V.D. 88
   UNITS: U.S. SURVEY FEET
   HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 80' 160'
GRAPHIC SCALE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

REMEDIAL ALTERNATIVE 3: GROUNDWATER CONTAINMENT SYSTEM USING GROUNDWATER EXTRACTION TRENCH AND ENVIRONMENTAL COVENANTS

ARCADIS

FIGURE
7-3

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
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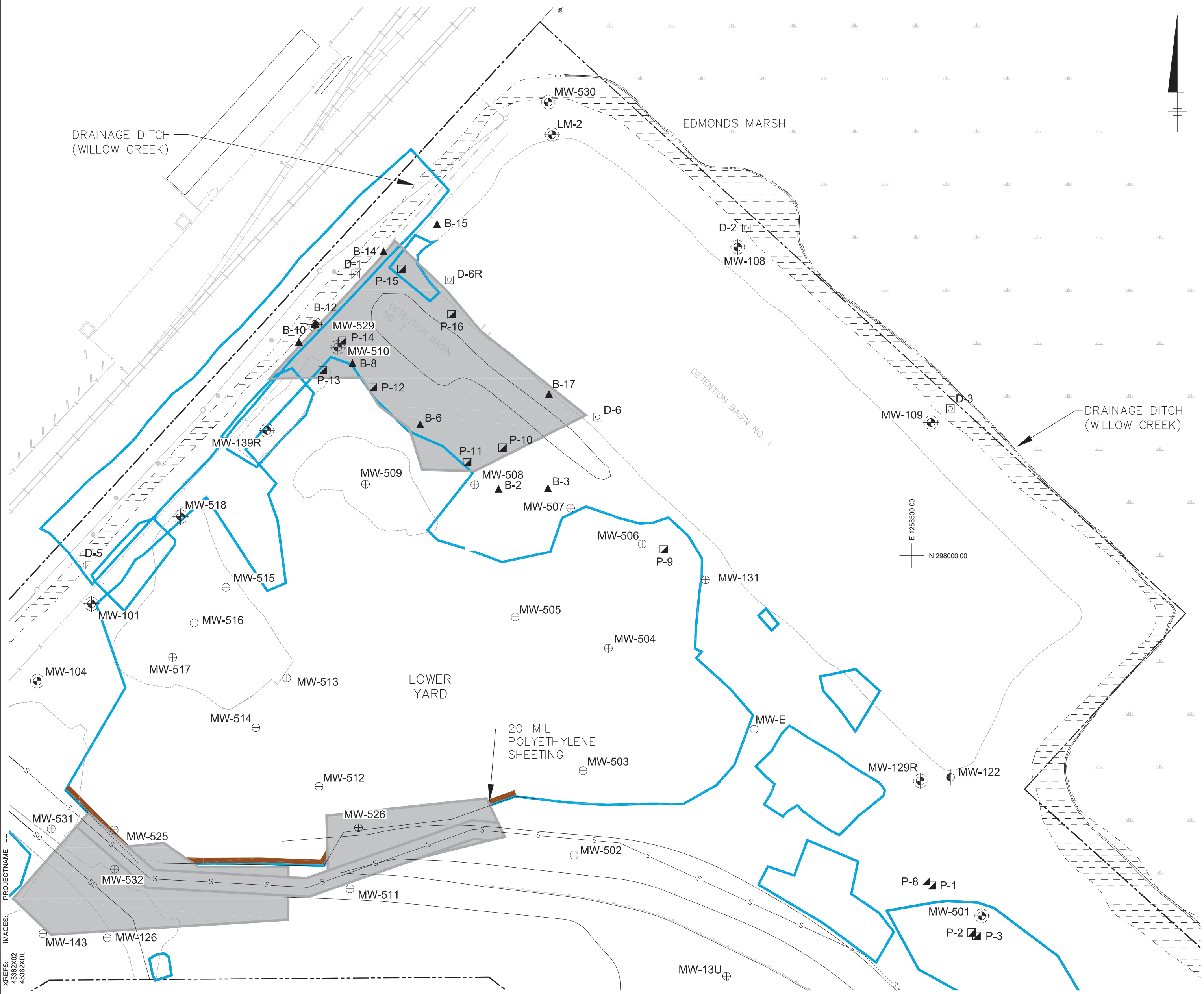


LEGEND:

- MW-203 ⊕ INTERIOR MONITORING WELL LOCATION AND DESIGNATION
- MW-122 DEEP MONITORING WELL LOCATION AND DESIGNATION
- MW-109 SURFACE WATER POINT OF COMPLIANCE MONITORING WELL LOCATION
- P-11 PIEZOMETER
- D-1 STAFF GAUGE
- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- 2007/2008 EXCAVATION BOUNDARIES
- LOWER YARD PROPERTY BOUNDARY
- S WSDOT STORM DRAIN LINE
- SD POINT EDWARDS STORM DRAIN LINE
- ▲ SOIL BORING
- EXCAVATION BOUNDARY

NOTES:

1. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
VERTICAL DATUM: N.A.V.D. 88
UNITS: U.S. SURVEY FEET
HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 80' 160'
GRAPHIC SCALE

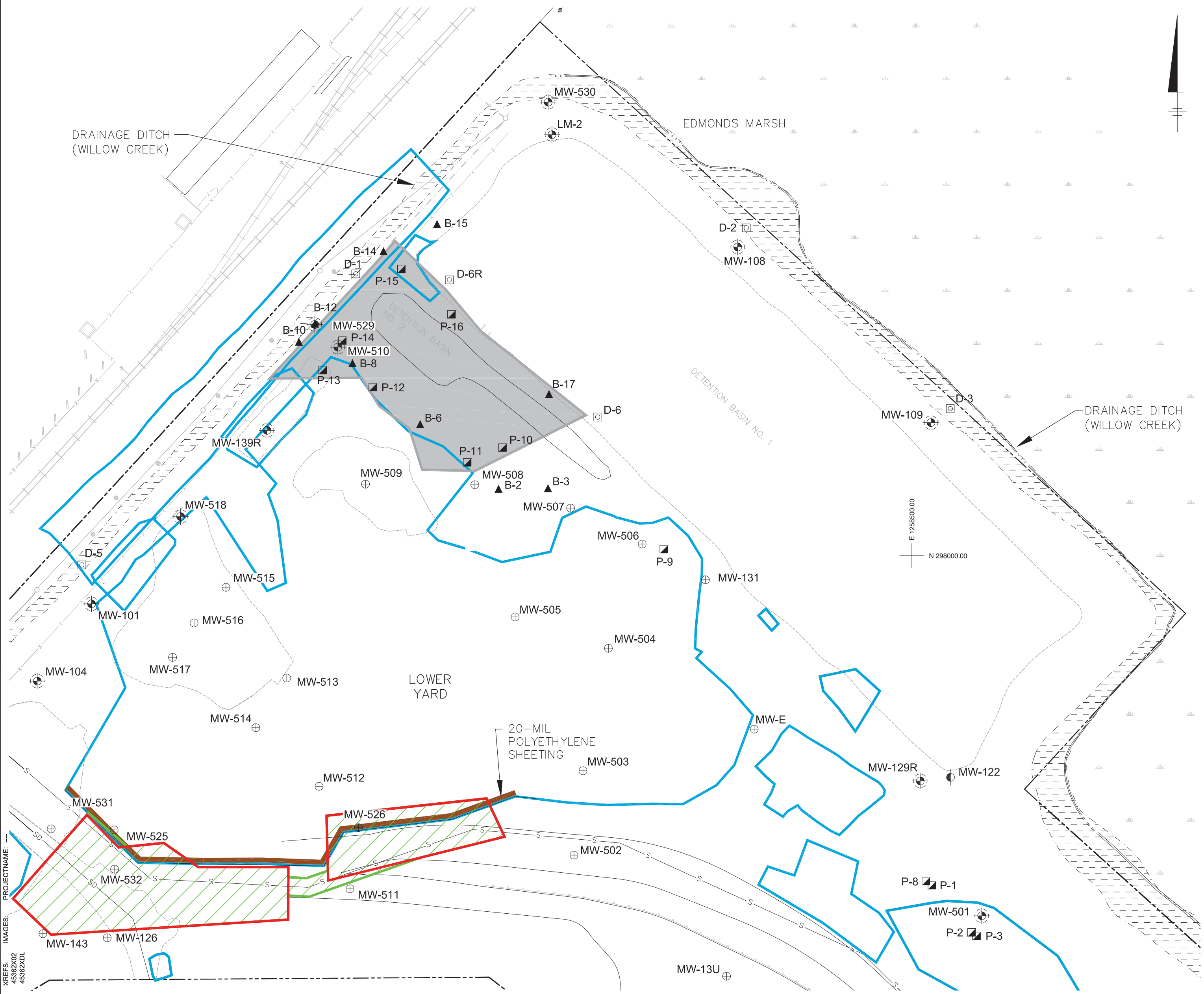
CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

REMEDIAL ALTERNATIVE 4: EXCAVATION (DB-2 AND WSDOT STORM WATER LINE) WITH MNA

ARCADIS

FIGURE
7-4

CITY: SYRACUSE, NY DIV/GROUP: ENV/REM-WIM-DV DB: P. LISTER PM: S. ZORN TM: P. GHATPANDE TR: D. RASAR LYR: ON=*;OFF=*REF*, (FRZ)
G:\ENVCAD\SYRACUSE\ACT\B0045362\0004\00006\DWG\45362B27.dwg LAYOUT: 7-4 SAVED: 12/20/2013 9:49 AM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: OCE TDS600 SV1F.CTB PLOTTED: 12/20/2013 9:50 AM BY: LISTER, PAUL
XREFS: 45362X02 45362XDL IMAGES: PROJECTNAME: ---



LEGEND:

- MW-203 ⊕ INTERIOR MONITORING WELL LOCATION AND DESIGNATION
- MW-122 DEEP MONITORING WELL LOCATION AND DESIGNATION
- MW-109 SURFACE WATER POINT OF COMPLIANCE MONITORING WELL LOCATION
- P-11 PIEZOMETER
- D-1 STAFF GAUGE
- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- 2007/2008 EXCAVATION BOUNDARIES
- LOWER YARD PROPERTY BOUNDARY
- WSDOT STORM DRAIN LINE
- POINT EDWARDS STORM DRAIN LINE
- SOIL BORING
- EXCAVATION BOUNDARY
- ISS TREATMENT AREAS
- ENVIRONMENTAL COVENANT AREA

NOTES:

1. 20–MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
VERTICAL DATUM: N.A.V.D. 88
UNITS: U.S. SURVEY FEET
HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. SOUTHEAST PORTION OF WSDOT STORM DRAIN LINE HAS NOT BEEN SURVEYED.

0 80' 160'
GRAPHIC SCALE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL BULK FUEL TERMINAL
EDMONDS, WASHINGTON
DRAFT FEASIBILITY STUDY REPORT

REMEDIAL ALTERNATIVE 5: EXCAVATION WITH MNA AND IN-SITU STABILIZATION WITH ENVIRONMENTAL COVENANTS

ARCADIS

FIGURE
7-5

ARCADIS

Appendix A

Selected Data from Previous Investigations

2007-2008 Phase I Remedial Implementation As-Built Report

TABLE 4
Excavation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase I Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX (mg/kg)				Total cPAHs Adjusted for Toxicity (mg/kg)	Gasoline (mg/kg)	Diesel (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			B	T	E	X					
			REL = 18 mg/kg				*CUL = 0.14 mg/kg*				*REL = 2,975*
B2-TP1-5	5	02/18/08	0.0305 U	0.0508 U	0.0508 U	0.102 U	0.0179	23.6 JZ	2,170 Q9	393 Q9	2,590 J
B2-TP1-10	10	02/18/08	0.0371 U	0.0618 U	0.0618 U	0.124 U	0.0370	9.96 JZ	211 Q9	60.8	282 J
B2-TP1-15	15	02/18/08	0.0325 U	0.0541 U	0.0541 U	0.108 U	0.00893	12.7 JZ	274 Q9	76.9	364 J
B2-TP2-5	5	02/18/08	0.0371 U	0.0619 U	0.0619 U	0.124 U	0.00853	6.19 U	54.6 Q9	103	161
B2-TP2-10	10	02/18/08	0.0319 U	0.0532 U	0.0532 U	0.106 U	0.00846	25.9 JZ	105 Q9	46.2	177 J
B2-TP2-13	13	02/18/08	0.341 U	0.568 U	0.568 U	3.40	0.519	659 JZ	1,680	1,120	3,460 J
EX-A1-C-16-7	7	11/15/07	0.0303 U	0.0504 U	0.0504 U	0.101 U	NA	5.04 U	11.9 U	29.6 U	23.3 UU
EX-A1-C-16-NSW-3	3	11/15/07	0.0301 U	0.0502 U	0.0502 U	0.100 U	0.00892	5.02 U	93.9 Q4	165 Q4	261
EX-A1-C-17-3	3	11/15/07	0.0608	0.0771	0.0499 U	0.0998 U	0.0154	19.5	70.6 Q4	123 Q4	213
EX-A1-D-16-12	12	11/19/07	0.0299 U	0.0498 U	0.0498 U	0.0996 U	NA	4.98 U	12.1 U	30.2 U	23.6 UU
EX-A1-D-17-12	12	11/15/07	0.0294 U	0.0490 U	0.0490 U	0.0981 U	NA	4.90 U	12.6 U	31.5 U	24.5 UU
EX-A1-D-17-ESW-5	5	11/15/07	0.0316 U	0.0526 U	0.0526 U	0.105 U	NA	5.26 U	11.7 U	29.1 U	23.0 UU
EX-A1-D-17-ESW-10	10	11/15/07	0.0272 U	0.0453 U	0.0453 U	0.0907 U	NA	4.53 U	11.7 U	29.4 U	22.8 UU
EX-A1-E-15-15	15	11/08/07	0.0299 U	0.0498 U	0.0498 U	0.0996 U	NA	4.98 U	12.3 U	30.7 U	24.0 UU
EX-A1-E-16-15	15	11/08/07	0.0279 U [0.0311 U]	0.0465 U [0.0518 U]	0.0465 U [0.0518 U]	0.0930 U [0.104 U]	NA [NA]	4.65 U [5.18 U]	11.6 U [12.6 U]	29.0 U [31.5 U]	22.6 UU [24.6 UU]
EX-A1-E-17-12	12	11/14/07	0.0291 U	0.0485 U	0.0485 U	0.0970 U	NA	4.85 U	12.2 U	30.4 U	23.7 UU
EX-A1-E-17-ESW-4	4	11/15/07	0.0637	0.0514 U	0.0514 U	0.103 U	NA	5.14 U	12.2 U	30.6 U	24.0 UU
EX-A1-F-15-15	15	11/08/07	0.0270 U	0.0451 U	0.0451 U	0.0902 U	NA	4.51 U	12.2 U	30.4 U	23.6 UU
EX-A1-F-16-15	15	11/08/07	0.137	0.0454 U	0.0454 U	0.0907 U	NA	4.54 U	12.0 U	30.1 U	23.3 UU
EX-A1-F-17-3	3	10/29/07	0.0267 U	0.0444 U	0.0444 U	0.0889 U	NA	4.44 U	11.2 U	28.0 U	21.8 UU
EX-A1-F-17-12	12	11/14/07	0.0301 U	0.0501 U	0.0501 U	0.100 U	NA	5.01 U	12.3 U	30.8 U	24.1 UU
EX-A1-F-18-4	4	10/29/07	0.0979 [0.0591]	0.0816 [0.0492]	0.351 [0.222]	1.01 [0.670]	0.0432 [0.0441]	201 JZ [139 JZ]	405 Q11 [1,020 Q11]	158 [339]	764 J [1,500 J]
EX-A1-F-18-5	5	11/05/07	0.0273 U [0.0291 U]	0.0455 U [0.0485 U]	0.0455 U [0.0485 U]	0.0911 U [0.0970 U]	NA [NA]	4.55 U [4.85 U]	11.3 U [11.3 U]	28.2 U [28.3 U]	22.0 UU [22.2 UU]
EX-A1-G-15-15	15	11/08/07	0.0289 U	0.0482 U	0.0482 U	0.0964 U	NA	4.82 U	11.7 U	29.3 U	22.9 UU
EX-A1-G-16-15	15	10/31/07	0.0387	0.0494 U	0.0494 U	0.0989 U	NA	4.94 U	11.7 U	29.3 U	23.0 UU
EX-A1-G-17-15	15	10/29/07	0.0291 U	0.0485 U	0.0485 U	0.0970 U	NA	4.85 U	12.0 U	30.1 U	23.5 UU
EX-A1-H-15-15	15	11/08/07	0.0291 U	0.0486 U	0.0486 U	0.0971 U	NA	4.86 U	12.8 U	31.9 U	24.8 UU
EX-A1-H-16-15	15	10/31/07	0.0303 U	0.0505 U	0.0505 U	0.101 U	NA	5.05 U	11.7 U	29.4 U	23.1 UU
EX-A1-H-17-15	15	10/29/07	0.0298 U [0.0282 U]	0.0497 U [0.0470 U]	0.0497 U [0.0470 U]	0.0993 U [0.0939 U]	NA [NA]	4.97 U [4.70 U]	12.8 U [12.7 U]	31.9 U [31.7 U]	24.8 UU [24.6 UU]
EX-A1-I-16-15	15	10/31/07	0.0285 U	0.0474 U	0.0474 U	0.0948 U	NA	4.74 U	12.5 U	31.1 U	24.2 UU
EX-A1-I-17-15	15	10/29/07	0.0317 U	0.0528 U	0.0528 U	0.106 U	NA	5.28 U	12.7 U	31.8 U	24.9 UU
EX-A1-J-16-15	15	10/31/07	0.0306 U	0.0511 U	0.0511 U	0.102 U	NA	5.11 U	12.7 U	31.7 U	24.8 UU
EX-A1-J-17-15	15	10/29/07	0.0316 U	0.0527 U	0.0527 U	0.105 U	NA	5.27 U	13.6 U	34.0 U	26.4 UU
EX-A1-J-19-8	8	10/23/07	0.0312 U	0.0519 U	0.0519 U	0.104 U	NA	5.19 U	12.6 U	31.5 U	24.6 UU
EX-A1-K-17-15	15	10/30/07	0.0308 U	0.0513 U	0.0513 U	0.103 U	NA	5.13 U	12.7 U	31.8 U	24.8 UU
EX-A1-K-18-12	12	10/23/07	0.0278 U	0.0463 U	0.0463 U	0.0926 U	NA	4.63 U	11.7 U	29.3 U	22.8 UU
EX-A1-K-18-SSW-3	3	10/30/07	0.0282 U	0.0470 U	0.0470 U	0.0941 U	NA	4.70 U	10.5 U	26.1 U	20.7 UU
EX-A1-K-18-SSW-8	8	10/30/07	0.0291 U	0.0486 U	0.0486 U	0.0972 U	NA	4.86 U	11.4 U	28.4 U	22.3 UU
EX-A1-K-19-3	3	10/30/07	0.0322 U	0.0536 U	0.0536 U	0.107 U	NA	5.36 U	11.6 U	29.0 U	23.0 UU
EX-A1-L-17-12	12	11/08/07	0.117	0.0465 U	0.0465 U	0.0930 U	NA	4.65 U	11.7 U	29.4 U	22.9 UU
EX-A2-O-9-10	10	01/28/08	0.369 U [0.344 U]	0.615 U [0.573 U]	0.989 [0.819]	1.72 [1.43]	0.0515 [0.0484]	466 JZ [389 JZ]	149 [371]	78.5 [91.5]	694 J [852 J]

TABLE 4
Excavation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase I Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX (mg/kg) B	T	E	X	Total cPAHs Adjusted for Toxicity (mg/kg)	Gasoline (mg/kg)	Diesel (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			REL = 18 mg/kg				CUL = 0.14 mg/kg				REL = 2,975
EX-A2-O-10-10	10	01/28/08	0.0299 U	0.169	0.0864	0.215	0.0239	73.9 JZ	30.6	29.3 U	119 J
EX-A2-O-11-10	10	01/28/08	0.0270 U	0.0450 U	0.0450 U	0.0900 U	NA	4.50 U	11.8 U	29.6 U	23.0 UU
EX-A2-O-12-10	10	01/28/08	0.0305 U	0.0508 U	0.0508 U	0.102 U	NA	5.08 U	13.0 U	32.5 U	25.3 UU
EX-A2-O-13-10	10	01/28/08	0.0351 U	0.0585 U	0.0585 U	0.117 U	NA	5.85 U	12.9 U	32.3 U	25.5 UU
EX-A2-N-16-SSW-6	6	02/20/08	0.0382 U	0.0636 U	0.0654	0.845	0.0868	489 JZ	6,770 D	577 U	7,550 J
EX-A2-O-15-SSW-6	6	02/20/08	1.69	0.645 U	1.07	3.10	0.0308	1,500 JZ	5,750 DQ10	579 U	7,540 J
EX-A2-P-9-15	15	01/30/08	0.0289 U	0.0482 U	0.0482 U	0.0965 U	NA	4.82 U	12.0 U	30.1 U	23.5 UU
EX-A2-P-10-11	11	01/30/08	0.0350 U	0.0583 U	0.0583 U	0.117 U	NA	5.83 U	12.7 U	31.8 U	25.2 UU
EX-A2-P-11-11	11	01/30/08	0.0301 U	0.0501 U	0.0501 U	0.100 U	NA	5.01 U	11.3 U	28.2 U	22.3 UU
EX-A2-P-12-10	10	01/30/08	0.0275 U	0.0458 U	0.0458 U	0.0916 U	0.00921	4.58 U	17.2 JY	43.2	62.7 J
EX-A2-P-13-10	10	01/30/08	0.0318 U	0.0531 U	0.0531 U	0.106 U	NA	5.31 U	12.9 U	32.4 U	25.3 UU
EX-A2-P-14-12	12	02/22/08	0.0364 U	0.0607 U	0.0607 U	0.326	0.00974	67.7 JZ	229	32.2	329 J
EX-A2-Q-9-12	12	02/01/08	0.0333 U	0.0555 U	0.0555 U	0.111 U	NA	5.55 U	11.8 U	29.5 U	23.4 UU
EX-A2-Q-10-12	12	02/01/08	0.0364 U	0.0606 U	0.0606 U	0.121 U	NA	6.06 U	11.9 U	29.8 U	23.9 UU
EX-A2-Q-11-12	12	02/01/08	0.0366 U	0.0610 U	0.0610 U	0.122 U	NA	6.10 U	12.2 U	30.5 U	24.4 UU
EX-A2-Q-12-13	13	02/01/08	0.0324 U	0.0539 U	0.0539 U	0.108 U	NA	5.39 U	12.2 U	30.6 U	24.1 UU
EX-A2-Q-13-12	12	02/22/08	0.0404 U	0.0673 U	0.0673 U	0.135 U	NA	6.73 U	12.8 U	32.1 U	25.8 UU
EX-A2-Q-14-6	6	02/20/08	0.169 J	0.0968 J	0.182 J	1.51 J	0.0241	570 JZ	2,250 J	236 JQ7	3,060 J
EX-A2-R-10-12	12	02/15/08	0.0422 U [0.0375 U]	0.0704 U [0.0626 U]	0.0704 U [0.0626 U]	0.141 U [0.125 U]	NA [NA]	7.04 U [6.26 U]	12.8 U [12.1 U]	31.9 U [30.3 U]	25.9 UU [24.3 UU]
EX-A2-R-11-12	12	02/15/08	0.0484 U	0.0806 U	0.0806 U	0.161 U	NA	8.06 U	13.8 U	34.6 U	28.2 UU
EX-A2-R-12-12	12	02/15/08	0.0380 U	0.0634 U	0.0634 U	0.127 U	NA	6.34 U	12.2 U	30.5 U	24.5 UU
EX-A2-R-13-12	12	02/22/08	0.0433 U	0.0721 U	0.0721 U	0.144 U	NA	7.21 U	13.2 U	33.0 U	26.7 UU
EX-A2-R-14-6	6	02/20/08	0.0380 U	0.0633 U	0.0633 U	0.127 U	0.0157	51.3 JZ	224	65.5	341 J
EX-A2-S-12-12	12	02/22/08	0.0406 U	0.0676 U	0.0676 U	0.135 U	NA	6.76 U	12.8 U	32.0 U	25.8 UU
EX-A2-S-12-SSW-6	6	02/15/08	0.0339 U	0.0565 U	0.0565 U	0.113 U	0.00815	224 JZ	900	37.4 Q7	1,160 J
EX-A2-S-13-6	6	02/15/08	0.0356 U	0.0594 U	0.0594 U	0.406	0.00861	194 JZ	683	54.8 Q7	932 J
EX-A3-AA-5-10	10	09/26/07	0.0290 U	0.0484 U	0.0484 U	0.0968 U	NA	4.84 U	12.3 U	30.7 U	23.9 UU
EX-A3-AA-6-10	10	09/21/07	0.0309 U	0.0515 U	0.0515 U	0.103 U	NA	5.15 U	10.9 U	27.1 U	21.6 UU
EX-A3-AA-7-10	10	09/21/07	0.0333 U	0.0556 U	0.0556 U	0.111 U	NA	5.56 U	12.5 U	31.3 U	24.7 UU
EX-A3-AA-7-ESW-4	4	09/20/07	0.0307 U	0.0511 U	0.0511 U	0.102 U	NA	5.11 U	12.7 U	31.8 U	24.8 UU
EX-A3-BB-6-10	10	09/21/07	0.0296 U [0.0299 U]	0.0493 U [0.0498 U]	0.0493 U [0.0498 U]	0.0986 U [0.0996 U]	NA [NA]	4.93 U [4.98 U]	12.7 U [13.0 U]	31.7 U [32.6 U]	24.7 UU [25.3 UU]
EX-A3-BB-7-10	10	09/21/07	0.0703	0.0527 U	0.0527 U	0.105 U	NA	5.27 U	11.9 U	29.7 U	23.4 UU
EX-A3-BB-7-ESW-4	4	09/21/07	0.158	0.152	0.0856	0.282	0.00997	88.0	18.9	32.6 U	123
EX-A3-CC-6-10	10	10/01/07	2.76	0.0582 U	0.0582 U	0.116 U	NA	7.09 J	12.3 U	30.9 U	28.7 J
EX-A3-CC-7-10	10	10/01/07	1.21 [1.73]	0.0671 U [0.0580 U]	0.0671 U [0.0580 U]	0.134 U [0.116 U]	NA [NA]	6.71 U [5.90]	12.1 U [12.1 U]	30.3 U [30.3 U]	24.6 UU [27.1]
EX-A3-CC-7-ESW-4	4	10/02/07	0.110	0.0512 U	0.245	0.221	0.00876	25.8	85.6 Q4	44.7 Q4	156
EX-A3-DD-6-10	10	10/02/07	0.0878	0.0534 U	0.0534 U	0.107 U	NA	5.34 U	11.9 U	29.6 U	23.4 UU
EX-A3-Y-4-8	8	09/21/07	0.0214 U	0.0357 U	0.0357 U	0.0713 U	NA	3.57 U	10.4 U	25.9 U	19.9 UU
EX-A3-Y-4-NSW-4	4	09/20/07	0.0267 U	0.0446 U	0.0446 U	0.0891 U	0.00868	8.24 JZ	169	140	317 J
EX-A3-Y-4-WSW-4	4	09/20/07	0.0114 U	0.0190 U	0.0190 U	0.0380 U	NA	1.90 U	10.4 U	25.9 U	19.1 UU
EX-A3-Y-5-8	8	09/21/07	0.0275 U	0.0458 U	0.0458 U	0.0916 U	NA	4.58 U	10.3 U	25.9 U	20.4 UU
EX-A3-Y-5-NSW-4	4	09/20/07	0.0498 U	0.0830 U	0.0830 U	0.166 U	0.00880	19.4 JZ	111	122	252 J
EX-A3-Y-6-8	8	09/20/07	3.32 U	5.53 U	5.53 U	11.1 U	0.176	3,000	6,340 J	1,270 J	10,600 J
EX-A3-Y-6-10	10	09/25/07	0.387	0.0500 U	0.0500 U	0.100 U	NA	5.25	12.2 U	30.5 U	26.6
EX-A3-Y-6-NSW-4	4	09/20/07	0.0232 U	0.0386 U	0.0386 U	0.134	0.00793	27.7 JZ	37.4	41.0	106 J
EX-A3-Y-7-8	8	09/20/07	0.194	0.315	0.330	0.403	0.0883	182 JZ	2,240 J	386 J	2,810 J
EX-A3-Y-7-10	10	09/25/07	0.0299 U	0.0498 U	0.0498 U	0.0996 U	NA	4.98 U	11.7 U	29.4 U	23.0 UU
EX-A3-Y-7-ESW-4	4	09/20/07	0.546	0.0518 U	0.0518 U	0.104 U	0.00908	9.13 JZ	103	91.9	204 J
EX-A3-Y-7-NSW-4	4	09/20/07	0.0393 [0.0562 U]	0.0532 [0.0937 U]	0.0735 [0.0937 U]	0.191 [0.187 U]	0.00929 [0.00876]	50.7 JZ [34.1 JZ]	62.9 [133]	60.0 [96.0]	174 J [263 J]
EX-A3-Z-4-10	10	09/21/07	0.0294	0.0485 U	0.0485 U	0.0969 U	NA	5.83	11.4 U	28.4 U	25.7
EX-A3-Z-5-10	10	09/21/07	0.0275 U	0.0459 U	0.0459 U	0.0918 U	NA	4.59 U	11.6 U	29.1 U	22.6 UU
EX-A3-Z-6-10	10	09/21/07	0.191	0.0520 U	0.0520 U	0.104 U	0.00944	5.20 U	18.8	32.0 U	37.4
EX-A3-Z-7-10	10	09/21/07	0.0503	0.0440 U	0.0440 U	0.0879 U	NA	4.40 U	11.1 U	27.8 U	21.7 UU
EX-A3-Z-7-ESW-4	4	09/20/07	0.0207 U	0.0345 U	0.0345 U	0.0690 U	NA	3.45 U	10.6 U	26.4 U	20.2 UU

TABLE 4
Excavation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase I Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX (mg/kg) B	BTEX (mg/kg) T	BTEX (mg/kg) E	BTEX (mg/kg) X	Total cPAHs Adjusted for Toxicity (mg/kg)	Gasoline (mg/kg)	Diesel (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			REL = 18 mg/kg				*CUL = 0.14 mg/kg*				*REL = 2,975*
EX-A4-F-6-4	4	09/12/07	0.0296 U [0.0255 U]	0.0494 U [0.0424 U]	0.0494 U [0.0424 U]	0.0988 U [0.0849 U]	0.00967 [0.00854]	4.94 U [4.24 U]	112 Q4 [209 Q4]	66.2 Q4 [109 Q4]	181 [320]
EX-A4-F-7-4	4	09/12/07	0.295	0.0487 U	0.130	0.415	0.00861	85.0 JZ	13.3 Q11	28.5 U	113 J
EX-A4-F-8-4	4	09/12/07	0.126	0.271	0.383	0.555	0.196	149 JZ	1,510 JQ4	710 JQ4	2,370 J
EX-A4-F-8-6	6	10/17/07	0.0740	0.0567 U	0.0567 U	0.129	0.0465	105 JZ	632	246	983 J
EX-A4-F-8-7	7	11/07/07	0.0313 U	0.0522 U	0.0522 U	0.104 U	NA	5.22 U	12.8 U	32.0 U	25.0 UU
EX-A4-F-8-NSW-3.5	3.5	11/13/07	0.0256 U	0.0427 U	0.0427 U	0.0853 U	NA	4.27 U	10.4 U	26.0 U	20.3 UU
EX-A4-F-8-NSW-4	4	11/07/07	0.0288 U	0.0480 U	0.0480 U	0.0960 U	0.0481	30.9 JZ	793 Q4	429	1,250 J
EX-A4-F-9-9	9	10/17/07	0.0646	0.0509 U	0.0619	0.102 U	NA	20.1	11.9 U	29.7 U	40.9
EX-A4-F-9-ESW-4	4	10/17/07	0.0349 U	0.0581 U	0.0581 U	0.116 U	0.0100	5.81 U	17.3 Q12	33.3 U	36.9
EX-A4-F-9-NSW-3.5	3.5	11/07/07	0.0318 U	0.0530 U	0.0530 U	0.106 U	0.0402	5.30 U	330 Q4	356	689
EX-A4-F-9-NSW-4	4	10/17/07	0.248	0.248	0.208	0.105 U	0.0710	219 JZ	731	222	1,170 J
EX-A4-G-6-9	9	10/01/07	0.0307 U	0.0512 U	0.0512 U	0.102 U	NA	5.12 U	12.7 U	31.8 U	24.8 UU
EX-A4-G-7-9	9	09/27/07	0.0295 U	0.0492 U	0.0492 U	0.0983 U	NA	4.92 U	12.7 U	31.7 U	24.7 UU
EX-A4-G-8-9	9	09/27/07	0.0311 U	0.0519 U	0.0519 U	0.104 U	NA	5.19 U	11.7 U	29.2 U	23.0 UU
EX-A4-G-9-9	9	10/17/07	0.0295 U	0.0492 U	0.0492 U	0.0985 U	NA	4.92 U	12.5 U	31.1 U	24.3 UU
EX-A4-G-9-ESW-4	4	10/17/07	0.0290 U [0.0283 U]	0.0483 U [0.0472 U]	0.0483 U [0.0472 U]	0.0965 U [0.0945 U]	0.00853 [0.00868]	9.59 JZ [4.72 U]	41.4 [33.5]	36.0 [32.7]	87.0 J [68.6]
EX-A4-H-6-9	9	09/27/07	0.0269 U [0.0295 U]	0.0448 U [0.0491 U]	0.0448 U [0.0491 U]	0.0897 U [0.0982 U]	NA [NA]	4.48 U [4.91 U]	12.6 U [12.4 U]	31.5 U [31.1 U]	24.3 UU [24.2 UU]
EX-A4-H-7-9	9	09/27/07	0.0318 U	0.0530 U	0.0530 U	0.106 U	NA	5.30 U	12.9 U	32.3 U	25.3 UU
EX-A4-H-8-4	4	09/12/07	0.0286 U	0.0476 U	0.0476 U	0.0952 U	0.0858	19.6 JZ	1,250 JQ4	788 JQ4	2,060 J
EX-A4-H-8-9	9	09/27/07	0.0885	0.0499 U	0.0499 U	0.0997 U	NA	4.99 U	12.3 U	30.8 U	24.0 UU
EX-A4-H-9-9	9	10/17/07	0.323	0.0736 U	0.0736 U	0.147 U	NA	7.36 U	16.8 U	42.0 U	33.1 UU
EX-A4-H-9-ESW-4	4	10/17/07	0.0273 U	0.0455 U	0.0455 U	0.0911 U	0.00861	4.55 U	203	50.3	256
EX-A4-I-6-9	9	09/21/07	0.0565 U	0.0942 U	0.0942 U	0.188 U	NA	9.42 U	19.9 U	49.7 U	39.5 UU
EX-A4-I-7-9	9	10/16/07	0.0372 U	0.0620 U	0.0620 U	0.124 U	NA	6.20 U	12.1 U	30.2 U	24.3 UU
EX-A4-I-8-9	9	10/16/07	0.0396 U	0.0660 U	0.0660 U	0.132 U	NA	6.60 U	12.1 U	30.2 U	24.5 UU
EX-A4-J-6-9	9	09/21/07	0.0288 U	0.0479 U	0.0479 U	0.0959 U	NA	4.79 U	12.1 U	30.4 U	23.6 UU
EX-A4-J-6-SSW-9	9	09/21/07	0.0304 U	0.0507 U	0.0507 U	0.101 U	0.0383	22.1	111 Q4	105 Q4	238
EX-A4-J-7-9	9	09/21/07	0.0299 U	0.0498 U	0.0498 U	0.0996 U	NA	4.98 U	12.2 U	30.4 U	23.8 UU
EX-A4-J-7-SSW-4	4	09/21/07	0.0342 U	0.0569 U	0.0569 U	0.114 U	0.0388	5.69 U	119 Q4	119 Q4	241
EX-A4-J-8-9	9	10/16/07	0.0340 U	0.0566 U	0.0566 U	0.113 U	NA	5.66 U	11.9 U	29.8 U	23.7 UU
EX-A4-K-8-9	9	10/16/07	0.0367 U	0.0612 U	0.0612 U	0.122 U	NA	6.12 U	12.3 U	30.8 U	24.6 UU
EX-B2-E-33(2)-6	6	02/27/08	0.0345 U	0.0575 U	0.0575 U	0.115 U	0.00872	25.1 JZ	203 Q9	126	354 J
EX-B2-E-33-6	6	02/25/08	0.0326 U	0.0543 U	0.0543 U	0.109 U	0.00883	8.75 JZ	129 Q10	86.6 Q10	224 J
EX-B2-E-34-6	6	02/25/08	0.0331 U	0.0552 U	0.0552 U	0.110 U	0.00923	32.2 JZ	101 Q9	54.2	187 J
EX-B2-E-35-(2)-6	6	02/27/08	0.0349 U	0.0582 U	0.0582 U	0.116 U	0.0702	16.5 JZ	1,950 J	1,490 J	3,460 J
EX-B2-E-35(3)-6	6	03/05/08	0.0370 U	0.0617 U	0.0617 U	0.163	0.0993	79.7 JZ	992 Q4	518 Q4	1,590 J
EX-B2-E-35-6	6	02/22/08	0.0336 U	0.0560 U	0.0560 U	0.176	0.117	66.7 JZ	1,270 Q9	687	2,020 J
EX-B2-E-36-6	6	02/27/08	0.0420 U	0.0700 U	0.0700 U	0.140 U	0.0243	20.0 JZ	402 Q9	155	577 J
EX-B2-E-40-4	4	01/23/08	0.0313 U	0.0522 U	0.0522 U	0.104 U	0.00922	5.22 U	48.9 J	48.5 Q4	100 J
EX-B2-E-41(2)-5	5	02/04/08	0.0289 U	0.0482 U	0.0482 U	0.104	0.0879	7.34 JZ	647 Q4	363 Q4	1,020 J
EX-B2-E-41-4	4	01/23/08	0.0262 U [0.0264 U]	0.0436 U [0.0440 U]	0.0436 U [0.0440 U]	0.0872 U [0.0880 U]	0.0528 [0.120]	13.5 JZ [13.3 JZ]	196 Q4 [208 Q4]	152 Q4 [182 Q4]	362 J [403 J]
EX-B2-F-32-12	12	03/03/08	0.108 U	0.180 U	0.180 U	0.360 U	NA	18.0 U	20.6 U	51.4 U	45.0 UU
EX-B2-F-33-12	12	02/28/08	0.0656 U [0.0670 U]	0.109 U [0.112 U]	0.109 U [0.112 U]	0.219 U [0.223 U]	NA [NA]	10.9 U [11.2 U]	16.0 U [15.6 U]	40.1 U [39.1 U]	33.5 UU [33.0 UU]
EX-B2-F-34-11	11	02/28/08	0.0603 U	0.101 U	0.101 U	0.201 U	NA	10.1 U	15.7 U	39.2 U	32.5 UU
EX-B2-F-35-12	12	02/25/08	0.105 U	0.175 U	0.175 U	0.349 U	NA	17.5 U	16.6 U	41.4 U	37.8 UU
EX-B2-F-36-13	13	02/22/08	0.0790 U	0.132 U	0.132 U	0.263 U	0.0205	13.2 U	331 Q9	105	443
EX-B2-F-36-NSW-6	6	02/22/08	0.0409 U	0.0682 U	0.0682 U	0.136 U	0.0305	69.9 JZ	215 Q9	70.9	356 J
EX-B2-F-37-13	13	02/22/08	0.0705 U	0.118 U	0.118 U	0.235 U	NA	11.8 U	16.9 U	42.2 U	35.5 UU
EX-B2-F-37-NSW-6	6	02/22/08	0.0378 U	0.0631 U	0.0631 U	0.126 U	0.00929	8.43	25.3 Q4	30.7 UQ4	64.4
EX-B2-F-38(2)-14	14	02/06/08	0.0570 U	0.0949 U	0.0949 U	0.190 U	NA	9.49 U	15.3 U	38.2 U	31.5 UU
EX-B2-F-38-8	8	01/31/08	0.0357 U	0.0595 U	0.0595 U	0.119 U	0.111	18.9 JZ	1,450	458	1,930 J
EX-B2-F-38-NSW(2)-5	5	02/06/08	0.0350 J	0.123 J	0.397 J	0.637 J	0.0317	214 JZ	329	137	680 J
EX-B2-F-38-NSW(2)-6	6	03/05/08	0.0307 U	0.0512 U	0.0512 U	0.102 U	0.0339	44.9 JZ	374 Q4	187 Q4	606 J
EX-B2-F-38-NSW-4	4	01/31/08	0.0295 U [0.0212 U]	0.0491 U [0.0354 U]	0.0491 U [0.0354 U]	0.0982 U [0.0708 U]	0.00831 [0.0287]	5.97 JZ [13.4 JZ]	25.0 [33.6 J]	28.0 U [28.0 U]	45.0 J [61.0 J]

TABLE 4
Excavation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase I Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX (mg/kg) B	T	E	X	Total cPAHs Adjusted for Toxicity (mg/kg)	Gasoline (mg/kg)	Diesel (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			REL = 18 mg/kg				*CUL = 0.14 mg/kg*				*REL = 2,975*
EX-B2-F-38-WSW-5	5	01/31/08	0.0291 U	0.0486 U	0.0486 U	0.0971 U	0.00909	19.2 JZ	105	48.8	173 J
EX-B2-F-39(2)-12	12	02/05/08	0.0580 U	0.0966 U	0.0966 U	0.193 U	NA	9.66 U	15.2 U	38.0 U	31.4 UU
EX-B2-F-39-8	8	01/28/08	0.0290 U [0.0287 U]	0.0483 U [0.0478 U]	0.0483 U [0.0478 U]	0.0966 U [0.0955 U]	0.0894 [0.00886]	5.35 JZ [5.58 JZ]	1,010 J [51.5 J]	250 J [28.8 UJ]	1,270 J [71.5 J]
EX-B2-F-39-NSW-4	4	01/28/08	0.0308 U	0.0514 U	0.0514 U	0.103 U	0.00853	5.14 U	39.6	28.2 U	56.3
EX-B2-F-40-8	8	01/25/08	0.170	0.216	0.210	0.696	0.00914	6.90	67.8 Q11	42.5	117
EX-B2-F-41-8	8	01/23/08	0.0288 U	0.0480 U	0.0480 U	0.0960 U	0.00847	19.0 JZ	111 Q4	64.3 Q4	194 J
EX-B2-F-41-ESW(2)-5	5	02/04/08	3.30	0.840	2.95	17.2	0.0753	127	513 Q4	478 Q4	1,120
EX-B2-F-41-ESW-4	4	01/23/08	0.0747	0.0420 U	0.319	0.0841 U	0.359	4.20 U	14.5 Q4	29.5 Q4	46.1
EX-B2-G-32-6	6	02/26/08	0.139 J	0.0781 J	1.02 J	2.09 J	0.00959	1,090	1,230 J	161 U	2,400 J
EX-B2-G-33(2)-6	6	02/28/08	0.0340 U	0.0567 U	0.0567 U	0.113 U	0.00891	13.1 JZ	32.7 Q9	28.9 U	60.3 J
EX-B2-G-33-6	6	02/25/08	0.371 U	0.618 U	0.961	2.88	0.139	1,510 JZ	4,860 J	1,690 J	8,060 J
EX-B2-G-34-10	10	02/25/08	0.0308 U	0.0513 U	0.0513 U	0.103 U	NA	5.13 U	11.0 U	27.6 U	21.9 UU
EX-B2-G-34-SSW-6	6	02/25/08	0.0429 U	0.0716 U	0.0716 U	0.143 U	0.0323	31.1 JZ	28.9	31.8 U	75.9 J
EX-B2-G-35-10	10	02/22/08	0.119 U	0.198 U	0.198 U	0.397 U	NA	19.8 U	22.4 U	56.1 U	49.2 UU
EX-B2-G-35-SSW-6	6	02/22/08	0.0361 U [0.0404 U]	0.0601 U [0.0674 U]	0.0601 UJ [0.245 J]	0.120 UJ [0.403 J]	0.0167 [0.0474]	6.91 JZ [102 JZ]	19.3 Q9 [42.6 Q9]	30.6 U [35.8]	41.5 J [180 J]
EX-B2-G-36-12	12	02/22/08	0.0423 U	0.0705 U	0.0705 U	0.141 U	0.0240	7.05 U	38.1 Q4	32.5 U	57.9
EX-B2-G-37-13	13	02/22/08	0.0414 U	0.0690 U	0.0690 U	0.138 U	NA	6.90 U	12.8 U	32.0 U	25.9 UU
EX-B2-G-38(2)-13	13	02/06/08	0.0332 U	0.0554 U	0.0554 U	0.111 U	NA	5.54 U	11.8 U	29.6 U	23.5 UU
EX-B2-G-38-8	8	01/31/08	0.0279 U	0.0465 U	0.0577	0.243	0.0702	87.0 JZ	1,020	335	1,440 J
EX-B2-G-38-WSW-5	5	01/31/08	0.0305 U	0.0508 U	0.0545	0.185	0.0516	100 JZ	651	317	1,070 J
EX-B2-G-39(2)-11	11	02/05/08	0.0662 U	0.110 U	0.110 U	0.291	NA	13.5	16.3 U	40.7 U	42.0
EX-B2-G-39-8	8	01/28/08	0.323 U	1.37	1.27	2.35	0.197	568 Q10a	3,450	1,140 Q7	5,160
EX-B2-G-39-SSW-4	4	01/28/08	0.0271 U	0.0452 U	0.0452 U	0.0904 U	0.00861	4.52 U	24.5	30.6	57.4
EX-B2-G-40-8	8	01/25/08	0.0317 U	0.0529 U	0.0529 U	0.106 U	0.00883	5.29 U	59.9 Q11	43.0	106
EX-B2-G-40-SSW-4	4	01/25/08	0.0287 U	0.0479 U	0.0479 U	0.0958 U	0.00906	4.79 U	22.3 Q11	32.6	57.3
EX-B2-G-41-8	8	01/24/08	0.0354 U	0.0939	0.0590 U	0.317	0.00891	61.1 JZ	125 J	110 Q4	296 J
EX-B2-G-41-ESW-4	4	01/24/08	0.0356 U	0.0593 U	0.0593 U	0.119 U	0.0415	5.93 U	438 Q4	361 Q4	802
EX-B2-G-41-SSW-4	4	01/24/08	0.0341 U	0.0568 U	0.0568 U	0.114 U	0.00853	5.68 U	20.1 Q4	57.1 Q4	80.0
EX-B2-H-35-6	6	02/27/08	0.0833 U	0.229	0.139 U	0.278 U	0.0123	18.5	41.4 Q4	40.7 UQ4	101
EX-B2-H-36-6	6	02/22/08	0.0426 U	0.0709 U	0.0790	0.363	0.0225	70.4 JZ	453 Q4	248 Q4	771 J
EX-B2-H-37(2)-6	6	03/05/08	0.0349 U	0.0582 U	0.0582 U	0.159	0.00868	75.0 JZ	312 Q4	513 Q4	900 J
EX-B2-H-37-5	5	02/22/08	0.0398 U	0.0663 U	0.0663 U	0.248	0.167	133 JZ	2,690 J	1,550 J	4,370 J
EX-B2-H-38(2)-10	10	02/06/08	0.0293 U	0.0488 U	0.0488 U	0.0976 U	NA	4.88 U	11.2 U	28.1 U	22.1 UU
EX-B2-H-38-5	5	01/31/08	0.0315 U	0.252 J	0.231 J	0.791 J	0.145	316 JZ	2,940	849	4,110 J
EX-B2-H-38-WSW(2)-5	5	02/06/08	0.0329 U	0.0549 U	0.0549 U	0.110 U	0.0160	6.75 JZ	128 Q4	96.1 Q4	231 J
EX-B2-H-38-WSW-5	5	01/31/08	0.292 URL1	0.487 URL1	0.796	1.25	0.186	406 JZ	2,220	667	3,290 J
EX-B3-E-32-6	6	02/26/08	0.0474 U	0.0790 U	0.0790 U	0.158 U	NA	7.90 U	13.2 U	33.1 U	27.1 UU
EX-B3-F-31-12	12	03/10/08	0.0604 U	0.101 U	0.101 U	0.201 U	NA	10.1 U	15.1 U	37.8 U	31.5 UU
EX-B3-F-31-NSW-6	6	03/10/08	0.0306 U	0.0510 U	0.0510 U	0.102 U	0.00891	5.10 U	13.8 Q4	29.7 U	31.2
EX-B3-G-29-5	5	03/11/08	0.0356 U	0.0594 U	0.0594 U	0.119 U	NA	5.94 U	11.5 U	28.8 U	23.1 UU
EX-B3-G-29-NSW-4	4	03/11/08	0.0313 U	0.0522 U	0.0522 U	0.104 U	0.0300	5.22 U	27.1 JY	161	191 J
EX-B3-G-29-SSW-5	5	03/11/08	0.0377 U [0.0345 U]	0.0629 U [0.0575 U]	0.0629 U [0.0575 U]	0.126 U [0.115 U]	NA [NA]	6.29 U [5.75 U]	12.4 U [11.3 U]	30.9 U [28.4 U]	24.8 UU [22.7 UU]
EX-B3-G-30-12	12	03/11/08	0.0352 U	0.0586 U	0.0586 U	0.117 U	NA	5.86 U	11.9 U	29.9 U	23.8 UU
EX-B3-G-30-NSW-6	6	03/11/08	0.108	0.0711 U	0.0711 U	0.142 U	0.0184	12.8 JZ	169 Q4	120 Q4	302 J
EX-B3-G-30-SSW-6	6	03/10/08	0.0322 U	0.0536 U	0.0536 U	0.107 U	NA	5.36 U	11.5 U	28.7 U	22.8 UU
EX-B3-G-31-12	12	03/10/08	0.0368 U	0.0613 U	0.0613 U	0.123 U	NA	6.13 U	12.5 U	31.3 U	25.0 UU
EX-B3-G-31-SSW-6	6	03/10/08	0.0427 U	0.0711 U	0.0711 U	0.224	NA	27.4	12.3 U	30.8 U	49.0
EX-B4-B-23-6	6	02/25/08	0.0297 U [0.0321 U]	0.263 J [0.0679 J]	0.0494 U [0.0535 U]	0.0988 U [0.107 U]	0.0145 [NA]	4.94 U [5.35 U]	15.5 JY [11.2 U]	27.8 U [28.0 U]	31.9 J [22.3 UU]
EX-B4-B-24-6	6	02/25/08	0.0366 U	0.0610 U	0.0610 U	0.122 U	NA	6.10 U	12.1 U	30.3 U	24.3 UU
EX-B5-B-20(2)-4	4	02/28/08	0.0354 U	0.0590 U	0.0590 U	0.118 U	NA	5.90 U	12.1 U	30.3 U	24.2 UU
EX-B5-B-20-4	4	02/22/08	0.0363 U	0.0605 U	0.0605 U	0.121 U	0.111	6.05 U	592 Q4	473 Q4	1,070
EX-B6-C-15-3	3	11/19/07	0.0335 U	0.0559 U	0.0559 U	0.112 U	NA	5.59 U	12.6 U	31.5 U	24.8 UU
EX-B6-D-13-3	3	11/19/07	0.0269 U	0.0448 U	0.0448 U	0.0895 U	0.00846	12.1	61.6	27.7 U	87.6
EX-B6-D-14-10	10	11/19/07	0.0321 U	0.0535 U	0.0535 U	0.107 U	NA	6.31	12.2 U	30.5 U	27.7

TABLE 4
Excavation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase I Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX (mg/kg) B	T	E	X	Total cPAHs Adjusted for Toxicity (mg/kg)	Gasoline (mg/kg)	Diesel (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			REL = 18 mg/kg				*CUL = 0.14 mg/kg*				*REL = 2,975*
EX-B6-D-14-NSW-3	3	11/19/07	0.0369 U	0.0616 U	0.0616 U	0.123 U	NA	6.16 U	15.0 U	37.4 U	29.3 UU
EX-B6-D-15-12	12	11/19/07	0.0332 U [0.0323 U]	0.0554 U [0.0538 U]	0.0554 U [0.0538 U]	0.111 U [0.108 U]	NA [NA]	5.54 U [5.79]	13.2 U [12.6 U]	33.0 U [31.6 U]	25.9 UU [27.9]
EX-B6-E-13-4	4	11/19/07	0.0261 U [0.0270 U]	0.0435 U [0.0449 U]	0.0435 U [0.0449 U]	0.0870 U [0.0899 U]	0.00853 [0.00853]	4.35 U [4.49 U]	146 J [33.6 J]	113 [28.4 U]	261 J [50.0 J]
EX-B6-E-14-10	10	11/19/07	0.0312 U	0.0520 U	0.0520 U	0.104 U	NA	5.20 U	12.1 U	30.2 U	23.8 UU
EX-B6-F-14-10	10	11/19/07	0.0302 U	0.0504 U	0.0504 U	0.101 U	NA	5.04 U	12.6 U	31.5 U	24.6 UU
EX-B6-F-14-WSW-3	3	11/19/07	0.0275 U	0.0459 U	0.0459 U	0.0918 U	0.00846	4.59 U	42.4 Q11	28.0 U	58.7
EX-B8-F-4-4	4	10/01/07	0.0278 U	0.0464 U	0.0464 U	0.0928 U	0.0222	53.6 JZ	1,070 Q4	496 Q4	1,620 J
EX-B8-F-4-9	9	10/22/07	0.224	0.0784	0.0625 U	0.125 U	0.0468	6.25 U	801 Q4	347 Q4	1,150
EX-B8-F-4-NSW-4	4	10/22/07	0.0326 U	0.0543 U	0.0543 U	0.109 U	0.0422	80.7	834 Q4	332 Q4	1,250
EX-B8-F-4-NSW-6	6	10/09/07	0.0318 U [0.0324 U]	0.0531 U [0.0540 U]	0.0531 U [0.0540 U]	0.106 U [0.108 U]	0.0424 [0.0854]	23.5 JZ [52.2 JZ]	1,310 Q4 [2,440 J]	496 Q4 [1,030 J]	1,830 J [3,520 J]
EX-B8-F-4NSW-6	6	10/15/07	0.0428 U	0.0713 U	0.0713 U	0.143 U	0.112	53.2 JZ	3,850 Q4	1,760 Q4	5,660 J
EX-B8-F-4-WSW-4	4	10/01/07	0.0400 U	0.0666 U	0.0666 U	0.133 U	NA	6.66 U	10.9 U	27.3 U	22.4 UU
EX-B8-F-5-4	4	10/01/07	0.0374 U	0.0623 U	0.0623 U	0.125 U	0.0885	94.8 JZ	462 J	424 J	981 J
EX-B8-F-5-NSW-6	6	10/09/07	0.0292 U	0.0487 U	0.0487 U	0.0975 U	0.00909	16.3 JZ	422 Q4	187 Q4	625 J
EX-B8-G-4-9	9	10/01/07	0.0308 U	0.0514 U	0.0514 U	0.103 U	0.00921	5.14 U	18.2	30.5 U	36.0
EX-B8-G-4-WSW-4	4	10/01/07	0.0271 U	0.0452 U	0.0452 U	0.0904 U	0.0808	5.76 JZ	133 J	245 J	384 J
EX-B8-G-5-9	9	10/01/07	0.0319 U	0.0532 U	0.0532 U	0.106 U	NA	5.32 U	13.3 U	33.2 U	25.9 UU
EX-B8-H-4-9	9	10/01/07	0.0324 U	0.0540 U	0.0540 U	0.108 U	NA	5.40 U	11.9 U	29.8 U	23.6 UU
EX-B8-H-4-WSW-4	4	10/01/07	0.0279 U	0.0465 U	0.0465 U	0.0931 U	0.0768	86.7 JZ	2,080 Q4	1,100 Q4	3,270 J
EX-B8-H-5-9	9	10/01/07	0.0353 U	0.0588 U	0.0588 U	0.118 U	NA	5.88 U	12.2 U	30.4 U	24.2 UU
EX-B8-I-4-9	9	10/01/07	0.0817	0.0498 U	0.0498 U	0.0996 U	NA	4.98 U	12.2 U	30.4 U	23.8 UU
EX-B8-I-4-WSW-4	4	10/01/07	0.0323 U [0.0334 U]	0.0539 U [0.0557 U]	0.0539 U [0.0557 U]	0.108 U [0.111 U]	0.0991 [0.0524]	25.4 JZ [34.7 JZ]	3,130 Q4 [1,990 Q4]	1,480 Q4 [1,010 Q4]	4,640 J [3,030 J]
EX-B8-I-5-9	9	10/01/07	0.0292 U	0.0486 U	0.0486 U	0.0972 U	NA	4.86 U	12.1 U	30.2 U	23.6 UU
EX-B8-J-4-4	4	10/01/07	0.0217 U	0.0362 U	0.0362 U	0.0723 U	0.165	80.5 JZ	1,530 Q4	798 Q4	2,410 J
EX-B8-J-4-5	5	10/23/07	0.0251 U	0.0419 U	0.0419 U	0.0838 U	0.0170	4.19 U	146 Q4	167 Q4	315
EX-B8-J-4-SSW-2.5	2.5	10/23/07	0.0331 U	0.0552 U	0.0552 U	0.110 U	NA	5.52 U	10.9 U	27.3 U	21.9 UU
EX-B8-J-5-4	4	10/01/07	0.0272 U	0.0453 U	0.0453 U	0.0907 U	0.00831	4.53 U	35.9 JY	43.8	82.0 J
EX-B8-J-5-9	9	10/01/07	0.0366 U	0.0610 U	0.0610 U	0.122 U	NA	6.10 U	11.3 U	28.4 U	22.9 UU
EX-B9-M-4-11	11	02/20/08	0.0315 U	0.0524 U	0.0524 U	0.105 U	NA	5.24 U	11.6 U	29.1 U	23.0 UU
EX-B9-M-4-NSW-6	6	02/19/08	0.329 U	0.548 U	0.548 U	1.71	0.00907	755 JZ	439 Q4	211 Q4	1,410 J
EX-B9-M-4-WSW-6	6	02/19/08	0.336 U	0.561 U	0.561 U	1.84	0.0173	816 JZ	537 JX	141 U	1,420 J
EX-B9-M-5-11	11	02/19/08	0.0411 U	0.0685 U	0.0685 U	0.137 U	NA	6.85 U	13.0 U	32.5 U	26.2 UU
EX-B9-M-5-NSW-6	6	02/19/08	0.0285 U	0.0475 U	0.0750 J	0.375 J	0.00823	98.5 JZ	40.9 Q4	27.1 UQ4	167 J
EX-B9-M-6-11	11	02/19/08	0.0364 U [0.0453 U]	0.0606 U [0.0755 U]	0.0606 U [0.0755 U]	0.121 U [0.151 U]	NA [NA]	6.06 U [7.55 U]	12.5 U [13.4 U]	31.4 U [33.4 U]	25.0 UU [27.2 UU]
EX-B9-M-6-NSW-6	6	02/19/08	0.0383 U	0.0638 U	0.291	0.426	NA	16.2	13.0 U	32.6 U	39.0
EX-B9-N-4-11	11	02/20/08	0.0349 U	0.0582 U	0.0582 U	0.116 U	NA	5.82 U	12.1 U	30.3 U	24.1 UU
EX-B9-N-4-WSW-6	6	02/20/08	0.0338 U	0.250 J	0.172 J	0.871 J	0.00891	276 JZ	139 Q4	128 Q4	543 J
EX-B9-N-5-12	12	02/13/08	0.0343 U	0.0572 U	0.0572 U	0.114 U	NA	5.72 U	11.8 U	29.6 U	23.6 UU
EX-B9-O-4-12	12	02/20/08	0.0373 U [0.0373 U]	0.0622 U [0.0621 U]	0.0622 U [0.0621 U]	0.128 [0.209]	NA [NA]	20.2 [15.9]	12.3 U [12.5 U]	30.7 U [31.2 U]	41.7 [37.8]
EX-B9-O-4-WSW-6	6	02/20/08	0.0322 U	0.0536 U	0.0536 U	0.107 U	0.00800	50.7 JZ	24.4	26.5 U	88.4 J
EX-B9-O-5-12	12	02/13/08	0.0365 U [0.0354 U]	0.0609 U [0.0591 U]	0.0609 U [0.0591 U]	0.122 U [0.118 U]	NA [NA]	6.09 U [5.91 U]	11.8 U [11.9 U]	29.6 U [29.7 U]	23.7 UU [23.8 UU]
EX-B9-P-4-12	12	02/20/08	0.0396 U	0.0660 U	0.0660 U	0.132 U	NA	8.18	12.6 U	31.5 U	30.2
EX-B9-P-4-SSW(2)-6	6	02/25/08	0.332 U	0.553 U	0.553 U	3.82	0.0194	967 JZ	470 JX	138 U	1,510 J
EX-B9-P-4-SSW-6	6	02/20/08	0.295 U	0.491 U	0.595	3.53	0.0316	898 JZ	1,430 Q4	248 Q4	2,580 J
EX-B9-P-4-WSW-6	6	02/20/08	0.0333 U	0.0556 U	0.0556 U	0.111 U	NA	5.56 U	11.8 U	29.5 U	23.4 UU
EX-B9-P-5-12	12	02/13/08	0.0315 U	0.0525 U	0.0525 U	0.105 U	NA	5.25 U	11.6 U	29.0 U	22.9 UU
EX-B9-Q-5-6	6	02/13/08	0.0175 U	0.0291 U	0.0291 U	0.0582 U	0.0145	2.91 U	56.5 Q4	35.4 Q4	93.4
EX-B10-N-6-10	10	02/08/08	0.0361 U	0.0601 U	0.0601 U	0.120 U	NA	6.01 U	12.4 U	31.1 U	24.8 UU
EX-B10-O-6-10	10	02/08/08	0.0352 U	0.0586 U	0.0586 U	0.117 U	NA	5.86 U	12.3 U	30.8 U	24.5 UU
EX-B10-O-7-12	12	01/16/08	0.0302 U [0.0330 U]	0.0503 U [0.0550 U]	0.0503 U [0.0550 U]	0.101 U [0.110 U]	NA [NA]	5.03 U [5.50 U]	12.2 U [13.3 U]	30.5 U [33.3 U]	23.9 UU [26.1 UU]
EX-B10-O-8-12	12	01/16/08	0.0316 U	0.0527 U	0.0527 U	0.105 U	NA	5.27 U	12.7 U	31.8 U	24.9 UU
EX-B10-P-6-10	10	02/08/08	0.0400 U	0.0666 U	0.0666 U	0.176	NA	8.23	12.6 U	31.6 U	30.3
EX-B10-P-7-15	15	01/30/08	0.0328 U	0.0546 U	0.0546 U	0.109 U	NA	9.68	13.2 U	32.9 U	32.7
EX-B10-P-8-15	15	01/30/08	0.0322 U	0.0536 U	0.0536 U	0.107 U	NA	5.36 U	12.2 U	30.5 U	24.0 UU

TABLE 4
Excavation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase I Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX (mg/kg) B	BTEX (mg/kg) T	BTEX (mg/kg) E	BTEX (mg/kg) X	Total cPAHs Adjusted for Toxicity (mg/kg)	Gasoline (mg/kg)	Diesel (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			REL = 18 mg/kg				*CUL = 0.14 mg/kg*				*REL = 2,975*
EX-B10-Q-6-11	11	02/08/08	0.0343 U	0.0572 U	0.0572 U	0.114 U	NA	5.73	12.8 U	32.1 U	28.2
EX-B10-Q-7-15	15	01/30/08	0.0309 U	0.0516 U	0.0516 U	0.103 U	NA	5.16 U	12.5 U	31.3 U	24.5 UU
EX-B11-Q-8-14	14	01/30/08	0.0306 U [0.0317]	0.0510 U [0.0496 U]	0.0510 U [0.0496 U]	0.102 U [0.0991 U]	0.00891 [NA]	5.80 [4.96 U]	20.1 JY [11.8 U]	29.7 U [29.5 U]	40.8 J [23.1 UU]
EX-B11-R-6-5	5	02/08/08	0.0346 U [0.0340 U]	0.0577 U [0.0566 U]	0.0577 U [0.0566 U]	0.115 U [0.113 U]	0.0224 [0.0258]	56.8 JZ [168 JZ]	1,510 [1,310]	296 [265]	1,860 J [1,740 J]
EX-B11-R-7-12	12	01/22/08	0.0331	0.0688	0.0509 U	0.145	NA	5.09 U	12.0 U	30.0 U	23.5 UU
EX-B11-R-7-WSW-5	5	01/18/08	0.0297 U	0.0495 U	0.0495 U	0.0989 U	0.107	80.4 JZ	7,130	1,360 Q7	8,570 J
EX-B11-R-8-12	12	01/30/08	0.0303	0.0993	0.109	0.565	NA	13.9	11.8 U	29.6 U	34.6
EX-B11-R-9-12	12	02/12/08	0.0612	0.0555 U	0.0555 U	0.111 U	NA	5.55 U	11.7 U	29.3 U	23.3 UU
EX-B11-S-7-12	12	01/22/08	0.0402	0.122	0.0601	0.333	NA	6.08	12.1 U	30.2 U	27.2
EX-B11-S-7-WSW-5	5	01/18/08	0.0290 U	0.0483 U	0.0483 U	0.0966 U	NA	4.83 U	10.9 U	27.2 U	21.5 UU
EX-B11-S-8-12	12	01/30/08	0.0287 U	0.0478 U	0.0478 U	0.0955 U	NA	8.58	12.1 U	30.2 U	29.7
EX-B11-S-9-12	12	02/12/08	0.0413	0.0628 U	0.150	0.457	0.00929	38.7 JZ	67.6	31.1 U	122 J
EX-B11-S-10-2	2	02/15/08	0.0408 U	0.0680 U	0.0680 U	0.136 U	NA	6.80 U	12.7 U	31.8 U	25.7 UU
EX-B11-S-11-12	12	02/14/08	0.0398 U	0.0663 U	0.0663 U	0.133 U	NA	6.63 U	12.3 U	30.7 U	24.8 UU
EX-B11-T-7-12	12	01/22/08	0.0310	0.0851	0.103	0.532	0.00891	48.4 JZ	52.3	29.6 U	116 J
EX-B11-T-7-WSW-5	5	01/18/08	0.0290 U	0.0484 U	0.0484 U	0.0967 U	NA	9.95 JZ	10.9 U	27.2 U	29.0 J
EX-B11-T-8-12	12	01/30/08	0.231	0.561	0.150	0.778	NA	6.50	11.9 U	29.9 U	27.4
EX-B11-T-9-12	12	02/12/08	0.193	0.0636 U	0.0647	0.127 U	NA	6.36 U	12.5 U	31.4 U	25.1 UU
EX-B11-T-10-10	10	02/14/08	0.0342 U	0.0570 U	0.0570 U	0.114 U	NA	5.70 U	12.3 U	30.6 U	24.3 UU
EX-B11-T-11-12	12	02/14/08	0.0306 U	0.0510 U	0.0510 U	0.102 U	NA	5.10 U	11.7 U	29.2 U	23.0 UU
EX-B11-T-11-ESW-6	6	02/15/08	0.0382 U	0.0637 U	0.0637 U	0.127 U	NA	6.37 U	12.5 U	31.4 U	25.1 UU
EX-B11-U-7-5	5	01/18/08	0.0290 U	0.0484 U	0.0484 U	0.0967 U	NA	4.84 U	11.0 U	27.5 U	21.7 UU
EX-B11-U-8-14	14	01/30/08	2.59	3.57	1.59	7.94	NA	48.6	11.9 U	29.7 U	69.4
EX-B11-U-9-12	12	01/31/08	0.461	0.824	0.460	1.71	NA	15.8	12.1 U	30.3 U	37.0
EX-B11-U-10-10	10	02/14/08	1.20	0.0890 U	0.0890 U	0.178 U	NA	8.90 U	14.0 U	34.9 U	28.9 UU
EX-B11-U-10-SSW-5	5	02/12/08	14.9	0.606 U	1.48	1.21 U	0.159	214	957 Q4	639 Q4	1,810
EX-B11-U-11-5	5	02/12/08	0.0429 U	0.0716 U	0.0716 U	0.143 U	0.0260	8.80 JZ	423 Q4	131 Q4	563 J
EX-B11-V-8-5	5	01/31/08	0.127	0.219	0.196	0.218	0.0172	175 JZ	616	28.0 U	805 J
EX-B11-V-9-5	5	01/31/08	0.142 J	0.302 J	1.17 J	2.36 J	0.00872	405 JZ	265	84.4	754 J
EX-B13-AA-2-10	10	09/26/07	0.0346	0.0564 U	0.0564 U	0.113 U	NA	12.8	12.5 U	31.1 U	34.6
EX-B13-AA-2-NSW-4	4	09/19/07	0.0306 U	0.0511 U	0.0511 U	0.102 U	0.0126	5.11 U	35.2	101	139
EX-B13-AA-2-WSW-4	4	09/19/07	0.0303 U	0.0505 U	0.0505 UJ	0.101 U	NA	5.05 U	11.0 U	27.5 U	21.8 UU
EX-B13-AA-3-10	10	09/26/07	0.0322 U	0.0537 U	0.0537 U	0.107 U	NA	5.37 U	12.9 U	32.2 U	25.2 UU
EX-B13-AA-3-NSW-4	4	09/19/07	0.0265 U	0.0441 U	0.0441 U	0.0883 U	NA	4.41 U	10.5 U	26.2 U	20.6 UU
EX-B13-AA-4-10	10	09/26/07	0.0313 U	0.0522 U	0.0522 U	0.104 U	NA	5.22 U	11.7 U	29.2 U	23.1 UU
EX-B13-BB-2-10	10	09/25/07	0.0336 U	0.0560 U	0.0560 U	0.112 U	NA	5.60 U	11.8 U	29.5 U	23.5 UU
EX-B13-BB-2-WSW-4	4	09/19/07	0.476	0.959	0.993	1.12	0.0335	774 JZ	1,030 J	105 J	1,910 J
EX-B13-BB-3-10	10	09/25/07	0.0281 U [0.0319 U]	0.0468 U [0.0532 U]	0.0468 U [0.0532 U]	0.0935 U [0.106 U]	NA [NA]	4.98 U [5.32 U]	10.7 U [11.5 U]	26.7 U [28.8 U]	21.2 UU [22.8 UU]
EX-B13-BB-4-10	10	09/25/07	0.0283 U	0.0472 U	0.0472 U	0.0945 U	NA	4.72 U	12.7 U	31.8 U	24.6 UU
EX-B13-BB-5-10	10	09/27/07	0.0295 U	0.0491 U	0.0491 U	0.0983 U	NA	4.91 U	11.4 U	28.5 U	22.4 UU
EX-B13-CC-1-4	4	10/10/07	0.0432 U	0.104	0.0720 U	0.144 U	NA	20.2	18.4 U	45.9 U	52.4
EX-B13-CC-1-10	10	10/08/07	0.952	3.90	2.99	2.51	0.0881	1,630	3,810 J	656 J	6,100 J
EX-B13-CC-2-4	4	09/25/07	8.83	4.68 U	4.68 U	9.37 U	0.0499	3,020	2,520	582	6,120
EX-B13-CC-2-10	10	10/08/07	0.0278 U	0.0463 U	0.0463 U	0.0926 U	NA	4.63 U	11.3 U	28.1 U	22.0 UU
EX-B13-CC-3-10	10	09/27/07	0.0285 U	0.0475 U	0.0475 U	0.0951 U	NA	4.75 U	12.1 U	30.2 U	23.5 UU
EX-B13-CC-4-10	10	09/27/07	0.0279 U	0.0465 U	0.0465 U	0.0931 U	NA	4.65 U	12.0 U	30.1 U	23.4 UU
EX-B13-CC-5-10	10	09/27/07	0.0299 U	0.0498 U	0.0498 U	0.0997 U	NA	4.98 U	12.5 U	31.2 U	24.3 UU
EX-B13-DD-1-4	4	10/08/07	0.0408 U	0.0679 U	0.0679 U	0.136 U	NA	6.79 U	14.7 U	36.7 U	29.1 UU
EX-B13-DD-2-10	10	10/08/07	0.0291 U	0.0484 U	0.0484 U	0.0968 U	NA	4.84 U	11.8 U	29.5 U	23.1 UU
EX-B13-DD-3-10	10	10/02/07	0.0279 U	0.0465 U	0.0465 U	0.0929 U	NA	4.65 U	11.1 U	27.8 U	21.8 UU
EX-B13-DD-4-10	10	10/02/07	0.173	0.0461 U	0.0461 U	0.0921 U	NA	4.61	11.7 U	29.1 U	25.0
EX-B13-DD-5-10	10	10/02/07	0.0637	0.0451 U	0.0451 U	0.0901 U	NA	4.51 U	11.6 U	28.9 U	22.5 UU
EX-B13-EE-1-4	4	10/08/07	0.0283 U	0.0472 U	0.0472 U	0.0944 U	NA	4.72 U	12.2 U	30.4 U	23.7 UU
EX-B13-EE-2-10	10	10/08/07	0.0272 U	0.0453 U	0.0453 U	0.0905 U	NA	4.53 U	11.6 U	28.9 U	22.5 UU

TABLE 4
Excavation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase I Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX (mg/kg) B	T	E	X	Total cPAHs Adjusted for Toxicity (mg/kg)	Gasoline (mg/kg)	Diesel (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			REL = 18 mg/kg				CUL = 0.14 mg/kg				REL = 2,975
EX-B13-EE-3-10	10	10/05/07	0.0298 U	0.0496 U	0.0496 U	0.0992 U	NA	4.96 U	11.5 U	28.8 U	22.6 UU
EX-B13-EE-3-SSW-4	4	10/05/07	0.0509	0.0502 U	0.0502 U	0.100 U	NA	6.85	12.2 U	30.6 U	28.3
EX-B13-EE-4-10	10	10/05/07	0.0296 U [0.0292 U]	0.0494 U [0.0487 U]	0.0494 U [0.0487 U]	0.0987 U [0.0974 U]	NA [NA]	4.94 U [4.87 U]	11.7 U [11.1 U]	29.3 U [27.8 U]	23.0 UU [21.9 UU]
EX-B13-EE-4-SSW-4	4	10/05/07	0.0314 U	0.0523 U	0.0523 U	0.105 U	NA	5.23 U	12.6 U	31.5 U	24.7 UU
EX-B13-FF-2-4	4	10/09/07	0.0302 U	0.0504 U	0.0504 U	0.101 U	NA	5.04 U	12.8 U	32.0 U	24.9 UU
EX-B13-FF-3-10	10	10/09/07	0.0447	0.0538 U	0.0538 U	0.108 U	NA	8.17	11.7 U	29.4 U	28.7
EX-B13-FF-3-ESW-4	4	10/09/07	0.0289 U	0.0481 U	0.0481 U	0.0963 U	NA	4.81 U	12.7 U	31.8 U	24.7 UU
EX-B13-GG-3-4	4	10/09/07	0.136	0.0462 U	0.0462 U	0.0925 U	NA	4.62 U	12.9 U	32.2 U	24.9 UU
EX-B14-DD-7-2.5	2.5	08/23/07	1.85	0.0664 U	0.0844	0.133 U	0.0121	70.6	151	82.0	304
EX-B14-DD-7-WSW-2.5	2.5	09/10/07	14.6	2.94	7.66	8.28	0.0111	2,940 J	3,640 J	213	6,790 J
EX-B14-DD-8-5	5	08/23/07	0.0500 [0.0302 U]	0.0519 U [0.0504 U]	0.0519 U [0.0504 U]	0.104 U [0.101 U]	0.226 [0.222]	40.3 JZ [23.3 JZ]	990 Q4 [425 Q4]	861 Q4 [396 Q4]	1,890 J [844 J]
EX-B14-DD-8-6	6	09/04/07	0.0999 [0.0912]	0.0496 U [0.0507 U]	0.0549 [0.0507 U]	0.0993 U [0.101 U]	0.00945 [0.00929]	13.9 [11.9]	70.8 JQ4 [28.3 JQ4]	75.1 JQ4 [30.9 UQ4]	160 J [71.1 J]
EX-B14-DD-NSW-2.5	2.5	08/23/07	0.0885 J [1.32 J]	0.0509 U [0.0687 U]	0.0509 U [0.0768]	0.102 U [0.137 U]	0.0112 [0.0244]	25.0 [72.9 JZ]	157 Q4 [188]	83.6 Q4 [88.7]	266 [350 J]
EX-B14-EE-5-4	4	09/10/07	0.404	0.0701 U	0.662	0.800	NA	445 JZ	12.1 U	30.3 U	466 J
EX-B14-EE-6-8	8	09/10/07	0.239	0.0541 U	0.0541 U	0.108 U	NA	5.41 U	11.7 U	29.2 U	23.2 UU
EX-B14-EE-7-8	8	08/23/07	0.0581 U	0.0968 U	0.0968 U	0.194 U	NA	9.68 U	17.9 U	44.7 U	36.1 UU
EX-B14-EE-8-4	4	08/23/07	0.255	0.0490 U	0.0490 U	0.0980 U	NA	4.90 U	12.7 U	31.7 U	24.7 UU
EX-B14-EE-WSW-4	4	08/23/07	2.30	0.539 U	4.91	7.39	0.224	1,040 JZ	3,290 J	598 UJ	4,630 J
EX-B14-FF-6-4	4	09/07/07	0.213	0.0536 U	0.0536 U	0.107 U	NA	5.57	12.6 U	31.4 U	27.6
EX-B14-FF-7-8	8	08/23/07	0.0763 U	0.127 U	0.127 U	0.254 U	NA	12.7 U	20.1 U	50.3 U	41.6 UU
EX-B14-FF-8-4SW	4	08/22/07	0.0505 U	0.0841 U	0.0841 U	0.168 U	0.0119	8.41 U	523	144	671
EX-B14-FF-WSW-4	4	08/23/07	0.100	0.0489 U	0.0489 U	0.0977 U	0.0107	16.3	64.2	34.6	115
EX-B14-GG-7-8	8	08/23/07	0.0266 U	0.0444 U	0.0444 U	0.0888 U	NA	4.44 U	12.1 U	30.4 U	23.5 UU
EX-B14-GG-WSW-4	4	08/23/07	0.0275 U	0.0458 U	0.0458 U	0.0915 U	0.0218	8.72	428 Q4	138 Q4	575
EX-B14-HH-6-4	4	08/23/07	0.0302 U [0.0285 U]	0.0504 U [0.0475 U]	0.0504 U [0.0475 U]	0.101 U [0.0949 U]	0.0107 [0.0107]	5.04 U [4.75 U]	40.1 Q4 [44.6 Q4]	80.6 Q4 [90.5 Q4]	123 [137]
EX-B14-HH-6F	6	08/23/07	0.0260 U	0.0433 U	0.0433 U	0.0866 U	0.0110	4.33 U	38.3 Q12	29.4 U	55.2
EX-B14-HH-7-4SW	4	08/23/07	0.0277 U	0.0461 U	0.0461 U	0.0923 U	0.0117	9.66 JZ	29.1 JY	29.5 U	53.5 J
EX-B15-HH-2-4	4	08/28/07	0.0901	0.0563 U	0.0563 U	0.184	NA	5.63 U	13.2 U	33.0 U	25.9 UU
EX-B15-HH-3-ESW-4	4	08/28/07	0.0319 U	0.0532 U	0.0532 U	0.106 U	NA	5.32 U	11.9 U	29.8 U	23.5 UU
EX-B15-HH-3-NSW-4	4	08/28/07	0.356	0.0539 U	0.0539 U	0.108 U	NA	5.39 U	13.0 U	32.4 U	25.4 UU
EX-B15-II-2-8	8	08/28/07	0.0571	0.0789 U	0.0789 U	0.158 U	NA	12.6	15.4 U	38.4 U	39.5
EX-B15-II-2-WSW-4	4	08/28/07	1.10	0.0517 U	0.143	0.133	NA	29.2	12.9 U	32.4 U	51.9
EX-B15-II-3-8	8	08/28/07	0.0264 U	0.0440 U	0.0440 U	0.0880 U	NA	4.40 U	11.6 U	29.1 U	22.6 UU
EX-B15-II-4-ESW-4	4	08/28/07	0.0316 U	0.0527 U	0.0527 U	0.169	0.0115	209 JZ	676	153	1,040 J
EX-B16-MM-1-6SW	6	08/20/07	0.305 U	0.508 U	0.807	1.02 U	0.00911	293 JZ	656	78.3 Q7	1,030 J
EX-B17-RR-1-6SW	6	08/20/07	0.0488 U	0.0814 U	0.0814 U	0.163 U	0.0113	8.14 U	51.2 JY	72.5 J	128 J
EX-B17-SS-1-6SW	6	08/20/07	0.0270 U	0.0450 U	0.0450 U	0.0900 U	NA	4.50 U	12.0 U	30.1 U	23.3 UU
EX-B18-UU-1-6SW	6	08/17/07	0.290 U [0.288 U]	0.484 U [0.480 U]	0.691 [0.554]	2.55 [1.94]	0.0435 [0.0103]	693 JZ [611 JZ]	1,140 J [376 J]	146 U [58.5 U]	1,910 J [1,020 J]
EX-B18-VV-1-6SW	6	08/17/07	1.56 U	2.60 U	2.60 U	5.82	0.0457	2,150 JZ	2,670 J	312 U	4,980 J
EX-B20-O-14-12	12	01/18/08	0.0303 U	0.0505 U	0.0505 U	0.101 U	NA	5.05 U	12.1 U	30.1 U	23.6 UU
EX-B20-O-15-12	12	01/18/08	0.0299 U	0.0499 U	0.0499 U	0.0998 U	NA	4.99 U	12.4 U	31.1 U	24.2 UU
EX-B20-F-19-6	6	10/18/07	0.0538	0.0521 U	0.0763	0.320	NA	23.0	12.4 U	31.1 U	44.8
EX-B20-F-19-NSW-3	3	10/26/07	0.0271 U	0.0451 U	0.0451 U	0.0902 U	NA	4.51 U	11.1 U	27.8 U	21.7 UU
EX-B20-F-20-10	10	10/30/07	0.0290 U	0.0484 U	0.0484 U	0.0968 U	0.0230	4.84 U	53.4	31.1 U	71.4
EX-B20-F-20-NSW-4	4	10/30/07	0.0286 U [0.0292 U]	0.0476 U [0.0486 U]	0.0476 U [0.0486 U]	0.0952 U [0.0972 U]	NA [NA]	4.76 U [4.86 U]	11.1 U [11.3 U]	27.8 U [28.3 U]	21.8 UU [22.2 UU]
EX-B20-F-21-4	4	10/17/07	0.0316 U	0.0526 U	0.0526 U	0.105 U	NA	5.26 U	12.0 U	30.0 U	23.6 UU
EX-B20-G-13-12	12	11/26/07	0.0268 U	0.0447 U	0.0447 U	0.0895 U	0.00823	4.47 U	100 J	27.3 U	116 J
EX-B20-G-14-12	12	11/20/07	0.0292 U	0.0486 U	0.0486 U	0.0973 U	NA	4.86 U	12.1 U	30.3 U	23.6 UU
EX-B20-G-14-WSW-4	4	11/20/07	0.0299 U	0.0498 U	0.0498 U	0.0995 U	0.00815	4.98 U	48.5 Q11	32.9	83.9
EX-B20-G-18-15	15	10/18/07	0.0276 U	0.0460 U	0.0460 U	0.0919 U	NA	5.04 U	12.1 U	30.3 U	23.7 UU
EX-B20-G-19-15	15	10/18/07	0.0377 U	0.0628 U	0.0628 U	0.126 U	NA	6.28 U	12.0 U	30.1 U	24.2 UU
EX-B20-G-20-15	15	10/18/07	0.0365	0.0488 U	0.179	0.0976 U	NA	4.88 U	11.8 U	29.4 U	23.0 UU
EX-B20-G-21-10	10	10/17/07	0.271 U	0.792	0.451 U	0.903 U	0.00944	123 JZ	1,020	59.0	1,200 J
EX-B20-G-21-ESW-5	5	10/26/07	0.0273 U	0.0455 U	0.0455 U	0.0910 U	0.00891	4.55 U	36.0 C8	29.3 U	52.9

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11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX (mg/kg) B	T	E	X	Total cPAHs Adjusted for Toxicity (mg/kg)	Gasoline (mg/kg)	Diesel (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			REL = 18 mg/kg				*CUL = 0.14 mg/kg*				*REL = 2,975*
EX-B20-H-10-4	4	11/30/07	0.0291 U	0.0484 U	0.0484 U	0.0968 U	0.00858	4.84 U	148 Q4	195 Q4	345
EX-B20-H-11-4	4	11/29/07	0.0298 U	0.0497 U	0.0497 U	0.0994 U	NA	4.97 U	11.0 U	27.5 U	21.7 UU
EX-B20-H-12-6	6	11/29/07	0.0284 U [0.0291 U]	0.0473 U [0.0485 U]	0.0473 U [0.0485 U]	0.0946 U [0.0970 U]	0.00823 [0.00831]	4.73 U [4.85 U]	28.9 Q11 [35.8 Q11]	27.4 U [27.6 U]	45.0 [52.0]
EX-B20-H-12-NSW-2	2	11/29/07	0.0262 U	0.0437 U	0.0437 U	0.0873 U	NA	4.37 U	11.3 U	28.3 U	22.0 UU
EX-B20-H-13-12	12	11/26/07	0.0330 U	0.0550 U	0.0550 U	0.110 U	NA	5.50 U	12.3 U	30.7 U	24.3 UU
EX-B20-H-14-12	12	11/20/07	0.0319 U	0.0531 U	0.0531 U	0.106 U	0.00959	5.31 U	70.9 Q11	31.6 U	89.4
EX-B20-H-14-WSW-4	4	11/20/07	0.0277 U [0.0306 U]	0.0461 U [0.0510 U]	0.0461 U [0.0510 U]	0.0922 U [0.102 U]	0.00876 [0.00846]	4.61 U [5.10 U]	27.1 Q11 [20.4 Q11]	28.5 U [27.6 U]	43.7 [36.8]
EX-B20-H-18-15	15	10/18/07	0.0299 U [0.0301 U]	0.0498 U [0.0502 U]	0.0498 U [0.0502 U]	0.0997 U [0.100 U]	NA [NA]	4.98 U [5.02 U]	12.0 U [12.2 U]	30.0 U [30.5 U]	23.5 UU [23.9 UU]
EX-B20-H-19-15	15	10/18/07	0.0276 U	0.0460 U	0.0689	0.0920 U	NA	4.60 U	12.1 U	30.2 U	23.5 UU
EX-B20-H-20-15	15	10/18/07	0.107	0.0671 U	0.474	0.378	NA	10.5	13.8 U	34.5 U	34.7
EX-B20-H-21-10	10	10/18/07	0.0683 U	0.114 U	0.114 U	0.228 U	0.0153	11.4 U	506	72.1	584
EX-B20-H-21-ESW-5	5	10/26/07	0.0271 U	0.0452 U	0.0452 U	0.0903 U	0.00891	7.14 JZ	58.7 J	29.1 U	80.4 J
EX-B20-I-9-9	9	10/17/07	0.0440 U	0.0733 U	0.0733 U	0.147 U	NA	7.33 U	15.6 U	39.1 U	31.0 UU
EX-B20-I-10-10	10	11/29/07	0.0308 U	0.0514 U	0.0514 U	0.103 U	NA	5.14 U	12.7 U	31.8 U	24.8 UU
EX-B20-I-11-10	10	11/29/07	0.0329 U	0.0549 U	0.0549 U	0.110 U	NA	7.89	12.2 U	30.6 U	29.3
EX-B20-I-11-NSW-6	6	11/29/07	0.0299 U	0.0499 U	0.0499 U	0.0997 U	0.00815	5.84 JZ	63.6 Q11	26.9 U	82.9 J
EX-B20-I-12-10	10	11/29/07	0.0296 U	0.0493 U	0.0493 U	0.0985 U	NA	5.87	12.4 U	31.0 U	27.6
EX-B20-I-13-12	12	11/26/07	0.0291 U	0.0485 U	0.0485 U	0.0971 U	NA	4.85 U	11.8 U	29.4 U	23.0 UU
EX-B20-I-14-12	12	11/20/07	0.0314 U	0.0524 U	0.0524 U	0.105 U	NA	5.24 U	13.0 U	32.5 U	25.4 UU
EX-B20-I-15-15	15	11/05/07	0.0315 U	0.0525 U	0.0525 U	0.105 U	NA	5.25 U	13.6 U	34.0 U	26.4 UU
EX-B20-I-18-15	15	10/19/07	0.0392	0.0498 U	0.156	0.0997 U	NA	4.98 U	12.6 U	31.6 U	24.6 UU
EX-B20-I-19-15	15	10/18/07	0.0361 U [0.0326 U]	0.0601 U [0.0543 U]	0.0601 U [0.0543 U]	0.120 U [0.109 U]	NA [NA]	6.01 U [5.43 U]	13.3 U [13.1 U]	33.2 U [32.9 U]	26.3 UU [25.7 UU]
EX-B20-I-20-8	8	10/18/07	0.0303 U	0.0505 U	0.0505 U	0.101 U	NA	5.05 U	12.7 U	31.7 U	24.7 UU
EX-B20-I-21-4	4	10/30/07	0.0254 U	0.0423 U	0.0423 U	0.0846 U	0.0231	4.83 JZ	37.8	49.7	92.3 J
EX-B20-J-9-9	9	10/17/07	0.0310 U	0.0517 U	0.0517 U	0.103 U	0.00906	37.0 JZ	12.9	29.8 U	64.8 J
EX-B20-J-10-10	10	11/29/07	0.0340 U	0.0945	0.0567 U	0.123	NA	18.1	12.7 U	31.8 U	40.4
EX-B20-J-11-11	11	12/13/07	0.0301 U	0.0502 U	0.0502 U	0.100 U	NA	5.02 U	12.6 U	31.6 U	24.6 UU
EX-B20-J-12-10	10	11/28/07	0.0329	0.0539 U	0.0539 U	0.108 U	NA	5.39 U	12.3 U	30.8 U	24.2 UU
EX-B20-J-13-12	12	11/26/07	0.0304 U	0.0507 U	0.0507 U	0.101 U	NA	5.07 U	12.2 U	30.4 U	23.8 UU
EX-B20-J-14-12	12	11/20/07	0.0302 U	0.0503 U	0.0503 U	0.101 U	0.00891	5.03 U	29.6 Q11	29.3 U	46.8
EX-B20-J-15-15	15	11/05/07	0.0346 U	0.0577 U	0.0577 U	0.115 U	NA	5.77 U	13.2 U	32.9 U	25.9 UU
EX-B20-J-18-15	15	10/19/07	0.0293 U	0.0489 U	0.0489 U	0.0978 U	NA	4.89 U	12.2 U	30.5 U	23.8 UU
EX-B20-J-20-4	4	10/30/07	0.0355 U	0.0592 U	0.0592 U	0.118 U	NA	5.92 U	13.9 UC	34.8 U	34.3
EX-B20-K-7-5	5	01/10/08	0.0349 U	0.0918	0.0928	0.416	0.00936	65.1 JZ	16.1 JY	41.1	122 J
EX-B20-K-9-9	9	10/16/07	0.0385 U	0.0642 U	0.0642 U	0.128 U	NA	8.19	12.3 U	30.9 U	29.8
EX-B20-K-10-10	10	11/30/07	0.0315 U	0.0525 U	0.0525 U	0.105 U	NA	5.25 U	12.9 U	32.3 U	25.2 UU
EX-B20-K-11-10	10	11/29/07	0.0290 U	0.0483 U	0.0483 U	0.0967 U	NA	4.83 U	12.4 U	31.0 U	24.1 UU
EX-B20-K-12-12	12	11/29/07	0.0310 U	0.0517 U	0.0517 U	0.103 U	NA	5.17 U	12.8 U	32.1 U	25.0 UU
EX-B20-K-13-12	12	11/26/07	0.0305 U	0.0508 U	0.0508 U	0.102 U	NA	5.08 U	13.1 U	32.8 U	25.5 UU
EX-B20-K-14-12	12	11/20/07	0.0283 U	0.0471 U	0.0471 U	0.0943 U	NA	4.71 U	12.3 U	30.8 U	23.9 UU
EX-B20-K-15-15	15	11/05/07	0.0282 U	0.0470 U	0.0470 U	0.0940 U	NA	4.70 U	12.2 U	30.5 U	23.7 UU
EX-B20-K-16-15	15	10/31/07	0.0279 U	0.0466 U	0.0466 U	0.0932 U	NA	4.66 U	12.4 U	31.0 U	24.0 UU
EX-B20-L-7-5	5	02/08/08	0.0256 U	0.0427 U	0.128	0.217	0.00956	41.3 JZ	84.8	64.8	191 J
EX-B20-L-8-10	10	12/11/07	0.0337 U	0.0561 U	0.0561 U	0.112 U	NA	6.07	13.7 U	34.1 U	30.0

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Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX (mg/kg)				Total cPAHs Adjusted for Toxicity (mg/kg)	Gasoline (mg/kg)	Diesel (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			B	T	E	X					
			REL = 18 mg/kg				CUL = 0.14 mg/kg				REL = 2,975
EX-B20-L-8-WSW5	5	01/07/08	0.0410 [0.0430]	0.123 [0.142]	0.0586 U [0.0651]	0.131 [0.110 U]	0.0104 [0.00973]	26.8 JZ [36.4 JZ]	107 Q4 [154 Q4]	81.4 JQ4 [202 JQ4]	215 J [392 J]
EX-B20-L-9-10	10	12/11/07	0.0320 U	0.0534 U	0.0534 U	0.107 U	NA	5.34 U	12.8 U	31.9 U	25.0 UU
EX-B20-L-10-10	10	11/30/07	0.0310 U	0.0516 U	0.0516 U	0.103 U	NA	5.16 U	12.6 U	31.4 U	24.6 UU
EX-B20-L-11-10	10	12/07/07	0.0322 U	0.0537 U	0.0537 U	0.107 U	NA	5.37 U	13.1 U	32.7 U	25.6 UU
EX-B20-L-12-12	12	11/29/07	0.0321 U	0.0536 U	0.0536 U	0.107 U	NA	5.36 U	12.1 U	30.3 U	23.9 UU
EX-B20-L-13-12	12	11/26/07	0.0295 U	0.0492 U	0.0492 U	0.0983 U	NA	4.92 U	12.8 U	32.0 U	24.9 UU
EX-B20-L-14-12	12	11/20/07	0.0292 U	0.0486 U	0.0486 U	0.0972 U	NA	4.86 U	12.2 U	30.5 U	23.8 UU
EX-B20-L-15-15	15	11/05/07	0.0282 U	0.0471 U	0.0471 U	0.0941 U	NA	4.71 U	12.3 U	30.8 U	23.9 UU
EX-B20-L-16-15	15	10/31/07	0.0297 U	0.0496 U	0.0496 U	0.0992 U	NA	4.96 U	12.7 U	31.7 U	24.7 UU
EX-B20-M-6-5	5	02/08/08	0.778 J	0.278 U	13.8 J	40.1 J	0.103	4,630 JZ	5,250 JQ10	7,070 J	17,000 J
EX-B20-M-7-10	10	02/08/08	0.0376 U	0.0627 U	0.0627 U	0.125 U	NA	6.27 U	12.0 U	29.9 U	24.1 UU
EX-B20-M-8-12	12	01/16/08	0.0297 U	0.0495 U	0.0495 U	0.0990 U	NA	9.22	11.9 U	29.8 U	30.1
EX-B20-M-9-12	12	01/16/08	0.0319 U	0.0532 U	0.0532 U	0.106 U	NA	9.88	12.3 U	30.8 U	31.4
EX-B20-M-10-12	12	12/07/07	0.0363	0.0534 U	0.0534 U	0.107 U	NA	8.72	12.5 U	31.2 U	30.6
EX-B20-M-11-12	12	12/07/07	0.0314 U	0.0523 U	0.0523 U	0.105 U	NA	5.23 U	12.7 U	31.7 U	24.8 UU
EX-B20-M-12-12	12	12/07/07	0.0299 U [0.0310 U]	0.0498 U [0.0517 U]	0.0498 U [0.0517 U]	0.0997 U [0.103 U]	NA [NA]	4.98 U [5.17 U]	11.5 U [11.0 U]	28.9 U [27.4 U]	22.7 UU [21.8 UU]
EX-B20-M-13-14	14	12/07/07	0.0332 U	0.0554 U	0.0554 U	0.111 U	NA	5.54 U	13.8 U	34.5 U	26.9 UU
EX-B20-M-14-11	11	12/07/07	0.0306 U	0.0510 U	0.0510 U	0.102 U	NA	5.10 U	11.9 U	29.7 U	23.4 UU
EX-B20-M-15-11	11	12/07/07	0.0316 U	0.0527 U	0.0527 U	0.105 U	NA	5.27 U	11.5 U	28.8 U	22.8 UU
EX-B20-M-16-15	15	11/09/07	0.0302 U	0.0504 U	0.0504 U	0.101 U	NA	5.04 U	11.9 U	29.8 U	23.4 UU
EX-B20-M-16-SSW-12	12	11/09/07	0.0298 U	0.0497 U	0.0497 U	0.0995 U	NA	4.97 U	10.8 U	26.9 U	21.3 UU
EX-B20-M-17-10	10	11/09/07	0.0297 U	0.0495 U	0.0495 U	0.0989 U	NA	4.95 U	12.0 U	30.0 U	23.5 UU
EX-B20-M-17-ESW-5	5	11/09/07	0.0303 U	0.0505 U	0.0505 U	0.101 U	NA	5.05 U	12.4 U	30.9 U	24.2 UU
EX-B20-M-17-SSW-4	4	11/09/07	1.09	0.504 U	0.504 U	1.04	0.412	1,090 JZ	13,000	271 UQ7	14,400 J
EX-B20-M-17-SSW-6	6	01/28/08	0.577	0.529 U	0.529 U	1.21	0.166	1,380 Q10a	13,600 J	1,380 UJ	15,700 J
EX-B20-N-7-8	8	01/16/08	0.0324 U	0.0540 U	0.0540 U	0.108 U	NA	8.29	11.9 U	29.7 U	29.1
EX-B20-N-7-WSW-4	4	01/16/08	0.0293 U	0.0489 U	0.0489 U	0.0978 U	0.0152	33.5 JZ	148 Q4	125 Q4	307 J
EX-B20-N-8-12	12	01/16/08	0.0318 U	0.0530 U	0.0530 U	0.106 U	NA	5.30 U	12.8 U	31.9 U	25.0 UU
EX-B20-N-9-12	12	01/16/08	0.0313 U	0.0521 U	0.0521 U	0.104 U	NA	5.21 U	12.6 U	31.6 U	24.7 UU
EX-B20-N-10-12	12	01/08/08	0.0292 U	0.0487 U	0.0487 U	0.0974 U	NA	4.87 U	11.7 U	29.2 U	22.9 UU
EX-B20-N-11-12	12	01/08/08	0.0292 U	0.0487 U	0.0487 U	0.0975 U	NA	5.56	12.1 U	30.2 U	26.7
EX-B20-N-12-12	12	01/08/08	0.0282 U	0.0470 U	0.0470 U	0.0941 U	NA	4.70 U	11.9 U	29.9 U	23.3 UU
EX-B20-N-13-12	12	01/08/08	0.0310 U	0.0517 U	0.0517 U	0.103 U	NA	5.17 U	12.4 U	31.0 U	24.3 UU
EX-B20-N-14-12	12	12/11/07	0.0308 U	0.0513 U	0.0513 U	0.103 U	NA	5.13 U	12.3 U	30.7 U	24.1 UU
EX-B20-N-15-12	12	12/11/07	0.0338 U	0.0563 U	0.0563 U	0.113 U	NA	5.63 U	13.1 U	32.7 U	25.7 UU
EX-B20-N-16-4	4	11/09/07	2.02	1.74	2.41	2.52	0.409	2,120 JZ	14,700	312 Q7	17,100 J
EX-B20-N-16-12	12	11/13/07	0.0322 U	0.0537 U	0.0537 U	0.107 U	NA	5.37 U	11.6 U	29.1 U	23.0 UU
EX-B21-ESW-2	2	10/11/07	0.0354 U	0.0591 U	0.0591 U	0.118 U	NA	5.91 U	11.0 U	27.5 U	22.2 UU
EX-B21-FLOOR-4	4	10/11/07	0.0303 U	0.0506 U	0.0506 U	0.101 U	NA	5.06 U	11.8 U	29.5 U	23.2 UU
EX-B21-NSW-2	2	10/11/07	0.0300 U	0.0500 U	0.0500 U	0.100 U	0.00883	5.00 U	12.4 JY	44.6	59.5 J
EX-SDTI-5-NSW-4	4	08/22/07	0.0320 U	0.0533 U	0.0533 U	0.107 U	NA	5.33 U	12.8 U	31.9 U	25.0 UU
EX-SDTI-5-SSW-4	4	08/22/07	0.0344 U	0.0574 U	0.0574 U	0.115 U	NA	5.74 U	13.0 U	32.4 U	25.6 UU
EX-SDTI-ESW-4	4	08/22/07	0.0400 U	0.0667 U	0.0667 U	0.133 U	0.0107	6.67 U	30.1 Q11	35.6 U	51.2
EX-SDTI-FF-S-8	8	08/22/07	0.0333 U	0.0556 U	0.0556 U	0.111 U	0.00951	5.56 U	32.3 Q11	64.7	99.8
EX-SDTI-GG-ESW-4	4	08/22/07	0.0304 U	0.0507 U	0.0507 U	0.101 U	NA	5.07 U	12.3 U	30.6 U	24.0 UU
EX-SDTI-GG-S-8	8	08/22/07	0.0286 U	0.0477 U	0.0477 U	0.0953 U	0.00936	4.77 U	12.1 U	42.4	50.8
EX-SDTI-GG-WSW-4	4	08/22/07	0.0322 U	0.0537 U	0.0537 U	0.107 U	0.00929	5.37 U	36.8 Q11	31.5 U	55.2
EX-SDTI-WSW-4	4	08/22/07	0.0757	0.0580 U	0.0580 U	0.116 U	NA	9.40	12.2 U	30.6 U	30.8
EX-WW-G-27-2SW	2	08/07/07	0.0287 U	0.0479 U	0.0479 U	0.0958 U	0.00924	4.79 U	14.9 JY	49.7	67.0 J
EX-WW-G-27-4	4	08/07/07	0.0299 U	0.0498 U	0.0498 U	0.0997 U	NA	4.98 U	10.9 U	27.3 U	21.6 UU
EX-WW-H-27-2.5	2.5	08/07/07	0.0384 U	0.0639 U	0.0639 U	0.128 U	0.0321	6.39 U	16.4 JY	60.0	79.6 J
EX-WW-H-28-2	2	08/07/07	0.0294 U	0.0491 U	0.0491 U	0.0981 U	0.00891	6.07	21.4 JY	68.1	95.6 J
EX-WW-H-29-1	1	08/07/07	0.0335 U	0.0559 U	0.0559 U	0.112 U	0.00808	4.59 U	20.0 JY	78.9	101 J
EX-WW-I-26-1	1	08/07/07	0.0254 U	0.0424 U	0.0424 U	0.0848 U	0.00934	4.24 U	12.3 JY	44.3	58.7 J

TABLE 4
Excavation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase I Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX *(mg/kg)*				Total cPAHs Adjusted for Toxicity *(mg/kg)*	Gasoline *(mg/kg)*	Diesel *(mg/kg)*	Heavy Oil (Lube) *(mg/kg)*	Total TPH *(mg/kg)*
			B	T	E	X					
			REL = 18 mg/kg				***CUL = 0.14 mg/kg***				***REL = 2,975***
P-B15-NE-SW	4	08/16/07	0.598	0.692	2.35	2.87	NA	874 J	763 JX	637	2,270 J
P-B15-NW-SW	4	08/16/07	8.73	5.36 U	63.5	18.5	NA	6,610	1,910 JX	580 UJ	8,810 J

Notes:
BTEX analyzed by EPA Method 8021B.
cPAHs analyzed by EPA Method 8270 SIM.
Gasoline analyzed by method NWTPH-G.
Diesel and Heavy Oil (Lube) analyzed by method NWTPH-D Extended.
Total TPH calculated by summing the concentrations of gasoline, diesel and heavy oil. If one or more TPH constituents were reported as Non-Detect, half of the reporting limit value was added to the total.
cPAHs adjusted for toxicity according to WAC 173-340-708(8) and *Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II Technical Support Document for Describing Available Cancer Potency Factors* . Office of Environmental Health Hazard Assessment, California EPA, May 2005. If one or more adjusted cPAH constituents were reported as Non-Detect, half of the reporting limt was used in calculations.
Highlighted cells indicate concentration exceeds REL or CUL.
[ ] = Bracketed data indicate duplicate sample.

feet bgs = Feet below ground surface
BTEX = Benzene, toluene, ethylbenzene, and total xylenes
mg/kg = Milligrams per kilogram
cPAHs = Carcinogenic polyaromatic hydrocarbons
TPH = Total petroleum hydrocarbons
REL = Remediation level
CUL = Cleanup level
NA = Not analyzed
EPA = Environmental Protection Agency

Lab Qualifiers	Definition
C	Calibration Verification recovery was above the method control limit for this analyte. Analyte not detected, data not impacted.
C8	Calibration Verification recovery was above the method control limit for this analyte. A high bias may be indicated.
D	Compound quantitated using a secondary dilution.
J	Indicates an estimated value.
JX	Results in the diesel organic range are primarily due to overlap from a gasoline range product.
JY	Results in the diesel organics range are primarily due to overlap from a heavy oil range product.
JZ	Detected hydrocarbons in the gasoline range appear to be due to overlap of diesel range hydrocarbons.
Q10	Hydrocarbon pattern most closely resembles a blend of gasoline and diesel range hydrocarbons.
Q10a	Hydrocarbon pattern most closely resembles a blend of gasoline and diesel range hydrocarbons.
Q11	Detected hydrocarbons in the diesel range do not have a distinct diesel pattern and may be due to heavily weathered diesel.
Q12	Detected hydrocarbons in the diesel range do not have a distinct diesel pattern and may be due to heavily weathered diesel or possibly biogenic interference.
Q4	The hydrocarbons present are a complex mixture of diesel range and heavy oil range organics.
Q7	The heavy oil range organics present are due to hydrocarbons eluting primarily in the diesel range.
Q9	Hydrocarbon pattern most closely resembles transformer oil.
U	The compound was analyzed for but not detected. The associated value is the compound quantitation limit.
RL1	Reporting limit raised due to sample matrix effects.
UJ	The compound was analyzed for but not detected. The associated value is the estimated compound quantitation limit.
UU	The constituents making up the total are all non-detects.

TABLE 5
Soil Sample Arsenic Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase I Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Date Sampled	Sample Depth (feet bgs)	Arsenic *(mg/kg)*
			CUL = 20 mg/kg
EX-B19-YY-3-1	3/5/2008	1	5.08
EX-B19-YY-2-1	3/5/2008	1	9.84
EX-B19-YY-1-1	3/5/2008	1	5.45
EX-B19-ZZ-1-1	3/5/2008	1	**25.0 [30.9]**
EX-B19-ZZ-2-1	3/5/2008	1	8.56
EX-B19-ZZ-3-1	3/5/2008	1	5.54
EX-B19-ZZ-1-2	3/7/2008	2	**30.7**
EX-B19-ZZ-1-2.5	3/12/2008	2.5	<5.54

Notes:
feet bgs = Feet below ground surface
mg/kg = Milligrams per kilogram.
CUL = Cleanup level
[ ] Indicate Duplicate samplDuplicate samples immediately preceed the parent sample.
Highlighted cells indicate concentration exceeds REL or CUL.

Lab Qualifiers	Definition
<	The compound was analyzed for but not detected. The associated value is the compound quantitation limit.

TABLE 8
Confirmation Boring Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase I Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Date Sampled	Sample Depth (feet bgs)	BTEX (mg/kg) B	T	E	X	Total cPAHs Adjusted for Toxicity (mg/kg)	Gasoline (mg/kg)	Diesel (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			REL = 18 mg/kg				CUL = 0.14 mg/kg				REL = 2,975
SB-1-11.5	04/03/08	11.5	0.0304 U	0.0507 U	0.0507 U	0.101 U	NA	5.07 U	11.4 U	28.6 U	22.5 UU
SB-2-11	04/03/08	11	0.0609 U	0.102 U	0.102 U	0.203 U	NA	10.2 U	15.6 U	38.9 U	32.4 UU
SB-3-10.5	04/03/08	10.5	0.0335 U	0.0559 U	0.0559 U	0.112 U	NA	5.59 U	12.0 U	30.0 U	23.8 UU
SB-3-12	04/03/08	12	0.0372 U	0.0620 U	0.0620 U	0.124 U	NA	6.20 U	11.9 U	29.7 U	23.9 UU
SB-4-10.5	04/04/08	10.5	0.0307 U	0.0511 U	0.0511 U	0.102 U	NA	5.11 U	11.3 U	28.1 U	22.3 UU
SB-5-11.5	04/04/08	11.5	0.0394	0.0513 U	0.0513 U	0.103 U	NA	5.13 U	10.9 U	27.4 U	21.7 UU
SB-6-11.0	04/04/08	11	0.0356 U	0.0594 U	0.0594 U	0.119 U	NA	5.94 U	11.8 U	29.5 U	23.6 UU
SB-7-11.5	04/04/08	11.5	0.0334 U	0.0556 U	0.0556 U	0.111 U	NA	5.56 U	11.5 U	28.8 U	22.9 UU
SB-8-11.0	04/04/08	11	0.0501	0.0505 U	0.0505 U	0.101 U	NA	5.05 U	11.4 U	28.5 U	22.5 UU
SB-9-11.0	04/04/08	11	0.0401	0.0543 U	0.0543 U	0.109 U	NA	5.43 U	11.5 U	28.7 U	22.8 UU
SB-10-11.0	04/04/08	11	0.0341 U [0.0350 U]	0.0569 U [0.0584 U]	0.0569 U [0.0584 U]	0.114 U [0.117 U]	NA [NA]	5.69 U [5.84 U]	11.8 U [11.6 U]	29.6 U [28.9 U]	23.5 UU [23.2 UU]
SB-11-11.0	04/04/08	11	0.0556 U	0.0927 U	0.0927 U	0.185 U	NA	9.27 U	14.2 U	35.5 U	29.5 UU
SB-12-11.5	04/04/08	11.5	0.0348 U	0.0580 U	0.0580 U	0.116 U	NA	5.80 U	12.1 U	30.2 U	24.1 UU
SB-13-11	04/11/08	11	0.0465 U	0.0776 U	0.0776 U	0.155 U	NA	7.76 U	13.1 U	32.8 U	26.8 UU
SB-14-11	04/11/08	11	0.0385 U	0.0642 U	0.0642 U	0.128 U	NA	6.42 U	12.4 U	31.1 U	25.0 UU
SB-15-10.5	04/14/08	10.5	0.0354 U [0.0366 U]	0.0590 U [0.0611 U]	0.0590 U [0.0611 U]	0.118 U [0.122 U]	NA [NA]	5.90 U [6.11 U]	11.9 U [11.9 U]	29.7 U [29.7 U]	23.8 UU [23.9 UU]
SB-16-9.5	04/14/08	9.5	0.0312 U	0.0519 U	0.0519 U	0.104 U	NA	5.19 U	11.1 U	27.6 U	21.9 UU
SB-17-11.5	04/14/08	11.5	0.0321 U	0.0535 U	0.0535 U	0.107 U	NA	5.35 U	11.8 U	29.4 U	23.3 UU
SB-18-11	04/11/08	11	0.711	5.53	4.20	3.24	0.00842	1,070 JZ	299	45.0	1,410 J
SB-19-12	04/11/08	12	0.0292 U	0.0486 U	0.0486 U	0.0972 U	NA	4.86 U	11.5 U	28.6 U	22.5 UU
SB-20-9.5	04/14/08	9.5	0.0323 U	0.0538 U	0.0538 U	0.108 U	NA	5.38 U	11.8 U	29.5 U	23.3 UU
SB-21-10.5	04/14/08	10.5	0.0348 U	0.0581 U	0.0581 U	0.116 U	NA	5.81 U	12.3 U	30.6 U	24.4 UU
SB-22-10	04/11/08	10	0.0371 U [0.0371 U]	0.0618 U [0.0619 U]	0.0618 U [0.0619 U]	0.124 U [0.124 U]	NA [NA]	6.18 U [6.19 U]	12.8 U [12.3 U]	32.1 U [30.6 U]	25.5 UU [24.5 UU]
SB-23-11	04/11/08	11	0.0357 U	0.0595 U	0.0595 U	0.119 U	NA	5.95 U	12.2 U	30.5 U	24.3 UU
SB-24-10	04/11/08	10	0.0398 U	0.0663 U	0.0663 U	0.133 U	NA	6.63 U	12.9 U	32.3 U	25.9 UU
SB-25-11	04/11/08	11	0.0359 U	0.0598 U	0.0598 U	0.120 U	NA	5.98 U	12.0 U	30.0 U	24.0 UU
SB-26-10.5	04/14/08	10.5	0.0339 U	0.0565 U	0.0565 U	0.113 U	NA	5.65 U	11.6 U	29.1 U	23.2 UU
SB-27-10	04/14/08	10	0.200	0.0537 U	0.0537 U	0.107 U	0.00896	13.8 JZ	279	29.2 U	307 J
SB-28-9	04/11/08	9	0.0313 U	0.0522 U	0.0522 U	0.104 U	0.00838 UU	6.59	11.9	27.7 U	32.3
SB-29-9	04/08/08	9	0.0708	0.0566 U	0.0566 U	0.113 U	NA	10.7	11.4 U	28.4 U	30.6
SB-30-9.5	04/10/08	9.5	0.0343 U	0.0572 U	0.0572 U	0.114 U	NA	5.72 U	11.6 U	29.1 U	23.2 UU
SB-31-9.5	04/10/08	9.5	0.0420 U	0.0699 U	0.0699 U	0.140 U	NA	6.99 U	12.9 U	32.4 U	26.1 UU
SB-32-9.5	04/10/08	9.5	0.0541 U [0.0538 U]	0.0902 U [0.0897 U]	0.0902 U [0.0897 U]	0.180 U [0.179 U]	NA [NA]	9.02 U [8.97 U]	14.4 U [14.4 U]	36.0 U [36.0 U]	29.7 UU [29.7 UU]
SB-33-11	04/10/08	11	0.0471 U	0.0786 U	0.0786 U	0.157 U	NA	7.86 U	13.2 U	32.9 U	27.0 UU
SB-34-11	04/10/08	11	0.0344 U	0.0574 U	0.0574 U	0.115 U	NA	5.74 U	11.8 U	29.5 U	23.5 UU
SB-35-9	04/10/08	9	0.0442 U	0.0736 U	0.0736 U	0.147 U	NA	7.36 U	12.7 U	31.7 U	25.9 UU
SB-36-12	04/10/08	12	0.0252 U	0.0420 U	0.0420 U	0.0839 U	NA	4.20 U	10.9 U	27.2 U	21.2 UU

TABLE 8
Confirmation Boring Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase I Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Date Sampled	Sample Depth (feet bgs)	BTEX (mg/kg) B	T	E	X	Total cPAHs Adjusted for Toxicity (mg/kg)	Gasoline (mg/kg)	Diesel (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			REL = 18 mg/kg				*CUL = 0.14 mg/kg*				*REL = 2,975*
SB-37-9	04/08/08	9	0.224 [0.225]	0.0566 U [0.0647 U]	0.0566 U [0.0647 U]	0.113 U [0.129 U]	NA [NA]	5.66 U [6.47 U]	12.0 U [12.8 U]	29.9 U [31.9 U]	23.8 UU [25.6 UU]
SB-38-8.5	04/08/08	8.5	0.0749	0.0634 U	0.0634 U	0.127 U	NA	6.34 U	12.0 U	29.9 U	24.1 UU
SB-38-10	04/08/08	10	0.108	0.0585 U	0.0585 U	0.117 U	0.00929 UU	5.85 U	12.3 U	30.8 U	24.5 UU
SB-39-14	04/10/08	14	0.0285 U	0.0475 U	0.0475 U	0.0951 U	NA	4.75 U	11.3 U	28.4 U	22.2 UU
SB-40-11	04/10/08	11	0.0365 U	0.0609 U	0.0609 U	0.122 U	NA	6.09 U	12.1 U	30.1 U	24.1 UU
SB-41-10	04/10/08	10	0.0346 U	0.0576 U	0.0576 U	0.115 U	NA	5.76 U	11.8 U	29.6 U	23.6 UU
SB-42-10	04/09/08	10	0.0464 U [0.0821]	0.0774 U [0.0822 U]	0.166 [0.152]	0.327 [0.231]	NA [NA]	7.74 U [8.22 U]	14.1 U [14.8 U]	35.2 U [37.1 U]	28.5 UU [30.1 UU]
SB-43-11.5	04/09/08	11.5	0.0420 U	0.0699 U	0.0699 U	0.140 U	NA	6.99 U	13.3 U	33.3 U	26.8 UU
SB-44-11	04/09/08	11	0.205	0.0548 U	0.0548 U	0.110 U	NA	5.48 U	11.8 U	29.4 U	23.3 UU
SB-45-10	04/08/08	10	0.206	0.0591 U	0.0591 U	0.118 U	NA	5.91 U	11.4 U	28.4 U	22.9 UU
SB-46-6	04/08/08	6	0.0323 U	0.0538 U	0.0538 U	0.108 U	NA	5.38 U	11.5 U	28.8 U	22.8 UU
SB-46-10.5	04/08/08	10.5	0.0311 U	0.0518 U	0.0518 U	0.104 U	NA	5.18 U	11.4 U	28.5 U	22.5 UU
SB-47-10	04/09/08	10	0.0437 U	0.0729 U	0.0729 U	0.146 U	NA	7.29 U	12.9 U	32.2 U	26.2 UU
SB-48-11.5	04/09/08	11.5	0.0459 U	0.0765 U	0.0765 U	0.153 U	NA	7.65 U	13.6 U	34.1 U	27.7 UU
SB-49-10.5	04/09/08	10.5	0.0333 U	0.0555 U	0.0555 U	0.111 U	NA	5.55 U	11.8 U	29.4 U	23.4 UU
SB-50-10.5	04/09/08	10.5	0.0350 U	0.0583 U	0.0583 U	0.117 U	NA	5.83 U	12.1 U	30.2 U	24.1 UU
SB-51-9.5	04/08/08	9.5	0.0350 U	0.0583 U	0.0583 U	0.117 U	NA	5.83 U	12.1 U	30.3 U	24.1 UU
SB-52-9.5	04/08/08	9.5	0.0317 U	0.0528 U	0.0528 U	0.106 U	NA	5.28 U	11.4 U	28.5 U	22.6 UU
SB-53-10.5	04/09/08	10.5	0.0309 U	0.0515 U	0.0515 U	0.103 U	NA	14.8	10.8 U	27.1 U	33.8
SB-54-10.5	04/09/08	10.5	0.0373 U	0.0622 U	0.0622 U	0.124 U	NA	6.22 U	12.1 U	30.3 U	24.3 UU
SB-55-11.5	04/07/08	11.5	0.0606 U	0.101 U	0.101 U	0.202 U	NA	10.1 U	15.7 U	39.2 U	32.5 UU
SB-56-14.5	04/08/08	14.5	0.0337 U	0.0561 U	0.0561 U	0.112 U	NA	5.61 U	11.7 U	29.3 U	23.3 UU
SB-57-10.5	04/07/08	10.5	0.0307 U	0.0511 U	0.0511 U	0.102 U	NA	5.11 U	11.3 U	28.2 U	22.3 UU
SB-58-11.0	04/07/08	11	0.0359 U	0.0598 U	0.0598 U	0.120 U	NA	5.98 U	11.6 U	29.1 U	23.3 UU
SB-59-5.5	04/08/08	5.5	0.0311 U	0.0518 U	0.0518 U	0.104 U	NA	5.18 U	11.4 U	28.5 U	22.5 UU
SB-60-10.5	04/07/08	10.5	0.0825 [0.0864]	0.0741 U [0.0637 U]	0.0741 U [0.0637 U]	0.148 U [0.127 U]	NA [NA]	7.41 U [6.37 U]	12.3 U [21.7]	30.8 U [29.0 U]	25.3 UU [39.4]
SB-61-10.5	04/07/08	10.5	0.0511 U	0.0852 U	0.0852 U	0.170 U	NA	8.52 U	15.1 U	37.8 U	30.7 UU
SB-62-10.5	04/07/08	10.5	0.0607 U	0.101 U	0.101 U	0.202 U	NA	10.1 U	15.8 U	39.5 U	32.7 UU
SB-63-5.5	04/07/08	5.5	0.327 U	0.577	1.11	6.56	0.107	2,190 JZ	2,970 J	193 J	5,350 J
SB-63-6.0	04/07/08	6	0.157 J	0.194 J	2.16 J	8.43 J	NA	978 JZ	20.2 U	50.4 U	1,010 J
SB-64-2.5	04/07/08	2.5	0.656	2.75	1.72	7.15	0.108	1,540 JZ	5,810 J	362 J	7,710 J
SB-64-5.5	04/07/08	5.5	0.139 J	2.42 J	0.782 J	3.20 J	0.0452 UU	534 JZ	444	32.2	1,010 J
SB-64-7.0	04/07/08	7	0.325	0.157 U	0.157 U	0.730	NA	63.1	19.9 U	49.7 U	97.9

TABLE 8
Confirmation Boring Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase I Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Notes:
BTEX analyzed by EPA Method 8021B.
cPAHs analyzed by EPA Method 8270 SIM.
Gasoline analyzed by method NWTPH-G.
Diesel and Heavy Oil (Lube) analyzed by method NWTPH-D Extended.
Total TPH calculated by summing the concentrations of gasoline, diesel and heavy oil. If one or more TPH constituents were reported as Non-Detect, half of the reporting limit value was added to the total.
cPAHs adjusted for toxicity according to WAC 173-340-708(8) and *Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II Technical Support Document for Describing Available Cancer Potency Factors* .
Highlighted cells indicate concentration exceeds REL or CUL.
[ ] = Bracketed data indicate duplicate sample.

feet bgs = Feet below ground surface
BTEX = Benzene, toluene, ethylbenzene, and total xylenes
mg/kg = Milligrams per kilogram
cPAHs = Carcinogenic polyaromatic hydrocarbons
TPH = Total petroleum hydrocarbons
REL = Remediation level
CUL = Cleanup level
NA = Not analyzed
EPA = Environmental Protection Agency

Lab Qualifiers	Definition
J	Indicates an estimated value.
JZ	Detected hydrocarbons in the gasoline range appear to be due to overlap of diesel range hydrocarbons.
U	The compound was analyzed for but not detected. The associated value is the compound quantitation limit.
UJ	The compound was analyzed for but not detected. The associated value is the estimated compound quantitation limit.
UU	The constituents making up the total are all non-detects.

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TABLE 3
Excavation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase II Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX *(mg/kg)*				Total cPAHs Adjusted for Toxicity *(mg/kg)*	Diesel Range Organics *(mg/kg)*	Gasoline Range Organics *(mg/kg)*	Heavy Oil (Lube) *(mg/kg)*	Total TPH (mg/kg)
			B	T	E	X					
Site Soil Remediation Level (REL)/Cleanup Level (CUL) (mg/kg)			**18**	--	--	--	**0.14**	--	--	--	**2,975**
EX-AW-E-23-5	5	09/11/08	0.0404 U	0.0674 U	0.0674 U	0.135 U	0.278	596	109	410	1,120
EX-AW-E-23-5(2)	5	09/17/08	0.0363 U	0.0605 U	0.0605 U	0.121 U	NA	11.9 U	6.05 U	29.7 U	23.8 UU
EX-AW-E-24-10	10	09/11/08	0.0354 U	0.0590 U	0.0590 U	0.118 U	0.00891	28.1	5.90 U	29.0 U	45.6
EX-AW-E-24-NSW-5	5	09/11/08	0.0363 U	0.0605 U	0.0605 U	0.121 U	0.00892	357	30.0 JZ	134	521 J
EX-AW-E-25-10	10	09/11/08	0.0405 U	0.0675 U	0.0675 U	0.135 U	0.00982	102	6.75 U	32.8 U	122
EX-AW-E-25-ESW-5	5	09/11/08	0.0327 U [0.0339 U]	0.228 J [0.470 J]	0.0545 U [0.0564 U]	0.109 U [0.320 J]	0.00846 [0.00838]	18.4 [24.6]	75.2 JZ [171 JZ]	28.2 U [27.5 U]	108 J [209 J]
EX-AW-E-25-NSW-5	5	09/11/08	0.0373 U	0.0621 U	0.0621 U	0.124 U	0.00898	16.1	6.21 U	29.7 U	34.1
EX-AW-F-23-5	5	09/11/08	0.0359 U	0.0598 U	0.0598 U	0.120 U	0.00950	2,840	5.98 U	692	3,530
EX-AW-F-23-5(2)	5	09/12/08	0.0339 U	0.0565 U	0.0565 U	0.113 U	NA	11.6 U	5.65 U	29.1 U	23.2 UU
EX-AW-F-24-5	5	09/11/08	0.0345 U	0.0575 U	0.0575 U	0.115 U	NA	10.9 U	12.0	27.3 U	31.1
EX-AW-F-25-5	5	09/11/08	0.0277 U	0.0461 U	0.0461 U	0.0923 U	0.0181	58.1	6.68 JZ	71.8	137 J
EX-AW-F-25-ESW-5	5	09/11/08	0.0372 U	0.0620 U	0.0620 U	0.124 U	0.00846	62.6	6.20 U	27.9 U	79.7
EX-B1-C-46-4	4	08/08/08	0.355	1.06	0.294 U	3.20	0.228	2,920	260 JZ	911	4,090 J
EX-B1-C-46-4(2)	4	09/02/08	0.0302 U	0.0503 U	0.0503 U	0.101 U	0.0142	46.8 JY	5.03 U	92.7	142 J
EX-B1-C-47-4	4	08/08/08	0.0309 U	0.0679	0.0515 U	0.166	0.0414 UU	236	51.8 JZ	123	411 J
EX-B1-D-43-4	4	08/19/08	4.39	32.3	22.5	117	NA	11.6 U	2,000 J	29.0 U	2,020 J
EX-B1-D-44-12	12	08/18/08	0.121 U	0.202 U	0.202 U	0.404 U	0.0369 UU	25.6	20.2 U	60.3 U	65.9
EX-B1-D-44-NSW-4	4	08/18/08	1.23	2.68	0.470 U	9.81	0.554	9,620 J	678 JZ	3,350 J	13,600 J
EX-B1-D-44-NSW-4(2)	4	09/02/08	0.0508	0.107	0.0452 U	0.0903 U	0.0188	101	32.6	153	287
EX-B1-D-45-12	12	08/14/08	0.224 [0.0598 U]	0.956 J [0.0996 UJ]	1.41 J [0.0996 UJ]	4.87 J [0.199 UJ]	NA [NA]	14.6 U [15.4 U]	76.1 JZ [9.96 UJ]	36.4 U [38.5 U]	102 J [31.9 UU]
EX-B1-D-45-NSW-4	4	09/02/08	0.0316 U	0.0526 U	0.0526 U	0.105 U	0.0152	28.8 JY	5.26 U	69.0	100 J
EX-B1-D-46-12	12	08/11/08	0.113 U	0.189 U	0.189 U	0.378 U	0.0431	69.6 JY	18.9 U	158	237 J
EX-B1-D-47-4	4	08/08/08	0.0349 U	0.0582 U	0.0582 U	0.116 U	0.123	135	36.6 JZ	105	277 J
EX-B1-E-41-8	8	08/27/08	0.0325 U	0.0542 U	0.0542 U	0.108 U	0.0205	173	9.58	153	336
EX-B1-E-41-NSW-4	4	08/27/08	0.0314 U	0.0524 U	0.0524 U	0.105 U	NA	10.6 U	7.74	26.6 U	26.3
EX-B1-E-42-8	8	08/27/08	0.0327 U	0.0544 U	0.0544 U	0.109 U	0.0172	130	13.0	122	265
EX-B1-E-42-NSW-4	4	08/27/08	0.156	0.283	2.54	5.88	0.0714	76.8	223	83.1	383
EX-B1-E-43-12	12	08/21/08	0.259 U	0.431 U	0.431 U	0.863 U	NA	40.8 U	43.1 U	102 U	93.0 UU

TABLE 3
Excavation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase II Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX (mg/kg)				Total cPAHs Adjusted for Toxicity (mg/kg)	Diesel Range Organics (mg/kg)	Gasoline Range Organics (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			B	T	E	X					
Site Soil Remediation Level (REL)/Cleanup Level (CUL) (mg/kg)			**18**	--	--	--	**0.14**	--	--	--	**2,975**
EX-B1-E-44-12	12	08/19/08	0.143 U	0.239 U	0.239 U	0.477 U	NA	28.0 U	23.9 U	69.9 U	60.9 UU
EX-B1-E-45-12	12	08/14/08	0.106 U	0.177 U	0.177 U	0.354 U	NA	19.8 U	17.7 U	49.6 U	43.6 UU
EX-B1-E-46-12	12	08/13/08	0.133 U	0.221 U	0.221 U	0.442 U	NA	23.0 U	22.1 U	57.6 U	51.4 UU
EX-B1-E-47-4	4	08/08/08	0.0336 U	0.147	0.0561 U	0.116	0.0172	21.1	5.61 U	26.9 U	37.4
EX-B1-E-47-SSW-4	4	08/08/08	0.351 U	0.586 U	0.743	4.44	0.756	11,400 J	493 JZ	3,820 J	15,700 J
EX-B1-E-47-SSW-4(2)	4	09/02/08	0.0280 U	0.0466 U	0.0466 U	0.0932 U	NA	10.8 U	4.66 U	27.0 U	21.2 UU
EX-B1-F-42-8	8	08/27/08	0.0332 U	0.0553 U	0.0553 U	0.111 U	0.0165	144	12.4	114	270
EX-B1-F-42-SSW-4	4	08/27/08	0.0327 U [0.0306 U]	0.0546 U [0.0511 U]	0.0546 U [0.0511 U]	0.109 U [0.102 U]	NA [NA]	10.7 U [10.6 U]	5.46 U [5.11 U]	26.8 U [26.6 U]	21.5 UU [21.2 UU]
EX-B1-F-43-4	4	08/21/08	0.0288 U	0.0481 U	0.0481 U	0.0961 U	0.0184	231	35.6 JZ	275	542 J
EX-B1-F-44-4	4	08/18/08	0.0298 U	0.0497 U	0.0497 U	0.0994 U	0.212	58.3	4.97 U	60.2	121
EX-B1-F-45-10	10	08/15/08	0.0671 U	0.112 U	0.112 U	0.224 U	NA	16.8 U	11.2 U	41.9 U	35.0 UU
EX-B1-F-45-SSW-4	4	08/18/08	0.0296 U	0.0493 U	0.0493 U	0.0986 U	0.0719	95.5	21.4 JZ	115	232 J
EX-B1-F-46-4	4	08/08/08	4.81	9.05	4.52	48.6	1.14	8,430 J	1,650 JZ	2,500 J	12,600 J
EX-B1-F-47-4(2)	4	09/02/08	0.0291 U	0.0486 U	0.0486 U	0.0971 U	NA	10.9 U	4.86 U	27.2 U	21.5 UU
EX-B7-B3-4	4	08/01/08	0.0377 U	0.0628 U	0.0628 U	0.126 U	0.0411	1,990	6.28 U	2,060	4,050
EX-B7-B4-4	4	08/01/08	0.366 U [0.0548 U]	0.610 U [0.0913 U]	0.610 U [0.0913 U]	1.22 U [0.183 U]	0.0488 [0.0517]	1,120 [960]	61.0 U [9.13 U]	629 [544]	1,780 [1,510]
EX-B7-B-4-5	5	09/10/08	0.0383 U	0.0638 U	0.0638 U	0.128 U	0.00944 UU	64.2	20.9	30.7 U	100
EX-B8-H-3-10	10	09/10/08	0.0385 U	0.0642 U	0.0642 U	0.128 U	NA	12.2 U	6.42 U	30.5 U	24.6 UU
EX-B8-H-3-NSW-5	5	09/10/08	0.0322 U	0.0537 U	0.0537 U	0.107 U	0.0266	10.9 U	5.37 U	31.2	39.3
EX-B8-H-3-WSW-5	5	09/10/08	0.0427 U	0.0712 U	0.0712 U	0.142 U	0.0439	58.0 JY	7.12 U	342	404 J
EX-B8-I-3-10	10	09/10/08	0.0412 U	0.0686 U	0.0686 U	0.137 U	NA	12.4 U	6.86 U	31.0 U	25.1 UU
EX-B8-I-3-WSW-5	5	09/10/08	0.0833 U	0.139 U	0.139 U	0.278 U	0.0728	2,740	15.0	2,590	5,350
EX-B8-I-3-WSW-5(2)	5	09/11/08	0.0525 U	0.0875 U	0.0875 U	0.175 U	0.0589	352	8.75 U	354	710
EX-B8-J-3-10	10	09/10/08	0.0369 U	0.0616 U	0.0616 U	0.123 U	NA	11.8 U	6.16 U	29.5 U	23.7 UU
EX-B8-J-3-SSW-5	5	09/10/08	0.0302 U [0.0338 U]	0.0504 U [0.0564 U]	0.0504 U [0.0564 U]	0.101 U [0.113 U]	0.00793 UU [0.00793 UU]	51.5 [335 JY]	9.14 [5.64 U]	41.1 [315]	102 [653 J]
EX-B8-J-3-WSW-5	5	09/10/08	0.0302 U	0.0503 U	0.0503 U	0.101 U	0.00800 UU	270 JY	5.03 U	278	551 J
EX-B9-N-3-5	5	09/09/08	0.0331 U	0.0551 U	0.0551 U	0.110 U	NA	10.8 U	5.51 U	26.9 U	21.6 UU
EX-B9-O-3-10	10	09/09/08	0.0353 U	0.0588 U	0.0588 U	0.118 U	NA	11.7 U	9.57	29.3 U	30.1
EX-B9-O-3-WSW-5	5	09/09/08	0.0322 U	0.0537 U	0.0537 U	0.107 U	NA	10.5 U	5.37 U	26.2 U	21.0 UU
EX-B9-P-3-10	10	09/09/08	0.0360 U	0.0600 U	0.0600 U	0.120 U	NA	12.0 U	11.4	29.9 U	32.4
EX-B9-P-3-SSW-5	5	09/09/08	0.0320 U	0.0533 U	0.0533 U	0.107 U	NA	10.6 U	5.33 U	26.4 U	21.2 UU

TABLE 3
Excavation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase II Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX *(mg/kg)*				Total cPAHs Adjusted for Toxicity *(mg/kg)*	Diesel Range Organics *(mg/kg)*	Gasoline Range Organics *(mg/kg)*	Heavy Oil (Lube) *(mg/kg)*	Total TPH (mg/kg)
			B	T	E	X					
Site Soil Remediation Level (REL)/Cleanup Level (CUL) (mg/kg)			**18**	--	--	--	**0.14**	--	--	--	**2,975**
EX-B9-P-3-WSW-5	5	09/09/08	0.0327 U	0.0545 U	0.0545 U	0.109 U	NA	10.3 U	5.45 U	25.9 U	20.8 UU
ISP-E-17-2	2	09/17/08	0.0310 U	0.0516 U	0.0516 U	0.103 U	NA	10.4 U	5.16 U	26.1 U	20.8 UU
ISP-E-18-2	2	09/17/08	0.0312 U	0.0519 U	0.0519 U	0.104 U	0.0248	15.2	5.19 U	27.9 U	31.7
ISP-E-19-2	2	09/22/08	0.0337 U	0.0562 U	0.0562 U	0.112 U	0.00868 UU	51.3 J	5.62 U	42.8	96.9 J
ISP-E-20-2	2	09/22/08	0.0333 U	0.0555 U	0.0555 U	0.111 U	0.0212	105	7.17 JZ	67.4	180 J
ISP-E-21-2	2	09/22/08	0.0318 U	0.0530 U	0.0530 U	0.113	0.00850	16.7	25.0 JZ	27.7 U	55.6 J
ISP-F-17-2	2	09/17/08	0.0319 U	0.0532 U	0.0532 U	0.106 U	NA	10.4 U	5.32 U	26.0 U	20.9 UU
ISP-F-18-2	2	09/17/08	0.0267 U	0.0445 U	0.0445 U	0.0890 U	0.0170	29.0	4.45 U	32.9	64.1
ISP-F-19-2	2	09/22/08	0.0329 U	0.0549 U	0.0549 U	0.110 U	0.0523	14.3	5.49 U	27.5 U	30.8
ISP-F-20-2	2	09/22/08	0.0351 U	0.0585 U	0.0585 U	0.117 U	0.0498	11.6	5.85 U	27.1 U	28.1
ISP-F-21-2	2	09/22/08	0.0344 U	0.0574 U	0.0574 U	0.115 U	NA	11.0 U	5.74 U	27.4 U	22.1 UU
ISP-G-17-2	2	09/17/08	0.0314 U	0.0524 U	0.0524 U	0.105 U	NA	10.4 U	5.24 U	26.1 U	20.9 UU
ISP-G-18-2	2	09/17/08	0.0314 U	0.0523 U	0.0523 U	0.105 U	NA	10.6 U	5.23 U	26.4 U	21.1 UU
ISP-G-19-2	2	09/22/08	0.0305 U [0.0301 U]	0.0508 U [0.0502 U]	0.0508 U [0.0502 U]	0.102 U [0.100 U]	0.306 [0.0187]	38.9 [47.5]	5.08 U [5.02 U]	27.5 U [27.5 U]	55.2 [63.8]
ISP-G-19-2(2)	2	09/25/08	0.0344 U	0.0573 U	0.0573 U	0.115 U	0.0161	75.5	5.73 U	57.1	135
ISP-G-20-2	2	09/22/08	0.0328 U	0.0546 U	0.0546 U	0.109 U	0.00823 UU	11.4	5.46 U	27.1 U	27.7
ISP-G-21-2	2	09/22/08	0.0322 U	0.0536 U	0.0536 U	0.107 U	0.0335	74.1	9.03 JZ	35.0	118 J
EX-RRT-ZZ-2-4	4	08/01/08	0.0552 U	0.0920 U	0.0920 U	0.184 U	NA	15.2 U	20.3	38.0 U	46.9
EX-RRT-ZZ-2-ESW-3	3	08/01/08	0.0800 U	0.133 U	0.133 U	0.560 J	NA	18.2 U	46.4 J	45.4 U	78.2 J
RRT-YY-2-6	6	08/04/08	0.105 U	0.376 J	0.174 U	1.61 J	NA	20.8 U	39.9 J	52.0 U	76.3 J
RRT-YY-2-WSW-3	3	08/04/08	0.0397 U [0.0357 U]	0.0661 U [0.0595 U]	0.0661 U [0.0595 U]	0.132 U [0.119 U]	0.00808 UU [0.00808 UU]	27.1 JY [26.8 JY]	6.61 U [5.95 U]	32.9 [31.6]	63.3 J [61.4 J]
RRT-ZZ-2-NSW-3	3	08/04/08	0.0349 U	0.0581 U	0.0581 U	0.116 U	0.00853 UU	30.2 J	5.81 U	60.4	93.5 J
RRT-ZZ-3-NSW-3	3	08/04/08	0.0382 U	0.0637 U	0.0637 U	0.127 U	NA	11.8 U	6.37 U	29.4 U	23.8 UU

TABLE 3
Excavation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase II Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Notes:
BTEX analyzed by EPA Method 8021B.
cPAHs analyzed by EPA Method 8270 SIM.
Gasoline analyzed by method NWTPH-G.
Diesel and Heavy Oil (Lube) analyzed by method NWTPH-D Extended.
Total TPH calculated by summing the concentrations of gasoline, diesel and heavy oil. If one or more TPH constituents were reported as Non-Detect, half of the reporting limit value was added to the total.
cPAHs adjusted for toxicity according to WAC 173-340-708(8) and *Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II Technical Support Document for Describing Available Cancer Potency Factors.* Office of Environmental Health Hazard Assessment, California EPA, May 2005. If one or more adjusted cPAH constituents were reported as Non-Detect, half of the reporting limt was used in calculations.
Highlighted cells indicate concentration exceeds REL or CUL.
NA = Indicates analysis not conducted.
[ ] = Bracketed data indicate duplicate sample.

BTEX = Benzene, toluene, ethylbenzene, and total xylenes
EPA = Environmental Protection Agency
mg/kg = Milligrams per kilogram
cPAHs = Carcinogenic polynuclear aromatic hydrocarbons
REL = Remediation level
CUL = Cleanup level
TPH = Total petroleum hydrocarbons
bgs = below ground surface

Lab Qualifiers	Definition
J	Indicates an estimated value.
JY	Results in the diesel organics range are primarily due to overlap from a heavy oil range product.
JZ	Detected hydrocarbons in the gasoline range appear to be due to overlap of diesel range hydrocarbons.
Q4	The hydrocarbons present are a complex mixture of diesel range and heavy oil range organics.
U	The compound was analyzed for but not detected. The associated value is the compound quantitation limit.
UJ	The compound was analyzed for but not detected. The associated value is the estimated compound quantitation limit.
UU	The constituents making up the total are all non-detects.

TABLE 6
Monitoring Well Installation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
Phase II Remedial Implementation As-built Report
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX *(mg/kg)*				Total cPAHs Adjusted for Toxicity *(mg/kg)*	Diesel Range Organics *(mg/kg)*	Gasoline Range Organics *(mg/kg)*	Heavy Oil (Lube) *(mg/kg)*	Total TPH (mg/kg)
			B	T	E	X					
Site Soil Remediation Level (REL)/Cleanup Level (CUL) (mg/kg)			**18**	**--**	**--**	**--**	**0.14**	**--**	**--**	**--**	**2,975**
MW-129R-4.5	4.5	10/14/08	0.0303 U	0.0506 U	0.0506 U	0.101 U	0.0439	823	24.4 JZ	178	1,030 J
MW-129R-7.0	7	10/14/08	0.0446 U	0.0743 U	0.0743 U	0.149 U	0.0479 UU	2,690	7.43 U	313	3,010
MW-502-6.0	6	10/14/08	0.0337 U	0.0562 U	0.0562 U	0.112 U	NA	11.6 U	5.62 U	29.0 U	23.1 UU
MW-511-8.5	8.5	10/14/08	0.0378 U [0.0361 U]	0.0630 U [0.0601 U]	0.0630 U [0.0601 U]	0.126 U [0.120 U]	NA [NA]	11.7 U [11.5 U]	6.30 U [6.01 U]	29.2 U [28.8 U]	23.6 UU [23.2 UU]
MW-510-6.5	6.5	10/08/08	0.0462 U	0.0770 U	0.0770 U	0.154 U	0.0200 UU	80.5	7.70 U	33.0 U	101
MW-510-12.5	12.5	10/08/08	0.0345 U	0.0574 U	0.0574 U	0.115 U	NA	11.9 U	5.74 U	29.6 U	23.6 UU

Notes:
BTEX analyzed by EPA Method 8021B.
cPAHs analyzed by EPA Method 8270 SIM.
Gasoline analyzed by method NWTPH-G.
Diesel and Heavy Oil (Lube) analyzed by method NWTPH-D Extended.
Total TPH calculated by summing the concentrations of gasoline, diesel and heavy oil. If one or more TPH constituents were reported as Non-Detect, half of the reporting limit value was added to the total.
cPAHs adjusted for toxicity according to WAC 173-340-708(8) and *Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II Technical Support Document for Describing Available Cancer Potency Factors* . Office of Environmental Health Hazard Assessment, California EPA, May 2005. If one or more adjusted cPAH constituents were reported as Non-Detect, half of the reporting limt was used in calculations.
Highlighted cells indicate concentration exceeds REL or CUL.
NA = Indicates analysis not conducted.
[ ] = Bracketed data indicate duplicate sample.

BTEX = Benzene, toluene, ethylbenzene, and total xylenes
EPA = Environmental Protection Agency
mg/kg = Milligrams per kilogram
cPAHs = Carcinogenic polynuclear aromatic hydrocarbons
REL = Remediation level
CUL = Cleanup level
TPH = Total petroleum hydrocarbons

Lab Qualifiers	Definition
J	Indicates an estimated value.
JZ	Detected hydrocarbons in the gasoline range appear to be due to overlap of diesel range hydrocarbons.
U	The compound was analyzed for but not detected. The associated value is the compound quantitation limit.
UU	The constituents making up the total are all non-detects.

2008 Additional Site Investigation and Groundwater Monitoring Report

Table 1

Additional Site Investigation
Soil Analytical Data
Former Unocal Terminal
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX[1] (EPA Method 8021B) *(mg/kg)*				Total Adjusted cPAHs[2] (EPA Method 8270 SIM) *(mg/kg)*	NWTPH-G *(mg/kg)*	NWTPH-D Extended *(mg/kg)*		Total TPH[3] *(mg/kg)*
			B	T	E	X		Gasoline	Diesel	Heavy Oil (Lube)	
Site Soil Remediation Level (REL)/Cleanup Level (CUL) (mg/kg)			**18**	**--**	**--**	**--**	**0.14**	**--**	**--**	**--**	**2,975**
SB-65-6.5	6.5	06/26/08	35.8 J	47.2 J	3.79 J	4.35 J	1.01	3,820	9,450 J	3,660 J	16,900 J
SB-65-8.0	8	06/26/08	14.5	78.0	2.96 U	48.9	0.0928	2,290	1,910	186	4,390
SB-65-16.0	16	06/26/08	0.0588	0.241	0.0575 U	0.782	0.00883 UU	13.1	176	35.6	225
SB-65-20	20	06/26/08	0.259	1.13	0.0432 U	3.79	0.0161	59.2	136	28.6 U	210
SB-65-23	23	06/26/08	0.275	1.43	0.0677	4.66	0.0158	61.3	85.1	28.8 U	161
SB-66-6.0	6	06/26/08	0.0746	0.281	0.0598 U	2.92	0.209	467 JZ	9,790 J	1,640 J	11,900 J
SB-66-11.5	11.5	06/30/08	0.0381 U	0.0635 U	0.0635 U	0.127 U	0.00914 UU	6.35 U	15.0	30.4 U	33.4
SB-66-15	15	06/30/08	0.0331 U	0.0552 U	0.0552 U	0.110 U	NA	5.52 U	11.6 U	29.1 U	23.1 UU
SB-67-5.5	5.5	06/24/08	0.0398 U	0.0663 U	0.0663 U	0.133 U	NA	6.63 U	11.9 U	29.7 U	24.1 UU
SB-68-4.0	4	06/24/08	0.334 U	29.7	0.653	88.7	0.165	4,090	1,240	141	5,470
SB-68-5.5	5.5	06/24/08	0.350 U	32.9 J	0.583 U	166	0.101	3,960	633	143 U	4,660
SB-68-13.5	13.5	06/25/08	0.0367 U	0.403	0.0612 U	2.65	0.00898 UU	73.7	11.9	29.7 U	100
SB-68-15.0	15	06/25/08	0.0364 U	0.0606 U	0.0606 U	0.121 U	NA	6.06 U	12.0 U	30.1 U	24.1 UU
SB-69-6.0	6	06/26/08	0.149 J	4.34 J	1.07 J	48.3	0.236 UU	1,770	1,870	157 U	3,720
SB-69-12.0	12	06/26/08	0.0385 U	0.0642 U	0.0642 U	0.128 U	NA	6.42 U	11.9 U	29.7 U	24.0 UU
SB-69-15.0	15	06/26/08	0.0393 U [0.0384 U]	0.0654 U [0.0639 U]	0.0654 U [0.0639 U]	0.131 U [0.128 U]	NA	6.54 U [6.39 U]	11.9 U [14.4]	29.7 U [30.1 U]	24.1 UU [32.6]
SB-70-6.0	6	06/24/08	0.0371 U	0.0618 U	0.0618 U	0.124 U	NA	6.18 U	10.9 U	27.2 U	22.1 UU
SB-70-7.0	7	06/25/08	0.0369 U	0.0616 U	0.0616 U	0.123 U	NA	6.16 U	11.5 U	28.8 U	23.2 UU
SB-70-12.5	12.5	06/25/08	0.0366 U	0.0611 U	0.0611 U	0.122 U	NA	6.11 U	11.6 U	29.1 U	23.4 UU
SB-70-20.5	20.5	06/25/08	0.0340 U	0.0567 U	0.0567 U	0.113 U	NA	5.67 U	11.8 U	29.4 U	23.4 UU
SB-71-8.0	8	06/25/08	0.0368 U	0.0614 U	0.0614 U	0.123 U	NA	6.14 U	11.7 U	29.3 U	23.6 UU
SB-71-15.5	15.5	06/25/08	0.0363 U	0.0605 U	0.0605 U	0.121 U	0.00876 UU	6.05 U	11.6 U	42.1	50.9
SB-71-24.0	24	06/25/08	0.0366 U	0.0610 U	0.0610 U	0.122 U	NA	6.10 U	11.8 U	29.4 U	23.7 UU
SB-72-6.5	6.5	06/25/08	0.0371 U	0.0619 U	0.0619 U	0.124 U	NA	6.19 U	11.7 U	29.3 U	23.6 UU
SB-72-15.5	15.5	06/25/08	0.0348 U	0.0581 U	0.0581 U	0.116 U	NA	5.81 U	12.1 U	30.1 U	24.0 UU
SB-72-24.5	24.5	06/25/08	0.0400 U [0.0421 U]	0.0667 U [0.0701 U]	0.0667 U [0.0701 U]	0.133 U [0.140 U]	NA	6.67 U [7.01 U]	12.5 U [12.6 U]	31.2 U [31.5 U]	25.2 UU [25.6 UU]
SB-73-6.0	6	06/26/08	0.0445 U	0.0741 U	0.0741 U	0.148 U	NA	7.41 U	13.0 U	32.6 U	26.5 UU
SB-73-15.0	15	06/26/08	0.0369 U	0.0615 U	0.0615 U	0.123 U	NA	6.15 U	12.0 U	30.1 U	24.1 UU
SB-74-6.0	6	06/26/08	0.0375 U	0.0625 U	0.0625 U	0.125 U	NA	6.25 U	12.2 U	30.4 U	24.4 UU
SB-74-15	15	06/26/08	0.0380 U	0.0634 U	0.0634 U	0.127 U	NA	6.34 U	12.2 U	30.4 U	24.5 UU
SB-75-6.0	6	06/26/08	0.0406 U	0.0677 U	0.0677 U	0.135 U	NA	6.77 U	12.2 U	30.5 U	24.7 UU
SB-75-15.0	15	06/26/08	0.0398 U	0.0663 U	0.0663 U	0.133 U	NA	6.63 U	12.3 U	30.8 U	24.9 UU

Table 1

Additional Site Investigation
Soil Analytical Data
Former Unocal Terminal
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX[1] (EPA Method 8021B) *(mg/kg)*				Total Adjusted cPAHs[2] (EPA Method 8270 SIM) *(mg/kg)*	NWTPH-G *(mg/kg)*	NWTPH-D Extended *(mg/kg)*		Total TPH[3] *(mg/kg)*
			B	T	E	X		Gasoline	Diesel	Heavy Oil (Lube)	
Site Soil Remediation Level (REL)/Cleanup Level (CUL) (mg/kg)			18	--	--	--	0.14	--	--	--	2,975
SB-76-4.5	4.5	06/30/08	0.0389 U	0.0648 U	0.316	0.130 U	NA	9.14	11.4 U	28.5 U	29.1
SB-76-9	9	06/30/08	0.0436 U	0.0727 U	0.0727 U	0.145 U	0.198	7.66 JZ	14,500 J	2,550 J	17,100 J
SB-76-10.5	10.5	06/30/08	0.0501 U	0.0835 U	0.0835 U	0.167 U	0.190	40.1 JZ	2,090 J	409 J	2,540 J
SB-76-14	14	06/30/08	0.0288 U [0.0355 U]	0.0480 U [0.0591 U]	0.0480 U [0.0591 U]	0.0959 U [0.118 U]	NA	4.80 U [5.91 U]	12.0 U [11.9 U]	30.0 U [29.8 U]	23.4 UU [23.8 UU]
SB-77-6	6	06/30/08	0.0392 U	0.0653 U	0.0653 U	0.131 U	NA	6.53 U	12.0 U	29.9 U	24.2 UU
SB-77-9.5	9.5	06/30/08	0.0439 U	0.0731 U	0.0731 U	0.146 U	0.214	7.31 U	7,120 J	757 J	7,880 J
SB-77-14	14	06/30/08	0.0336 U	0.0561 U	0.0561 U	0.112 U	NA	5.61 U	11.8 U	29.5 U	23.5 UU
SB-78-5.5	5.5	06/30/08	6.57 J	9.74 J	42.4 J	49.6 J	0.0183	693	257	356	1,310
SB-78-8.5	8.5	06/30/08	0.0351 U	0.0585 U	0.0585 U	0.117 U	NA	5.85 U	11.4 U	28.4 U	22.8 UU
SB-78-10	10	06/30/08	0.0325 U	0.0542 U	0.0542 U	0.108 U	NA	15.1 JZ	11.4 U	28.6 U	35.1 J
SB-78-12.5	12.5	06/30/08	0.0353 U	0.0589 U	0.0589 U	0.118 U	NA	5.89 U	12.2 U	30.6 U	24.3 UU
SB-79-5	5	06/30/08	0.0344 U	0.0573 U	0.0573 U	0.115 U	NA	5.73 U	11.0 U	27.5 U	22.1 UU
SB-79-8.5	8.5	06/30/08	0.0348 U	0.0581 U	0.0581 U	0.116 U	0.276	32.5 JZ	2,960 J	964 J	3,960 J
SB-79-10	10	06/30/08	0.0468 U	0.0779 U	0.0779 U	0.156 U	0.0198	19.7 JZ	137	37.0	194 J
SB-79-11.5	11.5	06/30/08	0.0550 U	0.0916 U	0.0916 U	0.183 U	NA	9.16 U	13.1 U	32.7 U	27.5 UU
SB-80-7.5	7.5	06/26/08	0.0392 U	0.0654 U	0.0654 U	0.131 U	0.693	24.5 JZ	1,870	2,770	4,660 J
SB-80-11.0	11	06/26/08	0.0518 U	0.0864 U	0.0864 U	0.173 U	NA	8.64 U	13.6 U	34.0 U	28.1 UU
SB-81-5	5	06/30/08	0.0301 U	0.0501 U	0.0501 U	0.100 U	0.0896	21.1 JZ	34.4	49.4	105 J
SB-81-9.5	9.5	06/30/08	0.0414 U	0.0691 U	0.0691 U	0.138 U	NA	6.91 U	12.6 U	31.4 U	25.5 UU
SB-81-15.5	15.5	06/30/08	0.0333 U	0.0556 U	0.0556 U	0.111 U	NA	5.56 U	11.6 U	29.0 U	23.1 UU
SB-82-7	7	07/01/08	0.0349 U	0.0581 U	0.0581 U	0.116 U	NA	5.81 U	11.9 U	29.7 U	23.7 UU
SB-82-9	9	07/01/08	0.0455 U	0.0758 U	0.0758 U	0.152 U	NA	7.58 U	13.6 U	33.9 U	27.5 UU
SB-83-7	7	07/01/08	0.0333 U	0.0555 U	0.0555 U	0.111 U	0.00891	5.55 U	16.8	29.6 U	34.4
SB-83-8.5	8.5	07/01/08	0.0502 U	0.0837 U	0.0837 U	0.167 U	0.0108	8.37 U	18.7	35.6 U	40.7
SB-84-6	6	07/01/08	0.0610 U	0.102 U	0.102 U	0.203 U	0.0119	10.2 U	20.7	43.3	69.1
SB-84-8	8	07/01/08	0.0745 U	0.124 U	0.124 U	0.248 U	NA	12.4 U	17.6 U	44.0 U	37.0 UU
SB-85-5.5	5.5	07/02/08	0.0357 U	0.0596 U	0.0596 U	0.119 U	0.0225	5.96 U	75.4	28.2 U	92.5
SB-85-7.5	7.5	07/02/08	0.114 U	0.218 J	0.189 U	1.09 J	NA	177 J	21.2 U	52.9 U	214 J
SB-86-4.5	4.5	07/02/08	0.0324 U	0.0540 U	0.0540 U	0.108 U	0.0182	5.40 U	31.1 JY	77.9	112 J
SB-86-6.5	6.5	07/02/08	0.0513 U	0.0856 U	0.0856 U	0.171 U	NA	8.56 U	14.2 U	35.4 U	29.1 UU
SB-87-6.0	6	07/25/08	0.0600	0.0825	0.0464 U	0.153	0.0535	74.2 JZ	79.8	88.6	243 J
SB-87-14.0	14	07/25/08	0.0477	0.0686 U	0.0686 U	0.137 U	NA	6.86 U	12.2 U	30.4 U	24.7 UU
SB-88-8.0	8	07/25/08	0.0145 U	0.0242 U	0.0242 U	0.0484 U	0.0167	2.59	35.9	98.5	137

Table 1

Additional Site Investigation
Soil Analytical Data
Former Unocal Terminal
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX[1] (EPA Method 8021B) *(mg/kg)*				Total Adjusted cPAHs[2] (EPA Method 8270 SIM) *(mg/kg)*	NWTPH-G *(mg/kg)*	NWTPH-D Extended *(mg/kg)*		Total TPH[3] *(mg/kg)*
			B	T	E	X		Gasoline	Diesel	Heavy Oil (Lube)	
Site Soil Remediation Level (REL)/Cleanup Level (CUL) (mg/kg)			18	--	--	--	0.14	--	--	--	2,975

Notes
Shaded data indicates concentrations greater than the applicable site Remedial Action Levels.
(mg/kg)= milligram per kilogram (parts per million)
bgs= below ground surface
[1] B= Benzene, T= Toluene, E= Ethylebenzene, X= Total Xylenes
[2] Carcinogenic Polynuclear Aromatic Hydrocarbons (cPAHs). cPAHs adjusted for toxicity according to WAC 173-340-708(8) and Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II Technical Support Document for Describing Available Cancer Potency Factors. Office of Environmental Health Hazard Assessment, California EPA. May 2005. If one or more adjusted cPAH constituents were reported as Non-Detect, half of the reporting limt was used in calculations.
[3]Total TPH calculated by summing the concentrations of gasoline, diesel and heavy oil. If any TPH constituents were reported as Non-Detect, half of the reporting limit value was used.
NA = Indicates analysis not conducted.
[ ] = Bracketed data indicate duplicate sample.

Lab Qualifiers Definition

Lab Qualifiers	Definition
J	Indicates an estimated value.
JY	Results in the diesel organics range are primarily due to overlap from a heavy oil range
JZ	Detected hydrocarbons in the gasoline range appear to be due to overlap of diesel range hydrocarbons
U	The compound was analyzed for but not detected. The associated value is the compound quantitation limit
UU	The constituents making up the total are all non-detects.

ARCADIS

2011 Final Site Investigation
Completion Report

TABLE 1
Tidal Study Results Summary
Former Unocal Terminal
11720 Unoco Road
Edmonds, Washington

Well ID	GWE (feet)		Depth (feet)		Salinity (PSU)			Amplitude (feet)	
	Max	Min	Max	Min	Max	Min	Avg	Max	Min
LM-2	6.68	6.50	5.34	5.16	12.32	8.94	11.07	--	--
MW-8R	6.42	5.77	4.60	3.95	0.22	0.18	0.19	0.31	0.02
MW-104	5.42	4.53	8.34	7.45	0.14	0.11	0.12	0.53	0.03
MW-122	-1.06	-1.39	8.40	8.07	0.39	0.38	0.38	0.33	0.02
MW-129R	7.28	6.76	6.99	6.47	0.69	0.63	0.67	0.37	0.03
MW-149R	6.10	4.59	5.92	4.41	0.34	0.23	0.29	1.15	0.07
MW-500	13.35	12.63	8.46	7.74	0.44	0.30	0.37	--	--
MW-501	12.98	12.60	9.74	9.36	0.17	0.15	0.17	--	--
MW-502	8.92	8.66	8.02	7.76	0.17	0.14	0.17	--	--
MW-515	7.47	7.21	7.57	7.31	0.21	0.18	0.19	--	--
MW-518	6.98	6.19	4.88	4.09	0.32	0.27	0.30	0.56	0.02
Staff Gauge ID	**GWE (feet)**		**Depth (feet)**		**Salinity (PSU)**			**Amplitude (feet)**	
	Max	**Min**	**Max**	**Min**	**Max**	**Min**	**Avg**	**Max**	**Min**
D-1	8.20	5.95	2.53	0.28	27.76	0.22	10.72	1.96	0.02
D-2	8.13	5.63	2.11	-0.39	27.56	0.10	10.68	1.84	0.04
D-3	8.11	5.59	2.37	-0.15	27.96	0.00	9.73	2.12	0.02
D-5	8.76	4.81	2.65	-1.30	27.76	0.00	11.55	3.73	0.19
D-6	6.84	5.54	2.43	2.43	1.80	1.47	1.68	--	--
TB	5.56	3.06	3.36	0.86	30.08	0.31	12.91	2.22	0.04

Notes:
GWE = Groundwater Elevations in feet above mean sea level
PSU = Practical Salinity Units

TABLE 2
Well Construction Details Summary
Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

Well ID	Date Installed	Top of Casing (feet amsl) [a]	Well Diameter (inches)	Well Material	Pipe Schedule	Slotted Screen Size (inches)	Borehole Diameter (inches)	Top of Screen (feet bgs)	Bottom of Screen (feet bgs)	Well Depth (feet bgs)	Borehole Depth (feet bgs)	Top of Filter Pack (feet bgs)	Bottom of Filter Pack (feet bgs)	Depth to Bottom - 2008 (feet btoc) [b]
LM-2	4/18/1989	8.14	2	PVC	40	0.02	--	2.5	8	8	9.1	2	9	7.8
MW-8R	10/9/2008	13.82	2	PVC	40	0.01	8	3	13	13	13	2	13	13
MW-104	12/22/1992	14.08	2	PVC	40	0.02	10	5	15	15	16.5	7	15	18.2
MW-122	9/27/1995	15.54	2	PVC	40	0.01	--	30	40	40	41.5	27.66	41.5	42.65
MW-129R	10/14/2008	12.92	2	PVC	40	0.01	8	3	13	13	13.5	2	13.5	12.9
MW-149R	10/8/2008	12.18	2	PVC	40	0.01	8	3	13	13	13.5	2	13	13
MW-500	10/14/2008	16.64	2	PVC	40	0.01	8	3	13	13	13	2	13	12.75
MW-501	10/14/2008	15.24	2	PVC	40	0.01	8	3	13	13	13	2	13	13
MW-502	10/14/2008	13.00	2	PVC	40	0.01	8	3	13	13	13	2	13	13.1
MW-515	10/10/2008	11.60	2	PVC	40	0.01	8	3	13	13	13	2	13	12.7
MW-518	10/8/2008	14.60	2	PVC	40	0.01	8	3.5	13.5	13.5	13.5	2	13.5	13.5
MW-521	10/9/2008	12.18	2	PVC	40	0.01	8	3	13	13	13	2	13	12.7
MW-522	10/9/2008	13.82	2	PVC	40	0.01	8	3	13	13	13	2	13	12.7
MW-523	10/8/2008	13.53	2	PVC	40	0.01	8	3	13	13	13	2	13	12.7

Notes:
(a) Vertical Datum: N.A.V.D. 88
(b) Depth to bottom was gauged on October 20, 2008, following well development activities.
amsl = above mean sea level
-- = Data not available
bgs = below ground surface
btoc = below top of casing

TABLE 3

Hydraulic Conductivity Step Test Data Summary

Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

<table>
<tr><th>Well ID</th><th>Date</th><th>Pump Used</th><th>Initial DTW (feet)</th><th>Flow Rate (GPM)</th><th>Maximum Drawdown (feet)</th><th>Notes</th></tr>
<tr><td rowspan="3">MW-104</td><td rowspan="3">5/11/2011</td><td rowspan="3">2" Submersible Pump</td><td rowspan="3">7.90</td><td>0.50</td><td>0.45</td><td rowspan="3">Test terminated due to pump failure.</td></tr>
<tr><td>1.0</td><td>1.37</td></tr>
<tr><td>1.5</td><td>2.80</td></tr>
<tr><td rowspan="2">MW-129R</td><td rowspan="2">5/12/2011</td><td rowspan="2">2" Submersible Pump</td><td rowspan="2">5.35</td><td>0.50</td><td>5.84</td><td rowspan="2">Well pumped dry at 0.5 GPM.</td></tr>
<tr><td>0.25</td><td>5.65</td></tr>
<tr><td rowspan="3">MW-149R</td><td rowspan="3">5/11/2011</td><td rowspan="3">2" Submersible Pump</td><td rowspan="3">6.63</td><td>0.50</td><td>1.07</td><td rowspan="3"></td></tr>
<tr><td>1.0</td><td>1.98</td></tr>
<tr><td>1.5</td><td>2.96</td></tr>
<tr><td rowspan="4">MW-500</td><td rowspan="2">5/10/2011</td><td rowspan="2">Peristaltic Pump</td><td rowspan="2">3.81</td><td>0.10</td><td>1.30</td><td rowspan="2">Test terminated after 109 minutes. Stabilized drawdown not achieved.</td></tr>
<tr><td>0.19</td><td>5.55</td></tr>
<tr><td rowspan="2">5/12/2011</td><td rowspan="2">2" Submersible Pump</td><td rowspan="2">3.80</td><td>0.25</td><td>3.30</td><td rowspan="2">Test terminated due to well pumping dry at 0.5 GPM flow rate.</td></tr>
<tr><td>0.50</td><td>7.61</td></tr>
<tr><td rowspan="3">MW-518</td><td rowspan="3">5/11/2011</td><td rowspan="3">2" Submersible Pump</td><td rowspan="3">8.01</td><td>0.25</td><td>0.36</td><td rowspan="3">Test terminated after 60 minutes.</td></tr>
<tr><td>1.0</td><td>1.39</td></tr>
<tr><td>1.5</td><td>1.90</td></tr>
<tr><td rowspan="6">MW-8R</td><td rowspan="3">5/12/2011</td><td rowspan="3">2" Submersible Pump</td><td rowspan="3">8.03</td><td>0.25</td><td>0.11</td><td rowspan="3">Test terminated due to pump tubing failure.</td></tr>
<tr><td>0.50</td><td>0.12</td></tr>
<tr><td>1.5</td><td>1.26</td></tr>
<tr><td rowspan="3">5/18/2011</td><td rowspan="3">2" Submersible Pump</td><td rowspan="3">7.50</td><td>2.0</td><td>0.17</td><td rowspan="3"></td></tr>
<tr><td>4.0</td><td>0.46</td></tr>
<tr><td>5.0</td><td>0.59</td></tr>
<tr><td rowspan="4">LM-2</td><td>5/11/2011</td><td>2" Submersible Pump</td><td>1.48</td><td>0.25</td><td>4.59</td><td>Well pumped dry.</td></tr>
<tr><td rowspan="3">5/13/2011</td><td rowspan="3">Peristaltic Pump</td><td rowspan="3">1.47</td><td>0.10</td><td>1.80</td><td></td></tr>
<tr><td>0.15</td><td>2.18</td><td></td></tr>
<tr><td>0.18</td><td>3.43</td><td></td></tr>
</table>

Notes:
DTW: Depth to water
btoc: below top of casing
GPM: Gallons per minute

TABLE 4
Short Duration Hydraulic Conductivity Test Data Summary
Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

Well ID	Date	Pump Used	Initial DTW (feet)	Flow Rate (GPM)	Maximum Drawdown (feet)	Notes
MW-104	5/16/2011	2" Submersible Pump	7.73	3.0	5.18	Test terminated after 88 minutes.
MW-129R	5/17/2011	2" Submersible Pump	5.10	0.30	4.39	Test terminated after 60 minutes.
MW-149R	5/16/2011	2" Submersible Pump	6.45	2.0	4.24	Test terminated after 60 minutes.
MW-500	5/13/2011	2" Submersible Pump	3.79	0.30	7.32	Well pumped dry.
	5/13/2011	2" Submersible Pump	3.79	0.25	7.75	Well pumped dry.
LM-2	5/17/2011	2" Submersible Pump	1.20	0.30	5.40	Well pumped dry.
	5/17/2011	2" Submersible Pump	1.20	0.20	5.44	Well pumped dry.
MW-518	5/17/2011	2" Submersible Pump	8.71	2.5	3.28	Test terminated after 90 minutes.
MW-8R	5/16/2011	2" Submersible Pump	7.70	5	0.62	Test terminated after 60 minutes.

Notes:
DTW: Depth to water
btoc: below top of casing
GPM: Gallons per minute

TABLE 5
Long Term Hydraulic Conductivity Test Data Summary
Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

Well ID	Date	Pump Used	Initial DTW (feet)	Flow Rate (GPM)	Maximum Drawdown (feet)	Notes
MW-8R	5/19/11 - 5/20/11	2" Submersible Pump	7.65	5.0	0.88	Test conducted for 24hrs, with no stoppages. Flow rate was confirmed every hour.
MW-521	5/19/11 - 5/20/11	NA	6.01	NA	no measurable drawdown	observation well
MW-522	5/19/11 - 5/20/11	NA	7.69	NA	no measurable drawdown	observation well
MW-523	5/19/11 - 5/20/11	NA	7.38	NA	no measurable drawdown	observation well

Notes:
DTW: Depth to water
btoc: below top of casing
GPM: Gallons per minute
NA: Not Applicable

TABLE 7
Detention Basin No.2 Investigation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX (mg/kg)				Total cPAHs Adjusted for Toxicity (mg/kg)	Diesel Range Organics (mg/kg)	Gasoline Range Organics (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			B	T	E	X					
Site Soil Remediation Level (REL)/Cleanup Level (CUL) (mg/kg)			18	--	--	--	0.14	--	--	--	2975
B1-4.5-5	4.5-5	08/22/11	0.0022 U	NA	NA	NA	0.00052	3.1 U X	1.1 U	14 X	16
B1-9.5-10	9.5-10	08/22/11	0.23 W	NA	NA	NA	0.0082	5.3	25 W	42	72
B1-14-14.5	14-14.5	08/22/11	0.17	NA	NA	NA	N/A	4.8 U	2.1 U	16 U	11 UU
B2-4-4.5	4-4.5	08/22/11	0.018 UW	NA	NA	NA	0.051	620	9.2 U W	720	1,345
B2-7-7.5	7-7.5	08/22/11	0.0020 U	NA	NA	NA	0.00073	30	1 U	37	68
B2-9.5-10	9.5-10	08/22/11	0.0019 U	NA	NA	NA	0.002	100	16	100	216
B2-12-12.5	12-12.5	08/22/11	0.0020 U	NA	NA	NA	0.00088	130	2	530	662
B2-14.5-15	14.5-15	08/22/11	0.0024 U	NA	NA	NA	N/A	3.4 U	1.2 U	11 U	8 UU
B3-4.5-5	4.5-5	08/22/11	0.0022 U	NA	NA	NA	N/A	3.2 U	1.1 U	11 U	8 UU
B3-7-7.5	7-7.5	08/22/11	0.0021 U	NA	NA	NA	0.00076	110 X	1.1 U	70 X	181
B3-12-12.5	12-12.5	08/22/11	0.0020 U	NA	NA	NA	0.00077	43 X	6.8	46 X	96
B3-14-14.5	14-14.5	08/22/11	0.0040	NA	NA	NA	N/A	3.3 U	1.3	11 U	8
B4-4.5-5	4.5-5	08/22/11	0.0020 U	NA	NA	NA	0.00053 UU	160	1 U	53 U	187
B4-9.5-10	9.5-10	08/22/11	0.024 W	NA	NA	NA	0.0075	2,900	13 W	1,500	**4,413**
B4-13-13.5	13-13.5	08/22/11	0.010	NA	NA	NA	0.0006	4.2	1.8	12 U	12
B4-14.5-15	14.5-15	08/22/11	0.021 U W	NA	NA	NA	N/A	3.6 U	11 U W	12 U	13 UU
B5-4.5-5	4.5-5	08/22/11	0.0022 U	NA	NA	NA	N/A	3.5 U	1.1 U	12 U	8 UU
B5-9-9.5	9-9.5	08/22/11	0.083 U W	NA	NA	NA	0.0138	16,000	42 U W	11,000	**27,021**
B5-11.5-12	11.5-12	08/22/11	0.0023 U	NA	NA	NA	N/A	3.8 U	1.2 U	13 U	9 UU
B5-13.5-14	13.5-14	08/22/11	0.0024 U	NA	NA	NA	N/A	3.7 U	1.2 U	12 U	8 UU
B6-4.5-5	4.5-5	08/22/11	0.021 U W	NA	NA	NA	0.09	470	190 W	310	970
B6-7-7.5	7-7.5	08/22/11	0.55 U	NA	NA	NA	**0.36**	16,000 Y	720	4,900 Y	**21,620**
B6-9-9.5	9-9.5	08/22/11	0.97	NA	NA	NA	**3.2 T**	170,000 Y	2,400	48,000 Y	**220,400**
B6-11-11.5	11-11.5	08/22/11	0.023 U W	NA	NA	NA	0.012	230 Z	30 W	57 Z	317
B6-13-13.5	13-13.5	08/22/11	0.0028 U	NA	NA	NA	N/A	3.5 U	1.4 U	12 U	8 UU

TABLE 7
Detention Basin No.2 Investigation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX (mg/kg)				Total cPAHs Adjusted for Toxicity (mg/kg)	Diesel Range Organics (mg/kg)	Gasoline Range Organics (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			B	T	E	X					
Site Soil Remediation Level (REL)/Cleanup Level (CUL) (mg/kg)			**18**	**--**	**--**	**--**	**0.14**	**--**	**--**	**--**	**2975**
B7-4.5-5	4.5-5	08/22/11	0.083 U W	NA	NA	NA	0.071	260	230 W	210	700
B7-8-8.5	8-8.5	08/22/11	1.5 U W	NA	NA	NA	**2.8 T**	72,000	1,400 W	38,000	**111,400**
B7-9.5-10	9.5-10	08/22/11	0.030 U W	NA	NA	NA	0.037 T	4,200	47 W	1700	**5947**
B7-14-14.5	14-14.5	08/22/11	0.0021 U	NA	NA	NA	N/A	3.6 U	1 U	12 U	8 UU
B8-4.5-5	4.5-5	08/23/11	0.24 U T	NA	NA	NA	0.114	11,000	1,000	4,500	**16,500**
B8-7.5-8	7.5-8	08/23/11	0.0029	NA	NA	NA	0.077	6,800	260	2,300	**9,360**
B8-9.5-10	9.5-10	08/23/11	3.2	NA	NA	NA	**0.5 T**	50,000	730	25,000	**75,730**
B8-11-11.5	11-11.5	08/23/11	0.51 W	NA	NA	NA	0.09	4,900	300 W	3,000	**8,200**
B8-13.5-14	13.5-14	08/23/11	0.0073	NA	NA	NA	**0.1**	40	1.2 U	14	55
B8-14.5-15	14.5-15	08/23/11	0.0056	NA	NA	NA	N/A	3.5 U	1.2 U	12 U	8 UU
B9-4.5-5	4.5-5	08/23/11	0.0022 U	NA	NA	NA	N/A	3.2 U	1.1 U	27	29
B9-8.5-9	8.5-9	08/23/11	0.023 U W	NA	NA	NA	**0.29**	14,000	270 W	6,700	**20,970**
B9-9.5-10	9.5-10	08/23/11	0.0025 U	NA	NA	NA	0.0024	23	1.2 U	12 U	30
B9-10.5-11	10.5-11	08/23/11	0.0030 U	NA	NA	NA	0.025	640	1.5 U	280	921
B9-11-11.5	11-11.5	08/23/11	1.1 W	NA	NA	NA	**0.15 T**	11,000	950 W	4,300	**16,250**
B9-12.5-13	12.5-13	08/23/11	0.0026 U V	NA	NA	NA	0.00065	8.3	1.3 U	13 U	15
B10-0.5-1	0.5-1	08/25/11	0.030 U W	NA	NA	NA	**0.2**	360	15 U W	390	758
B10-1.5-2	1.5-2	08/25/11	0.046 U W	NA	NA	NA	0.018	12	23 U W	62	86
B10-2.5-3	2.5-3	08/25/11	0.030 U W	NA	NA	NA	0.00068 UU	4.1 U	15 U W	27	37
B10-3.5-4	3.5-4	08/25/11	0.0037 U V	NA	NA	NA	0.00072	15	1.8 U V	41	57
B11-4.5-5	4.5-5	08/23/11	0.0027 U	NA	NA	NA	**0.24**	360	1.3 U U	650	1,011
B11-7.5-8	7.5-8	08/23/11	0.25 U W	NA	NA	NA	0.012	24,000 S	240 W	11,000	**35,240**
B11-8.5-9	8.5-9	08/23/11	0.15 U W	NA	NA	NA	0.012	7.5	75 U W	15 U	53
B11-9.5-10	9.5-10	08/23/11	0.0034	NA	NA	NA	**1.6 T**	5.3	1.3 U	12 U	12
B11-10-10.5	10-10.5	08/23/11	0.1 U W	NA	NA	NA	**3.4**	25,000	150 W	12,000	**37,150**
B11-11-11.5	11-11.5	08/23/11	0.0042 U V	NA	NA	NA	0.01	310	2.1 U	150	461
B11-13.5-14	13.5-14	08/23/11	0.002 U	NA	NA	NA	N/A	3.5 U	1 U	12 U	8 UU

TABLE 7
Detention Basin No.2 Investigation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX (mg/kg)				Total cPAHs Adjusted for Toxicity (mg/kg)	Diesel Range Organics (mg/kg)	Gasoline Range Organics (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			B	T	E	X					
Site Soil Remediation Level (REL)/Cleanup Level (CUL) (mg/kg)			**18**	**--**	**--**	**--**	**0.14**	**--**	**--**	**--**	**2975**
B12-0.5-1	0.5-1	08/24/11	0.033 U W	NA	NA	NA	0.0117	140	17 U W	150	299
B12-1-1.5	1-1.5	08/24/11	0.038 U W	NA	NA	NA	0.00072 UU	120	34 W	100	254
B12-2.5-3	2.5-3	08/24/11	0.051 U W	NA	NA	NA	0.079	160	25 U W	75	248
B12-3.5-4	3.5-4	08/24/11	0.0028 U	NA	NA	NA	0.00063	4.1	1.4 U	28	33
B13-4.5-5	4.5-5	08/23/11	0.025 U W	NA	NA	NA	0.0046	11	12 U W	64	81
B13-6-6.5	6-6.5	08/23/11	0.031 U W	NA	NA	NA	0.036	110	15 U W	250	368
B13-7-7.5	7-7.5	08/23/11	0.16 U W	NA	NA	NA	0.054 R	12,000	200 W	7,400 U	**15,900**
B13-9-9.5	9-9.5	08/23/11	0.018	NA	NA	NA	N/A	3.7 U	1.3 U	12 U	9 UU
B13-10-10.5	10-10.5	08/23/11	0.071 U W	NA	NA	NA	0.026	1,300	110 W	740	2,150
B13-11.5-12	11.5-12	08/23/11	0.0056	NA	NA	NA	N/A	4 U	1.4 U	13 U	9 UU
B14-0.5-1	0.5-1	08/25/11	0.11 U W	NA	NA	NA	0.029	16	57 U W	110	155
B14-1.5-2	1.5-2	08/25/11	0.023 U W	NA	NA	NA	N/A	NA	11 U W	NA	6 UU
B14-2.5-3	2.5-3	08/25/11	0.051 U W	NA	NA	NA	N/A	5 U	25 U W	17 U	24 UU
B14-3.5-4	3.5-4	08/25/11	0.058 U W	NA	NA	NA	0.0009	7.4	29 U W	76	98
B15-4.5-5	4.5-5	08/23/11	0.0025 U	NA	NA	NA	0.0005	4.5	1.3 U	17	22
B15-6.5-7	6.5-7	08/23/11	0.0026 U V	NA	NA	NA	N/A	3.6 U	1.3 U	18	20
B15-8.5-9	8.5-9	08/23/11	0.0048 U V	NA	NA	NA	0.0008	7.8	2.4 U	54	63
B15-11-11.5	11-11.5	08/23/11	0.029 U W	NA	NA	NA	N/A	4 U	15 U W	13 U	16 UU
B16-3.5-4	3.5-4	08/24/11	0.023 U W	NA	NA	NA	0.018	100	11 U W	280	386
B16-4-4.5	4-4.5	08/24/11	0.27 U W	NA	NA	NA	**0.1**	280	140 U W	940	1,290
B16-4.5-5	4.5-5	08/24/11	0.0024 U	NA	NA	NA	0.00123	4	1.2 U	12 U	11
B16-6-6.5	6-6.5	08/24/11	0.0031 U	NA	NA	NA	N/A	3.9 U	1.5 U	13 U	9 UU
B17-3.5-4	3.5-4	08/24/11	0.025 U W	NA	NA	NA	0.00109	550	12 U W	1,200	1,756
B17-4-4.5	4-4.5	08/24/11	0.0066	NA	NA	NA	0.0008 UU	14,000	2.3 U	8,200	**22,201**
B17-4.5-5	4.5-5	08/24/11	0.34 U W	NA	NA	NA	**116 R**	55	170	43	268
B17-5.5-6	5.5-6	08/24/11	0.033 U W	NA	NA	NA	N/A	4.3 U	17 U W	14 U	18 UU

TABLE 7
Detention Basin No.2 Investigation Soil Sample Analytical Results
Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

Sample ID	Sample Depth (feet bgs)	Date Sampled	BTEX (mg/kg)				Total cPAHs Adjusted for Toxicity (mg/kg)	Diesel Range Organics (mg/kg)	Gasoline Range Organics (mg/kg)	Heavy Oil (Lube) (mg/kg)	Total TPH (mg/kg)
			B	T	E	X					
Site Soil Remediation Level (REL)/Cleanup Level (CUL) (mg/kg)			**18**	**--**	**--**	**--**	**0.14**	**--**	**--**	**--**	**2975**

Notes:
BTEX analyzed by EPA Method 8021B.
cPAHs analyzed by EPA Method 8270 SIM.
Gasoline analyzed by method NWTPH-G.
Diesel and Heavy Oil (Lube) analyzed by method NWTPH-D Extended.
Total TPH calculated by summing the concentrations of gasoline, diesel and heavy oil. If one or more TPH constituents were reported as Non-Detect, half of the reporting limit value was added to the total.

cPAHs adjusted for toxicity according to WAC 173-340-708(8) and *Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II Technical Support Document for Describing Available Cancer Potency Factors* . Office of Environmental Health Hazard Assessment, California EPA, May 2005. If one or more adjusted cPAH constituents were reported as Non-Detect, half of the reporting limt was used in calculations.
Highlighted cells indicate concentration exceeds REL or CUL.
NA = Indicates analysis not conducted.
[ ] = Bracketed data indicate duplicate sample.

BTEX = Benzene, toluene, ethylbenzene, and total xylenes
EPA = Environmental Protection Agency
mg/kg = Milligrams per kilogram
cPAHs = Carcinogenic polynuclear aromatic hydrocarbons
REL = Remediation level
CUL = Cleanup level
TPH = Total petroleum hydrocarbons

Lab Qualifiers	Definition
J	Indicates an estimated value.
JZ	Detected hydrocarbons in the gasoline range appear to be due to overlap of diesel range hydrocarbons.
R	The GC/MS semivolatile internal standard peak areas were outside of the QC limits for both the initial injection and the re-injection. The values here are from the initial injection of the sample
S	Due to the nature of the sample extrac matrix, the extract could only be concentrated to a final volume of 10ml instead of the usual volume of 5ml. The reporting limits were raised accordingly
T	Reporting limits were raised due to interference from the sample matrix
U	The compound was analyzed for but not detected. The associated value is the compound quantitation limit.
UU	The constituents making up the total are all non-detects.
V	The recovery for the sample surrogate is outside the QC acceptance limits as noted on the QC Summary. A reanalysis was not performed to confirm a matrix effect
W	Reporting limits were raised due to sample foaming
X	The LCS recovery is outside the QC limits. Results from the re-extraction are within the limits. The hold time had expired prior to the re-extraction; therefore, all results are reported from the original extraction. Similar results were obtained in both extracts.
Y	Due to dilution of the sample extract, capric acid recovery could not be determined.
Z	The caprice acid reverse surrogate recovery is 0%

TABLE 8
LNAPL Baildown Test Log
Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

Site Name	Edmonds Terminal	**Test Well ID**	MW-510
Date and Time In	8/24/11 7:30 AM	**Date and Time Out**	8/24/11 3:00 PM
Personnel	Scott Zorn/Seamas McGuire	**Weather**	Sun
Well Construction Details			
Top of Casing Elevation (ft amsl)	12.53	**Screen Slot Size (in)**	0.01
Total Well Depth (ft)	13	**Filter Pack Type**	#2/12 silica
Depth to Top of Screen (ft)	3	**Depth to Bottom of Screen (ft)**	13
Well Casing Diameter (in)	2	**Borehole Diameter (in)**	8
Initial Test Conditions			
Static Depth to LNAPL (ft)	7.06	**Test Date**	8/24/2011
Static Depth to Water (ft)	7.07	**Start Time**	7:45 AM
LNAPL Thickness (ft)	0.01	**Initial LNAPL Volume in Well (gal)**	0.0016
LNAPL Removal Information			
LNAPL Removal Method/Equipment	Bailer	**Time LNAPL Removal Begins**	7:53 AM
Volume of LNAPL Removed (gal)	0.0016	**Time LNAPL Removal is Completed**	7:53 AM
Volume of Groundwater Removed (gal)	0.0044		

Baildown Test Data

Elapsed Time (min)	Time	Depth to LNAPL (ft)	Depth to Water (ft)	Ground Water Elevation (ft)	Tide Elevation (Ft above Mean Lower Low Water)	Observations
2	7:55 AM	7.1	7.1	5.43	0.4264	LNAPL appears to have a darker color and lower viscocity
3	7:56 AM	7.11	7.11	5.42	0.4264	
5	7:58 AM	7.1	7.1	5.43	0.4592	Much darker in color
7	8:00 AM	7.09	7.09	5.44	0.4592	
9	8:02 AM	7.09	7.09	5.44	0.492	
11	8:04 AM	7.09	7.09	5.44	0.492	
13	8:06 AM	7.1	7.1	5.43	0.5248	
15	8:08 AM	7.1	7.1	5.43	0.5248	
22	8:15 AM	7.1	7.1	5.43	0.5904	
25	8:28 AM	7.1	7.11	5.42	0.7544	
30	8:33 AM	--	7.12	5.41	0.8528	
35	8:38 AM	--	7.12	5.41	0.9184	LNAPL on probe - DTP not measured
45	8:48 AM	7.13	7.13	5.4	1.0824	
55	8:58 AM	7.13	7.13	5.4	1.2464	
65	9:08 AM	7.15	7.15	5.38	1.4432	LNAPL on probe - DTP not measured
75	9:18 AM	--	7.15	5.38	1.6728	
85	9:28 AM	--	7.16	5.37	1.9024	Very small amount of LNAPL on probe
95	9:38 AM	--	7.18	5.35	2.1648	No LNAPL on probe
105	9:48 AM	--	7.16	5.37	2.3944	Very small amount on probe
115	9:58 AM	--	7.17	5.36	2.6568	very small amount of LNAPL
125	10:08 AM	--	7.17	5.36	2.9848	Very small amount of LNAPL
135	10:18 AM	--	7.17	5.36	3.2472	Very small amount of LNAPL
145	10:28 AM	--	7.17	5.36	3.5424	Very small amount of LNAPL
155	10:38 AM	--	7.17	5.36	3.8704	Very small amount of LNAPL
165	10:48 AM	--	7.17	5.36	4.1656	Very small amount of LNAPL
175	10:58 AM	7.17	7.17	5.36	4.4936	LNAPL on probe - sheen
185	11:08 AM	--	7.16	5.37	4.7888	Small LNAPL on probe
300	1:03 PM	--	7.05	5.48	8.0688	very small amount on tip
389	2:22 PM	--	6.86	5.67	9.348	very small amount on tip
423	3:14 PM	--	6.79	5.74	9.7088	very small amount on tip

2012 Final Conceptual Site Model

TABLE 7
Sediment Sample Analytical Results - June 2012
Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

				Sample ID	US-100		DUP-1		US-101		US-102	
				Sample Date	7/30/2012		7/30/2012		7/30/2012		7/30/2012	
Chemical	**Units**	**SQS[1]**	**CSL[1]**	**LAET[2]**								
Volatile Organic Compounds												
Benzene	mg/kg	NA	NA	NA	0.002	U	0.001	U	0.004	U	0.003	U
Ethylbenzene	mg/kg	NA	NA	NE	0.004	U	0.003	U	0.009	U	0.005	U
Toluene	mg/kg	NA	NA	NA	0.004	U	0.003	U	0.009	U	0.005	U
Xylene (Total)	mg/kg	NA	NA	NE	0.004	U	0.003	U	0.009	U	0.005	U
Petroleum Hydrocarbons												
GRO	mg/kg	NA	NA	NA	45	U	41	U	140	U	100	U
DRO	mg/kg	NA	NA	NA	7.7	U	11		29		17	
HO	mg/kg	NA	NA	NA	26	U	59		170		110	
Metals												
Arsenic	mg/kg	57	93	130	8.53		6.87		29.1		20.2	
Copper	mg/kg	390	390	390	5.7		5.05		43.6		21.6	
Lead	mg/kg	450	530	430	11.2		10		107		60.6	
Zinc	mg/kg	410	960	460	51.5		41.4		319		144	
Conventionals												
TOC	mg/kg	NA	NA	NA	19200		18800		64700		65200	
TOC	%	NA	NA	NA	2		2		6		7	
Moisture	%	NA	NA	NA	60.8		60.2		83.6		77.5	
Ammonia-Nitrogen	mg/kg	NA	NA	NA	148		163		863		402	
PAHs[3]												
Acenaphthene	mg/kg	16	57	0.13	0.27	U	0.27	U	0.012	U	0.0089	U
Acenaphthylene	mg/kg	66	66	0.07	0.57		0.34		0.014		0.013	
Anthracene	mg/kg	220	1200	0.28	0.45		0.39		0.034		0.023	
Benzo(a)anthracene	mg/kg	110	270	0.96	0.63		0.64		0.16		0.061	
Benzo(a)pyrene	mg/kg	99	210	1.10	0.68		0.69		0.22		0.084	
Benzo(b)fluoranthene	mg/kg	NA	NA	NA	1.15		1.22		0.42		0.15	
Benzo(g,h,i)perylene	mg/kg	31	78	0.67	0.89		0.69		0.19		0.067	
Benzo(k)fluoranthene	mg/kg	NA	NA	NA	0.36		0.44		0.14		0.06	
Chrysene	mg/kg	110	460	0.95	0.94		1.01		0.28		0.11	
Dibenz(a,h)anthracene	mg/kg	12	33	0.23	0.27	U	0.27	U	0.042		0.015	
Fluoranthene	mg/kg	160	1200	1.30	2.40		2.29		0.46		0.21	
Fluorene	mg/kg	23	79	0.12	0.45		0.53		0.059		0.028	
Indeno(1,2,3-cd)pyrene	mg/kg	34	88	0.60	0.68		0.53		0.17		0.057	
Naphthalene	mg/kg	99	170	0.23	2.92		1.38		0.052		0.059	
Phenanthrene	mg/kg	100	480	0.66	2.29		1.91		0.18		0.11	
Pyrene	mg/kg	1000	1400	2.40	2.34		2.18		0.44		0.19	
Total LPAH[4]	mg/kg	370	780	1200	6.68		4.55		0.34		0.23	
Total HPAH[5]	mg/kg	960	5300	7900	10.05		9.69		2.52		1.00	

Notes:
PAH = Polycyclic aromatic hydrocarbons
LPAH = low molecular weight PAH
HPAH = high molecular weight PAH
SQS = Sediment Quality Standards
CSL = Cleanup Screening Levels
NA = Not applicable
NE= Not evaluated because these analytes do not have SQS or CSL.
U = Indicates the value was below the Method Detection Limit.

1. SQS and CSL from Chapter 173-204 WAC Sediment Management Standards. PAH results for US-100 and DUP-1 are organic carbon normalized.
2. LAET from Puget Sound Dredged Disposal Analysis. 1996. Progress Re-evaluation Puget Sound Apparent Effects Thresholds (AETs). LAET value is the lowest concentration of the echinoderm, microtox, and oyster AETs from Table 9.
3. Samples US-100 and DUP-1 required normalization as TOC fell in the range of 0.2 to 4%. PAH values were normalized by dividing the original concentration by the TOC percentage expressed as a decimal.
4. Total LPAH is the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene. Non-detect values are treated as zero in the summation.
5. Total HPAH is the sum of fluoranthene, pyrene, benz(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene. Non-detect values are treated as zero in the
6. US-100 and DUP-1 were compared to SQS and CSL screening criteria and US-101 and US-102 were compared to LAET based on TOC concentrations and Ecology guidance (Washington Department of Ecology. 1992 and 1993. Organic Carbon Normalization of Sediment Data)
7. All results are reported on a dry weight basis except as indicated in footnote 3.

ARCADIS

Appendix B

Soil Vapor Sampling Procedures

ARCADIS

Chevron - Soil Vapor and
Indoor Air Sampling Technical
Toolkit (v1.8)

Soil Vapor & Indoor Air Sampling Technical Toolkit

Version 1.8

This work was funded by Chevron Environmental Management Company and performed by Chevron Energy Technology Company, Health, Environment and Safety Group, Environmental Unit.

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Environmental Unit
Health, Environment and Safety Department
Chevron Energy Technology Company

March 20, 2013

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1 INTRODUCTION

The Chevron (CVX) Soil Vapor Sampling Technical Toolkit provides technical guidance to suppliers conducting vapor migration pathway (VIP) investigations at petroleum hydrocarbon contaminated sites. The toolkit is a collation of identified "best practices" in planning and conducting soil vapor surveys. Maintaining consistency in best practices across the Chevron portfolio is a primary driver for this toolkit, as this will enhance the defensibility of the soil vapor data gathered at these sites. The toolkit is intended to remain "evergreen": that is, as new best practices are developed, the toolkit will be edited to incorporate those developments. In this manner the most up-to-date technologies and methods can be implemented in the field.

The toolkit is primarily focused on petroleum hydrocarbon impacted sites; that is, sites where biodegradation of vapor phase contaminants can play a role in attenuation. However, many elements of the toolkit can also be applied at sites where biodegradation of vapor phase contaminants is unlikely to occur (e.g., chlorinated solvent contaminated sites). The toolkit is organized into sections focusing on soil vapor sampling probes, soil vapor sampling, analytical techniques, and data reporting. Diagrams are included to provide further description of the processes and equipment discussed. Further technical information and advice is available by contacting the Chevron Energy Technology Co. VIP Team members:

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2 SOIL VAPOR PROBE INSTALLATION

All standard protocols required before initiating any drilling activities (e.g., regulatory permits, underground utility markings, clearances from overhead lines etc.) need to be followed when preparing the site for installation of soil vapor probes.

2.1 Permanent vs. Temporary Probes

Permanent soil vapor sampling probes are required for soil vapor surveys conducted for human health risk assessment to ensure that samples from a given location can be collected repeatedly. **Chevron recommends permanent probes to increase the accuracy and technical defensibility of samples used to assess human health risk.** Temporary probes (which are sampled only once) are suitable only for non-human health risk assessment soil vapor samples, such as in support of delineation of a vapor phase contaminant plume.

Permanent probes also facilitate repeated sampling rounds if this is deemed necessary to represent soil vapor concentrations during different seasons, during high and low water table conditions, or during periods of frozen ground. If a sample is only taken once at a particular point, the result could be misleading due to variable water table elevations, and the variation of NAPL/air interaction that comes with these seasonal changes.

2.2 Borehole Clearance

The use of air knife for borehole clearance is not recommended for direct emplacement of soil vapor sampling points at shallow depths (e.g., 5 ft). This is because air knife utilizes high pressure air and is expected to significantly disturb the soil vapor profile around the installation, and it could take weeks to months for the profile to re-equilibrate (API 2005). Instead, hand auguring is preferred for installing soil vapor sampling points at a shallow depth of 5 ft.

Air knife borehole clearance (typically performed to a depth of 8 ft) is acceptable for installation of deeper soil vapor sampling points (10 ft deep or greater). Following the borehole clearance, these deeper points could be installed using either direct push or hollow stem auger methods.

2.3 Water Table Elevation and Soil Vapor Sampling Probe Depth

Prior to installing permanent soil vapor probes it is critical to review the historical range of site groundwater elevation data to determine the proper depth for probe installation. Soil vapor sampling probes should ideally be installed so that the vapor sampling screen is situated 2 to 3 ft above the historical high groundwater elevation, which will reduce the likelihood that the probe will be submerged during periods of elevated groundwater, and will enable the probe to sample that interval of the subsurface with the potentially highest soil vapor volatile organic compound (VOC) concentrations.

The US EPA and most state regulatory guidance require a minimum of 5 ft depth for the shallowest soil vapor sampling probes. For sites with shallow water tables (high water table elevation is within 5-7 ft of the surface) it is acceptable to place the soil vapor sampling probe at a depth of 5 ft, even though this depth may cause the point to be submerged, or occluded with water from the capillary fringe during certain portions of the season. **Placing soil vapor sampling points at depths less than 5 ft. should be performed only on an exception basis and with approval of Chevron Project Manager**. **When approval has been granted to install a soil vapor sampling point shallower than 5 ft, it is critical to take extra care to ensure there are no leaks due to potential short-circuiting from the surface.**

2.4 Single vs. Multilevel Soil Vapor Sampling

Chevron recommends installation of multilevel probes in order to understand the source of soil vapors (impacted vadose zone soil vs. impacted groundwater) and to qualitatively evaluate the depth and degree of biodegradation of soil vapors in the vadose zone (using concentration versus depth profiles of VOCs, methane, oxygen and carbon dioxide). In addition, several VI guidance documents (e.g., CA DTSC, 2011) recommend multilevel probe installation, with the sample containing the highest concentration (regardless of depth) used for comparison to Tier I screening tables.

EPA and most state regulatory guidance documents state that soil vapor samples used for vapor intrusion screening should not be collected shallower than 5 ft depth. Agency guidance states that this is intended to minimize the potential for short-circuiting of atmospheric air into soil vapor samples. **See section 2.3 for sites where depth to groundwater is about 5 ft or less from the ground surface or less**. The deepest probe should be installed 2 to 3 ft above the historical high groundwater elevation, with shallower probes installed at defined intervals above the deepest probe (e.g., 5 ft intervals). For example, at a site where the seasonal high groundwater elevation is 18 ft below grade, probes could be emplaced at depths of 15, 10, and 5 ft below grade.

2.5 Soil Vapor Probe Installation using Hollow-stem Augers

A conventional drill rig equipped with a hollow-stem auger should be used for permanent soil vapor probe installation. Use of methods such as rotosonic, air rotary, or mud rotary drilling methods can influence soil vapor sample results and/or alter the physical properties of the subsurface adjacent to the sampling probe, although they may be necessary due to stratigraphic limitations (e.g., cobbles). **If rotosonic, air rotary, or mud rotary drilling methods are deemed necessary they should be utilized only on an exception basis and with approval of the Chevron Project Manager**.

2.5.1 Soil Sample Collection

During drilling, soil cores should be collected for lithologic and stratigraphic description, and, **if required by CEMC project managers, for evaluation of soil porosity and moisture content (ASTM D2216) for potential vapor transport modeling**. Soil samples should be collected and preserved for off-site chemical and physical analyses. Sampling interval selection is site specific, based on stratigraphic heterogeneity and Chevron recommends continuous logging and taking soil sample at each lithology or planned screen interval. Chemical analyses are chosen based on the site contaminants, but typically would include TPHg and TPHd (EPA 8015B) and BTEX (EPA 8260B) for gasoline release sites. Undisturbed soil samples should be collected in stainless steel or brass liners and capped with Teflon® sheeting and plastic end caps and placed in re-sealable plastic bags. The liners should then be stored in iced coolers and transported to a certified laboratory under chain-of-custody documentation.

2.5.2 Soil Vapor Sampling Probe Construction

After the borehole is drilled to its maximum depth, the deepest soil vapor sampling probe is installed (Figure 1). Each sampling probe tip should be approximately 6 inches long, and of small diameter (¼-inch is typical) to minimize dead space within the probe. Screens constructed of stainless steel and PVC are acceptable, Each 6-inch-long screen tip is vertically centered in a 1-ft long interval containing standard sand pack, resulting in 3 inches of sand being above and below each screen. It is important to correctly size the sand pack for the probe screen diameter. Each sand pack is covered with a 1 ft interval of dry granular bentonite, which is then covered with ≥ 2 ft of hydrated granular bentonite slurry to the bottom of the next sand pack (i.e., the next sampling interval). The dry granular bentonite is emplaced immediately above the sand pack to ensure that hydrated granular bentonite slurry does not flow down to the probe screen and seal it off from the adjacent soil. Following the emplacement of 1 ft of dry granular bentonite immediately

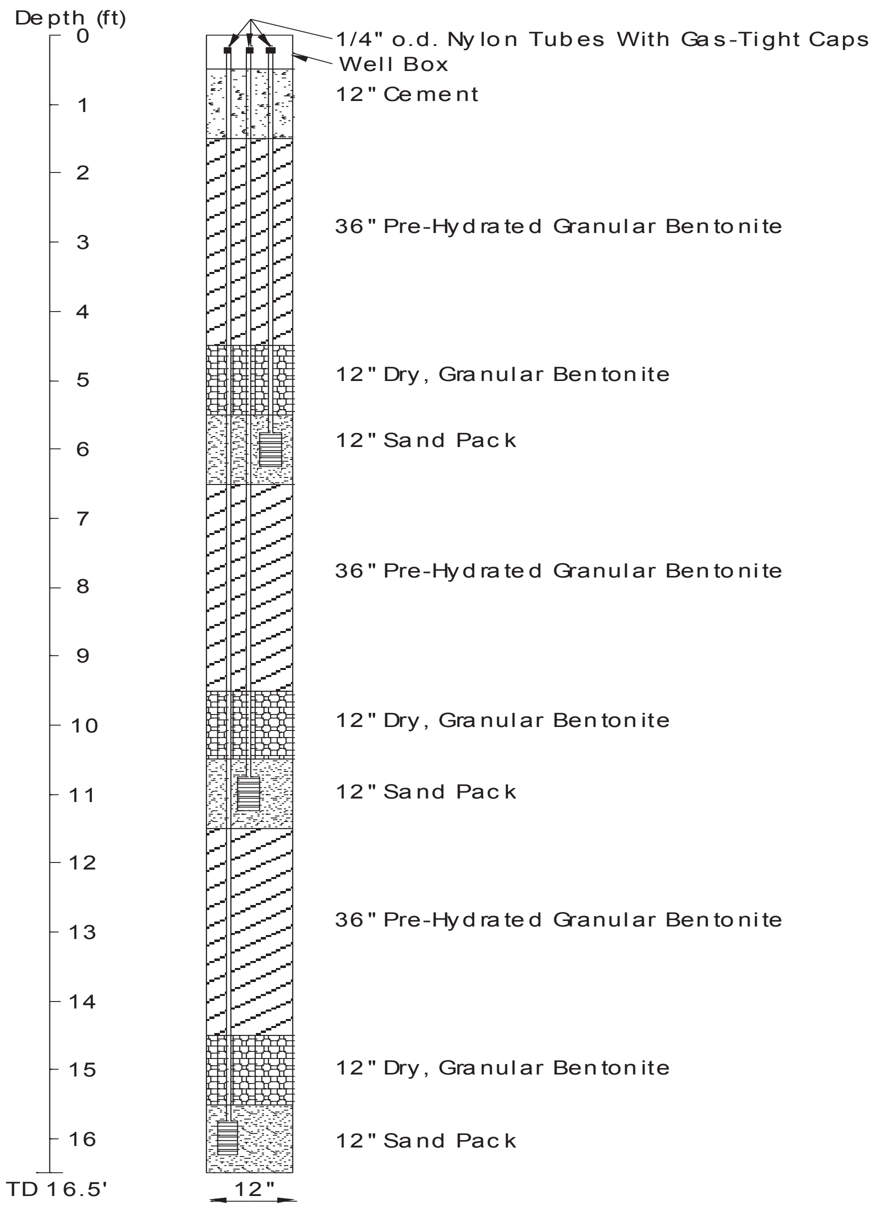

Figure 1. Augered, permanent multilevel soil vapor sampling probe (by Chuck Zuspan, ETC)

above the uppermost sampling interval (sand pack), the remainder of the borehole should be filled with hydrated granular bentonite slurry (mixed at the surface and poured in) and, at the top, a 1-ft cement cap. A flush-mounted, locked utility vault of sufficient size to contain the tubing lines should be set in the cement cap.

Probes should have screen and end caps fitted with a Swagelok® fitting connected to the upper end cap. Use chromatography-grade 316 stainless steel compression fittings to ensure that fitting materials are not a source of VOCs. Tubing should be ¼-inch outer diameter Teflon® or Nylon or stainless steel. Hose clamps, push-on barbed fittings, and other types of connectors should be avoided as they may not provide an air-tight seal. Two studies have been done to evaluate different types of tubing. Air Toxics (Hayes et. al, 2006) conducted tests of three tubing types (Teflon®, nylon, PEEK) that showed little difference in the tubing type with respect to cleanliness and inertness to the chemicals tested. Low-level blanks were detected in nylon, but the values were far below required soil-gas risk-based screening levels. An earlier study presented at a conference in 2004 (Ouellette, 2004) compared the adsorption of a hydrocarbon standard by five tubing types (Teflon®, nylon, polyethylene, vinyl and flexible Tygon®). Nylon and Teflon® showed insignificant adsorption (<10%), but the others showed higher adsorption, especially the flexible tubing, where losses of the tested hydrocarbon standard were up to 80 percent. **For this reason, flexible tubing materials such as Polyethylene, vinyl and Tygon® are not acceptable for use at Chevron sites**.

Also very important is where the tubing is stored and how it is handled. Any type of tubing will become contaminated and contribute to false positives if it is stored near volatile chemicals. For this reason, all tubing should be new, carefully stored, and blank tested (see QA/QC section).

Each of the tubing lines must be clearly and permanently marked at the land surface to denote its corresponding screened interval. Do not use markers. Each tube must be fitted with a gas-tight, Swagelok® valve or cap at the ground surface to eliminate the potential for atmospheric air getting into the tubing. If a cap is used, it must be removed before sampling, which creates an opportunity for atmospheric air entry to the probe, so the period between removing the cap and assembling the sampling train should be as brief as possible and purging (discussed later in this toolkit) is required before sampling.

2.6 Soil Vapor Sampling using Direct-push Techniques

Single or multilevel soil vapor sampling can be performed with a direct-push rig (e.g., Geoprobe®) in certain soil type (e.g. non-clayey soil). These rigs can install permanent soil vapor sampling probes, or can be used to collect soil vapor data during a direct-push where no permanent probe is installed. **Chevron requires human health risk assessments to be performed with data collected from permanent soil vapor sampling probes** but soil vapor samples collected from tubing during a single push (temporary direct-push, e.g. Post-Run Tubing System) can be useful to delineate areas of elevated soil vapor concentrations, and can help identify location and depth of permanent soil vapor sampling probes if needed (but not for human health risk assessment).

2.6.1 Temporary Direct-Push Soil Vapor Sampling (Post-Run Tubing System)

Soil vapor surveys using direct push techniques (non-permanent installations) are sometimes useful in determining the depth and extent of localized petroleum hydrocarbon vapors, especially when sourced from residual soil contamination in the vadose zone.

Once delineated, these data can be used to determine the location of permanently installed sampling probes for human health risk assessment.

Temporary direct-push soil vapor concentration data does not represent the most technically defensible sampling available, since it is difficult to insure that samples from temporary direct-push probes have not leaked to the surface (which might yield false-negative data), and the technique precludes collection of multiple samples over time to verify the presence or absence of temporal variation. **As a result, use of temporary direct-push soil vapor sample data in assessing human health risk should only be considered on an exception basis and with approval of Chevron Project Manager.**

The Post-Run Tubing (PRT) system involves the use of a drive point holder (located just above the drive point) that also serves as the soil vapor sampling probe (Figure 2). Both expendable and retrievable drive point/drive point holder systems are available. The PRT system allows for soil vapor samples to be obtained from multiple depths from a single borehole during a single sampling event. First, the drill rods and drive point/drive point holder are pushed to the shallowest designated depth. Then, an adapter connected to Teflon® or nylon (Nylaflow®) sampling tubing that extends to the ground surface is attached to the drive point holder. Leakage of atmospheric air through the drive rods into the drive point holder (the vapor sampling probe) is prevented by o-rings that are part of the adaptor assembly. After obtaining a soil vapor sample (described in Section 3), the adaptor/tubing assembly is removed, and the tubing is discarded. The drive point/drive point holder is then pushed deeper into the subsurface until the next designated sampling depth is reached. The adaptor/tubing assembly, with a new piece of tubing attached, is then connected to the drive point holder and the soil vapor sampling process is repeated. This process can be repeated over multiple depths, but if lower concentrations exist beneath high concentrations, the samples in the deeper interval may have a positive bias. With the expendable PRT system, the drive point/drive point holder assembly remains in the subsurface when the rods are withdrawn, while for the retrievable PRT system the entire apparatus is removed.

There is no sand pack or hydrated bentonite seal needed in the borehole annulus. However, there is potential for cross-contamination resulting from contaminants being pushed downward by the drilling rods. Avoid lateral movement of the drive rods during the push and sampling processes, and if the probe is deflected by cobbles, or wavering of the rig, it is preferable to remove the probe, and retry to obtain a linear unwavering entry to avoid leakage along the outer wall of the casing. To avoid potential surface leakage due to these difficulties, a surface seal of hydrated granular bentonite is recommended with the PRT system.

2.6.2 Permanent Direct-push Soil Vapor Sampling Probes

Direct-push techniques to install permanent soil vapor sampling probes involves use of a truck-mounted hydraulic ram to push hollow metal rods equipped with a drive point to a designated depth. Table 1 describes the advantages and disadvantages of using direct push techniques over hollow-stem auger for installing soil vapor probes.

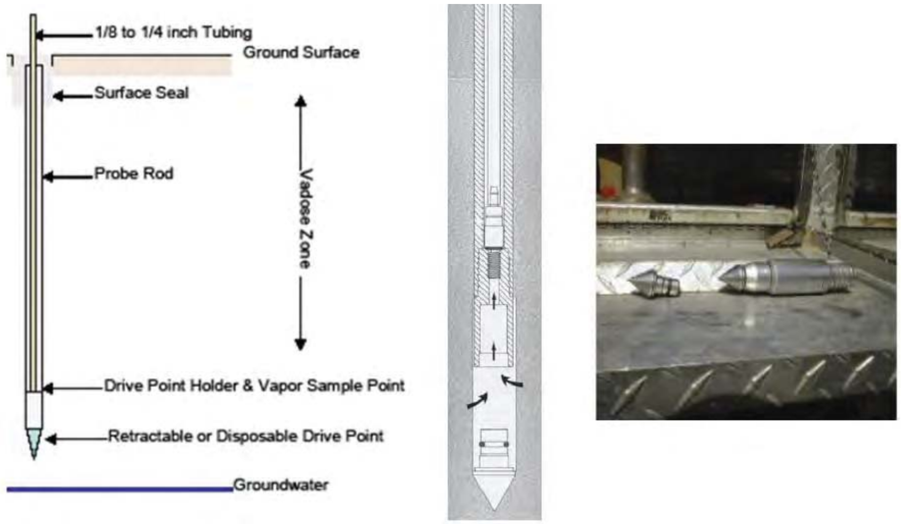

Figure 2. Direct-push soil vapor sampling probe (PRT; Geoprobe ®)

Pro Direct Push	Con Direct Push
• Usually quicker and cheaper to install and cause less disruption to subsurface, therefore requires far less equilibration time prior to sampling. • Optimal for shallow-depth (up to about 20 ft), or in conjunction with an on-site, mobile laboratory enabling real-time adjustments to the sampling program. • Allows soil vapor sample collection very close to the building minimizing concern about interpolation or extrapolation of data to conditions beneath the building	• Multi-level sampling requires larger footprint. • Likely to fail in some lithologies (e.g. soil with cobbles, calcified sediments etc). • Difficult to obtain soil samples for chemical and physical analyses. • Difficult to install sand packs and bentonite seals through direct push rods.

Table 1. Pros and Cons for direct-push technique over hollow-stem auger for probe installation.

The soil vapor sampling probes consist of an implant of tubular stainless steel screen with a length of 6 inches, outer diameter of ¼ inch, and typically a pore size of 0.0057 inches. Note that the implant is not retrievable and at site closure must be abandoned in place. The implant is connected to a Teflon® or nylon (Nylaflow®) sampling tube of sufficient length to reach the ground surface. A direct-push rig (i.e., Geoprobe®) is used to push a series of drive rods to a designated depth. When this depth is reached, the implant is slid down the bore of the drive rods and is attached to the drive point at the bottom. Then the drive rods are removed, leaving the implant and drive point in the subsurface (Figure 3).

As the drive rods are removed the borehole may collapse around the sampling probe. Also, as the drive rods are removed a sand pack can be installed around the implant, followed by a hydrated granular bentonite seal extending to the ground surface. A surface seal of hydrated granular bentonite is applied where the drive rods meet the ground surface.

One of the potential drawbacks of soil vapor sampling probe implants is the difficulty in installing a sand pack and hydrated granular bentonite seal through the drive rods as they are removed from the borehole. As a result, lateral movement of the sampling tubes and drive rods should be avoided to prevent atmospheric air from entering the soil vapor sample. Soil vapor probes installed using direct push technique as described above are acceptable for human health risk assessment.

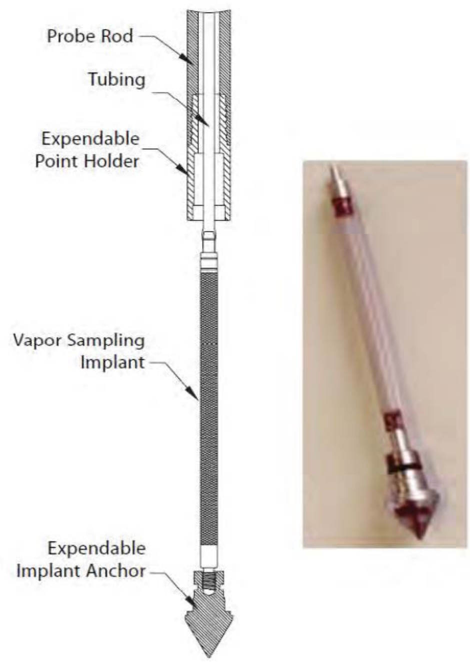

Figure 3. Direct-push soil vapor sampling probe (implant type; Geoprobe®).

3 NEAR-SLAB SOIL VAPOR SAMPLING

The proper collection of near-slab soil vapor samples is a critical step in producing reliable concentration data. A number of factors are important in ensuring the reliability of the data; each is discussed below. Note that some regulatory agencies have specific guidelines for soil vapor collection that may differ from those within the Chevron Sampling Toolkit. **Where possible, Chevron recommends following the Sampling Toolkit protocols unless specifically directed to do otherwise by local agencies.**

Prior to beginning a near-slab soil vapor sampling program, it is important to obtain the correct sampling equipment and to write a site-specific sampling plan. Written documentation of the equipment used and the sampling processes employed is critical.

Consistency in equipment and sampling processes between probe locations and between multiple sampling events is important in order to minimize potential discrepancies in soil vapor concentration data.

Chevron recommends that near-slab soil vapor probes be installed at a minimum two depths (when possible based on depth to groundwater) at each sampling location: one at a shallow depth (i.e. near ground surface, e.g. 5 ft bgs) and one at a deeper depth (i.e. close to groundwater capillary fringe). This is to help identify the likely source of soil vapors (from the groundwater or from contaminated soils in the vadose zone). Also, given the typical screening rationale for near slab soil vapor sampling, in general Chevron recommends conducting one round of near-slab soil vapor sampling (unless there is significant groundwater fluctuation at the site).

3.1 Sampling Equipment

Numerous types and combinations of tubing, connectors, valves, and pumps have been used for soil vapor sampling. The tubing, gauges, and pump (if any) should be connected by tubing that is flexible, air-tight, and has a low capacity for adsorption of VOC's. **Teflon® or Nylon tubing (marketed under the NylaFlow® name) with ¼-" OD is recommended. Tygon®, rubber, and Polyethylene tubing should not be used. Swagelok® type connectors/fittings (Figure 4) should be used for all connections between tubing and other sampling components to ensure that fitting materials are not a source of VOCs.** These connectors are air-tight and reliable. Hose clamps, push-on barbed fittings, and other types of connectors should be avoided as they may not provide an air-tight seal. The lack of an air-tight seal can allow air to enter the sample, thus diluting the vapor concentrations and compromising the integrity of the sample. Leak testing (discussed in Section 3.4) is used to ensure the integrity of soil vapor samples.

A vacuum must be created in order to draw the soil vapor to the ground surface. The vacuum can be created by a battery powered pump, a syringe, or a sampling container that is under a vacuum (such as a Summa™ canister, discussed below). **If a pump is used, it is important to ensure that the sample collection point is on the intake side of the pump.** This will prevent any contaminants present in the pump from being drawn

Figure 4. Swagelok® connectors (image from equipsales.com)

into the vapor sample. A typical soil vapor sampling train using a helium shroud (for leak detection) and a flow-calibrated pump (for purging) is shown in Figure 5.

Although a number of sampling containers have been used for soil vapor sample collection, including Summa™ canisters, Tedlar® bags, Cali-5-Bond® bags, syringes, and sorbent sampling tubes, at Chevron sites, **Summa™ canisters (Figure 6) are required for soil vapor samples, for they provide samples with the highest possible integrity when collected using the appropriate sampling protocol.** Tedlar® bags are not recommended, primarily because of the concerns about integrity of soil vapor samples beyond a holding time of 48 hours as well as presence of trace levels of VOCs in new Tedlar bags (Hartman, 2006). Soil vapor samples can be collected in syringes for on-site soil vapor analyses *only* where the sample is immediately injected into a gas chromatograph (GC).

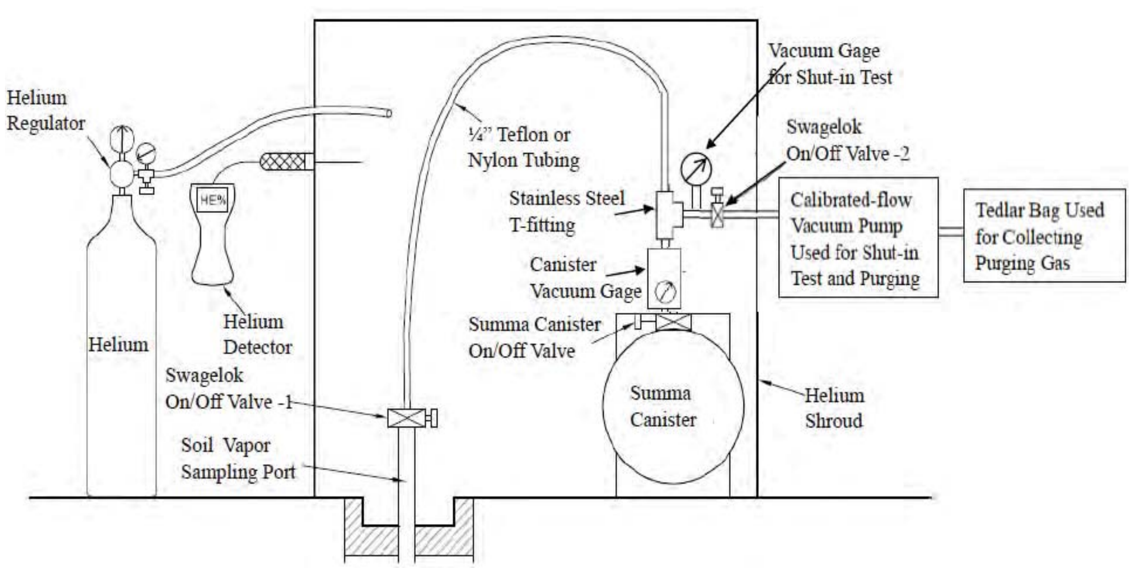

Figure 5. Picture of a sampling system for soil gas sampling train leak test, soil gas purging and sampling (Adapted from ARCADIS)

A Summa™ canister is a stainless steel, gas-tight, opaque and laboratory-certified clean sample container with a passivated internal surface. The passivation process utilizes electro polishing and chemical deactivation to create a chemically inert surface. Containers range in size from < 1 L to 15 L and are provided by the analytical laboratory. Canisters are typically certified clean at the 10 % level (i.e. every one out of 10 canisters is certified after cleaning) or at the 100 % level (i.e. every canister is certified after cleaning). The cleaning process is the same for both certification levels and utilizes dilution, heat, and high vacuum. The certification process utilizes EPA Method TO-15 (GC/MS) to ensure that VOC concentrations are <1 ppb_v. **It is acceptable to use canisters certified at the 10% level for soil vapor sampling activities. However, the use of 100 % certified canisters is required for sub-slab soil vapor, indoor air and ambient air sampling in order to minimize potential interferences in analyzing low**

VOC concentrations for human health risk assessment. The required size of the canister depends upon the laboratory's capabilities. **Before ordering canisters, contact the laboratory to inquire about what size canisters are required to meet the reporting levels necessary to meet site data quality objectives.**

After cleaning, the canister is evacuated until a vacuum of 29.9 in Hg is obtained. The canister will hold a vacuum of greater than 25 in Hg for more than 30 days. The maximum holding time for canisters following sample collection varies from state to state. Check the locally applicable regulations to determine the maximum holding time for the site in question. As discussed below, the soil vapor sample flows into the canister due to the pressure gradient between the vadose zone and the canister. A flow controller/particulate filter, provided by the laboratory, controls the vapor flow rate into the canister. Be aware that the flow controller may be defective and it is best practice to have some extra available.

Figure 6. 6 L Summa^{TM} canister with ¼" stainless steel bellows valve (image from Air Toxics Ltd.)

Regardless of the design of the sampling equipment, there are a number of important topics to address in order to obtain reliable soil vapor concentration data. These topics are discussed below.

3.2 Field Activities Prior to Sampling/Documentation

Written documentation of field conditions during sampling is required. This includes weather conditions (temperature, barometric pressure, wind direction and speed, humidity, degree of cloud cover); surface soil conditions (presence of standing water, wet soil, irrigation activities, etc.) and groundwater elevations. Some agencies are concerned that the rain will affect the validity of the sample (> 0.5 inch precipitation during 24-hour period as in California EPA, 2012). Under wet soil conditions, one should follow the state soil vapor sampling guidance for detailed requirements on soil gas sampling or consult with Chevron project manager if no such state guidance exists. Maintain detailed field records of all activities, conditions, and sampling processes, including names of field personnel, dates and times, etc. It is important to maintain consistency in sampling activities between sampling events (e.g., purging volume and purge rate, sampling volume, leak testing methods, equipment used). Carefully plan all sampling activities to maintain consistency between sampling events and to avoid errors that can affect soil vapor concentrations.

3.3 Equilibration Time

The installation of soil vapor sampling probes can introduce oxygen into anaerobic portions of the vadose zone. An equilibration time is required to account for the effects of soil vapor probe installation; this allows for equilibration of vapor component concentrations between the probe and subsurface (API 2005). Soil vapor samples should not be obtained until after the equilibration time is reached. **Probes installed using hollow stem or hand auger methods should be allowed at least 48 hours of equilibration time while probes installed using direct-push techniques should be allowed at least two hours of equilibrium time (California EPA, 2012).**

3.4 Evaluating Leaks in Sampling Train

Leakage of atmospheric air into the sampling equipment during sampling can compromise sample integrity and dilute measured soil vapor hydrocarbon concentrations, possibly to the point of an incorrect decision such as failing to identify a concentration of concern (i.e., a "false negative"). Contaminants in ambient air can also enter the sampling system and be interpreted as originating from diffusive transport from a subsurface source (i.e., a "false positive"). Air leakage can occur at the land surface into the probe and, more typically, through loose fittings in the above-ground sampling equipment.

Leakage of air into the below-ground sampling system is unlikely if the probe has been properly constructed and a proper bentonite or concrete surface seal (described earlier) has been emplaced. Temporary (direct-push) probes are most susceptible to leakage around the rods. Sub-slab soil vapor sampling probes also are susceptible to leakage of indoor air due to the difficulties of ensuring a proper seal between stainless steel probe and slab concrete. Sampling equipment must be thoroughly inspected to ensure tight fittings between all components. Be aware that leakage locations may not be obvious. Elevated O_2 concentrations in samples from deeper depths in multi-level probes may be indicative of leakage, but in some cases this alone would not provide definitive evidence for leakage. If O_2 concentrations remain high with increasing depth and petroleum hydrocarbon concentrations are also high, this is evidence that leakage is likely to be occuring. **To minimize the potential for leakage, the soil vapor sampling rate should be kept at < 200 mL/min per EPA guidance (Section 3.6).** Repair or replacement of the sampling probe may be necessary if it is determined that leakage through the probe is occurring. Refer to state or regional guidance to determine if a prescribed course of action applies for probe replacement.

After the soil vapor sampling ports and probes are constructed and installed and soil vapor has equilibrated, leaks in the sampling train should be tested, including a complete shut-in test and system leak test.

3.4.1 Shut-in Test

After the soil vapor probe construction, soil vapor sampling probe installation, and sufficient time for the soil vapor to reach equilibrium, a shut-in test should be conducted to check for leaks in the above-ground sampling system. The equipment set-up for shut-in test is also shown in Figure 5. In this case, the helium shroud and the Tedlar bag may not be needed. To conduct a shut-in test, assemble the above-ground valves, lines and fittings downstream from the top of the probe as shown in Figure 5. The Swagelok valve-1 and Summa Canister valve are kept closed, evacuate the system to a minimum measured vacuum of about 100 inches of water using a purge pump and close Swagelok valve-2. Observe the vacuum gauge connected to the system with a "T"-fitting for at least one minute or longer. If there is any observable loss of vacuum, adjust the fittings until the vacuum in the sample train does not noticeably dissipate. After the shut-in test is validated, the sampling train should not be altered. The vacuum gauge should be calibrated and sensitive enough to indicate a water pressure change of 0.5 inches. If the shut-in test failed, then specific measures are needed such as tightening all the fittings and repeating the test until it is validated before proceeding to the next test.

3.4.2 Leak Test

3.4.2.1 Leak test tracer

A tracer is used to test for an ambient air leakage into the sampling system. Numerous tracer compounds have been referenced in regulatory and industry guidance documents, including isopropanol, isobutene, propane, butane, helium, and sulphur hexaflouride. **Chevron does not recommend use of isopropanol** because, due to its high vapor pressure, even a small leak will result in laboratory dilutions that will compromise the data quality objectives (i.e. reporting limits higher than screening levels). **Chevron does not recommend use of isobutene, propane, or butane** as leak detection tracers because their purity cannot be easily verified, resulting in a likelihood of low level impurities such as BTEX compounds. **Chevron does not recommend use of sulphur hexaflouride** because it has a very high greenhouse gas potential, and therefore difficult to acquire and use as a tracer compound. **Chevron does not recommend use of Freon** because it is not possible to determine the degree of leakage that has taken place and there is a possibility that Freon is present in the soil gas due to ubiquitous use of Freon as coolant for air conditioning units. **Chevron recommends use of laboratory grade helium as a leak detection tracer gas where practical to do so, based on accessibility.** Helium is readily available, has low toxicity, does not disrupt analytical measurements, will not be found at fuel contaminated sites, and has a high purity. Small volume bottles of helium can be purchased at party stores but contain industrial grade helium, which may contain organic compounds as impurities. **Lab grade helium is recommended**, and will require time for the sampling crew to acquire through the analytical laboratory or an alternate source. A possible drawback of helium is that its small molecular size may cause it to permeate the sampling materials more readily than larger VOC molecules (Hartman, 2006). Of all the tracer compounds described in various regulatory guidance documents, only the leak detection method using helium gas provides a quantitative estimate of leakage rate. **If lab-grade helium supply is scarce (as has been recently reported), Chevron recommends using 1,1-difluroethane (1,1-DFA) as an alternative leak tracer gas, with prior concurrence from EMC project manager and ETC.**

Small amounts of sample train leakage may be permissible, subject to regulatory standards and analytical limits applicable to the site. **For sites located in California, Chevron follows the CAEPA guidance (CAEPA, 2012) and recommends a maximum leak percentage of 5% be used to determine sample validity. For sites located outside California, Chevron recommends a maximum leak percentage of 10% be used to determine sample validity**. This is consistent with the VI guidance in New Jersey (NJDEP 2012). The presence of any leakage should be recorded, as should all techniques used in the leak testing process. Maintain consistency of the leak testing process over multiple sampling events.

Where multi-level soil vapor probes are intended to acquire soil vapor concentrations to be used either as a basis for an attenuation factor screening step, or as a source term for Johnson & Ettinger modeling, leakage of as much as 10% may allow back calculation of an adjusted soil vapor concentration. However, this may not be possible if the overall compounds of interest concentrations are low, and the reporting limits have been increased above acceptable screening values due to the necessity to dilute the sample to avoid loading the GC column with tracer gas. In such cases, the probes must be re-sampled.

3.4.2.2 Leak test using helium as a tracer

The New York State Department of Health (NYSDOH, 2006) has prepared guidance for using helium as a tracer gas, suggests construction of a shroud around the sampling probe but not the sampling train. To test the integrity of the whole sampling train, **Chevron recommends building a shroud to cover the entire sampling train (probe to Summa canister) in order to detect possible leaks in all fittings and tubing of the sampling system (Figure 5 and Figure 7).** This enables detection of helium ingress into the sampling train and can be used to estimate the leakage rate as shown at the end of this section. The shroud should be filled with helium before purging the sampling point. It is important to ensure that the pressure in the shroud is close to atmospheric pressure, so that normal sampling conditions exist (NYSDOH, 2006). **Introducing helium from a pressurized cylinder for several seconds will generally be sufficient to create concentrations in the shroud up to 10% by volume or higher. The helium concentration in the shroud should be monitored and maintained relatively stable at the target concentration, i.e. 10% or higher (CAEPA, 2012) during the course of soil vapor sampling.** This can be done with a helium detector connected to a port on the shroud. Portable detectors are available for rental. It is required that the selected portable detector have a minimum helium detection limit of 0.5% by volume.

The following guidance on constructing the helium shroud is adapted from the EPRI Reference Handbook for Site-Specific Assessment of Subsurface Vapor Intrusion to Indoor Air (EPRI, 2005). The shroud can be in the form of a clear plastic container (e.g. large Tupperware™ or Rubbermaid® container or a tent made of clear plastic sheet large enough to surround the soil vapor probe and valves and fittings at the top of the probe as in Figure 5 and Figure 7. The shroud will typically have three ports, one for helium addition, one port for monitoring helium concentration inside the shroud and another port for the ¼-inch Nylon tubing coming out of the shroud for the vacuum pump located outside the shroud.

Chevron recommends using one Summa canister under a helium shroud for leak-test (helium checking in the soil gas sample) and soil vapor sampling (chemical analysis in the soil vapor sample) simultaneously. A separate Summa Canister is not needed for leak-test. Figure 5 illustrates conducting a simultaneous leak-test and soil vapor sampling from a sub-slab soil vapor sampling point. In this case, the Tedlar bag may not needed and the Swagelok valve 2 remains closed. Turn on the Summa canister valve to collect a soil vapor sample for analysis of helium and chemicals in the lab. To access the sampling train, the shroud can be lifted and the canister valves opened. The shroud can then be placed back again on the ground/floor and filled with helium within a half-minute or less. The samples typically take at least 5 minutes to fill, so the first few seconds of no helium in the shroud is not problematic as long as the helium concentration in the shroud is maintained relatively stable at the target concentration.

The analytical laboratory should be notified that helium is to be used as a leak detection tracer prior to sampling. The integrity of the soil vapor samples can be assessed by estimating the % leakage as follows.

$$\%leakage = \frac{\text{helium concentration in the soil vapor sample (ug/m}^3\text{)}}{\text{average helium concentration measured inside the shroud (ug/m}^3\text{)}} \times 100$$

3.5 Purging

The US EPA conducted a comparison of chlorinated hydrocarbon soil vapor concentrations collected utilizing a broad range of purge volumes (0.5 to 100L) at a site with relatively coarse-grained soils and found no significant differences based on the purge volumes (DiGiulio et al 2006b). McAlary and Creamer (2006) performed similar experiments at a Chevron research site for high concentration petroleum hydrocarbon vapors and also observed no effect in sample concentration as a function of purge volume. While it is not clear to what degree purging may affect sample concentration, all regulatory guidance requires stagnant air in the sampling tubes be removed prior to sample collection. This is believed to ensure that the soil vapor sample is representative of actual soil vapor concentrations.

Field notes containing information about the above-ground sampling equipment and below-ground tubing length and inner diameter should be used to calculate the "dead volume" to be purged. The "dead volume" should also include the borehole sand pack. The volume of a sample container, such as a Summa™ canister (which is not used during purging), should not be included in this calculation. **Check to make sure that all connections, fittings, etc. are tightly fit in the sampling equipment prior to purging**.

Figure 7. Helium shroud used for leak-testing soil vapor sampling train.

Figure 5 also shows the equipment set-up recommended by Chevron when purging a soil vapor sampling port. In some cases, the regulatory agency requires one to develop the number of purging volumes. In that case, as shown in Figure 5, a battery powered, flow-calibrated pump and a Tedlar bag can be used to purge the system and determine the number of required purge volumes. The purging gas collected by the Tedlar bag is analyzed on site for chemical concentrations till the concentrations become stabilized. From the volume of gas purged which is measured by the flow-calibrated pump, the number of purging volume can be determined and recorded and then the soil vapor sampling can proceed. If the number of purging volumes is not required, Tedlar bag only serves as a collector of purging gas to protect the environment from potential adverse impact from the contaminants in the soil vapor.

The maximum flow rate for purging should not exceed the flow rate limit used for subsequent sampling (< 200 mL/min). Guidance documents from different agencies recommend different purge volumes, ranging from 1 to 10 purge volumes (CSDDEH, 2002; API, 2004, CAEPA, 2012). **Chevron recommends that 3 volumes be purged unless otherwise required by applicable guidance.** The purge test data (calculated purge volume, purging rate, and duration of purging) should be recorded for each soil vapor sampling point. It is important to ensure that the same purge volumes and rates are used at a given probe for each sampling event.

For fine-grained soils large sample volumes are often not possible or difficult to collect. Also, if large sample volumes are attempted, the chances of leakage in the sampling train increase. A larger sample volume also increases the uncertainty about the location of soil vapor sampled. Given these uncertainties, it is best to minimize the "dead volume" that needs to be purged in the sampling train.

3.6 Sample collection

There are numerous combinations of tubing, connectors, pumps, and sampling containers that have been used for soil vapor sample collection. As noted above, the design of the sampling equipment should be such that the dead volume is minimized in order to keep the necessary purge volume small. In all cases, a vacuum is used to draw soil vapor from the subsurface to the sample container. Note that equipment must be decontaminated prior to sampling, shut-in test should be performed before purging and sampling, and leak-testing should be performed during the sampling process. An example of the equipment arrangement used for soil vapor purging (with a flow-calibrated pump) and sampling (with Summa™ canister) is shown previously in Figure 5. In Figure 5, to collect a sample, Swagelok valve 1 and the Summa canister valve should be open and Swagelok valve 2 should be closed. The soil vapor sample collected will be analyzed for helium (for leak test), COCs and fixed gases.

The exact procedure used in obtaining a soil vapor sample will vary as a function of the equipment used, but the following considerations are important to ensure that a high quality sample is collected.

3.6.1 Vacuum And Flow Rate Considerations

The vacuum and resulting sampling flow rate should be minimized in order to limit enhanced volatilization of VOCs from water and soil into the soil vapor sample. Consistency in vacuum and sample flow rates should be maintained between sampling probes and over multiple sampling events. The vacuum and flow rate should be documented in the field notes. A flow rate between 100 ml/min and 200 ml/min and a vacuum less than 100 inches of water (approx. 7.3 in Hg at 4^{o}C) should be maintained during purging and sampling (California EPA, 2012).

The Summa™ canister system utilizes a flow controller to control the flow rate. The flow controller contains a critical orifice flow restrictor intended to maintain a relatively constant flow rate over a 0.5 to 8 hour period, even though the vacuum in the canister is decreasing over that time (which would otherwise cause the flow rate to concurrently decrease). A vacuum gauge is built in to the flow controller to monitor sampling progress. The laboratory (e.g., Eurofins Air Toxics Inc.) sets up the flow controller for the flow rate specified. Table 2 shows the range of flow rates for given sampling time intervals. A particulate filter is built into the flow controller device which serves to prevent particulates from fouling the flow controller or entering the Summa™ canister. The recommended sampling time interval for soil vapor samples is approximately 30 minutes, but in any case the flow rate should not exceed 200 mL/min.

Sampling Interval (hrs)	0.5	1	2	4	8	12	24
6 L Canister	167	83.3	41.7	20.8	11.5	7.6	3.5
1 L Canister	26.6	13.3	6.7				

Table 2. Flow rates (mL/min) for given sampling time intervals using the flow controller (from Eurofins Air Toxics Inc.)

3.6.2 Other Sampling Considerations

Once the above listed topics have been addressed, after making certain that all connections between the Summa™ canister, flow controller, and all other portions of the sampling equipment are tight, and arrangements have been made with the analytical laboratory regarding sample shipment and analysis, soil vapor sampling can commence. Sampling of all probes should preferably be completed within a one day time period, with a maximum collection period of one week. Sample collection from a purged soil vapor probe should begin as soon as possible once purging is completed. Leak-testing should be performed concurrently with sampling as described above. To begin sampling, open the valve on the Summa™ canister. As the canister fills, observe the vacuum gauge on the flow controller to ensure that the vacuum in the canister is decreasing over time. If the flow controller is working correctly, the planned sampling completion time will be reached when the canister vacuum has decreased to 5 in Hg. Note that low permeability soils characterized by low soil vapor flow rates may require sampling to cease before the canister vacuum has decreased to 5 in Hg.

Quality control (QC) of soil vapor samples must be addressed through the collection of equipment blanks and field duplicates. An equipment blank should be collected at the site during sampling activities by collecting a sample of clean air or nitrogen through the probe materials before installation in the ground. Analysis of the equipment blank can provide information on the cleanliness of new materials and/or the effectiveness of decontamination procedures used in the field. Clean stainless steel, Nylon or Teflon® tubing and a certified regulator should be used. Only 100% certified canisters (the sample canister and the source canister/cylinder, if applicable) should be used to collect equipment blank. **Trip blanks were previously recommended, however with the use of 100% certified Summa™ canisters, trip blanks are not necessary**.

At least one duplicate sample should be obtained each day of sampling, or from at least 10 % of the samples obtained. A duplicate sample should be collected by using a splitter (such as a T fitting) located between the flow controller and sample canisters, with separate sampling tubes connecting the splitter to two Summa™ canisters as shown in Figure 8. The flow controller must be set such that the flow rate from the sampling probe is < 200 mL/min; this will double the required sampling time since two canisters are being filled simultaneously.

After sample collection, canisters must not be chilled since contaminants may condense in the canister at low temperatures. Make certain that all samples are correctly and clearly labeled. Follow standard chain-of-custody procedures, including noting the final canister vacuum and serial numbers of the canisters and flow controllers. The laboratory checks the vacuum on receipt to ensure that there were no leaks during shipment. See Section 3.1 for canister maximum holding time information. Document all procedures, sampling times, conditions, problems, etc

If the initial assessment of subsurface soil vapors indicates potential for vapor intrusion to indoor air, further characterization will usually require entry into the affected building(s) to conduct sub-slab vapor sampling and concurrent indoor and ambient outdoor air sampling as described in the following sections. EMC environmental attorneys will be able to help in getting the necessary access agreements before these sampling activities commence.

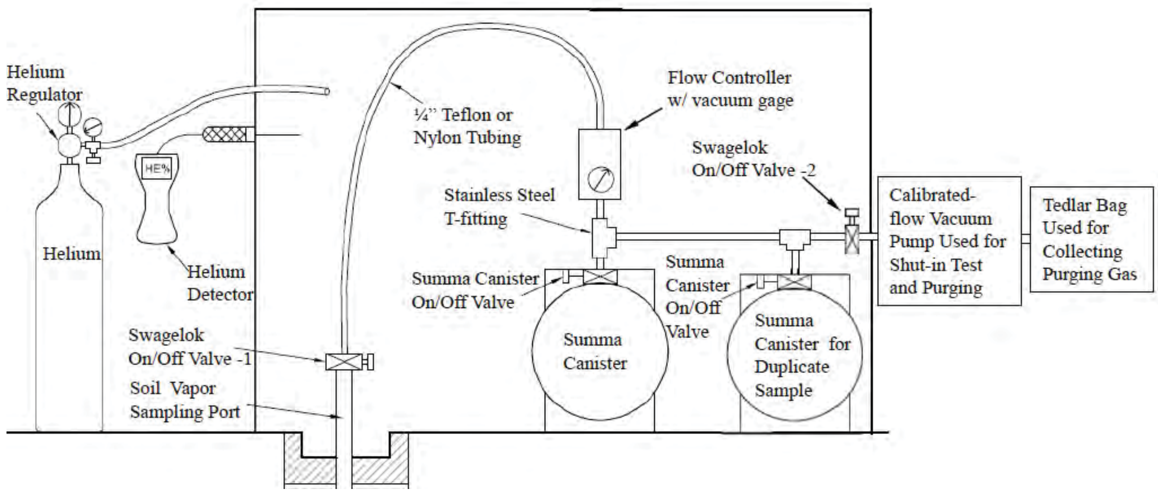

Figure 8. Soil vapor sampling train using two Summa canisters for a sample and a duplicate sample (Adapted from ENSR)

4 SUB-SLAB VAPOR SAMPLING

4.1 Sub-slab soil vapor probe installation

Sub-slab vapor sampling probes allow for collection of soil vapor data from directly beneath the slab from a layer of granular fill material that is highly permeable and well-drained for structural purposes. These samples are useful to evaluate a possible relationship to indoor air samples and are recommended if indoor sampling is deemed necessary. It is critical to obtain building construction details as much as possible (i.e., slab thickness, depth and type, presence of vapor barrier, location of utility trenching etc) to appropriately locate sub-slab vapor sampling locations. **Sub-slab sampling may not be possible when groundwater or a partially saturated capillary fringe is present directly below the slab.** Do not drill through the slab if it is suspected that the penetration could allow groundwater to enter the building during high water table conditions. Also, it is important to determine prior to drilling if the slab has a vapor barrier; if so, **make sure the vapor barrier is not punctuated during the drilling**. **Drilling through tension slabs is not recommended.** Tension slabs contain embedded steel cables that have been pulled tight after the concrete has cured. The tension in the cables strengthens the slab and helps prevent cracking. The slab can be damaged if a cable is cut during drilling.

Petroleum hydrocarbons are amenable to aerobic biodegradation. Therefore, a conservative approach supports obtaining soil vapor samples at the center of the slab where lowest oxygen concentrations in soil are likely to occur (California EPA 2011) and away from utility conduits,. **At least two probes should be placed, for foundation area**

up to 5000 ft^2 with one located in the center of the slab, and the other in the likely direction of potential subsurface impacts, (California EPA, 2005, 2011). US EPA recommends several probes for single-family dwellings to assess spatial variability (e.g., 3 to 5; DiGiulio, 2006a).

Prior to drilling holes in a slab, identify and mark utilities coming into the building from the outside (e.g., gas, water, sewer, electrical lines) and determine any internal locations where utilities penetrate the slab (e.g., furnace, water heater, circuit breaker box, water or sewer lines). **Avoid installing sub-slab monitoring points where the utilities penetrate the slab as these may be potential entry points for downward oxygen migration through the slab. Also, avoid installing sub-slab points along straight-line points where utility trenches may have been installed beneath the slab during building construction.**

Prior to fabrication of sub-slab vapor probes, remove carpeting from the drilling location, if present. This can be done by cutting a small ½ inch square flap that can be glued back down after the probe is installed. Obtain any available information (e.g., from the owner, construction plans) to determine the thickness of the slab. **Do not drill a pilot hole to assess the thickness of a slab.** As illustrated in Figure 9, use a rotary hammer drill to create a "shallow" (e.g., 2.5 cm or 1 inch deep) "outer" hole (e.g., 2.2 cm or 7/8 inch diameter) that partially penetrates the slab. Do not completely penetrate the slab with the shallow hole. Use a small portable vacuum cleaner to remove cuttings from the hole. Removal of cuttings in this manner in a non-penetrated slab will not compromise soil vapor samples because of lack of pneumatic communication between sub-slab material and the vacuum cleaner.

Next, use the rotary hammer drill to create a smaller diameter "inner" hole (e.g., 0.8 cm or 5/16 inch diameter) through the remainder of the slab and some depth (e.g., 7 to 8 cm or 3 inch) into sub-slab material. Drilling into sub-slab material will create an open cavity which will prevent obstruction of probes by small pieces of gravel.

The basic design of a sub-slab vapor probe is illustrated in Figure 10. Once the thickness of the slab is known, tubing should be cut to ensure that the probe tubing does not reach the bottom of the hole (to avoid obstruction of the probe with sub-slab material). **Chevron prefer use of stainless steel tubing materials although recent data comparing the performance of Teflon® and Nylon tubing with stainless steel tubing suggest that it would be appropriate to use these materials for constructing the sub-slab vapor probes too (Hartman 2008).** An advantage in using Nylon and Teflon® tubing is that there will likely be fewer sealing difficulties between the probe and concrete. If using stainless steel, construct sub-slab vapor probes from small diameter (e.g., 0.64 cm or ¼ inch outer diameter (OD) x 0.46 cm or 0.18 inch inner diameter (ID)) chromatography grade 316 stainless steel tubing and stainless-steel compression to thread fittings (e.g., 0.64 cm or ¼ inch OD x 0.32 cm or ⅛ inch (ID) Swagelok® or NPT female thread connectors) as illustrated in Figure 10. **Use stainless-steel to ensure that construction materials are not a source of VOCs.** Brass fittings (tubing, nipples and couplings) readily available at hardware stores are machined using cutting oils and could be a potential source of trace level VOCs and as such are not recommended to be used for constructing sub-slab vapor probes. In addition, use of Teflon® tape is recommended on any NPT threaded joints to ensure a good seal and to reduce the torque needed install and remove the probe plug, thus reducing the stress on the cement bond.

Set the sub-slab vapor probe in the hole. As illustrated in Figure 10, the top of the probe should be completed flush with the slab and have recessed stainless steel plugs so as not interfere with day-to-day use of the building. **The seal between the stainless steel sub-slab probe and the concrete floor is a common source of leakage.** Modeling clay or cement is typically used for surface seals. Unfortunately, there are few sealants that are non-adsorptive, do not give off vapors, and adhere well to both concrete and metal surfaces. Hydrating (swelling) cement adheres reasonably well to concrete, but not as well to metal tubing, so it is not unusual for the tubing to spin while fittings are being attached. Attaching all fittings before the probe is installed may minimize stresses on the seal. Mix a quick-drying Portland cement which is "VOC free" with water (e.g. hydro-cement available at building supply stores) which expands upon drying to ensure a tight seal) to form a slurry, Inject or push the slurry into the annular space between the probe and outside of the "outer" hole. Allow the cement to cure for at least 24 hours prior to sampling.

4.2 Sub-slab soil vapor sampling train tests, purging and sampling

After sub-slab soil vapor sampling probes are installed and soil vapor reaches equilibrium, a shut-in test should be done before purging and sampling. The procedures of shut-in test and leak test while sampling are the same as described in section 3 and as shown in Figure 5 and Figure 7.

After shut-in test, the probe is ready for purging and sampling. Please refer to section 3 for procedures of purging and sampling. **For sub-slab soil vapor sampling, 1 L 100 % certified Summa™ canisters are preferred in order to minimize the volume of soil vapor collected.** Collecting a smaller sub-slab sample will minimize the duration of inconvenience to the building occupants by minimizing the amount of time the helium shroud has to be monitored.

5 INDOOR AND AMBIENT (OUTDOOR) AIR SAMPLING

In some situations, it may be necessary to conduct indoor air and ambient air sampling to assess the potential for vapor intrusion to indoor air from subsurface contamination. **It is recommended to collect these concurrently with the sub-slab soil vapor samples.** Indoor air samples may contain BTEX and other VOCs within the concentration ranges commonly seen as background values measured at sites where no subsurface petroleum hydrocarbon contamination is known to be present. Unfortunately, these background VOC concentrations are also within (or even greater than) the range of risk-based concentrations (RBC) assuming a cancer risk range of 1E-06 to 1E-04 or hazard quotient of 1 (Figure 11, from Dawson & McAlary, 2009). There are many sources of background contamination inside buildings. Materials and substances commonly found in commercial and residential settings, such as paints, paint thinners, gasoline-powered machinery, building materials, cleaning products, dry cleaned clothing, and cigarette smoke, can potentially contribute to VOC detections in indoor air testing. Table 3 shows a list of common household petroleum – related VOC sources (NJDEP 2005). In urban areas, outdoor air also often contains background concentrations of VOCs that exceed

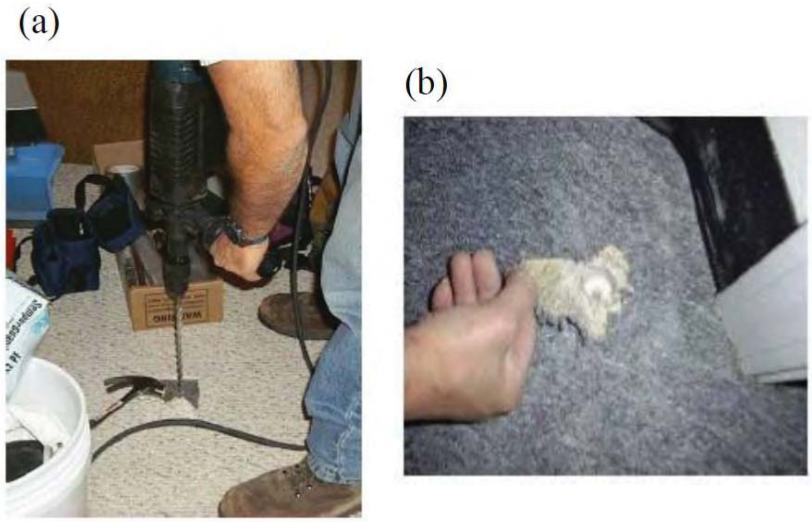

Figure 9. (a)Drilling through a slab, and (b) inner and outer holes (EPA).

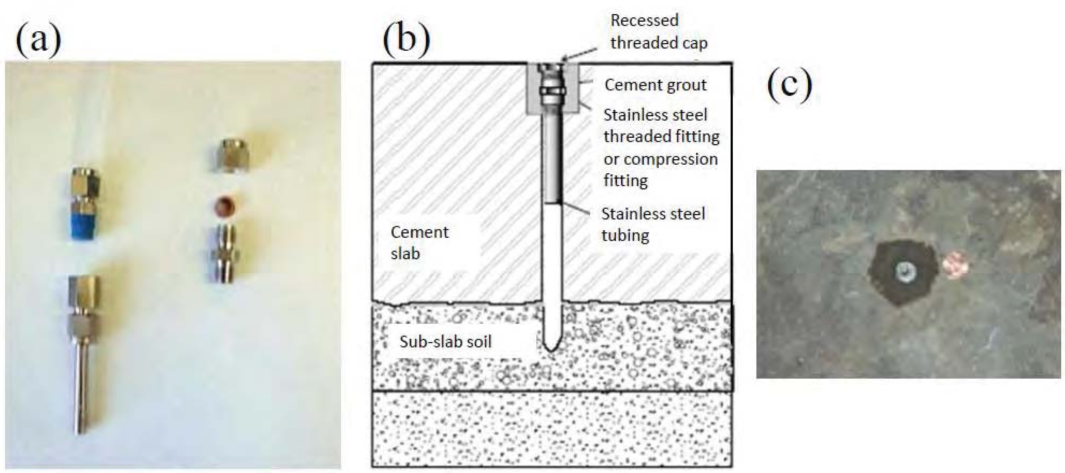

Figure 10. (a) Stainless steel sub-slab vapor probe components; (b) general schematic of sub-slab vapor probe and (c) completed sub-slab vapor probe. (EPA)

risk-based indoor air target levels. **Therefore, outdoor ambient air samples should be collected whenever indoor air samples are collected to characterize the contribution from outdoor air.** It is not recommended to collect indoor air samples from buildings outside the assessed footprint of VOCs in the subsurface in an attempt to characterize the contribution from indoor sources, because consumer products, building materials and occupant habits vary from building to building.

5.1 Indoor Air Sampling

Given the multitude of sources for VOCs in indoor air and that for some VOCs, the background indoor air concentrations could exceed the risk-based concentrations, it is critical to carefully plan any sampling event. Specifically for benzene in urban environments, indoor air sampling is not considered to be a first choice assessment option for residential structures unless the State has raised the acceptable indoor air benzene values above ambient levels. **This toolkit makes recommendations on the key elements of the plan. The project team should also consult appropriate state guidance for detailed information on indoor air sampling strategies, building inspection/surveys and household products inventory forms** (e.g., NYSDOH 2005, 2006, MADEP 2002, California EPA 2011, ITRC 2007).

Indoor air sampling may require multiple visits to the subject building(s). A pre-sampling site visit should be arranged at least 24 hours in advance of the sampling (NYSDOH 2005, MADEP 2002, California EPA 2011). This is used to interview the occupants and doing a building survey to gather the following information.

- Contact information for the occupants and owner
- Type of building construction
- Foundation characteristics
- Heating, Ventilating and Air Conditioning (HVAC) system details
- Water wells and sewage disposal

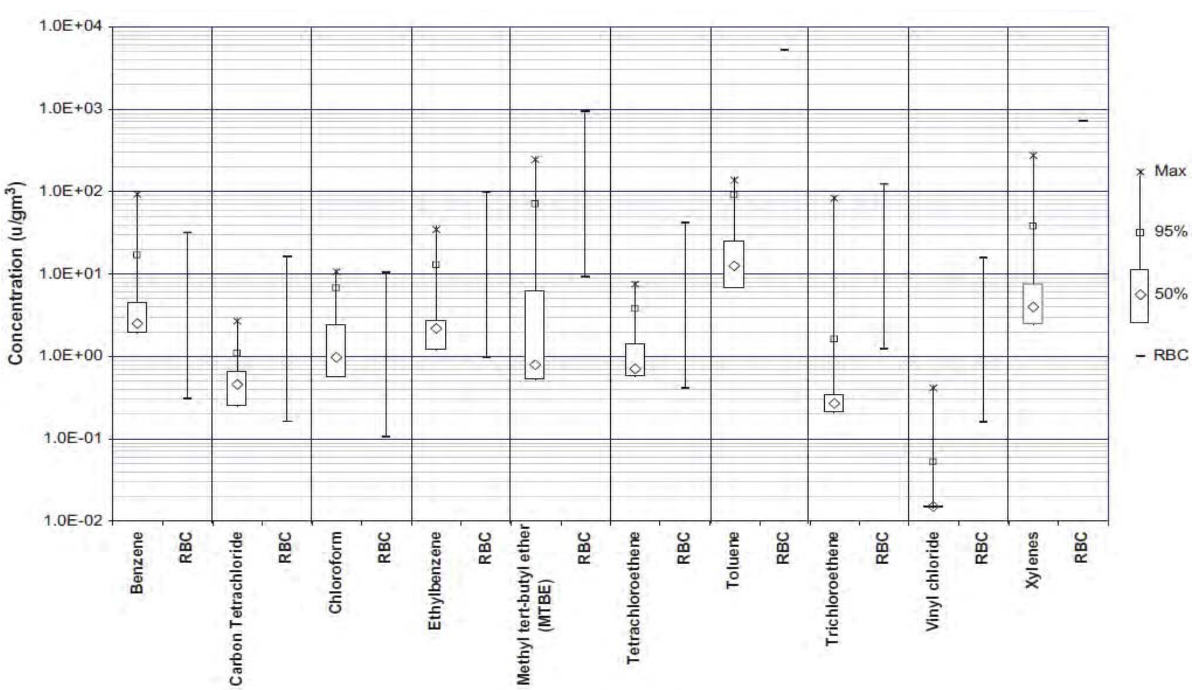

Figure 11. VOC concentrations in background indoor air compared to RBC.

- Potential indoor sources of VOC vapors, particularly those containing hydrocarbons, such as fuels, combustion products, cleaners, solvents and lubricants containing petroleum distillates and tobacco products. It is advisable to remove consumer products that contain VOCs or SVOCs from the building and any attached garage or shed at the time of the pre-sampling survey. Any unavoidable exceptions should be documented (including appropriate photographs) and highlighted with the results of the indoor air analysis.
- Plan view showing the sampling location(s) and pertinent information on floor layout including chemical storage areas, garages, doorways, stairways, basement sumps, plumbing and electrical conduits, elevator shafts etc.
- Potential outdoor sources of VOCs in ambient outdoor air. This will include a diagram of the area surrounding the building(s) being sampled showing potential sources such as service stations, repair shops, retail shops, landfills etc.

Indoor air sampling should be done in an environment that is representative of normal building use. Heating and air conditioning systems should be operated normally for the season and time of day. **Use 6 L 100% certified Summa™ canisters placed in the center of the room on the lowest floor at 3 to 5 ft above floor level to provide a sample representative of the breathing zone.** In order to mimic the anticipated daily exposure by inhalation, the **sampling duration for commercial/industrial buildings is 8 hours and for residential building is 24 hours (California EPA 2011).** Upon deployment of the sampling equipment, the Building Survey Form is updated to include the location of the sampling equipment, time, date, identification number, and environmental conditions.

As far as possible, the following activities should be avoided during the indoor air sampling event. Any unavoidable exceptions should be documented and highlighted with the results of the indoor air analysis:

- Allowing containers of gasoline or oil within the building or garage area, except for heating fuel oil tanks.
- Cleaning, waxing or polishing of furniture or floors (if cleaning is needed, use water only).
- Smoking cigars, cigarettes or pipes.
- Using air fresheners or odor eliminators.
- Using materials containing VOCs (dry markers, white out, glues, etc.).
- Using cosmetics including hairspray, nail polish, nail polish removers, perfume, and cologne.
- Applying pesticides.

5.2 Outdoor Ambient Air Sampling

Chevron recommends collecting ambient air samples at the same time the indoor air samples are collected. This will provide information about outside influences on indoor air quality. The outdoor ambient air sample will identify vapors from automotive fuels and exhaust, point sources such as gasoline stations, stack emissions and possible unique situations (paving crews, forest fires etc). **Use 6 L 100% certified Summa canisters**

placed 3-5 ft above grade at an upwind location protected from the elements (wind, rain, snow or ice) on the upwind side of the building (5-15 ft away). It is recommended that ambient air sampling begin at least 1 hour prior to indoor air sampling and should continue at least 30 minutes prior to the end of the indoor air sampling period.

6 ANALYTICAL TECHNIQUES

The analytical methods used are specific to the components analyzed and the reporting limits required to meet the data quality objectives. For example, reporting limits for fixed gases such as O_2, CO_2, N_2, and CH_4 of about 1% v/v are sufficient for interpretation; whereas VOCs such as benzene often have target concentrations in the low µg/m^3 range or lower, although this varies considerably between States. **Analytical reporting limits for indoor air samples should be lower than the risk-based target indoor air concentration, unless it is technically impracticable.** Analytical reporting limits for soil vapor samples could be higher because soil vapor concentrations attenuate upon entry to indoor air to varying degree. These could be estimated as a ratio of the indoor air target concentration to a conservative attenuation factor for the location of soil vapor sample (e.g., 1 for crawl space, 0.05 for sub-slab vapor and 0.002 for a deeper soil vapor sample in CAEPA 2011 VI guidance). Confer with the laboratory and applicable guidance to ensure that the necessary detection limits are met.

Before sampling and analysis begins, refer to applicable state and/or regional guidance and regulations to ensure that all requirements are complied with in sampling and analysis, including the number of analytes, analytical methods, reporting limits, and any requirement for state certification of the analytical laboratory. Maintain consistency of analytical methods between sampling events, as this can help reduce uncertainties in data results and interpretation. Table 4 provides a summary of required analytes for different samples and recommended analytical methods used for several common analytes during vapor intrusion investigations (adapted from API 2005).

Prior to sampling and analysis, the specific chemical components of concern at the site should be identified. These components commonly consist of the VOCs and SVOCs that have been identified as chemicals of interest at the site. In addition, some regulatory agencies have specified which chemicals of interest must be included in the list of analytes.

Prior to analysis, it is important to verify that a calibration for the chemicals of interest, or at a minimum calibration for the classes of chemicals of interest, has been developed. The mass spectrometer (MS) yields different response factors for different classes of compounds. **The tracer compound (helium) used during leak testing should also be included in the list of laboratory analyses for soil vapor samples. A laboratory-modified version of ASTM method D1946 may be needed because helium is not listed as an analyte in the method.** The analytical method used should be capable of quantifying these components at a concentration such that the subsurface vapor to indoor air exposure pathway can be adequately evaluated.

Chemical	Common Household Sources
Acetone	Rubber cement, cleaning fluids, scented candles and nail polish remover
Benzene	Automobile exhaust, gasoline, cigarette smoke, scented candles, scatter rugs and carpet glue
1,3-Butadiene	Automobile exhaust and residential wood combustion
2-Butanone (MEK)	Automobile exhaust, printing inks, fragrance/flavoring agent in candy and perfume, paint, glue, cleaning agents and cigarette smoke
Ethylbenzene	Paint, paint thinners, insecticides, wood office furniture, scented candles and gasoline
Formaldehyde	Building materials (particle board), furniture, insulation and cigarette smoke
n-Heptane	Gasoline, nail polishes, wood office furniture and petroleum products
n- Hexane	Gasoline, rubber cement, typing correction fluid and aerosols in perfumes
Methyl isobutyl ketone (MIBK)	Paints, varnishes, dry cleaning preparations, naturally found in oranges, grapes and vinegar
Methyl tert butyl ether (MTBE)	Gasoline (oxygenating agent)
Naphthalene	Cigarette smoke, automobile exhaust, residential wood combustion, insecticides and moth balls
Styrene	Cigarette smoke, automobile exhaust, fiberglass, rubber and epoxy adhesives, occurs naturally in various fruits, vegetables, nuts and meats
Tertiary butyl alcohol (TBA)	Gasoline (oxygenating agent)
Toluene	Gasoline, automobile exhaust, polishes, nail polish, synthetic fragrances, paint, scented candles, paint thinner, adhesives and cigarette smoke
1, 2, 4-Trimethylbenzene	Gasoline and automobile exhaust
1, 3, 5–Trimethylbenzene	Gasoline and automobile exhaust
2 ,2, 4-Trimethylpentane	Gasoline and automobile exhaust
Xylenes, total	Water sealer, gasoline, automobile exhaust, markers, paint, floor polish and cigarette smoke

Table 3 Common household sources of petroleum hydrocarbons in background indoor air (Adapted from NJDEP, 2005)

6.1 VOCs/SVOCs

Gas chromatography/mass spectrometer (GC/MS) methods are recommended for all VOC and SVOC analyses. In the past we have recommended using EPA method TO-15 for analyzing VOC and SVOC concentrations in all types of VI investigations, however, a number of studies (Hayes et al 2005, Picker 2005 and Digiulio et al 2006a) have compared analytical results using methods TO-15 and 8260B. These data indicate that both give equivalent results down to levels as low as 10 $\mu g/m^3$. TO methods and hardware are designed for measuring low VOC levels in ambient air and not for high concentrations likely to be seen in soil vapor samples (which can exceed 100000 $\mu g/m^3$). **It is recommended that method 8260B be used for analyzing soil vapor samples and TO-15 be used for analyzing sub-slab vapor, indoor air and outdoor ambient air samples.** High concentrations in soil vapor samples can lead to system carryover, large dilutions and contaminated Summa™ canisters increasing the potential for false positives, elevated reporting levels and problems associated with managing canisters (Hartman 2006).

Naphthalene must be analyzed in all cases, and when using TO-15 (for sub-slab vapor, indoor air or outdoor ambient air), the laboratory must be notified of this request prior to ordering the Summa™ canisters from the laboratory. In method

(a)

Sample Matrix	Indoor air	Outdoor air	Sub-slab soil vapor	Near-slab soil vapor
Analyte Required	All COCs no fixed gases	All COCs no fixed gases	All COCs and fixed gases	All COCs and fixed gases

(b)

Analytical Methods Recommended for Some Analytes		
Anayltes	**Field Method**	**Fixed Lab Method**
BTEX	Method 8260	Method 8260 or TO-15
TPH	Method 8015	Method 8015 or TO-15
Naphthalene	N/A	TO-15 and/or TO-17
O_2	Field meter w/ galvanic electrochemical cell (BP 1998)	EPA Method 3C or ASTM Method D1946
CO_2	Field meter w/ Infrared analyzer (BP 1998)	
CH_4	Field meter (CRWQCB)	
Helium	Field meter (Mark Model 9821 Helium Detector)	

Table 4 **(a) Required analytes for different samples and (b) recommended analytical methods used for several common analytes (Adapted from API 2005).**

TO-15 the detector (i.e. MS) can be operated in either the full scan mode (for standard method detection limit of 1 to 5 $\mu g/m^3$), or selected ion monitoring (SIM) mode to improve the method detection limit (< 1 $\mu g/m^3$) for a selected set of analytes. Sub-slab **soil vapor samples should not be analyzed in the SIM mode for two reasons:** One, it is not necessary as the risk-based soil vapor screening levels are generally higher than 5 $\mu g/m^3$ (Hartman 2006) and two, there is a potential for interference from the natural organic matter in the soil (EPRI 2005). **At this point, Chevron recommends using TO-15 method to do naphthalene sample collection and the lab conducting analysis should utilize certain procedures specified Appendix E in CAEPA's "Advisory Active Soil Gas Investigation" (CAEPA, 2012). Chevron does not recommend using TO-17 method due to the lack of the universal acceptance by most regulatory agencies.** Should the TO-17 method be required by the local agency, a detailed description of how soil vapor samples are to be collected in the field should be included with clear explanatory text and illustrative figures in work plan documents.

6.2 Fixed Gases

ASTM Method D1946, a gas chromatography/thermal conductivity detector (GC/TCD) method, is recommended for analysis of fixed gases, including O_2 and CO_2. For CH_4, ASTM Method D1946 can also be used, with a flame ionization detector (FID) in place of a TCD.

6.3 Data reporting

Soil vapor concentrations are reported in units of µg/L, $\mu g/m^3$, ppm_v, and ppb_v. Unlike concentration units for groundwater, these units are not directly interchangeable. The molecular weight (MW) of the compound in question is a factor in the conversion from units of parts per billion (ppb_v) to mass per unit volume ($\mu g/m^3$) as follows (API 2005) assuming temperature at 273 K and pressure at 1 atm.:

$$concentration(\mu g/m^3) = concentration(ppb_v) \times 0.04 \times MW$$

USEPA website also provides a useful conversion spreadsheet at:
http://www.epa.gov/athens/learn2model/part-two/onsite/ia_unit_conversion.html

Data are usually reported in table format, which is adequate for understanding and interpreting soil vapor concentrations over time and space. However, depth profiles for multi-level soil vapor sampling probes can be used in order to visualize changes in VOC concentrations and respiration/fixed gases over a given depth interval (as in Figure 12 particularly for assessing biodegradation of petroleum hydrocarbon vapors). Figure 12 shows the vertical soil vapor profiles for benzene vapors sourced from the smear zone or dissolved groundwater plume and oxygen suggesting that downward diffusion of oxygen from surface may have contributed to the significant attenuation of benzene over a 10-ft depth interval due to the aerobic biodegradation of benzene diffusing upward. On the other hand, if higher soil vapor concentrations are detected in the shallower probes than in the deeper probes, it is usually an indication of soil vapors sourced from hydrocarbon impacted soil in the vadose zone. Plotting data in visual formats often enhances the message that the text is providing.

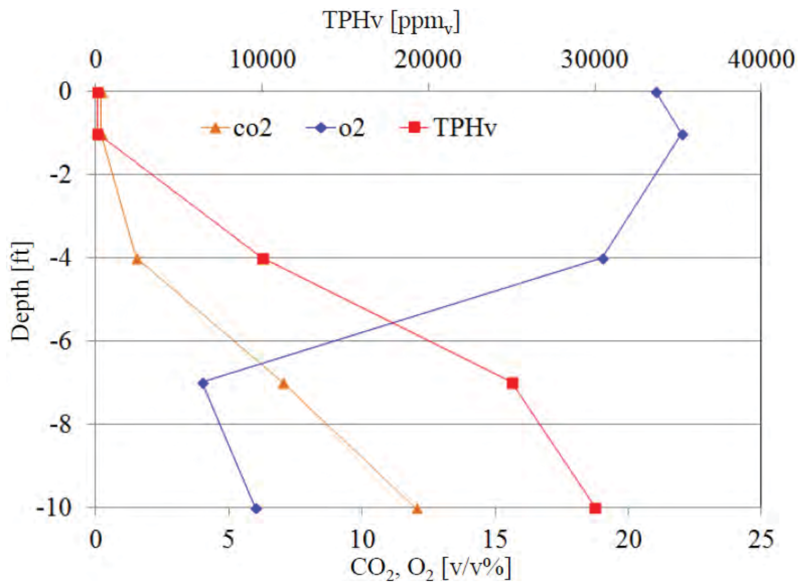

Figure 12. Vertical profile of TPHv, O_2, and CO_2.

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ARCADIS SOP (#112409) – Soil-Gas Sampling and Analysis Using USEPA Method TO-17 and TO-15

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Soil-Gas Sampling and Analysis Using USEPA Method TO-17 and TO-15

SOP #112409

Rev. #: 1

Rev Date: July 9, 2010

Approval Signatures

Prepared by: ______________________ Date: 07/09/2010

Mitch Wacksman, Michael Strickler and Andrew Gutherz

Approved by: ______________________ Date: 07/09/2010

Christopher Lutes and Nadine Weinberg

I. Scope and Application

This document describes the procedures to collect subsurface soil-gas samples from sub-slab sampling ports and soil vapor monitoring points for the analysis of volatile organic compounds (VOCs) including volatile polyaromatic hydrocarbons (PAHs) by United States Environmental Protection Agency (USEPA) Method TO-17 (TO-17) and USEPA Method TO-15.

The TO-17 method uses a glass or stainless steel tube packed with a sorbent material. Sorbents of increasing strength and composition are packed within the tube. The specific sorbent material packed within each tube is selected based on the target compounds and desired reporting limits. A measured volume of soil-gas is passed through the tube during sample collection.

The TO-15 method uses 1-liter 3-liter or 6-liter SUMMA® passivated stainless steel canister. An evacuated SUMMA canister (less than 28 inches of mercury [Hg]) will provide a recoverable whole-gas sample of approximately 5 liters when allowed to fill to a vacuum of approximately 6 inches of Hg. The whole-air sample is then analyzed for VOCs using a quadrupole or ion-trap gas chromatograph/mass spectrometer (GS/MS) system to provide compound detection limits of 0.5 parts per billion volume (ppbv). Optionally the canister sample can also be analyzed for fixed gasses such as Helium, Carbon dioxide and oxygen. .

Following sample collection the TO-17 tube and TO-15 canister is sent to the laboratory where the sampling media is analyzed for the target compounds.

The following sections list the necessary equipment and provide detailed instructions for the collection of soil-gas samples for analysis using TO-17 and TO-15.

Soil vapor samples can be collected from sub-slab sample probes or soil-vapor ports. Refer to the appropriate standard operating procedure (SOP) from the ARCADIS SOP library for a description of construction methods.

II. Personnel Qualifications

ARCADIS field sampling personnel will have current health and safety training, including 40-hour HAZWOPER training, site supervisor training, site-specific training, first-aid, and cardiopulmonary resuscitation (CPR), as needed. ARCADIS field sampling personnel will be well versed in the relevant standard operating procedures (SOPs) and possess the required skills and experience necessary to successfully complete the desired field work. ARCADIS personnel responsible for leading soil-gas sample collection activities must have previous soil-gas sampling experience.

III. Health and Safety Considerations

All sampling personnel should review the appropriate health and safety plan (HASP) and job loss analysis (JLA) prior to beginning work to be aware of all potential hazards associated with the job site and the specific task. Field sampling equipment must be carefully handled to minimize the potential for injury and the spread of hazardous substances. For sub-slab vapor probe installation, drilling with an electric concrete impact drill should be done only by personnel with prior experience using such a piece of equipment and with the appropriate health and safety measures in place as presented in the JLA

IV Equipment List

The equipment required for collect soil-gas samples for analysis using method TO-15 and TO-17 is presented below:

- Appropriate personal protective equipment (PPE; as presented in the site specific HASP and the JLA)
- TO-17 tubes pre-packed by the laboratory with the desired sorbent. Specific sorbents will be recommended by the laboratory considering the target compound list and the necessary reporting limits;
- TO-17 sample flow rate calibration tubes (provided by the laboratory);
- Stainless steel SUMMA® canisters (1-liter, 3-liter, or 6-liter; order at least 5% extra, if feasible) (batch certified canisters or individual certified canisters as required by the project)
- Flow controllers with in-line particulate filters and vacuum gauges; flow controllers are pre-calibrated to specified sample duration (e.g., 30 minutes, 8 hours, 24 hours) or flow rate (e.g., 200 milliliters per minute [mL/min]); confirm with the laboratory that the flow controller comes with an in-line particulate filter and pressure gauge (order at least 5% extra, if feasible). Flow rate should be selected based on expected soil type (see below).
- Two decontaminated Swagelok or stainless-steel or comparable two-way ball or needle valve (sized to match sample tubing).
- 1/4-inch outer diameter (OD) tubing (Teflon® or Teflon-lined polyethylene);
- Stainless steel or comparable Swagelok® or equivalent compression fittings for 1/4-inch OD tubing;

- Stainless steel “T” fitting (if sample train will be assembled with an inline vacuum gauge a four-way fitting will be needed);
- Three Stainless steel duplicate “T” fittings ;
- 2 Portable vacuum pumps capable of producing very low flow rates (e.g., 10 to 200 mL/min) with vacuum gauge;
- Vacuum gauge if monitoring vacuum reading during sample collection is necessary and portable vacuum pump is not equipped with a vacuum gauge;
- Rotameter or an electric flow sensor if vacuum pump does not have a flow gauge (Bios DryCal or equivalent);
- Tracer gas testing supplies (refer to Adminstering Tracer Gas SOP #41699);
- Photoionization Detector (PID) (with a lamp of 11.7 eV);
- Appropriate-sized open-end wrench (typically 9/16-inch, 1/2-inch , and 3/4-inch);
- 2 Tedlar bags;
- Portable weather meter, if appropriate;
- Chain-of-custody (COC) form;
- Sample collection log;
- Gel ice; and
- Field notebook.

V. Cautions

The following cautions and field tips should be reviewed and considered prior to collecting soil-gas samples.

- Sampling personnel should not handle hazardous substances (such as gasoline), permanent marking pens (sharpies), wear/apply fragrances, or smoke cigarettes/cigars before and/or during the sampling event.

- Care should be taken to ensure that the appropriate sorbent is used in the TO-17 tube preparation. Sorbent should be selected in consultation with the analytical laboratory and in consideration of the target compound list, the necessary reporting limits and the expected range of concentrations in field samples. The expected range of concentrations in field samples may be estimated from previous site data, release history and professional judgment informed by the conceptual site model.

- Flow rates for sample collection with TO-17 sorbent tubes should be determined well in advance of field work in consultation with the laboratory.

- A Shipping Determination must be performed, by DOT-trained personnel, for all environmental samples that are to be shipped, as well as some types of environmental equipment/supplies that are to be shipped.

- At the sampling location, keep the tubes in their storage and transportation container to equilibrate with ambient temperature prior to attaching to the sample train.

- Always use clean gloves when handling sampling tubes.

- Seal clean, blank sorbent tubes and sampled tubes using inert, Swagelok®-type fittings and PTFE ferrules. Wrap capped tubes individually in uncoated aluminum foil. Use clean, sealable glass jars or metal cans containing a small packet of activated charcoal or activated charcoal/silica gel for storage and transportation of multiple tubes. This activated charcoal is not analyzed, but serves as a protection for the analytical sorbent tube. Store the multi-tube storage container in a clean environment at 4ºC.

- Keep the sample tubes inside the storage container during transportation and only remove them at the monitoring location after the tubes have reached ambient temperature. Store sampled tubes in a refrigerator at 4ºC inside the multi-tube container until ready for analysis.

- The purge flow rate of 100 ml/min should be suitable for a variety of silt and sand conditions but will not be achievable in some clays without excessive vacuum. A low vacuum (<10” of mercury) should be maintained. Record the measured flow rate and vacuum pressure during sample collection.

The cutoff value for vacuum differs in the literature from 10” of water column (ITRC 2007) to 136” of water column or 10” of mercury (http://www.dtsc.ca.gov/lawsregspolicies/policies/SiteCleanup/upload/SMBR_ADV_activesoilgasinvst.pdf). A detailed discussion of the achievable flow rates in various permeability materials can be found in Nicholson 2007. Related issues of contaminant partitioning are summarized in ASTM D5314-92. Passive sampling approaches can be considered as an alternative for clay soils. However most passive sampling approaches are not currently capable of quantitative estimation of soil gas concentration.

- It is important to record the canister pressure, start and stop times and ID on a proper field sampling form. You should observe and record the time/pressure at a mid-point in the sample duration. It is a good practice to lightly tap the pressure gauge with your finger before reading it to make sure it isn’t stuck.

- Ensure that there is still measureable vacuum in the SUMMA® after sampling. Sometimes the gauges sent from labs have offset errors, or they stick.

- When sampling carefully consider elevation. If your site is over 2,000’ above sea level or the difference in elevation between your site and your lab is more than 2,000’ then pressure effects will be significant. If you take your samples at a high elevation they will contain less air for a given ending pressure reading. High elevation samples analyzed at low elevation will result in more dilution at the lab, which could affect reporting limits. Conversely low elevation samples when received at high elevation may appear to not have much vacuum left in them. http://www.uigi.com/Atmos_pressure.html.

- If possible, have equipment shipped a two or three days before the sampling date so that all materials can be checked. Order replacements if needed.

- Requesting extra canisters and extra sorbent tubes from the laboratory should also be considered to ensure that you have enough equipment on site in case of an equipment failure.

- Shallow exterior soil-gas sampling should not proceed within 5 days following a significant rain event (1/2-inch of rainfall or more).

VI. Procedure

Soil-Gas Sample Preparation

<u>Selection of Sorbent and Sampling Volume (to be completed prior to sampling event)</u>

1. Identify the necessary final reporting limit for the target compound(s) in accordance with the project quality assurance plan and/or in consultation with the data end user.

2. Identify the necessary method reporting limit(s). The laboratory will be helpful in providing this information as it is typically specific to the sensitivity of the instrumentation.

3. The minimum sampling volume is the volume of soil-gas sample that must be drawn through the sorbent in order to achieve the desired final reporting limit. Calculate the minimum sampling volume using the following equation:

$$Minimum\ Sampling\ Volume\ (L) = \frac{Final\ Reporting\ Limit\ (\mu g)}{Action\ Level\ (\mu g/m^3)} \times \frac{1{,}000\ L}{m^3}$$

Where:

L = liters

μg = microgram

m = meter

4. If a timed sample duration is specified in the work plan, calculate the minimum flow rate. The minimum flow rate is the flow rate necessary to achieve the minimum sampling volume using the following formula:

$$Minimum\ Flow\ Rate\ (L/min) = \frac{Minimum\ Sampling\ Volume\ (L)}{Sample\ Duration\ (min)}$$

Where:

min = minutes

Then compare the minimum flow rate calculated to the requirements for maximum soil gas sampling without excessive danger of short circuiting, normally stated as 0.2 liters/minute, although it can be lower in tight soils. Soil vapor sampling flow rates should not exceed 200 ml/min.

5. Compare the minimum sampling volume to the safe sampling volume (SSV) for the sorbents selected. SSV for specific sorbents can be provide by the manufacture or the laboratory, being used (Table 1 and Appendix 1 in Method TO-17). Ensure that the compound will not breakthrough when sampling the volume calculated above.

Soil-Gas Sample Collection

Calibration of the sample pump prior to assembly of sampling train

1. Attach the sample flow rate calibration tube provided by the laboratory to the inlet of the sample pump using a section of tubing. Attach the flow calibrator to the inlet of the sample flow rate calibration tube. The sample flow rate calibration tube should be clearly marked by the laboratory with an arrow indicating flow direction (or as otherwise specified by the laboratory).

2. Turn on the sample pump and adjust the flow rate on the sample pump to achieve the desired minimum flow rate (calculated above) as measured by the flow calibrator.

3. Repeat until each sampling pump has been properly calibrated to its appropriate flow rate.

Assembly of combined TO-17 and TO-15 sampling train

1. Record the following information in the field notebook, if appropriate (contact the local airport or other suitable information source [e.g., site-specific measurements, weatherunderground.com] to obtain the information):

   a. wind speed and direction;

   b. ambient temperature;

   c. barometric pressure; and

   d. relative humidity.

2. If samples are being collected from temporary or permanent soil vapor points simply remove the cap or plug and proceed to step 3. When collecting samples from a sub-slab port remove the cap or plug from the sampling port. Connect a short piece of Teflon or Teflon-lined tubing to the sampling port using a Swagelok or equivalent stainless-steel or comparable compression fitting.

3. Connect the Teflon or Teflon-lined tubing to a stainless steel T fitting using a Swagelok or equivalent stainless-steel or comparableompression fitting.

4. Remove the brass cap from the SUMMA® canister and connect the flow controller with in-line particulate filter and vacuum gauge to the SUMMA® canister. Do not open the valve on the SUMMA® canister. Record in the field notebook and COC form the flow controller number with the appropriate SUMMA® canister number.

5. Connect the flow controller to the stainless steel T fitting using a Swagelok or equivalent stainless-steel or comparable compression fitting. The TO-15 leg of the combined sampling train is now complete.

6. Attach a length of Teflon or Teflon-lined tubing to the free end of the stainless steel T fitting using a Swagelok or equivalent stainless-steel or comparble compression fitting.

7. Complete the remainder of the sampling train as depicted in Figure 1.

Purge Sampling Assembly and Sampling Point Prior to Sample Collection.

1. Ensure the two-way valve next to the flow rate calibration tube is open and the two way valve next to the TO-17 sampling tubes is closed. Purge three volumes of air from the vapor probe and sampling line using the portable pump. Measure organic vapor levels with the PID. Lower flow rates may be necessary in silt or clay to avoid excessive vacuum. Vacuum reading greater than 136 inches of water column are clearly excessive. Other available sources cite a cutoff of greater than 10 inches of water column.

2. Check the seal established around the soil vapor probe and the sampling train fittings by using a tracer gas (e.g., helium) or other method established in applicable regulatory guidance documents. [Note: Refer to ARCADIS SOP "Administering Tracer Gas," adapted from NYSDOH 2005, for procedures on tracer gas use.]

3. When three volumes of air have been purged from the vapor probe and sampling line stop the purge pump and close the valve next to the flow rate calibration tube.

TO-15 Sample Collection

1. Open the SUMMA® canister valve to initiate sample collection. Record on the sample log (attached) the time sampling began and the canister pressure.

   If the initial vacuum pressure registered is not between -30 and -25 inches of Hg, then the SUMMA® canister is not appropriate for use and another canister should be used.

2. Take a photograph of the SUMMA® canister and surrounding area (unless photography is restricted by the property owner).

3. Check the SUMMA canister approximately half way through the sample duration and note progress on sample logs.

TO-15 Sample Termination

1. Arrive at the SUMMA® canister location at least 10 to 15 minutes prior to the end of the sampling interval.

2. Record the final vacuum pressure. Stop collecting the sample by closing the SUMMA® canister valves. The canister should have a minimum amount of vacuum (approximately 6 inches of Hg or slightly greater).

3. Record the date and time of valve closing in the field notebook, sample collection log, and COC form.

TO-17 Sample Collection

1. Record in the field notebook and COC form the tube number on the TO-17 tube.

2. Open the two-way valve next to the TO-17 tubes

3. Turn on the sample pump to begin sample collection. Use a stopwatch to ensure accuracy in pumping time. Record in the field notebook and the field sample log the time sampling began and the flow rate from each of the sample pumps.

Termination of Sample Collection

1. Stop the sample pumps after the desired volume of soil-gas has passed through the sorbent, and close the two-way valves next to the TO-17 sample tubes.

2. Record the stop time.

3. Detach the Tedlar bag from each sample pump and measure the helium concentration in the soil-gas collected by the Tedlar bag. Record any detections in the field book and sample collection log.

4. Open the two-way valve to permit flow through the flow rate calibration tube. Reconnect each of the sampling pumps and measure the flow rate. Record the post-sampling flow rates in the field log book and the sample collection logs. The post-sampling flow rate should match within 10% of the pre-sample flow rate. Average the pre-sampling and post-sampling flow rate and record in the field log book, and the sample collection log.

5. Calculate the sample volume using the average of the pre-sample and post-sample flow rate. Record the sample volume in the field log book, the sample collection log, and on the COC.

6. Package the tubes according to laboratory protocol on gel ice and ship to the laboratory for analysis.

VII. Waste Management

The waste materials generated during sampling activities should be minimal. PPE, such as gloves and other disposable equipment (i.e., tubing), will be collected by field personnel for proper disposal.

VIII. Data Recording and Management

Measurements will be recorded in the field notebook at the time of measurement with notations of the project name, sample date, sample start and finish time, sample location (e.g., GPS coordinates, distance from permanent structure), tube type and number and sample volume. Field sampling logs and COC records will be transmitted to the Project Manager.

IX. Quality Assurance

Duplicate samples should be collected in the field as a quality assurance step. Generally, duplicates are taken of 10% of samples, but project specific requirements should take precedence. Duplicate soil gas samples should be collected via a split sample train, allowing the primary and duplicate sample to be collected from the soil-gas probe simultaneously.

Quality assurance planning for method TO-17 should take careful note of the method requirement for distributed volume pairs. Although in some circumstances this requirement may be waived, this does constitute a deviation from the method as written. It is wise to discuss this decision with clients and/or regulators before sampling.

Soil-gas sample analysis will be performed using USEPA TO-17 methodology for a site specific constituent list defined in the work plan. Constituent lists and reporting limits must be discussed with the laboratory prior to mobilizing for sampling. Quality assurance parameters should be confirmed with the laboratory prior to sampling. Field quality assurance parameters should be defined in the site-specific work plan. A trip blank sample should accompany each shipment of soil-gas samples to the laboratory for analysis. Trip blanks assess potential sample contamination resulting from the transportation and storing of samples. Soil-gas sample analysis will generally be performed using USEPA TO-15 methodology or a project specific constituent list. Method TO-15 uses a quadrupole or ion-trap GC/MS with a capillary column to provide optimum detection limits (typically 0.5-ppbv for most VOCs).

X. References

New York State Department of Health (NYSDOH). 2005. DRAFT "Guidance for Evaluating Soil Vapor Intrusion in the State of New York" February 23, 2005.

AirToxics Ltd. "Sorbent & Solution Sampling Guide."

CITY: PETALUMA, CA DIV/GROUP: ENV DB: J. HARRIS LD:--- PIC:--- PM:(Reqd) TM:(Opt) LYR:(Opt)ON=*;OFF=*REF*
G:\ENVCAD\Petaluma\ACT\B0066121\0001\00001\66121T01.dwg LAYOUT: 1 SAVED: 7/13/2011 3:19 PM ACADVER: 18.0S (LMS TECH) PAGESETUP: SETUP1 PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 7/13/2011 3:21 PM BY: HARRIS, JESSICA
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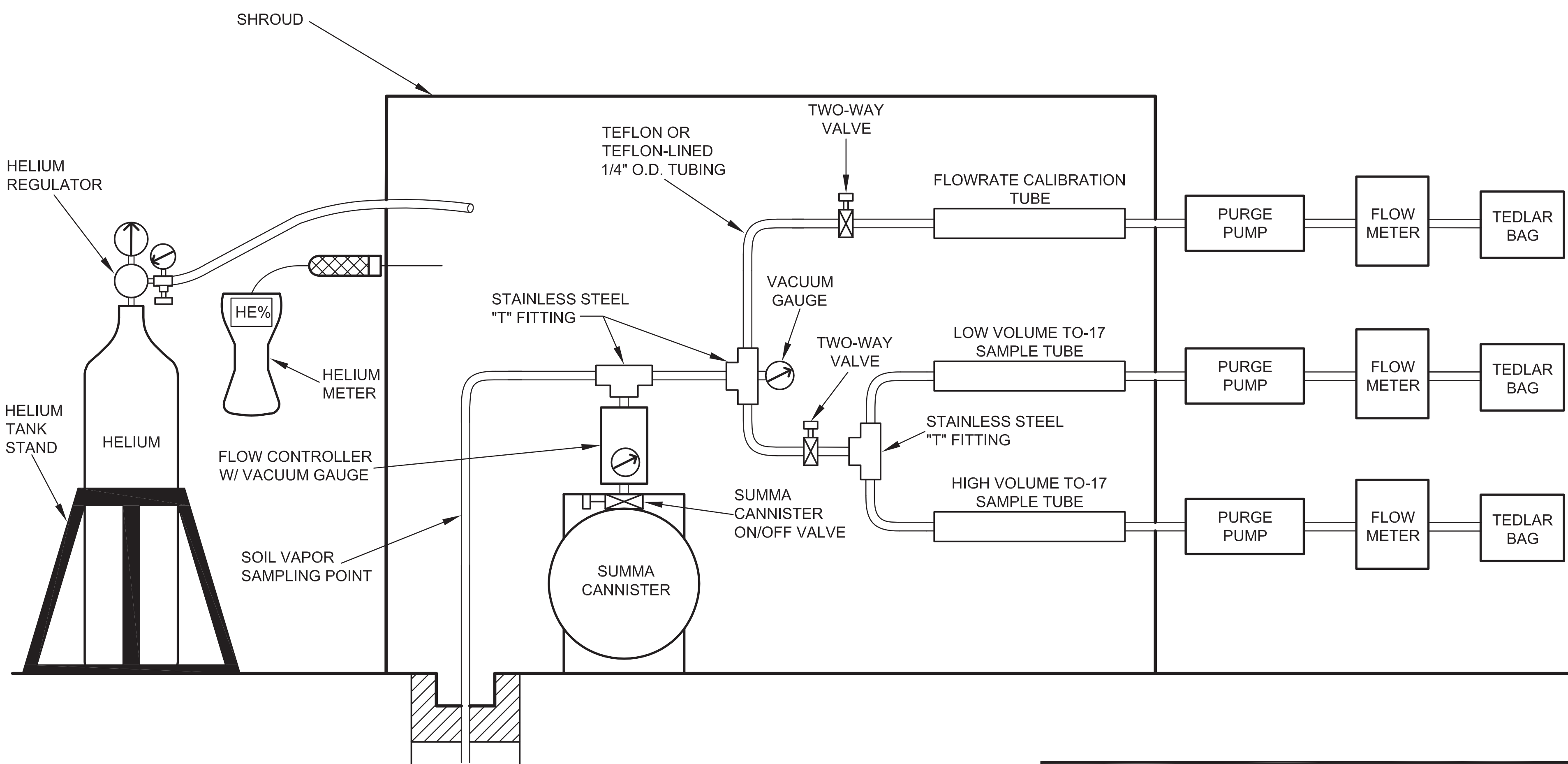

SOIL VAPOR SAMPLING EQUIPMENT ARRANGEMENT

ARCADIS

FIGURE 1

Appendix C

Chemical Analytical Data for 2013 Soil Vapor Sampling

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11/26/2013

Mr. Eric Epple
Arcadis U.S., Inc.
1100 Olive Way
Ste 800
Seattle WA 98101

Project Name: Edmonds Terminal
Project #: B0045362.0004
Workorder #: 1311468A

Dear Mr. Eric Epple

The following report includes the data for the above referenced project for sample(s) received on 11/25/2013 at Air Toxics Ltd.

The data and associated QC analyzed by Modified TO-15 are compliant with the project requirements or laboratory criteria with the exception of the deviations noted in the attached case narrative.

Thank you for choosing Air Toxics Ltd. for your air analysis needs. Air Toxics Ltd. is committed to providing accurate data of the highest quality. Please feel free to contact the Project Manager: Kelly Buettner at 916-985-1000 if you have any questions regarding the data in this report.

Regards,

Kelly Buettner

Project Manager

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WORK ORDER #: 1311468A

Work Order Summary

CLIENT:	Mr. Eric Epple Arcadis U.S., Inc. 1100 Olive Way Ste 800 Seattle, WA 98101	**BILL TO:**	Accounts Payable Arcadis U.S., Inc. 630 Plaza Drive Suite 600 Highlands Ranch, CO 80129
PHONE:	206-726-4728	**P.O. #**	B0045362.0004
FAX:	206-325-8218	**PROJECT #**	B0045362.0004 Edmonds Terminal
DATE RECEIVED:	11/25/2013	**CONTACT:**	Kelly Buettner
DATE COMPLETED:	11/26/2013		

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.	FINAL PRESSURE
01A	VP-1	Modified TO-15	1.8 "Hg	15 psi
02A	VP-2	Modified TO-15	3.1 "Hg	15.1 psi
03A	VP-3	Modified TO-15	1.2 "Hg	14.9 psi
04A	BD-1	Modified TO-15	1.4 "Hg	15 psi
05A	Equipment Blank	Modified TO-15	1 "Hg	15.1 psi
06A	Lab Blank	Modified TO-15	NA	NA
06B	Lab Blank	Modified TO-15	NA	NA
06C	Lab Blank	Modified TO-15	NA	NA
07A	CCV	Modified TO-15	NA	NA
07B	CCV	Modified TO-15	NA	NA
07C	CCV	Modified TO-15	NA	NA
08A	LCS	Modified TO-15	NA	NA
08AA	LCSD	Modified TO-15	NA	NA
08B	LCS	Modified TO-15	NA	NA
08BB	LCSD	Modified TO-15	NA	NA
08C	LCS	Modified TO-15	NA	NA
08CC	LCSD	Modified TO-15	NA	NA

CERTIFIED BY: Heidi Hayes DATE: 11/26/13

Technical Director

Certification numbers: AZ Licensure AZ0775, CA NELAP - 12282CA, NJ NELAP - CA016, NY NELAP - 11291, TX NELAP - T104704434-13-6, UT NELAP CA009332013-4, VA NELAP - 460197, WA NELAP - C935
Name of Accrediting Agency: NELAP/ORELAP (Oregon Environmental Laboratory Accreditation Program)
Accreditation number: CA300005, Effective date: 10/18/2013, Expiration date: 10/17/2014.
Eurofins Air Toxics Inc.. certifies that the test results contained in this report meet all requirements of the NELAC standards

180 BLUE RAVINE ROAD, SUITE B FOLSOM, CA - 9563
(916) 985-1000 . (800) 985-5955 . FAX (916) 985-1020

LABORATORY NARRATIVE
Modified TO-15
Arcadis U.S., Inc.
Workorder# 1311468A

Five 1 Liter Summa Canister samples were received on November 25, 2013. The laboratory performed analysis via modified EPA Method TO-15 using GC/MS in the full scan mode.

This workorder was independently validated prior to submittal using 'USEPA National Functional Guidelines' as generally applied to the analysis of volatile organic compounds in air. A rules-based, logic driven, independent validation engine was employed to assess completeness, evaluate pass/fail of relevant project quality control requirements and verification of all quantified amounts.

Method modifications taken to run these samples are summarized in the table below. Specific project requirements may over-ride the ATL modifications.

Requirement	***TO-15***	***ATL Modifications***
Initial Calibration	</=30% RSD with 2 compounds allowed out to < 40% RSD	</=30% RSD with 4 compounds allowed out to < 40% RSD
Blank and standards	Zero Air	UHP Nitrogen provides a higher purity gas matrix than zero air

Receiving Notes

There were no receiving discrepancies.

Analytical Notes

Samples VP-1, VP-2, VP-3 and BD-1 were transferred from Low Level analysis to full scan TO-15 due to high levels of target/non-target compounds.

Dilution was performed on sample VP-1 due to the presence of high level target species.

Dilution was performed on samples VP-2, VP-3 and BD-1 due to the presence of high level non-target species.

The recovery of surrogate 1,2-Dichloroethane-d4 in sample VP-1 was outside laboratory control limits due to high level hydrocarbon matrix interference. The surrogate recovery is flagged.

Definition of Data Qualifying Flags

Eight qualifiers may have been used on the data analysis sheets and indicates as follows:

B - Compound present in laboratory blank greater than reporting limit (background subtraction not performed).
J - Estimated value.
E - Exceeds instrument calibration range.
S - Saturated peak.
Q - Exceeds quality control limits.
U - Compound analyzed for but not detected above the reporting limit, LOD, or MDL value. See

data page for project specific U-flag definition.

UJ- Non-detected compound associated with low bias in the CCV

N - The identification is based on presumptive evidence.

File extensions may have been used on the data analysis sheets and indicates as follows:

a-File was requantified

b-File was quantified by a second column and detector

r1-File was requantified for the purpose of reissue

Summary of Detected Compounds
EPA METHOD TO-15 GC/MS

Client Sample ID: VP-1

Lab ID#: 1311468A-01A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	540	220000	1700	710000

Client Sample ID: VP-2

Lab ID#: 1311468A-02A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	4.5	100	14	340

Client Sample ID: VP-3

Lab ID#: 1311468A-03A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	10	14	34	46

Client Sample ID: BD-1

Lab ID#: 1311468A-04A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	4.2	94	14	300

Client Sample ID: Equipment Blank

Lab ID#: 1311468A-05A

No Detections Were Found.

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Client Sample ID: VP-1
Lab ID#: 1311468A-01A
EPA METHOD TO-15 GC/MS

File Name:	**14112524**	**Date of Collection: 11/21/13 12:44:00 P**
Dil. Factor:	**108**	**Date of Analysis: 11/26/13 08:44 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	540	220000	1700	710000
Naphthalene	2200	Not Detected	11000	Not Detected

Q = Exceeds Quality Control limits of 70% to 130%, due to matrix effects.

Container Type: 1 Liter Summa Canister

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	157 Q	70-130
Toluene-d8	90	70-130
4-Bromofluorobenzene	94	70-130

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Client Sample ID: VP-2

Lab ID#: 1311468A-02A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112513**	**Date of Collection: 11/21/13 11:30:00 A**
Dil. Factor:	**9.04**	**Date of Analysis: 11/26/13 11:40 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	4.5	100	14	340
Naphthalene	18	Not Detected	95	Not Detected

Container Type: 1 Liter Summa Canister

Surrogates	%Recovery	Method Limits
Toluene-d8	102	70-130
1,2-Dichloroethane-d4	81	70-130
4-Bromofluorobenzene	104	70-130

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Client Sample ID: VP-3

Lab ID#: 1311468A-03A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112514**	**Date of Collection:**	**11/21/13 10:10:00 A**
Dil. Factor:	**21.0**	**Date of Analysis:**	**11/26/13 12:22 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	10	14	34	46
Naphthalene	42	Not Detected	220	Not Detected

Container Type: 1 Liter Summa Canister

Surrogates	%Recovery	Method Limits
Toluene-d8	102	70-130
1,2-Dichloroethane-d4	107	70-130
4-Bromofluorobenzene	106	70-130

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Client Sample ID: BD-1

Lab ID#: 1311468A-04A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112511**	**Date of Collection:**	**11/21/13**
Dil. Factor:	**8.48**	**Date of Analysis:**	**11/26/13 10:37 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	4.2	94	14	300
Naphthalene	17	Not Detected	89	Not Detected

Container Type: 1 Liter Summa Canister

Surrogates	%Recovery	Method Limits
Toluene-d8	103	70-130
1,2-Dichloroethane-d4	90	70-130
4-Bromofluorobenzene	106	70-130

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Client Sample ID: Equipment Blank

Lab ID#: 1311468A-05A

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**e112516**	**Date of Collection:**	**11/21/13 1:08:00 PM**
Dil. Factor:	**2.10**	**Date of Analysis:**	**11/26/13 09:12 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.21	Not Detected	0.67	Not Detected
Naphthalene	1.0	Not Detected	5.5	Not Detected

Container Type: 1 Liter Summa Canister

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	98	70-130
Toluene-d8	98	70-130
4-Bromofluorobenzene	100	70-130

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Client Sample ID: Lab Blank
Lab ID#: 1311468A-06A
EPA METHOD TO-15 GC/MS

File Name:	**14112506**	**Date of Collection: NA**	
Dil. Factor:	**1.00**	**Date of Analysis: 11/25/13 04:09 PM**	

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	5.0	Not Detected	16	Not Detected
Naphthalene	20	Not Detected	100	Not Detected

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	101	70-130
Toluene-d8	95	70-130
4-Bromofluorobenzene	93	70-130

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Client Sample ID: Lab Blank

Lab ID#: 1311468A-06B

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**e112514**	**Date of Collection: NA**	
Dil. Factor:	**1.00**	**Date of Analysis: 11/25/13 09:34 PM**	

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.10	Not Detected	0.32	Not Detected
Naphthalene	0.50	Not Detected	2.6	Not Detected

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	99	70-130
Toluene-d8	97	70-130
4-Bromofluorobenzene	99	70-130

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Client Sample ID: Lab Blank

Lab ID#: 1311468A-06C

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112509**	**Date of Collection: NA**	
Dil. Factor:	**1.00**	**Date of Analysis: 11/26/13 09:08 AM**	

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.50	Not Detected	1.6	Not Detected
Naphthalene	2.0	Not Detected	10	Not Detected

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
Toluene-d8	103	70-130
1,2-Dichloroethane-d4	82	70-130
4-Bromofluorobenzene	105	70-130

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Client Sample ID: CCV
Lab ID#: 1311468A-07A
EPA METHOD TO-15 GC/MS

File Name:	**14112502**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/25/13 12:55 PM**

Compound	%Recovery
Benzene	105
Naphthalene	103

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	98	70-130
Toluene-d8	104	70-130
4-Bromofluorobenzene	102	70-130

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Client Sample ID: CCV

Lab ID#: 1311468A-07B

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**e112510**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/25/13 06:30 PM**

Compound	%Recovery
Benzene	87
Naphthalene	78

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	100	70-130
Toluene-d8	103	70-130
4-Bromofluorobenzene	104	70-130

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Client Sample ID: CCV

Lab ID#: 1311468A-07C

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112502**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/25/13 09:24 PM**

Compound	%Recovery
Benzene	115
Naphthalene	95

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
Toluene-d8	108	70-130
1,2-Dichloroethane-d4	82	70-130
4-Bromofluorobenzene	108	70-130

Client Sample ID: LCS

Lab ID#: 1311468A-08A

EPA METHOD TO-15 GC/MS

File Name:	**14112503**	**Date of Collection: NA**	
Dil. Factor:	**1.00**	**Date of Analysis:**	**11/25/13 01:42 PM**

Compound	%Recovery	Method Limits
Benzene	94	70-130
Naphthalene	87	60-140

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	100	70-130
Toluene-d8	101	70-130
4-Bromofluorobenzene	100	70-130

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Client Sample ID: LCSD

Lab ID#: 1311468A-08AA

EPA METHOD TO-15 GC/MS

File Name:	**14112504**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/25/13 03:01 PM**

Compound	%Recovery	Method Limits
Benzene	95	70-130
Naphthalene	78	60-140

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	102	70-130
Toluene-d8	100	70-130
4-Bromofluorobenzene	101	70-130

eurofins | Air Toxics

Client Sample ID: LCS

Lab ID#: 1311468A-08B

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**e112511**	**Date of Collection: NA**	
Dil. Factor:	**1.00**	**Date of Analysis: 11/25/13 07:15 PM**	

Compound	%Recovery	Method Limits
Benzene	91	70-130
Naphthalene	100	60-140

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	98	70-130
Toluene-d8	100	70-130
4-Bromofluorobenzene	103	70-130

eurofins | Air Toxics

Client Sample ID: LCSD

Lab ID#: 1311468A-08BB

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**e112512**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/25/13 07:55 PM**

Compound	%Recovery	Method Limits
Benzene	86	70-130
Naphthalene	94	60-140

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	102	70-130
Toluene-d8	97	70-130
4-Bromofluorobenzene	105	70-130

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Client Sample ID: LCS

Lab ID#: 1311468A-08C

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112505**	**Date of Collection: NA**	
Dil. Factor:	**1.00**	**Date of Analysis:**	**11/25/13 10:56 PM**

Compound	%Recovery	Method Limits
Benzene	122	70-130
Naphthalene	58 Q	60-140

Q = Exceeds Quality Control limits.

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
Toluene-d8	105	70-130
1,2-Dichloroethane-d4	80	70-130
4-Bromofluorobenzene	108	70-130

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Client Sample ID: LCSD

Lab ID#: 1311468A-08CC

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112506**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/25/13 11:25 PM**

Compound	%Recovery	Method Limits
Benzene	120	70-130
Naphthalene	61	60-140

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
Toluene-d8	102	70-130
1,2-Dichloroethane-d4	82	70-130
4-Bromofluorobenzene	109	70-130

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11/27/2013
Mr. Eric Epple
Arcadis U.S., Inc.
1100 Olive Way
Ste 800
Seattle WA 98101

Project Name: Edmonds Terminal
Project #: B0045362.0004
Workorder #: 1311468B

Dear Mr. Eric Epple

The following report includes the data for the above referenced project for sample(s) received on 11/25/2013 at Air Toxics Ltd.

The data and associated QC analyzed by Modified TO-15 APH are compliant with the project requirements or laboratory criteria with the exception of the deviations noted in the attached case narrative.

Thank you for choosing Air Toxics Ltd. for your air analysis needs. Air Toxics Ltd. is committed to providing accurate data of the highest quality. Please feel free to contact the Project Manager: Kelly Buettner at 916-985-1000 if you have any questions regarding the data in this report.

Regards,

Kelly Buettner

Kelly Buettner
Project Manager

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WORK ORDER #: 1311468B

Work Order Summary

CLIENT:	Mr. Eric Epple Arcadis U.S., Inc. 1100 Olive Way Ste 800 Seattle, WA 98101	**BILL TO:**	Accounts Payable Arcadis U.S., Inc. 630 Plaza Drive Suite 600 Highlands Ranch, CO 80129
PHONE:	206-726-4728	**P.O. #**	B0045362.0004
FAX:	206-325-8218	**PROJECT #**	B0045362.0004 Edmonds Terminal
DATE RECEIVED:	11/25/2013	**CONTACT:**	Kelly Buettner
DATE COMPLETED:	11/27/2013		

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.	FINAL PRESSURE
01A	VP-1	Modified TO-15 APH	1.8 "Hg	15 psi
01B	VP-1	Modified TO-15 APH	1.8 "Hg	15 psi
02A	VP-2	Modified TO-15 APH	3.1 "Hg	15.1 psi
02B	VP-2	Modified TO-15 APH	3.1 "Hg	15.1 psi
03A	VP-3	Modified TO-15 APH	1.2 "Hg	14.9 psi
03B	VP-3	Modified TO-15 APH	1.2 "Hg	14.9 psi
04A	BD-1	Modified TO-15 APH	1.4 "Hg	15 psi
04B	BD-1	Modified TO-15 APH	1.4 "Hg	15 psi
05A	Equipment Blank	Modified TO-15 APH	1 "Hg	15.1 psi
05B	Equipment Blank	Modified TO-15 APH	1 "Hg	15.1 psi
06A	Lab Blank	Modified TO-15 APH	NA	NA
06B	Lab Blank	Modified TO-15 APH	NA	NA
06C	Lab Blank	Modified TO-15 APH	NA	NA
06D	Lab Blank	Modified TO-15 APH	NA	NA
07A	CCV	Modified TO-15 APH	NA	NA
07B	CCV	Modified TO-15 APH	NA	NA
07C	CCV	Modified TO-15 APH	NA	NA
07D	CCV	Modified TO-15 APH	NA	NA

CERTIFIED BY: Heidi Hayes (signature) DATE: 11/27/13

Technical Director

Certification numbers: AZ Licensure AZ0775, CA NELAP - 12282CA, NJ NELAP - CA016, NY NELAP - 11291,
TX NELAP - T104704434-13-6, UT NELAP CA009332013-4, VA NELAP - 460197, WA NELAP - C935
Name of Accrediting Agency: NELAP/ORELAP (Oregon Environmental Laboratory Accreditation Program)
Accreditation number: CA300005, Effective date: 10/18/2013, Expiration date: 10/17/2014.
Eurofins Air Toxics Inc.. certifies that the test results contained in this report meet all requirements of the NELAC standards

180 BLUE RAVINE ROAD, SUITE B FOLSOM, CA - 9563
(916) 985-1000 . (800) 985-5955 . FAX (916) 985-1020

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LABORATORY NARRATIVE
Modified TO-15 & VPH Fractions
Arcadis U.S., Inc.
Workorder# 1311468B

Five 1 Liter Summa Canister samples were received on November 25, 2013. The laboratory performed analysis via EPA Method TO-15 and Air Toxics VPH (Volatile Petroleum Hydrocarbon) methods for the Determination of VPH Fractions using GC/MS in the full scan mode. The method involves concentrating up to 0.5 liters of air. The concentrated aliquot is then flash vaporized and swept through a water management system to remove water vapor. Following dehumidification, the sample passes directly into the GC/MS for analysis. This method is designed to measure gaseous phase aliphatic and aromatic compounds in ambient air and soil gas collected in stainless steel Summa canisters. Air Toxics VPH method is a hybrid of EPA TO-15, MADEP APH and WSDE VPH methods. Chromatographic peaks were identified via mass spectrum as either aliphatic or aromatic petroleum hydrocarbons and included in the appropriate range as defined by the method. The volatile Aliphatic hydrocarbons are collectively quantified within the C5 to C6 range, C6 to C8 range, C8 to C10 range and the C10 to C12 range. Additionally, the volatile Aromatic hydrocarbons are collectively quantified within the C8 to C10 range and the C10 to C12 range. The Aromatic ranges refer to the equivalent carbon (EC) ranges.

Aliphatic data is calculated from the Total Ion chromatogram which has been reprocessed in a duplicate file differentiated from the original by the addition of an alphanumeric extension. The Aromatic calculation also uses the information contained in the associated Extracted Ion file.

Receiving Notes

There were no receiving discrepancies.

Analytical Notes

Dilution was performed on samples VP-1, VP-2, VP-3 and BD-1 due to matrix interference.

Definition of Data Qualifying Flags

Eight qualifiers may have been used on the data analysis sheets and indicates as follows:

B - Compound present in laboratory blank greater than reporting limit (background subtraction not performed).
J - Estimated value.
E - Exceeds instrument calibration range.
S - Saturated peak.
Q - Exceeds quality control limits.
U - Compound analyzed for but not detected above the reporting limit.
UJ- Non-detected compound associated with low bias in the CCV
N - The identification is based on presumptive evidence.

File extensions may have been used on the data analysis sheets and indicates as follows:

a-File was requantified
b-File was quantified by a second column and detector

r1-File was requantified for the purpose of reissue

Summary of Detected Compounds
MODIFIED METHOD TO-15 GC/MS FULL SCAN

Client Sample ID: VP-1

Lab ID#: 1311468B-01A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
C5-C6 Aliphatic Hydrocarbons (ref. to Pentane + Hexane)	22000	4700000	70000	15000000
>C6-C8 Aliphatic Hydrocarbons (ref. to Heptane)	22000	4900000	88000	20000000
>C8-C10 Aliphatic Hydrocarbons (ref. to Decane)	22000	1100000	120000	6600000

Client Sample ID: VP-1

Lab ID#: 1311468B-01B

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
>C8-C10 Aromatic Hydrocarbons (ref. to 1,2,3-TMB)	22000	7000	100000	34000

Client Sample ID: VP-2

Lab ID#: 1311468B-02A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
C5-C6 Aliphatic Hydrocarbons (ref. to Pentane + Hexane)	90	1800	290	5700
>C6-C8 Aliphatic Hydrocarbons (ref. to Heptane)	90	6800	370	28000
>C8-C10 Aliphatic Hydrocarbons (ref. to Decane)	90	4300	530	25000
>C10-C12 Aliphatic Hydrocarbons (ref. to Dodecane)	90	1600	630	11000

Client Sample ID: VP-2

Lab ID#: 1311468B-02B

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
>C8-C10 Aromatic Hydrocarbons (ref. to 1,2,3-TMB)	90	240	440	1200

Client Sample ID: VP-3

Lab ID#: 1311468B-03A

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Summary of Detected Compounds
MODIFIED METHOD TO-15 GC/MS FULL SCAN

Client Sample ID: VP-3

Lab ID#: 1311468B-03A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
C5-C6 Aliphatic Hydrocarbons (ref. to Pentane + Hexane)	350	15000	1100	49000
>C6-C8 Aliphatic Hydrocarbons (ref. to Heptane)	350	120000	1400	480000
>C8-C10 Aliphatic Hydrocarbons (ref. to Decane)	350	48000	2000	280000
>C10-C12 Aliphatic Hydrocarbons (ref. to Dodecane)	350	3600	2400	25000

Client Sample ID: VP-3

Lab ID#: 1311468B-03B

No Detections Were Found.

Client Sample ID: BD-1

Lab ID#: 1311468B-04A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
C5-C6 Aliphatic Hydrocarbons (ref. to Pentane + Hexane)	85	1500	270	4800
>C6-C8 Aliphatic Hydrocarbons (ref. to Heptane)	85	5700	350	23000
>C8-C10 Aliphatic Hydrocarbons (ref. to Decane)	85	2600	490	15000
>C10-C12 Aliphatic Hydrocarbons (ref. to Dodecane)	85	1500	590	10000

Client Sample ID: BD-1

Lab ID#: 1311468B-04B

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
>C8-C10 Aromatic Hydrocarbons (ref. to 1,2,3-TMB)	85	210	420	1000

Client Sample ID: Equipment Blank

Lab ID#: 1311468B-05A

No Detections Were Found.

Air Toxics

Summary of Detected Compounds
MODIFIED METHOD TO-15 GC/MS FULL SCAN

Client Sample ID: Equipment Blank

Lab ID#: 1311468B-05B

No Detections Were Found.

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Client Sample ID: VP-1

Lab ID#: 1311468B-01A

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**14112619a**	**Date of Collection: 11/21/13 12:44:00 PM**
Dil. Factor:	**430**	**Date of Analysis: 11/27/13 07:34 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
C5-C6 Aliphatic Hydrocarbons (ref. to Pentane + Hexane)	22000	4700000	70000	15000000
>C6-C8 Aliphatic Hydrocarbons (ref. to Heptane)	22000	4900000	88000	20000000
>C8-C10 Aliphatic Hydrocarbons (ref. to Decane)	22000	1100000	120000	6600000
>C10-C12 Aliphatic Hydrocarbons (ref. to Dodecane)	22000	Not Detected	150000	Not Detected

Container Type: 1 Liter Summa Canister

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Client Sample ID: VP-1

Lab ID#: 1311468B-01B

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**14112619c**	**Date of Collection: 11/21/13 12:44:00 PM**
Dil. Factor:	**430**	**Date of Analysis: 11/27/13 07:34 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
>C8-C10 Aromatic Hydrocarbons (ref. to 1,2,3-TMB)	22000	7000	100000	34000
>C10-C12 Aromatic Hydrocarbons (ref. to 1,2,4,5-TMB)	22000	Not Detected	120000	Not Detected

Container Type: 1 Liter Summa Canister

Client Sample ID: VP-2

Lab ID#: 1311468B-02A

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112513a**	**Date of Collection: 11/21/13 11:30:00 AM**
Dil. Factor:	**9.04**	**Date of Analysis: 11/26/13 11:40 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
C5-C6 Aliphatic Hydrocarbons (ref. to Pentane + Hexane)	90	1800	290	5700
>C6-C8 Aliphatic Hydrocarbons (ref. to Heptane)	90	6800	370	28000
>C8-C10 Aliphatic Hydrocarbons (ref. to Decane)	90	4300	530	25000
>C10-C12 Aliphatic Hydrocarbons (ref. to Dodecane)	90	1600	630	11000

Container Type: 1 Liter Summa Canister

Client Sample ID: VP-2

Lab ID#: 1311468B-02B

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112513c**	**Date of Collection: 11/21/13 11:30:00 AM**
Dil. Factor:	**9.04**	**Date of Analysis: 11/26/13 11:40 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
>C8-C10 Aromatic Hydrocarbons (ref. to 1,2,3-TMB)	90	240	440	1200
>C10-C12 Aromatic Hydrocarbons (ref. to 1,2,4,5-TMB)	90	Not Detected	500	Not Detected

Container Type: 1 Liter Summa Canister

Client Sample ID: VP-3

Lab ID#: 1311468B-03A

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**14112622a**	**Date of Collection:**	**11/21/13 10:10:00 AM**
Dil. Factor:	**7.00**	**Date of Analysis:**	**11/27/13 09:14 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
C5-C6 Aliphatic Hydrocarbons (ref. to Pentane + Hexane)	350	15000	1100	49000
>C6-C8 Aliphatic Hydrocarbons (ref. to Heptane)	350	120000	1400	480000
>C8-C10 Aliphatic Hydrocarbons (ref. to Decane)	350	48000	2000	280000
>C10-C12 Aliphatic Hydrocarbons (ref. to Dodecane)	350	3600	2400	25000

Container Type: 1 Liter Summa Canister

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Client Sample ID: VP-3

Lab ID#: 1311468B-03B

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**14112622c**	**Date of Collection: 11/21/13 10:10:00 AM**
Dil. Factor:	**7.00**	**Date of Analysis: 11/27/13 09:14 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
>C8-C10 Aromatic Hydrocarbons (ref. to 1,2,3-TMB)	350	Not Detected	1700	Not Detected
>C10-C12 Aromatic Hydrocarbons (ref. to 1,2,4,5-TMB)	350	Not Detected	1900	Not Detected

Container Type: 1 Liter Summa Canister

Client Sample ID: BD-1

Lab ID#: 1311468B-04A

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	3112511a	Date of Collection:	11/21/13
Dil. Factor:	8.48	Date of Analysis:	11/26/13 10:37 AM

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
C5-C6 Aliphatic Hydrocarbons (ref. to Pentane + Hexane)	85	1500	270	4800
>C6-C8 Aliphatic Hydrocarbons (ref. to Heptane)	85	5700	350	23000
>C8-C10 Aliphatic Hydrocarbons (ref. to Decane)	85	2600	490	15000
>C10-C12 Aliphatic Hydrocarbons (ref. to Dodecane)	85	1500	590	10000

Container Type: 1 Liter Summa Canister

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Client Sample ID: BD-1

Lab ID#: 1311468B-04B

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112511c**	**Date of Collection:**	**11/21/13**
Dil. Factor:	**8.48**	**Date of Analysis:**	**11/26/13 10:37 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
>C8-C10 Aromatic Hydrocarbons (ref. to 1,2,3-TMB)	85	210	420	1000
>C10-C12 Aromatic Hydrocarbons (ref. to 1,2,4,5-TMB)	85	Not Detected	460	Not Detected

Container Type: 1 Liter Summa Canister

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Client Sample ID: Equipment Blank

Lab ID#: 1311468B-05A

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112510a**	**Date of Collection: 11/21/13 1:08:00 PM**
Dil. Factor:	**2.10**	**Date of Analysis: 11/26/13 09:57 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
C5-C6 Aliphatic Hydrocarbons (ref. to Pentane + Hexane)	21	Not Detected	68	Not Detected
>C6-C8 Aliphatic Hydrocarbons (ref. to Heptane)	21	Not Detected	86	Not Detected
>C8-C10 Aliphatic Hydrocarbons (ref. to Decane)	21	Not Detected	120	Not Detected
>C10-C12 Aliphatic Hydrocarbons (ref. to Dodecane)	21	Not Detected	150	Not Detected

Container Type: 1 Liter Summa Canister

Client Sample ID: Equipment Blank

Lab ID#: 1311468B-05B

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112510c**	**Date of Collection: 11/21/13 1:08:00 PM**
Dil. Factor:	**2.10**	**Date of Analysis: 11/26/13 09:57 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
>C8-C10 Aromatic Hydrocarbons (ref. to 1,2,3-TMB)	21	Not Detected	100	Not Detected
>C10-C12 Aromatic Hydrocarbons (ref. to 1,2,4,5-TMB)	21	Not Detected	120	Not Detected

Container Type: 1 Liter Summa Canister

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Client Sample ID: Lab Blank

Lab ID#: 1311468B-06A

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112509a**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/26/13 09:08 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
C5-C6 Aliphatic Hydrocarbons (ref. to Pentane + Hexane)	10	Not Detected	32	Not Detected
>C6-C8 Aliphatic Hydrocarbons (ref. to Heptane)	10	Not Detected	41	Not Detected
>C8-C10 Aliphatic Hydrocarbons (ref. to Decane)	10	Not Detected	58	Not Detected
>C10-C12 Aliphatic Hydrocarbons (ref. to Dodecane)	10	Not Detected	70	Not Detected

Container Type: NA - Not Applicable

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Client Sample ID: Lab Blank

Lab ID#: 1311468B-06B

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112509c**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/26/13 09:08 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
>C8-C10 Aromatic Hydrocarbons (ref. to 1,2,3-TMB)	10	Not Detected	49	Not Detected
>C10-C12 Aromatic Hydrocarbons (ref. to 1,2,4,5-TMB)	10	Not Detected	55	Not Detected

Container Type: NA - Not Applicable

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Client Sample ID: Lab Blank

Lab ID#: 1311468B-06C

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**14112607e**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/26/13 04:46 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
C5-C6 Aliphatic Hydrocarbons (ref. to Pentane + Hexane)	50	Not Detected	160	Not Detected
>C6-C8 Aliphatic Hydrocarbons (ref. to Heptane)	50	Not Detected	200	Not Detected
>C8-C10 Aliphatic Hydrocarbons (ref. to Decane)	50	Not Detected	290	Not Detected
>C10-C12 Aliphatic Hydrocarbons (ref. to Dodecane)	50	Not Detected	350	Not Detected

Container Type: NA - Not Applicable

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Client Sample ID: Lab Blank

Lab ID#: 1311468B-06D

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**14112607f**	**Date of Collection: NA**	
Dil. Factor:	**1.00**	**Date of Analysis:**	**11/26/13 04:46 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
>C8-C10 Aromatic Hydrocarbons (ref. to 1,2,3-TMB)	50	Not Detected	240	Not Detected
>C10-C12 Aromatic Hydrocarbons (ref. to 1,2,4,5-TMB)	50	Not Detected	270	Not Detected

Container Type: NA - Not Applicable

Client Sample ID: CCV

Lab ID#: 1311468B-07A

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112507a**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/26/13 07:09 AM**

Compound	%Recovery
C5-C6 Aliphatic Hydrocarbons (ref. to Pentane + Hexane)	93
>C6-C8 Aliphatic Hydrocarbons (ref. to Heptane)	87
>C8-C10 Aliphatic Hydrocarbons (ref. to Decane)	92
>C10-C12 Aliphatic Hydrocarbons (ref. to Dodecane)	94

Container Type: NA - Not Applicable

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Client Sample ID: CCV

Lab ID#: 1311468B-07B

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**3112507c**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/26/13 07:09 AM**

Compound	%Recovery
>C8-C10 Aromatic Hydrocarbons (ref. to 1,2,3-TMB)	87
>C10-C12 Aromatic Hydrocarbons (ref. to 1,2,4,5-TMB)	93

Container Type: NA - Not Applicable

Client Sample ID: CCV

Lab ID#: 1311468B-07C

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**14112606a**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/26/13 04:11 PM**

Compound	%Recovery
C5-C6 Aliphatic Hydrocarbons (ref. to Pentane + Hexane)	87
>C6-C8 Aliphatic Hydrocarbons (ref. to Heptane)	76
>C8-C10 Aliphatic Hydrocarbons (ref. to Decane)	85
>C10-C12 Aliphatic Hydrocarbons (ref. to Dodecane)	87

Container Type: NA - Not Applicable

Client Sample ID: CCV

Lab ID#: 1311468B-07D

MODIFIED METHOD TO-15 GC/MS FULL SCAN

File Name:	**14112606c**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/26/13 04:11 PM**

Compound	%Recovery
>C8-C10 Aromatic Hydrocarbons (ref. to 1,2,3-TMB)	77
>C10-C12 Aromatic Hydrocarbons (ref. to 1,2,4,5-TMB)	72

Container Type: NA - Not Applicable

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11/26/2013
Mr. Eric Epple
Arcadis U.S., Inc.
1100 Olive Way
Ste 800
Seattle WA 98101

Project Name: Edmonds Terminal
Project #: B0045362.0004
Workorder #: 1311468C

Dear Mr. Eric Epple

The following report includes the data for the above referenced project for sample(s) received on 11/25/2013 at Air Toxics Ltd.

The data and associated QC analyzed by Modified ASTM D-1946 are compliant with the project requirements or laboratory criteria with the exception of the deviations noted in the attached case narrative.

Thank you for choosing Air Toxics Ltd. for your air analysis needs. Air Toxics Ltd. is committed to providing accurate data of the highest quality. Please feel free to contact the Project Manager: Kelly Buettner at 916-985-1000 if you have any questions regarding the data in this report.

Regards,

Kelly Buettner

Kelly Buettner
Project Manager

WORK ORDER #: 1311468C

Work Order Summary

CLIENT:	Mr. Eric Epple Arcadis U.S., Inc. 1100 Olive Way Ste 800 Seattle, WA 98101	**BILL TO:**	Accounts Payable Arcadis U.S., Inc. 630 Plaza Drive Suite 600 Highlands Ranch, CO 80129
PHONE:	206-726-4728	**P.O. #**	B0045362.0004
FAX:	206-325-8218	**PROJECT #**	B0045362.0004 Edmonds Terminal
DATE RECEIVED:	11/25/2013	**CONTACT:**	Kelly Buettner
DATE COMPLETED:	11/26/2013		

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.	FINAL PRESSURE
01A	VP-1	Modified ASTM D-1946	1.8 "Hg	15 psi
02A	VP-2	Modified ASTM D-1946	3.1 "Hg	15.1 psi
03A	VP-3	Modified ASTM D-1946	1.2 "Hg	14.9 psi
04A	BD-1	Modified ASTM D-1946	1.4 "Hg	15 psi
05A	Equipment Blank	Modified ASTM D-1946	1 "Hg	15.1 psi
06A	Lab Blank	Modified ASTM D-1946	NA	NA
06B	Lab Blank	Modified ASTM D-1946	NA	NA
07A	LCS	Modified ASTM D-1946	NA	NA
07AA	LCSD	Modified ASTM D-1946	NA	NA

CERTIFIED BY: [signature] DATE: 11/26/13

Technical Director

Certification numbers: AZ Licensure AZ0775, CA NELAP - 12282CA, NJ NELAP - CA016, NY NELAP - 11291, TX NELAP - T104704434-13-6, UT NELAP CA009332013-4, VA NELAP - 460197, WA NELAP - C935
Name of Accrediting Agency: NELAP/ORELAP (Oregon Environmental Laboratory Accreditation Program)
Accreditation number: CA300005, Effective date: 10/18/2013, Expiration date: 10/17/2014.
Eurofins Air Toxics Inc.. certifies that the test results contained in this report meet all requirements of the NELAC standards

LABORATORY NARRATIVE
Modified ASTM D-1946
Arcadis U.S., Inc.
Workorder# 1311468C

Five 1 Liter Summa Canister samples were received on November 25, 2013. The laboratory performed analysis via Modified ASTM Method D-1946 for Methane and fixed gases in air using GC/FID or GC/TCD. The method involves direct injection of 1.0 mL of sample.

On the analytical column employed for this analysis, Oxygen coelutes with Argon. The corresponding peak is quantitated as Oxygen.

Method modifications taken to run these samples are summarized in the table below. Specific project requirements may over-ride the ATL modifications.

Requirement	***ASTM D-1946***	***ATL Modifications***
Calibration	A single point calibration is performed using a reference standard closely matching the composition of the unknown.	A 3-point calibration curve is performed. Quantitation is based on a daily calibration standard which may or may not resemble the composition of the associated samples.
Reference Standard	The composition of any reference standard must be known to within 0.01 mol % for any component.	The standards used by ATL are blended to a >/= 95% accuracy.
Sample Injection Volume	Components whose concentrations are in excess of 5 % should not be analyzed by using sample volumes greater than 0.5 mL.	The sample container is connected directly to a fixed volume sample loop of 1.0 mL on the GC. Linear range is defined by the calibration curve. Bags are loaded by vacuum.
Normalization	Normalize the mole percent values by multiplying each value by 100 and dividing by the sum of the original values. The sum of the original values should not differ from 100% by more than 1.0%.	Results are not normalized. The sum of the reported values can differ from 100% by as much as 15%, either due to analytical variability or an unusual sample matrix.
Precision	Precision requirements established at each concentration level.	Duplicates should agree within 25% RPD for detections > 5 X's the RL.

Receiving Notes

There were no receiving discrepancies.

Analytical Notes

There were no analytical discrepancies.

Definition of Data Qualifying Flags

Seven qualifiers may have been used on the data analysis sheets and indicate as follows:
B - Compound present in laboratory blank greater than reporting limit.
J - Estimated value.
E - Exceeds instrument calibration range.
S - Saturated peak.
Q - Exceeds quality control limits.
U - Compound analyzed for but not detected above the detection limit.
M - Reported value may be biased due to apparent matrix interferences.
File extensions may have been used on the data analysis sheets and indicates as follows:
a-File was requantified
b-File was quantified by a second column and detector
r1-File was requantified for the purpose of reissue

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Summary of Detected Compounds
NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

Client Sample ID: VP-1

Lab ID#: 1311468C-01A

Compound	Rpt. Limit (%)	Amount (%)
Oxygen	0.22	2.6
Methane	0.00022	29
Carbon Dioxide	0.022	11

Client Sample ID: VP-2

Lab ID#: 1311468C-02A

Compound	Rpt. Limit (%)	Amount (%)
Oxygen	0.23	1.6
Methane	0.00023	2.6
Carbon Dioxide	0.023	12

Client Sample ID: VP-3

Lab ID#: 1311468C-03A

Compound	Rpt. Limit (%)	Amount (%)
Oxygen	0.21	1.3
Methane	0.00021	23
Carbon Dioxide	0.021	11

Client Sample ID: BD-1

Lab ID#: 1311468C-04A

Compound	Rpt. Limit (%)	Amount (%)
Oxygen	0.21	4.0
Methane	0.00021	2.3
Carbon Dioxide	0.021	10

Client Sample ID: Equipment Blank

Lab ID#: 1311468C-05A

Compound	Rpt. Limit (%)	Amount (%)

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Summary of Detected Compounds
NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

Client Sample ID: Equipment Blank

Lab ID#: 1311468C-05A

Compound	Rpt. Limit (%)	Amount (%)
Oxygen	0.21	2.5

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Client Sample ID: VP-1

Lab ID#: 1311468C-01A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10112521**	**Date of Collection: 11/21/13 12:44:00 P**
Dil. Factor:	**2.15**	**Date of Analysis: 11/25/13 06:30 PM**

Compound	Rpt. Limit (%)	Amount (%)
Oxygen	0.22	2.6
Methane	0.00022	29
Carbon Dioxide	0.022	11
Helium	0.11	Not Detected

Container Type: 1 Liter Summa Canister

Client Sample ID: VP-2

Lab ID#: 1311468C-02A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10112520**	**Date of Collection:**	**11/21/13 11:30:00 A**
Dil. Factor:	**2.26**	**Date of Analysis:**	**11/25/13 06:01 PM**

Compound	Rpt. Limit (%)	Amount (%)
Oxygen	0.23	1.6
Methane	0.00023	2.6
Carbon Dioxide	0.023	12
Helium	0.11	Not Detected

Container Type: 1 Liter Summa Canister

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Client Sample ID: VP-3

Lab ID#: 1311468C-03A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10112522**	**Date of Collection:**	**11/21/13 10:10:00 A**
Dil. Factor:	**2.10**	**Date of Analysis:**	**11/25/13 06:58 PM**

Compound	Rpt. Limit (%)	Amount (%)
Oxygen	0.21	1.3
Methane	0.00021	23
Carbon Dioxide	0.021	11
Helium	0.10	Not Detected

Container Type: 1 Liter Summa Canister

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Client Sample ID: BD-1

Lab ID#: 1311468C-04A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10112523**	**Date of Collection: 11/21/13**
Dil. Factor:	**2.12**	**Date of Analysis: 11/25/13 07:47 PM**

Compound	Rpt. Limit (%)	Amount (%)
Oxygen	0.21	4.0
Methane	0.00021	2.3
Carbon Dioxide	0.021	10
Helium	0.11	Not Detected

Container Type: 1 Liter Summa Canister

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Client Sample ID: Equipment Blank

Lab ID#: 1311468C-05A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10112524**	**Date of Collection:**	**11/21/13 1:08:00 PM**
Dil. Factor:	**2.10**	**Date of Analysis:**	**11/25/13 08:12 PM**

Compound	Rpt. Limit (%)	Amount (%)
Oxygen	0.21	2.5
Methane	0.00021	Not Detected
Carbon Dioxide	0.021	Not Detected
Helium	0.10	Not Detected

Container Type: 1 Liter Summa Canister

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Client Sample ID: Lab Blank

Lab ID#: 1311468C-06A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10112505**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/25/13 10:30 AM**

Compound	Rpt. Limit (%)	Amount (%)
Oxygen	0.10	Not Detected
Methane	0.00010	Not Detected
Carbon Dioxide	0.010	Not Detected

Container Type: NA - Not Applicable

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Client Sample ID: Lab Blank

Lab ID#: 1311468C-06B

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10112506c**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/25/13 10:57 AM**

Compound	Rpt. Limit (%)	Amount (%)
Helium	0.050	Not Detected

Container Type: NA - Not Applicable

Client Sample ID: LCS

Lab ID#: 1311468C-07A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10112502**	**Date of Collection: NA**	
Dil. Factor:	**1.00**	**Date of Analysis:**	**11/25/13 09:18 AM**

Compound	%Recovery	Method Limits
Oxygen	102	85-115
Methane	101	85-115
Carbon Dioxide	100	85-115
Helium	98	85-115

Container Type: NA - Not Applicable

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Client Sample ID: LCSD

Lab ID#: 1311468C-07AA

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10112526**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 11/25/13 09:51 PM**

Compound	%Recovery	Method Limits
Oxygen	102	85-115
Methane	101	85-115
Carbon Dioxide	99	85-115
Helium	98	85-115

Container Type: NA - Not Applicable

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Appendix D

Applicable or Relevant and Appropriate Requirements

SUMMARY OF POTENTIALLY APPLICABLE REQUIREMENTS

According to WAC 173-340-360(2), all cleanup actions under the Model Toxics Control Act (MTCA) must comply with applicable state and federal laws. Such laws are defined under the MTCA as including Applicable or Relevant and Appropriate Requirements (ARARs). ARARs for the Lower Yard are discussed below:

Summary of Generally Applicable or Relevant and Appropriate Regulations

Clean Water Act (CWA)
Provisions set forth in the Federal Water Pollution Control Act (FWPCA), commonly referred to as the CWA, require the development of regulations to protect the nation's waters. Requirements of the CWA have been delegated to the State of Washington which has corresponding rules and regulations, encompassing all of those stated in the CWA. Therefore, potential discharges to surface water will be managed under the State program.

Resource Conservation and Recovery Act (RCRA)
Investigation –derived waste (IDW), soil, water or other substances removed from the site during the implementation of remedial activities will be handled per RCRA regulations and implemented according to WAC 173-303.

The Endangered Species Act
The only threatened or endangered species identified in the vicinity of the Terminal is the bald eagle. Bald eagles are frequently observed in flight over the Lower Yard, and they may perch in trees of the Upper Yard. Implementation of the remedial action in conformance with MTCA will result in the protection of wildlife, including any threatened and endangered species.

Migratory Bird Treaty Act
A great blue heron colony is found in the southeast Lower Yard. In 2007, testing was conducted to evaluate the level of disturbance in the areas adjacent to the great blue heron nests. The testing determined that the heron would not disturbed by site remediation activities conducted greater than 150 feet away from the nests. Site remedial activities will not be conducted less than 150 feet from the colony. Additionally, implementation of the remedial action in conformance with MTCA, will provide that wildlife, including migratory birds, will be protected.

The Safe Drinking Water Act
The groundwater CULs for the Lower Yard were established based on protection of surface water, since a determination was made that the groundwater beneath the Lower Yard is non-potable.

Natural Resource Damages
Remedial design and implementation will establish means and methods to ensure that the remedial action minimizes risks that could potentially damage natural resources, such as surface-water resources, groundwater resources, air resources, geologic resources, and biological resources. Damages to natural resource caused by remedial action implementation will be avoided, and are not expected to occur.

U.S. Department of Transportation Hazardous Materials Regulations
The U.S. Department of Transportation has published regulations, including communications and emergency response requirements, shipping, and packaging requirements (49 CFR 107, 171)), that govern the transportation of hazardous materials to or from the site. Hazardous waste generated at the site will be appropriately characterized to determine package, transportation and transportation requirements prior to implementing remedial action.

National Ambient Air Quality Standards Attainment Area
Air emissions generated by the remedial implementation at the site are subject to applicable air-quality standards in order to control or prevent the emission of air contaminants. The applicable pollutants at the site would be particulate matter (dust) and carbon monoxide. Degradation of ambient air quality caused by remedial action implementation at the site will be avoided, and is not expected to occur.

Occupational Safety and Health Administration (OSHA)
Site activities will be conducted in a manner compliant with OSHA standards and regulations (29 CFR 1910).

Model Toxics Control Act
All elements of the remedial design and site activities will occur in accordance with MTCA statutes and regulations.

National Pollutant Discharge Elimination System Stormwater Permit Program
A NPDES permit modification will be needed for discharge of treated water to Willow Creek. Effluent limitations, sampling parameters and discharge quality standards will be defined in this permit, which will affect the treatment technologies used in the treatment system. Consequently, design and operation of the system will conform to applicable regulations.

Air Quality Standards
During remedial implementation, engineering controls will be necessary to control particulate emissions. Air testing may be required to show that emissions meet the substantive requirements of applicable air quality permits and rules, as administered by the Puget Sound Clean Air Agency.

Noise Regulations
Site activities will be conducted at appropriate noise levels, according to the City of Edmonds Municipal Code. Noise production during remedial activities may limit operating hours of project work.

State Environmental Policy Act
The State Environmental Policy Act (SEPA) provides the framework for agencies to consider the environmental consequences of a proposed land use action. SEPA requires the preparation of an environmental checklist and review of the potential environmental impacts and mitigation measures used to protect the environment. A SEPA checklist will be prepared with the permitting of the remedial action to be conducted at the site.

Spill Prevention, Preparedness, and Response
A spill prevention, control, and countermeasures plan will be developed for the storage and handling of these materials. This will include potential groundwater treatment system facilities and heavy equipment used onsite, as well as any stored materials.

Minimum Standards for Construction and Maintenance of Wells, Regulation and Licensing of Well Contractors and Operators
Resource protection wells will be decommissioned, constructed and maintained according to the appropriate regulations

Washington Industrial Safety and Health Act
Site activities will be conducted in a manner compliant with Washington Industrial Safety and Health Act (WISHA) standards and regulations.

City of Edmonds Permits
The City of Edmonds requires permits for grading, excavation, and fill activities. All required permits needed from the City of Edmonds will be obtained during the design phase of the remedial action and will apply to all of the remedial activities.

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Appendix E

2007 TEE

TERRESTRIAL ECOLOGICAL EVALUATION

INTRODUCTION

This appendix presents the terrestrial ecological evaluation (TEE) for the lower yard of the Unocal Edmonds Bulk Fuel Terminal (Terminal), as required by WAC 173-340-7490. It is formatted consistent with the documentation forms provided by the Department of Ecology (Ecology) on its interactive website.

Site background and history are summarized in Section 2 of this report. Soils on site are mainly contaminated with petroleum, primarily in the diesel and oil range, from fuel storage and transfer activities. Union Oil Company (Union Oil) has performed interim actions to remove free product and soils in the areas of highest soil contamination. The completed interim actions, the planned interim action, and the nature of the future development of the lower yard minimize potential exposures to terrestrial receptors by reducing contaminant levels and controlling exposure pathways. Substantial amounts of contaminated soils have been removed, significantly reducing both the spatial extent of contamination and the concentrations of remaining contaminants.

Soils containing significant TPH concentrations remain in areas of the lower yard. Union Oil intends to complete remediation of the lower yard prior to redevelopment as a multi-modal transportation facility. After development, a large portion of the site will be covered with buildings and pavement. In covered areas, terrestrial receptors will be unable to contact soil contaminants.

RI/FS activities included sediment sampling for chemical analyses and bioassays in Willow Creek, adjacent to the lower yard. The RI also included whole effluent toxicity (WET) testing of groundwater beneath the lower yard. These data are discussed in Section 5 of this report. This appendix focuses on ecological issues related to the terrestrial environment only.

Environmental studies of the Edmonds Marsh, which is located on the opposite side of Willow Creek from the lower yard, were conducted in conjunction with the Final Environmental Impact Statement (EIS) conducted for the SR104 Edmonds Crossing Project (CH_2M Hill, 2004). Information from these studies was used in this TEE.

PRIMARY EXCLUSIONS

An answer of "Yes" to any one question in this section excludes the site from further TEE [WAC 173-340-7491(1)].

1a) Will soil contamination be located at least 6 feet beneath the ground surface and less than 15 feet [WAC 173-340-7491(1)(a)]?

No. Detectable concentrations of TPH will likely be present within 6 feet of ground surface following remediation.

1b) Will soil contamination be located at least 15 feet beneath the ground surface [WAC 173-340-7491(1)(a)]?

No. As noted above, detectable concentrations of TPH will likely be present within 15 feet of ground surface following remediation.

1c) Will soil contamination be located below the conditional point of compliance [WAC 173-340-7491(1)(a)]?

No. Union Oil does not plan to propose a conditional point of compliance.

2) Will soil contamination be covered by buildings, paved roads, pavement, or other physical barriers that will prevent plants or wildlife from being exposed [WAC 173-340-7491(1)(b)]?

No. After redevelopment as a multi-modal transportation terminal, there may be some uncapped areas that contain detectable concentrations of the IHSs.

3a) Is there less than 1.5 acres of contiguous undeveloped land on the site, or within 500 feet of any area of the site affected by hazardous substances (other than those substances listed in WAC 173-340-7491(1)(c)(ii)) [WAC 173-340-7491(1)(c)(i)]?

No. There are more than 1.5 acres of contiguous undeveloped land in a wooded area adjacent to the southwest portion of the lower yard.

3b) Is there less than 0.25 acres of contiguous undeveloped land on or within 500 feet of any area of the site affected by hazardous substances listed in WAC 173-340-7491(1)(c)(ii) [WAC 173-340-7491(1)(c)(ii)]?

Not applicable. The site is not contaminated with any of the listed substances.

4) Are concentrations of hazardous substances in the soil less than or equal to natural background concentrations of those substances at the point of compliance [WAC 173-340-7491(1)(d)]?

No. Ecology does not recognize natural background concentrations of petroleum hydrocarbons.

EXCLUSIONS CONCLUSION: The lower yard does not qualify for exclusion from the TEE.

SIMPLIFIED OR SITE-SPECIFIC EVALUATION

An answer of "Yes" to any one question below means the lower yard is required to undergo a site-specific TEE [WAC 173-340-7491(2)]. Otherwise, a simplified evaluation is allowed.

1) Is the site located on or directly adjacent to an area where management or land use plans will maintain or restore native or semi-native vegetation [WAC 173-340-7491(2)(a)(i)]?

Yes. Edmonds Marsh is directly adjacent to the eastern portion of the lower yard. According to the Final EIS for the Edmonds Crossing project [CH_2M Hill, 2004 (p. 3-41)], Edmonds Marsh has been rated by the City of Edmonds as a Category 1 (high quality) wetland based on its uniqueness, large size, and habitat for a state monitor species (great blue heron). It is designated by the city as a Wildlife Sanctuary on the City of Edmonds Environmentally Sensitive Areas map and as a Priority Habitat in the WDFW Priority Habitat and Species database. Category I wetlands are considered the most valuable, and their disturbance is rarely permitted.

2a) Is the site used by a threatened or endangered species [WAC 173-340-7491(2)(a)(ii)]? For animals, "used" means that individuals of a species have been observed to live, feed or breed at the site. For plants, "used" means that a plant species grows at the site or has been found growing at the site.

No. A Wildlife Habitat Study was performed in 1996 as part of the remedial investigation of the Terminal (Adolfson, 1996). Specific to threatened and endangered species, the study findings were as follows:

> Bald eagles are reported as nesting approximately one mile south of the Terminal. Bald eagle nests are not known to exist on the Terminal property or within one mile of the property boundary. During field surveys in 1995, bald eagles were observed perched in large deciduous trees located along the bluff to the south of the Terminal's pier.

No other threatened or endangered animal species were identified. Although bald eagles have been removed from the endangered list, they are still listed as threatened (www.wa.gov/wdfw/wlm/diversty/soc/threaten.htm). Observations by former site personnel indicate that bald eagle do not live at the Terminal, nor have bald eagles been seen perching in trees at the Terminal. As bald eagles are primarily fish eaters, the lower yard does not provide suitable foraging habitat. Bald eagles are seen in flight above the Terminal, but this behavior does not meet the definition of "use" (live, feed, or breed).

The Washington Department of Fish and Wildlife (WDFW) was contacted in the spring of 2002 for additional information. The Priority Habitats and Species Database and Wildlife Heritage Database show the Terminal to be in an area where priority habitats and species are unknown, or the area was not mapped. The area to the south of the Terminal is identified as a bald eagle use area (breeding occurrence).

2b) Is the site used by a wildlife species classified by the Washington State Department of Fish and Wildlife as a "priority species" or "species of concern" under Title 77 RCW [WAC 173-340-7491(2)(a)(ii)]?

No. The WDFW database (www.wa.gov/wdfw/wlm/diversty/soc/threaten.htm) was searched for mammalian, avian, reptilian, and amphibian species listed as expected to occur at the Terminal per the Wildlife Habitat Study. None of the species identified in the Wildlife Habitat Study is listed in the WDFW database as a "priority species" or "species of concern."

2c) Is the site used by a plant species classified by the Washington State Department of Natural Resources Natural Heritage Program as "endangered," "threatened," or "sensitive" under Title 79 RCW [WAC 173-340-7491(2)(a)(ii)]?

No. A review of the Washington State Department of Natural Resources' Natural Heritage Information System (www.wa.gov/htdocs/fr/nhp/refdesk/fsrefix.htm) was performed as part of the 1996 Wildlife Habitat Study. There are no records of significant natural features, rare plants, high quality native wetlands, or high quality native plant communities within the vicinity of the project area.

Additional studies have been performed for purposes of the Edmonds Crossing EIS. No endangered, threatened, or sensitive species were identified in studies performed in 2000 and 2001 (personal communication between Cathy Conolly of Adolfson Associates and Linda Dawson of Maul Foster & Alongi, Inc. on November 30, 2001).

3) Is the area of contamination located on a property that contains at least 10 acres of native vegetation within 500 feet of the area of contamination [WAC 173-340-7491(2)(a)(iii)]?

No. The lower yard (23 acres in area) was an active industrial site that has recently been subject to intensive remedial activity including excavation, backfilling, and grading, and it contains limited vegetation. A small area (approximately 2 acres) located in the southeast corner of the lower yard contains native vegetation. The lower yard will be redeveloped as a multi-modal transportation facility, so it will be primarily covered by buildings and pavement. At present, the lower yard offers limited, disturbed terrestrial habitat. The sparse vegetative cover, low species diversity, and amount of human disturbance in this area limit wildlife use of this habitat [Adolfson Associates, Inc., 1996 (p. 9)].

4) Has the department determined that the site may present a risk to significant wildlife populations [WAC 173-340-7491(2)(a)(iv)]?

No. Ecology has not determined that the lower yard may present a significant risk to wildlife populations.

SIMPLIFIED OR SITE-SPECIFIC EVALUATION CONCLUSION: A site-specific TEE is required because of the site's location next to Edmonds Marsh.

SIMPLIFIED EVALUATION

A simplified TEE is not allowed because a site-specific evaluation is required.

SITE-SPECIFIC EVALUATION

A site-specific TEE consists of two elements: problem formulation and the actual evaluation. After reviewing the problem formulation, Ecology may determine that additional evaluation is not necessary [WAC 173-340-7493(1)(d)].

Problem Formulation

Problem formulation involves identifying the following components of the site-specific TEE:

- Chemicals of ecological concern
- Exposure pathways
- Terrestrial ecological receptors of concern
- Toxicological assessment

The indicator hazardous substances (IHSs) chosen for the TEE are the following (see Section 5.1.3 of this report):

- GRO
- DRO
- HO
- Benzene
- CPAHs
- Arsenic

Following remediation, if the maximum or the upper 95 percent confidence limit concentrations of the IHSs do not exceed the ecological indicator concentrations in MTCA Table 749-3, they may be eliminated from further consideration [WAC 173-340-7493(2)(a)(i)]. Since the site will be used for commercial purposes, only the values in the wildlife column of the table are applicable [WAC 173-340-7493(2)(a)(i)]. The ecological indicator concentrations are 5,000 mg/kg for GRO, 6,000 mg/kg for DRO, 12 mg/kg for cPAHs (benzo(a)pyrene is used as a surrogate), and 132 mg/kg for arsenic in unsaturated soil. There are no table values for HO and benzene.

The petroleum indicator concentrations note that soil concentrations may not exceed residual saturation values. However, the TPH cleanup level (CUL) for the site (2,975 mg/kg; based on direct contact) exceeds the default residual saturation concentration. This higher CUL can be applied because an empirical demonstration (free product does not occur on the groundwater) will be used to show that post-remediation soil concentrations do not exceed residual saturation. The residual saturation requirements will be met at the conclusion of the remediation.

Institutional controls, in the form of deed restrictions, will be used to ensure that any soils exceeding the ecological indicator soil concentrations are capped, that the caps are maintained, and that if the coverings are disturbed, contaminated soils are handled appropriately [WAC 173-340-7493(2)(a)(ii)]. This will ensure there are no complete exposure pathways to soil concentrations of IHSs exceeding the ecological indicator soil concentrations. If there are no complete exposure pathways, no further evaluation is necessary [WAC 173-340-7493(2)(a)(ii)].

The combination of remedial actions, planned development, and institutional controls will minimize wildlife exposure to site-related contaminants. Evaluation of the first two components of problem formulation finds that additional evaluation is not necessary. Capping the soil with IHS concentrations exceeding those listed in MTCA Table 749-3 (wildlife column only) will allow the site-specific TEE to be ended.

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Appendix F

MTCATPH11.1 Worksheet and Calculation Summary

MTCATPH 11.1 Calculation Worksheet

		SB-183-2.5	SB-183-5.5	SB-184-2.5	SB-184-4.0	SB-185-4.0	SB-185-5.5	DB1-A-26wall1-4	DB1-A-1wall-2.5	DB1-A-21wall-2.5	DB1-A-25wall-3.5	SWLY-A-5wall-3.75	SWLY-A-14wall-3.75	SWLY-C-21wall-3.75	SWLY-D-3wall-3.75
Fraction/Constituent (mg/kg)															
Aliphatic	EC>5-6	4.95	2.45	44.85	22.84	37.3	31.3	2.25	2.25	2.4	9.89	4.75	9.75	45.49	68.7
	EC>6-8	5	2.5	350	83.8	178	199	2.5	2.5	2.5	10	5	10	312	826
	EC>8-10	5	24.9	530	166	137	94.9	2.5	2.5	19.5	41.7	277	66.5	287	19.6
	EC>10-12	80.7	111	649	342	287	249	2.5	2.5	81.8	80	908	173	353	16.3
	EC>12-16	641	558	1020	581	717	840	12.3	291	481	269	2500	431	732	39.1
	EC>16-21	1770	785	1270	717	858	1080	23.7	1030	973	438	1720	310	528	32.6
	EC>21-34	1400	443	500	245	306	395	51	1060	575	564	817	98.4	742	12.8
Aromatic	EC>8-10	16.49	10.38	617.5	241.38	338.9	333.1	2.43	2.43	2.43	54.34	26.36	21.46	299.51	280.1
	EC>10-12	102.79	85.4	1571.22	714.39	641.3	899.97	2.43	2.2	2.16	228.77	214.58	63.86	416.87	2.79
	EC>12-16	340	309	1420	624	325	978	19	22.5	92.5	483	1080	65.9	308	303
	EC>16-21	930.02	539.64	518.63	332.69	326.61	477.59	18.27	450.4	547.41	355.49	1679.85	158.38	326.32	28.84
	EC>21-34	698.95	452.95	345.95	212.95	215.95	294.95	82.25	642.8	337.9	565.9	886.99	67.45	573.8	7.55
	Benzene	0.015	0.015	0.554	0.15	1.15	1.15	0.015	0.015	0.015	0.046	0.032	0.06	2.42	4.47
	Toluene	0.025	0.025	4.09	1.16	2.42	3.33	0.025	0.025	0.025	0.095	0.11	0.1	1.43	6.25
	Ethylbenzene	0.171	0.086	4.19	1.49	27.1	43.9	0.025	0.025	0.025	0.572	0.298	0.523	6.39	17.9
	Xylenes	0.444	0.336	15.3	6.13	72	25	0.05	0.05	0.05	1.99	0.438	1.32	25.1	35
	Naphthalene	0.597	0.4	7	4.5	22	6.4	0.025	0.1	0.025	0.18	1	1.4	2.7	0.94
	1-methylnaphthalene	3.84	2	4.1	3	11	7.3	0.025	0.1	0.22	0.49	15	2.1	6.3	1.3
	2-methylnaphthalene	3.77	1.6	7.7	5.1	21	15	0.025	0.1	0.096	0.57	20	2.4	11	1.7
	n-Hexane	0.05	0.05	5.15	2.16	12.7	18.7	0.25	0.25	0.0965	0.113	0.25	0.25	4.51	17.9
	MTBE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	EDB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	EDC	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Benzo(a)anthrancene	0.234	0.0949	0.0976	0.0845	0.109	0.116	0.0776	0.1	0.152	0.131	0.0307	0.102	0.1	0.005
	Benzo(b)fluoranthene	0.0779	0.025	0.025	0.025	0.0617	0.0713	0.0893	0.1	0.108	0.12	0.005	0.115	0.1	0.005
	Benzo(k)fluoranthene	0	0	0	0	0	0	0.025	0.1	0.0721	0.0733	0.0166	0.124	0.1	0.005
	Benzo(a)pyrene	0.163	0.025	0.025	0.025	0.0545	0.0601	0.501	0.1	0.025	0.025	0.0108	0.0767	0.1	0.0264
	Chrysene	0.501	0.211	0.222	0.173	0.167	0.165	0.136	0.205	0.232	0.162	0.088	0.2	0.285	0.0154
	Dibenzo(a,h)anthracene	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.1	0.0721	0.0733	0.005	0.025	0.1	0.005
	Indeno(1,2,3-cd)pyrene	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.1	0.025	0.025	0.005	0.025	0.1	0.005
		6004.8379	3329.1379	8885.6536	4307.0975	4537.8722	5994.0524	222.4489	3512.55	3118.8387	3104.7556	10156.8191	1484.5207	4984.725	1722.9068

	SB-183-2.5	SB-183-5.5	SB-184-2.5	SB-184-4.0	SB-185-4.0	SB-185-5.5	DB1-A-26wall1-4	DB1-A-1wall-2.5	DB1-A-21wall-2.5	DB1-A-25wall-3.5	SWLY-A-5wall-3.75	SWLY-A-14wall-3.75	SWLY-C-21wall-3.75	SWLY-D-3wall-3.75
Method B Direct Contact CUL	3,049	2,996	2,673	2,617	2,789	2,761	44	2,395	3,608	3,009	2,495	1,306	2,967	6,148
Method B PoSW CUL	100% NAPL	100% NAPL	246	466	113	187	100% NAPL	100% NAPL	100% NAPL	100% NAPL	100% NAPL	100% NAPL	504	42
100% NAPL =	76,000	77,000					84,000	76,000	75,000	79,000	75,000	71,000		

Median Method B Direct Contact CUL	**2,775**	
Median Method B PoSW using MTCATPH 100% NAPL values		**73,000**

Notes

"100% NAPL" = Occasionally, for the evaluation of the soil-to-groundwater exposure pathway, TPH soil CUL exceeds the theoretical maximum TPH that would be reached if all of the air space in the porous medium is filled with petroleum product. It means the risk is acceptable even at this high soil TPH concentration. In this case, the soil-to-groundwater is not a critical pathway and "100% NAPL" will appear in the protective soil TPH concentration box.

Appendix G

Groundwater Model

Imagine the result

Chevron Environmental Management Company

Groundwater Flow Model for the Former Unocal Edmonds Bulk Fuel Terminal

November 8, 2013

Former Unocal Edmonds Bulk Fuel Terminal,
Edmonds, Washington

Evaluation of Remedial Alternatives

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Date:
November 8, 2013

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1. Introduction

Chevron Environmental Management Company (Chevron) retained ARCADIS, Inc. (ARCADIS) to develop a three-dimensional numerical groundwater flow model for the Former Unocal Edmonds Bulk Fuel Terminal (Site) located at 11720 Unoco Road, Edmonds, Washington (Figure 1). The purpose of the groundwater flow model is to simulate groundwater flow conditions at the Site, predict the hydraulic performance and effectiveness of four alternative groundwater remedial scenarios, and overall support the completion of the Site feasibility study (FS). Existing Site-related information, including hydrogeologic data collected by ARCADIS were utilized in developing the groundwater flow model.

This Report is being submitted under Agreed Order (No.DE 4460) which requires the Union Oil Company of California (Unocal), a wholly owned indirect subsidiary of the Chevron Corporation, to conduct an interim action to remediate soil, groundwater and sediments, and to monitor groundwater in the Lower Yard.

1.1 Background

Unocal operated the Terminal from 1923 to 1991. Fuel was brought to the Terminal on ships, pumped to the storage tanks in the Upper Yard, and loaded from the tanks into rail cars and trucks for delivery to customers. In addition, an asphalt plant operated at the Terminal from 1953 to the late 1970s.

Impacted media at the Site have been extensively characterized and remediated through numerous phases of site investigation and remedial activities which are documented in the FS. Previous remedial actions conducted between 2001 and 2008 have addressed potential impacts in the Upper Yard, Lower Yard and in the sediments of Willow Creek. Site-specific data and documents regarding historical Site operations, environmental investigations, and remediation are provided in the FS.

This analysis is focused on areas with remaining impacts as described in the FS. The areas with remaining impacts that are addressed in this groundwater modeling report are shown on Figure 2.

1.2 Site Description

The Site is located in Edmonds, Washington, adjacent to Puget Sound (Figure 1). As defined in the Agreed Order, the Site consists of three areas, the Upper Yard, Lower Yard and the Willow Creek Fish Hatchery (fish hatchery). Each area is currently a separate property but was once owned by Unocal. The Upper and Lower Yards were areas of operation for the former terminal. Although the fish hatchery was included in the Agreed Order, it was not used for operations or storage at the facility and is currently owned by the City of Edmonds. The Upper Yard was remediated to cleanup standards in 2003 and is now the location of a condominium complex. As part of the Agreed Order, monitoring is ongoing at the Lower Yard, which is the focus of this groundwater model.

The Lower Yard is approximately 22 acres in area, located north of the Upper Yard (Figure 2). The western boundary of the Lower Yard is the BNSF Railway (BNSF) property, and the northwestern boundary is Willow Creek and the BNSF railway. Further west of the Lower Yard is the Port of Edmonds Marina and Puget Sound. North and northeast of the Lower Yard are the Edmonds Marsh (also known as the Union Oil Marsh) and Willow Creek. East of the Lower Yard is the Edmonds Marsh and Willow Creek, and southeast is the Willow Creek Fish Hatchery. At its nearest point (the southwest corner of the Lower Yard), the Lower Yard boundary is approximately 160 feet from the Puget Sound shoreline.

A Site storm water conveyance system consisting of 12 storm drains collects surface water runoff from the Lower Yard and discharges into two storm-water detention basins designated as Detention Basin No.1 (DB-1) and DB-2 (Figure 2). Site storm-water is conveyed directly to DB-2 via gravity flow, and then is pumped from DB-2 to Willow Creek under Industrial Stormwater General Permit No. SO3-002953C. DB-1 acts as a retention pond for overflow from DB-2 during storm events. DB-1 is bounded to the northwest, northeast, and southeast by a manmade berm. The berm runs along the eastern property boundary, adjacent to Willow Creek. DB-1 is an un-lined pond with one above-ground pump and a piping system to the DB-2 outfall on the bank of Willow Creek. DB-2 has an impermeable liner, and two submersible pumps and a piping system to the DB-2 outfall.

Willow Creek runs along the northern portion of the western boundary and the entirety of the eastern boundary of the Lower Yard. Willow Creek is approximately 10 feet wide and is underlain by silt and sand material. The creek banks on the Site property boundary are steeply sloped and vegetated with native and non-native vegetation. Water depths in Willow Creek vary from 0 to 4 feet deep, depending on season and tidal cycles (ARCADIS, 2012a).

1.3 Scope and Objectives

The scope of the groundwater flow modeling tasks included:

- Reviewing historical data and refining the CSM;
- Developing, constructing, and calibrating the Site groundwater flow model; and
- Using the calibrated Site groundwater flow model to simulate and predict the performance of four potential groundwater remedial scenarios.

The objectives of the Site groundwater flow model are to:

- Develop a steady-state groundwater flow model calibrated for average flow conditions to support feasibility screening of alternative groundwater remedial scenarios;
- Develop conceptual-level design parameters for the four groundwater remedial scenarios, such as:
    - Number, location, and pumping rates of hypothetical extraction wells necessary for hydraulic containment
    - Location, dimensions, and pumping rate of a hypothetical groundwater interceptor trench for hydraulic containment
    - Construction dewatering rates during hypothetical soil excavation activities below the water table
- Simulate the four alternative remedial scenarios and perform predictive analyses to evaluate effectiveness.

2. Conceptual Site Model

A conceptual site model (CSM) is a narrative description of the principle components of a groundwater flow system and is developed from regional, local, and site-specific data. The primary components of a groundwater flow system include: (1) areal extent, configuration, and type of aquifers and aquitards; (2) hydraulic properties of aquifers and aquitards; (3) natural groundwater recharge and discharge zones; (4) anthropogenic influence on groundwater (sources and sinks); and, (5) areal and vertical distribution of groundwater hydraulic head potential. These aquifer system components serve as the framework for the construction of a numerical groundwater flow model. A comprehensive CSM was developed in 2013 (ARCADIS, 2013) and was the basis for developing the Site groundwater flow model. Following the development of the CSM, additional groundwater parameter data collection activities (i.e., pumping and slug tests) were completed to support development of the Site groundwater flow model. The CSM will not be reiterated herein; however a discussion of the data collection activities and results is presented below.

The CSM (ARCADIS 2013) summarized information from historical Site documents including facility history reports, subsurface investigations, groundwater investigations, interim action activities, and feasibility studies. Specific data and documents often referred to in the CSM report are the:

- Final compliance soil samples collected in 2007/2008 during remedial excavation activities and documented in the Phase I Remedial Implementation As-Built Report (ARCADIS, 2009);
- FINAL Phase II Remedial Implementation As-Built Report (ARCADIS, 2010a);
- 2008 site investigation work that was conducted in the vicinity of the Washington State Department of Transportation (WSDOT) stormwater line and the former asphalt warehouse (ARCADIS, 2010b);
- 2011 site investigation work that incorporated a tidal study, pumping tests and investigated soil conditions in the vicinity of Detention Pond No.2 (DB-2) (ARCADIS, 2012a); and
- Summary of the investigation activities conducted as part of the Revised Feasibility Study Work Plan (ARCADIS, 2012b) in August of 2012 which included additional groundwater monitoring well installation, additional groundwater sampling and sediment sampling.

Please refer to the historical documents for the historical data, tables, figures, and laboratory reports.

2.1 Local and Site Geology

Local and Site geology are thoroughly described in the CSM (ARCADIS, 2013) and FS and are shown on Figures 3 and 4 herein.

As shown on Figures 3 and 4, five hydrostratigraphic units have been identified in the Lower Yard and are discussed in detail below:

1. *2008 Fill* (Figures 3 and 4). The 2007-2008 Interim Action excavations were backfilled to 6 to 12 inches above the observed groundwater table in the open excavations with poorly graded coarse gravel (⅜ to 1 inch) with little to no fines. Backfill material above the coarse gravel to ground surface was a mixture of very fine to medium sand, trace silt, and fine to medium gravel materials.

2. *1929 Fill* (Figures 3 and 4). This unit consists of silty sands with gravel and sandy silts with gravel. During the 2007-2008 Interim Action excavations, subsurface materials encountered from ground surface to a depth of 8 to 15 feet below ground surface (bgs) were mostly fill material placed circa 1929 or later, during the creation of the Lower Yard facility.

3. *Marsh Deposits* (Figure 4). In many areas of the Lower Yard, beneath the 1929 Fill, there is a layer ranging from 1 foot to 15 feet thick composed of silt and sandy silt with large amounts of organic matter such as peat, and wood debris. This layer is encountered at depths ranging from 8 to 14 feet bgs, directly below the 1929 Fill material, and is interpreted to be representative of the former marsh horizon beneath the Lower Yard. This layer is typically demarcated by a 6 to 12 inch thick layer of decomposing vegetation.

4. *Beach Deposits* (Figures 3 and 4). Below the 1929 Fill and Marsh Deposits, a poorly graded sand formation of very fine to medium sand with fine gravel is present, containing organic material such as driftwood and seashells. This layer is interpreted to be representative of the former beach environment in the area prior to creation of the Lower Yard.

5. *Whidbey Formation* (Figures 3 and 4). This material is a poorly graded sand layer consisting of very fine to medium sand with fine gravel and is distinct from the overlying materials in the Lower Yard. It is present to the maximum explored depth of 41.8 feet bgs by Unocal. This unit contains interbedded sand with silt, and interbedded silt and sandy silt are also present. The interbeds range in thickness from less than 1 inch to several feet, and appear to be laterally discontinuous. This unit is interpreted to be alluvium, and is likely part of the Whidbey Formation.

2.2 Site Hydrogeology

Groundwater in the Lower Yard occurs under unconfined conditions and is typically first encountered at depths varying between approximately 5 and 10 feet below ground (Figures 3 and 4). Based on the results of high-resolution water level measurements obtained during a four-week tidal study performed at the Site in 2011, groundwater at the Site is influenced by daily tidal cycles in Puget Sound, which was found to have a tidal range of approximately 14 feet adjacent to the Site (ARCADIS, 2013). Results of the tidal study and routine groundwater monitoring data indicated the following:

- Shallow groundwater levels at the Site fluctuated on the order of approximately 0.1 to 1.2 feet in response to tidal fluctuations in Puget Sound;
- Groundwater levels in monitoring wells screened in the Whidbey Formation fluctuated on the order of approximately 0.02 to 0.3 feet in response to tidal fluctuations in Puget Sound;
- Surface water elevations in Willow Creek and in Edmonds Marsh north of the Site fluctuated on the order of approximately 0.02 to 3.7 feet;
- Groundwater level fluctuations were correlated with surface water level fluctuations, which indicates that groundwater at the Site is hydraulically connected to and interacts with surface water in Puget Sound, Willow Creek, and Edmonds Marsh;
- Groundwater elevations are higher than elevations in DB-1;
- Groundwater at the Site is not hydraulically connected with DB-2, except under high water level conditions;
- Conductivity of Site groundwater exceeds 1,000 microsiemens per centimeter (μs/cm) in many locations along the perimeter of the Site, indicating that groundwater at the Site is naturally subject to salt water intrusion due to tidal fluctuations at Puget Sound.

A groundwater elevation contour map based on data collected during the third quarter of 2013 is presented as Figure 2. As shown, groundwater elevations in the third quarter of 2013 varied between approximately 5.5 and 10.5 feet above mean sea level (ft amsl). The direction of the Site hydraulic gradient was oriented north toward Edmonds Marsh and northwest toward Puget Sound, and the magnitude of the hydraulic gradient averaged approximately 0.002 feet per foot (ft/ft; Figure 2).

Also as shown on Figure 2, there is a potentiometric mound located in the southeast Lower Yard area which is discussed further in the CSM (ARCADIS 2013). This potentiometric mound occurs in a topographically low area of the Site that is also located at the base of a steep hill. The potentiometric mound is associated with localized increased recharge to the water table (i.e., surface water infiltration) due primarily to topography.

Results of hydraulic conductivity tests conducted at Site monitoring wells in 2011 indicate that hydraulic conductivity values vary over approximately three to four orders of magnitude, depending on location, throughout the Lower Yard (ARCADIS, 2012a). Specifically, the 2011 hydraulic conductivity test results varied between approximately 0.06 feet per day (ft/day) and 345 ft/day. This information indicates that subsurface materials at the Site are highly heterogeneous. Furthermore, it was found that the 1929 Fill has a much lower permeability than the 2008 Fill. Particularly, hydraulic conductivity of the 1929 Fill ranged from approximately 0.2 to 15 ft/day and hydraulic conductivity of the 2008 Fill ranged from approximately 2.5 to 345 ft/day (ARCADIS, 2012a).

2.3 2013 Pumping Tests

2.3.1 Short-term, single-well constant-rate pumping tests

To support development of the Site groundwater flow model, short-term, single-well pumping tests were conducted at six monitoring wells (MW-122, MW-147, MW-510, MW-203, MW-511, and MW-522). During testing, these wells were pumped at a relatively constant rate, and changes in water levels were recorded using submerged pressure transducers equipped with a data logger and confirmed with manual depth-to-water measurements. Test durations varied between approximately 30 and 45 minutes. Appropriate flow rates for test analyses were identified based on periodic flow rate measurements and total pumping volumes recorded by site personnel during each test.

Drawdown and recovery data measured at each test well were analyzed using the AQTESOLV for Windows® software (Duffield, 2007). Two analytical models were used to analyze test data; drawdown data were evaluated using the Cooper-Jacob (1946) straight-line approximation of the Theis solution, and recovery data were analyzed using the Theis residual-drawdown method (Theis 1935) for several tests. Applicability of the Cooper-Jacob solution to drawdown data was assessed using test diagnostics (radial flow plots and derivative analysis). Time-drawdown data for several of the tests indicated variations in the flow rate; for these tests, an approximate fit was obtained to provide a general estimate of transmissivity and hydraulic conductivity. A summary of the analytical solutions applied to drawdown and/or recovery data for each test, and resultant hydraulic conductivity estimates, are presented in Table 1. The data and analyses are provided in Attachment 1. As shown, estimated hydraulic conductivity values measured in 2013 were found to vary between approximately 0.36 ft/day and 51 ft/day.

2.3.2 Slug Tests

A series of slug tests were conducted at five monitoring wells (MW-108, MW-109, MW-126, MW-522, MW-530) and three piezometers (P-4, P-8, P-16). Each series consisted of one to three slug tests at each well. Slug tests were performed on each monitoring well by submerging a disposable bailer below the water table, waiting until water levels returned to static conditions, and then removing the bailer from the well (i.e., slug out test or rising-head test) while measuring the water-level response until static conditions were again reached. Use of empty disposable bailers to create displacement instead of solid slugs precludes analysis of falling-head test data (slug-in) because it violates the assumption of instantaneous slug introduction. A pressure transducer equipped with a data logger was used to record changes in water level within the well during each test.

Response data (i.e., elapsed time and corresponding changes in water levels) collected during each test were converted to displacement data and analyzed using AQTESOLV for Windows® (Duffield, 2007) to obtain near-well hydraulic conductivity estimates (Table 2). Appropriate and applicable analytical solutions available in AQTESOLV were applied following the guidelines presented in *The Design, Performance, and Analysis of Slug Tests (*Butler, 1998). The Bouwer and Rice (1976) straight-line solution was selected for test data which exhibited the double-straight line pattern associated with filter pack drainage for wells screened across the water table. The Bouwer-Rice recommended head range for the best curve fit was employed for tests which did not exhibit effects of filter pack drainage. Test data collected at MW-530, P-4, and P-8 displayed a concave-upward shape on a semi-log (log-linear) plot, which is associated with horizontal flow conditions; consequently, the rising-head tests conducted at these wells were analyzed using the Cooper et al. (1967) model for fully-transient conditions. Water level responses to both tests conducted at MW-510 were coincident (very similar), therefore analysis of the second test was not necessary. Three tests were conducted at MW-530; the first test conducted at this well was not analyzed due to excessive noise in test data. AQTESOLV solution plots are provided in Attachment 2.

As shown in Table 2, estimated near-well hydraulic conductivities for site wells varied from 0.02 ft/day to 17.3 ft/day. Note that slug test results can be significantly impacted by drilling-induced disturbances (e.g., well skin effects and/or borehole damage) and insufficient well development. The impacts and effects caused by these near-well disturbances are difficult to avoid when performing slug tests and analyzing results. As such, hydraulic conductivity estimates derived from slug tests should be considered to be the lower bound of the hydraulic conductivity of the formation in the vicinity of the well (Butler, 1998). An example of this effect is shown by comparison of hydraulic conductivities estimated for well MW-522 from pumping test data (24 ft/day) and slug test data (17.3 ft/day).

The results from these tests were compiled with hydraulic conductivity estimates from previous investigations and used in parameterization of the groundwater flow model.

3. Groundwater Flow Model Construction

The primary phases in the development of the Site groundwater flow model included construction of a finite-difference grid for the model area, specification of model structure, assignment of boundary conditions, specification of hydraulic parameter values and zones, and selection of appropriate water-level measurements for calibration of the model. These elements form the hydrogeologic conceptual site model, which serves as the basis for the construction and subsequent calibration of the numerical model to observed groundwater flow conditions at the Site.

3.1 Code Selection and Description

For the construction and calibration of the numerical groundwater flow model at the Site, ARCADIS selected the simulation program MODFLOW, a publicly-available groundwater flow simulation program developed by the U.S. Geological Survey (USGS) (McDonald and Harbaugh, 1988). MODFLOW is thoroughly documented, widely used by consultants, government agencies and researchers, and is consistently accepted in regulatory and litigation proceedings. In addition, ARCADIS has developed utilities for use with MODFLOW to ease in the construction and calibration of groundwater models.

MODFLOW can simulate transient or steady-state saturated groundwater flow in one, two, or three dimensions and offers a variety of boundary conditions including specified head, areal recharge, injection or extraction wells, evapotranspiration, horizontal flow barriers (HFB), drains, and rivers or streams. Aquifers simulated by MODFLOW can be confined or unconfined, or convertible between confined and unconfined conditions. For the Site, which consists of a heterogeneous geologic system with variable unit thicknesses and boundary conditions, MODFLOW's three-dimensional capability and boundary condition versatility are essential for the proper simulation of groundwater flow conditions.

3.2 Model Discretization

The finite-difference technique employed in MODFLOW to simulate hydraulic head distributions in multi-aquifer systems requires horizontal and vertical discretization, or subdivision of the continuous aquifer system into a set of discrete blocks that form a three-dimensional model grid. Water levels computed for each block represent an average water level over the volume of the block. Thus, adequate discretization (i.e., a sufficiently fine grid) is required to resolve features of interest, and yet not be computationally burdensome. MODFLOW allows the use of variable grid spacing such that a model may have a finer grid in areas of interest where greater accuracy is required and a coarser grid in areas requiring less detail.

The Site groundwater model grid is shown on Figure 5. As shown, the model grid covers approximately 1.5 square miles. The boundaries of the model grid were specified to coincide with surface water bodies where present. Assigned head boundaries were selected based on estimated regional water level contours. The finite-difference grid is composed of 207 rows, 211 columns, and 4 layers for a total of 142,280 active nodes (Figure 5). The model grid was constructed using a variably spaced grid; in the area where groundwater remediation alternatives are being considered the grid cell size is 10 feet by 10 feet. At the perimeter of the model grid the largest cell size increases to a maximum of 100 feet by 200 feet.

CTECH Development Corporation’s Mining Visualization System (MVS) was utilized as part of the model development using lithologic information available from site monitoring wells and piezometers and limited, available information from soil borings completed in the surrounding area (off-site). This MVS-based representation of hydrostratigraphy was imported in the Groundwater Vistas (Rumbaugh and Rumbaugh, 2007) groundwater flow model interface and formed the basis for vertical discretization. A memorandum discussing the analysis of Site geologic data using MVS and additional figures produced through MVS is presented in Attachment 3.

The Site groundwater model layers are shown on Figure 6. The four model layers were defined to provide an approximate vertical profile of the Site hydrostratigraphy and also to allow for simulation of partially-penetrating extraction wells or interceptor trenches. Vertical discretization was also accomplished by assigning different hydraulic conductivity zones throughout the various layers as shown in Figure 6, to account for vertical heterogeneity.

Outside the vicinity of the Site, model layer elevations and trends were extended to the model boundaries.

3.3 Boundary Conditions

External boundary conditions must be imposed to define the spatial boundaries of the model on all sides of the model grid. In addition to these external boundary conditions, internal boundary conditions such as sources and sinks of groundwater including wells, drains, and rivers can be included within the model's boundaries. A boundary condition can represent different types of physical boundaries, depending on the rules that govern groundwater flow across the boundary.

The Site groundwater flow model boundary conditions are shown on Figure 7. As shown, there are five types of boundary conditions used in the Site groundwater flow model:

1. Constant head boundaries are used to represent relatively constant sources or sinks of groundwater, including large surface water features such as Puget Sound, and either provide or remove groundwater depending on the hydraulic gradient direction near the boundary;

2. River-type boundaries are used to represent rivers and streams which may either be sources of sinks of groundwater;

3. General head boundaries are used to represent constant fluxes of groundwater to or from a model;

4. Drains, which remove groundwater; and

5. Inactive or no-flow boundaries.

As shown on Figure 7, the western and northern model boundaries are coincident with the Puget Sound and were represented in the Site groundwater flow model using constant-head cells with surface water elevations derived from gauging data provided by NOAA. The constant head boundaries at Puget Sound were specified at the average surface water elevation in Puget Sound during model calibration, and adjusted to account for high-tide scenarios during predictive simulations. Puget Sound is assumed to fully penetrate the full thickness of the model domain and therefore constant head cells were applied to model layers 1 through 4.

Also as shown on Figure 7, the southern, northern, and eastern model boundaries were selected to be coincident with physically-based features, Deer Creek on the south and Shelleberger Creek on the north and east. These creeks were simulated in the Site groundwater flow model as river boundaries. Surface water elevations along Deer and Shelleberger Creeks were derived from the USGS topographic map and were used to specify the water levels in the river boundaries. Willow Creek was simulated as an internal river boundary. Surface water elevations along Willow Creek were derived from the USGS topographic map.

The southeastern perimeter of the Site groundwater flow model was assigned as a general head boundary through all model layers, representing regional groundwater flow entering the model domain from upland portions of the groundwater system. Data from the USGS were used to specify the general head boundaries.

DB-1 was simulated as an internal drain-type boundary which removes groundwater from the model because surface water elevations in DB-1 are lower than groundwater elevations measured in nearby monitoring wells. Furthermore, DB-1 is unlined and surface water is pumped out of DB-1 and into Willow Creek.

Precipitation infiltration, also known as recharge, is also considered a boundary condition because recharge can add water to the top of the model at the water table. Recharge reaching the water table was simulated using three zones in model layer 1 and was specified using knowledge of ground surface cover, topography, and annual precipitation rates. The off-site areas of the model, and portion of the site were assigned an initial recharge rate of 3.6 inches per year (in/yr), which is approximately 10% of annual recharge. Locally, higher precipitation rates were assigned. On the east side of the Lower Yard, a groundwater mound is regularly observed at the site. This mound was replicated in the model through the assignment of an area of elevated recharge representing run-off from the adjacent Upper Yard; a recharge rate of approximately 15 in/yr, which is approximately 40% of annual recharge. On the north side of the Lower Yard, an elevated recharge rate of 24 in/yr (approximately 60% of annual recharge) was applied to the gravel covered areas of the site. (*NOAA Online Weather Data, NOWData, Daily Climate Normals, 1981-2010, Precipitation, Seattle Tacoma Intl Ap* (NOAA, 2013). Recharge rates were also adjusted during calibration.

The bottom of the Site groundwater flow model was assigned as a no-flow boundary condition.

3.4 Hydraulic Parameters

The main hydraulic parameter that had to be specified in the Site groundwater flow model is soil hydraulic conductivity, because hydraulic conductivity governs groundwater flow rates and patterns under steady-state flow conditions. Specific yield and storativity are also important aquifer characteristics, but these storage parameters govern groundwater flow under transient conditions and were therefore not utilized.

The Site groundwater flow model was initialized using hydraulic conductivity values based on Site-specific hydraulic conductivity testing data, where available. For areas of the model domain without hydraulic conductivity testing data, hydraulic conductivity values were specified based on literature values associated with known soil types. During calibration, hydraulic conductivity zones were added and parameter values were adjusted within reasonable ranges to minimize the difference between observed and simulated groundwater elevations.

The final, calibrated hydraulic conductivity distributions for model layers 1 through 4 are shown on Figures 8 through 11, respectively. The hydraulic conductivity zones assigned in the model are summarized in Table 3.

As shown on Figure 8, model layer 1 is the most heterogeneous layer due to the presence of multiple soil types and excavated areas containing backfill. The hydraulic conductivity zones shown on Figure 8 represent 1929 fill materials, 2008 fill materials, off-shore gravel deposits, and the Whidbey formation and associated glacial deposits. The remainder of the hydraulic conductivity zones in layer 1 was specified during calibration. Hydraulic conductivity values used in layer 1 varied between 0.1 and 75 ft/day.

As shown on Figure 9, model layer 2 contained five hydraulic conductivity zones representing fill materials, marsh deposits, beach deposits, off-shore gravel deposits, and the Whidbey formation. Hydraulic conductivity values used in layer 2 varied between 0.25 and 75 ft/day.

As shown on Figure 10, model layer 3 contained three hydraulic conductivity zones representing marsh deposits, off-shore gravel deposits, and the Whidbey formation. Hydraulic conductivity values used in layer 3 varied between 1.5 and 75 ft/day.

As shown on Figure 11, model layer 4 consisted of the Whidbey formation with a hydraulic conductivity of 1.5 ft/day.

3.5 Calibration Targets

Calibration targets are a set of field measurements, typically groundwater elevations, used to test the ability of the groundwater flow model to reproduce observed conditions within a groundwater flow system. For the calibration of a steady-state (time-invariant) model, the goal in selecting calibration targets is to define a set of water-level measurements that represent the average elevation of the water table or potentiometric surface at locations throughout the Site.

Table 4 presents the monitoring wells and water-level elevations selected for the calibration of the Site groundwater flow model. As shown, calibration targets selected for the Site groundwater flow model are the average water-level elevations calculated from quarterly groundwater-level measurements collected in 2013 that comprise a total of 69 monitoring wells located throughout the site. This calibration target set was selected because it represents average groundwater elevation conditions.

4. Groundwater Flow Model Calibration

Calibration of a groundwater flow model refers to the process of estimating unknown model parameters, for example at un-sampled locations, by adjusting parameters within reasonable ranges until simulated groundwater levels are consistent with measured groundwater levels. Model calibration is typically an iterative procedure that involves adjustment of hydraulic properties or boundary conditions to achieve the best match between simulated and measured groundwater levels. Boundary condition values and hydraulic conductivity values at un-sampled locations were adjusted during calibration of the Site groundwater flow model.

4.1 Calibration Procedure

As discussed above, the Site groundwater flow model was calibrated using average groundwater levels measured at 69 Site monitoring wells in 2013 (Table 4). A representative groundwater contour map of the water table (i.e., layer 1) is shown on Figure 2.

Calibration of the Site groundwater flow model required numerous individual computer simulations. The parameter values and shapes of the hydraulic conductivity zones in the model were gradually varied within reason until an acceptable match was achieved with the CSM. Calibration was achieved using MODFLOW and parameter estimation techniques designed for use with MODFLOW.

4.2 Calibration Results

Calibration results for the final, calibrated Site groundwater flow model are shown visually as a scatter-plot on Figure 12. As shown, simulated groundwater levels were consistent with measured groundwater levels as indicated by a Pearson correlation coefficient of approximately 0.85. This result shows that the model is reasonably calibrated for the intended purpose. The scatter in the simulated and measured datasets is due primarily to the fact that groundwater at the Site is tidally influenced and groundwater levels fluctuate daily, which introduces uncertainty in groundwater level measurements. The scatter in the simulated and measured datasets is also due to the heterogeneity of soils at the Site.

Model calibration was also evaluated by analyzing simulated hydraulic head distributions across the Site and residual statistics, as described below.

4.2.1 Simulated Hydraulic Head Distributions

Another way to evaluate model calibration is by comparing contour maps of simulated and measured groundwater elevations to ensure that the Site groundwater flow model is capable of simulating actual hydraulic gradient patterns.

A contour map of simulated groundwater elevations at the water table (i.e., in layer 1) is presented as Figure 13. A visual comparison of Figure 13 (simulated groundwater elevations) and Figure 2 (measured groundwater elevations) shows that the Site groundwater flow model accurately simulates hydraulic gradient patterns present at the Site. Specifically, Figure 13 shows that the direction of the simulated hydraulic gradient is oriented north toward Edmonds Marsh and northwest toward Puget Sound, and the magnitude of the simulated hydraulic gradient averages approximately 0.002 ft/ft. Furthermore, the Site groundwater flow model accurately predicts the location and magnitude of the potentiometric mound located in the southeast Lower Yard area.

4.2.2 Analysis of Residuals

A “residual” is defined as the mathematical difference between a simulated and measured value, and the goal of model calibration is to minimize the sum of all residuals within a model. Therefore, analyzing residuals is another method for evaluating the robustness of model calibration.

Table 4 shows the residuals for each of the calibration targets in the calibrated Site groundwater flow model. These residuals were calculated by subtracting simulated groundwater elevations from observed groundwater elevations at the target locations. Thus, a negative residual indicates a location where the model has over-predicted the measured groundwater elevation and a positive residual indicates a location where the model has under-predicted the measured groundwater elevation.

As shown in Table 4, the Site groundwater model residuals are within approximately 10% of the observed head range (i.e., plus or minus 0.75 feet) and 90% of the calibration targets have residuals less than or equal to 1 foot, which indicates the model is well calibrated for its intended purpose. A summary of the residual statistics is shown below:

Table 5. Summary of Calibration Statistics

Model Calibration Statistic	Value
Number of Calibration Targets	69
Range in Measured Values	7.37 feet
Minimum Residual	-2.82 ft msl
Maximum Residual	2.06 ft msl
Residual Mean	0.01 ft msl
Residual Standard Deviation	0.75 ft
Residual Standard Deviation / Range	0.10

As shown, model residuals varied between approximately -2.82 and 2.06 ft msl which is consistent with the calibration scatter plot shown on Figure 13**.** This result indicates that simulated groundwater elevations were within approximately two to three feet of measured average groundwater elevations, which is considered acceptable given the tidally influenced nature of the groundwater system at the Site and the high degree of heterogeneity. The residual mean of 0.01 ft indicates that there is very little to negligible bias in the model predictions; in other words under-predicted values balanced out over-predicted values. The residual standard deviation of 0.75 feet also indicates that the Site groundwater flow model is well-calibrated. Importantly, the value of residual standard deviation divided by total range of measured values was 0.10 (i.e., 10%), which is generally considered to be an indication of a well-calibrated model (Anderson and Woessner, 1992).

These results indicate that a high degree of calibration has been achieved for the Site groundwater flow model. Overall the model shows a good match between simulated and measured groundwater elevations and is suitable for its intended purpose.

5. Evaluation of Potential Groundwater Remediation Scenarios

The calibrated Site groundwater flow model was used to evaluate four potential groundwater remediation scenarios as follows:

1. Hydraulic containment using a series of groundwater extraction wells.

2. Hydraulic containment using a groundwater interceptor trench.

3. Soil excavation near DB-1 and DB-2.

4. Soil excavation near the WSDOT owned storm drain line (south side of Lower Yard).

To accomplish this, internal boundary conditions such as extraction wells, high hydraulic conductivity zones, or vertical flow barriers were added to the Site groundwater flow model as necessary to simulate each scenario. After the internal boundary conditions were added, the Site groundwater flow model was run at steady-state conditions to estimate average flow rates and predict resulting changes in groundwater flow patterns. External boundary conditions were also modified during evaluation of the potential remediation scenarios to predict potential groundwater flow rates and patterns that may occur under high tide conditions and extreme rainfall events. High tides were simulated by raising the assigned constant head elevation by 5 ft. The extreme rainfall event incorporated both a high tide condition and a doubling of assigned recharge rates.

To evaluate the effectiveness of the hydraulic containment scenarios (i.e., Scenarios 1 and 2), the Site groundwater flow model was used to estimate the extent of the capture zone resulting from hypothetical groundwater extraction. A “capture zone” is defined as the spatial area that contributes groundwater to the pumping system; in other words, a capture zone is an area of hydraulic containment. The objective of these simulations was to adjust the locations of the simulated extraction wells or interceptor trenches, and to adjust the simulated groundwater extraction rates, until the shape of the predicted capture zone fully encompassed the target remediation area.

For the soil excavation area scenarios (i.e., Scenarios 3 and 4), the Site groundwater flow model was used to estimate the construction dewatering rates that would be required during remediation.

The following subsections describe the evaluation of these potential remediation scenarios.

5.1 Remediation Scenario 1 – Hydraulic Containment Using Extraction Wells

Remediation scenario 1 involves hydraulic containment of remaining impacts near DB-1 and DB-2 as shown on Figure 14 using a series of six groundwater extraction wells. A conceptual layout of the six groundwater extraction wells and the resulting predicted capture zone is shown on Figure 14. As shown, it is theoretically possible to hydraulically contain the remaining impacts near DB-1 and DB-2 using groundwater extraction wells pumping at a long-term average combined rate of approximately 3 to 5 gallons per minute, which would include both high-tide conditions and short-duration rainfall events.

This scenario is based on the following assumptions and limitations:

- The extraction wells would need to be installed to total depths of approximately 15 to 20 feet below ground;
- The intake portion of the extraction wells would need to extend to an elevation of approximately 0.25 ft msl or lower (i.e., drain elevation);
- The extraction wells are 100% efficient; and,
- The potential exists for pumping-induced salt-water intrusion to further degrade groundwater quality.

5.2 Remediation Scenario 2 – Hydraulic Containment Using an Interceptor Trench

Remediation scenario 2 involves hydraulic containment of remaining impacts near DB-1 and DB-2 as shown on Figure 15 using a groundwater interceptor trench. A conceptual layout of the groundwater interceptor trench and the resulting predicted capture zone is shown on Figure 15. As shown, it is theoretically possible to hydraulically contain the remaining impacts near DB-1 and DB-2 using a groundwater interceptor trench pumping at a long-term average rate of approximately 4 to 7 gallons per minute, which would include both high-tide conditions and short-duration rainfall events.

This scenario is based on the following assumptions and limitations:

- The interceptor trench would be installed to a total depth of approximately 15 to 20 feet below ground;
- The intake portion of the interceptor trench would need to extend to an elevation of approximately 0.25 ft msl or lower (i.e., drain elevation);

- The backfill of the interceptor trench would need to have a hydraulic conductivity of 1,000 feet per day; and,
- The potential exists for pumping-induced salt-water intrusion to further degrade groundwater quality.

5.3 Remediation Scenario 3 – Soil Excavation near DB-1 and DB-2

Remediation scenario 3 involves excavating remaining impacts below the water table near DB-1 and DB-2 from the approximate area shown on Figure 16 using conventional soil excavation and construction dewatering equipment. A conceptual layout of the excavation and the resulting predicted changes in groundwater flow patterns are shown on Figure 16. As shown, it is theoretically possible to excavate the remaining impacts near DB-1 and DB-2 using a construction dewatering strategy that would require an average pumping rate of approximately 10 gallons per minute. High tide or short-duration rainfall events may result in the need for excavation dewatering at an average rate of 23 gallons per minute.

This scenario is based on the following assumptions and limitations:

- The total depth of the construction dewatering system would need to be approximately 15 to 20 feet below ground;

- The intake portion of the construction dewatering system would need to extend to an elevation of approximately 0.25 ft msl or lower (i.e., drain elevation);

- Faster dewatering rates during the initial phase of excavation may be required; and,

- The potential exists for pumping-induced salt-water intrusion to further degrade groundwater quality.

5.4 Remediation Scenario 4 – Soil Excavation near the WSDOT storm drain

Remediation scenario 4 involves excavating remaining impacts below the water table near the WSDOT storm drain from the approximate area shown on Figure 17 using conventional sheet pile walls, soil excavation and construction dewatering equipment. A conceptual layout of the excavation and the resulting predicted changes in groundwater flow patterns are shown on Figure 17. As shown, it is theoretically possible to excavate the remaining impacts near the WSDOT storm drain using sheet pile walls and a construction dewatering strategy that would require an average pumping rate of approximately 60 gallons per minute. High tide or short-duration rainfall events may result in the need for excavation dewatering at an average rate of 75 gallons per minute.

This scenario is based on the following assumptions and limitations:

- The total depth of the construction dewatering system would need to be approximately 30 feet below ground;
- The intake portion of the construction dewatering system would need to extend to an elevation of approximately -15 ft msl or lower (i.e., drain elevation);
- The excavation may encounter fill materials, beach deposits, and marsh deposits, and would terminate at the top of the Whidbey Formation;
- The hydraulic conductivity of the sheet pile walls is 0.003 feet per day.
- Faster dewatering rates during the initial phase of excavation may be required; and,
- The potential exists for pumping-induced salt-water intrusion to further degrade groundwater quality.

6. Summary

Historic and recent hydrogeologic data collected at the Former Unocal Edmonds Bulk Fuel Terminal Site in Edmonds, Washington, and additional regional information found in the literature were used to construct and calibrate a three-dimensional groundwater flow model for the Site. The model was constructed to support the evaluation of four potential remediation scenarios. The model was used to evaluate groundwater flow under both existing (present day) conditions and the various remediation scenarios.

Results of the work provided conceptual design layouts and estimated groundwater extraction rates, and demonstrate that the four remediation scenarios are theoretically possible. However, the assumptions and limitations associated with each scenario should be carefully evaluated during completion of the feasibility study.

7. References

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Table 1
Constant-Rate Pumping Test Results

Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

Well ID	Date	Static Depth-to-Water (ft bTOC)	Calculated Water Column in well (ft)	Pumping Duration (min)	Pumping Rate (gpm)	Maximum Drawdown (ft)	Method of Analysis	Estimated Transmissivity (ft^2/day)	Calculated Hydraulic Conductivity (ft/day)
MW-122	3/5/2013	7.26	35.36	44.94	3.36	3.28	Cooper-Jacob	165	17
							Theis Recovery	188	19
MW-147	3/5/2013	5.29	8.11	29.95	3.67	1.69	Cooper-Jacob	360	47
							Theis Recovery	396	51
MW-510	3/6/2013	6.11	6.59	39.88	0.22	3.35	Cooper-Jacob	6.4	0.93
							Theis Recovery	2.5	0.36
MW-203	3/4/2013	22.23	8.37	29.87	2.50	0.94	Cooper-Jacob	191	21
MW-511	3/4/2013	7.16	7.84	29.90	3.50	2.54	Cooper-Jacob	97	12
MW-522	3/5/2013	8.20	5.05	29.83	0.55	0.62	Cooper-Jacob	117	24

Notes:

1. bTOC = below the top of casing
2. Cooper-Jacob modification of the Theis method. Cooper, H.H. and C.E. Jacob, 1946. A generalized graphical method for evaluating formation constants and summarizing well field history, Am. Geophys. Union Trans., vol. 27, pp. 526-534.
3. Theis method for analysis of residual drawdown (recovery data). Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.
4. Hydraulic conductivity was calculated by dividing estimated transmissivity results by the saturated screen length for each well.

Table 2
Slug Testing Results

Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

Well ID	Test ID	Date	Static Depth-to-Water (ft bTOC)	Calculated In-Well Water Column (ft)	Initial Displacement (Ho, ft)	Screened across the Water Table?	Method of Analysis	Estimated Hydraulic Conductivity (ft/day)
MW-108	1	3/6/2013	5.45	9.67	1.50	YES	Bouwer-Rice (6.11b)[1]	0.02
MW-109	1	3/7/2013	6.88	8.22	1.68	YES	Bouwer-Rice (6.11b)	0.091
MW-126	1	3/6/2013	4.05	9.75	1.62	YES	Bouwer-Rice (6.11b)	0.23
	2	3/7/2013	3.90	9.90	1.63	YES	Bouwer-Rice (6.11b)	0.21
MW-522	1	3/7/2013	8.09	5.16	1.67	YES	Bouwer-Rice (6.11b)	17.3
	2	3/7/2013	8.09	5.16	1.68	YES	NA[2]	NA
MW-530	1	3/6/2013	4.58	6.39	1.34	NO	NA[3]	NA
	2	3/7/2013	4.56	6.59	1.10	NO	Cooper-Bredehoeft-Papadopulos[4]	1.2
	3	3/7/2013	4.56	6.59	1.29	NO	Cooper-Bredehoeft-Papadopulos	0.88
P-16	1	3/6/2013	2.44	10.71	1.33	NO	Bouwer-Rice (3.1)[5]	0.85
P-4	1	3/7/2013	7.50	14.55	1.49	NO	Cooper-Bredehoeft-Papadopulos	0.34
P-8	1	3/7/2013	7.49	16.89	1.50	NO	Cooper-Bredehoeft-Papadopulos	0.3
	2	3/7/2013	7.49	16.89	0.62	NO	Cooper-Bredehoeft-Papadopulos	0.34

Notes:

1. Bouwer-Rice (1976) method, unconfined solution, with the Butler (6.11b) effective casing correction for wells screened across the water table (Butler, 1998).

2. Analysis of test not performed due to coincidence of repeat test data

3. Analysis of test not performed due to high levels of noise in test results

4. Hydraulic conductivity calculated by dividing estimated transmissivity by the saturated screen length for tests analyzed using the CBP solution.

Table 3.
Groundwater Flow Model Parameters

Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

Model Parameter	Model Layer	Modeled Range		Notes / Boundary Location / Unit Description
Areal Recharge (in/yr)	1	3.6, 15, and 24		model wide, east Lower Yard and North Lower Yard
Shelleberger Creek Stage (ft absl)	1	180 to 0		eastern model boundary
Deer Creek Stage (ft absl)	1	238 to 0		southern model boundary
Willow Creek Stage (ft absl)	1	145 to 0		internal boundary
Puget Sound Elevation (ft absl)	1 - 4	0		northern and western model boundary
Drain Elevation (DB-1)	1	6		on-site retention basin
General Head Boundary Elevation (ft absl)	1 - 4	290		southeastern model boundary
Hydraulic Conductivity (ft/d)		**Horizontal**	**Vertical**	
2008 Fill	1	25	1.5e-1	Coarse Sand, Gravel
1929 Fill	1	0.75	0.75	Silty Soil, Debris
Marsh Deposits	1, 2	0.85	8.5e-4	Silt
Beach Deposits	3	45	4.0e-1	Sand
Off-shore Gravel	1, 2, 3	75	75	Gravel
Whidbey Formation	1, 2, 3, 4	1.5	5e-1	Sand to Semi-Consolidated Sand

notes:
in/yr inches per year.
ft absl feet above sea level.
ft/d feet per day.

Table 4.
Calibration Targets and Residuals

Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

Well ID	Model Layer	Model Row	Model Column	Simulated Heads (ft msl)	Observed Heads (ft msl)	Residual[(1)] (ft)
LM-2	1	56	91	5.06	6.17	1.11
MW-8R	1	84	62	6.05	6.04	-0.01
MW-13U	1	90	98	8.17	8.76	0.59
MW-20R	1	81	67	6.20	5.87	-0.33
MW-101	1	75	72	6.25	6.44	0.19
MW-104	1	78	70	5.85	6.21	0.36
MW-108	1	60	99	6.17	6.35	0.18
MW-109	1	68	107	6.31	6.51	0.20
MW-122	4	82	108	7.59	8.02	0.43
MW-126	1	89	73	6.17	8.23	2.06
MW-129R	1	82	106	7.56	7.14	-0.42
MW-131	1	74	98	7.31	6.92	-0.39
MW-135	1	93	119	10.02	7.46	-2.56
MW-136	1	99	125	8.73	8.41	-0.32
MW-139R	1	68	80	6.45	7.04	0.59
MW-143	1	88	70	6.18	7.88	1.70
MW-147	1	89	57	6.04	5.94	-0.10
MW-149R	1	98	49	6.45	5.75	-0.70
MW-151	1	94	57	6.17	6.49	0.32
MW-203	1	100	109	11.49	8.66	-2.83
MW-500	1	92	113	12.44	12.62	0.18
MW-501	1	88	109	12.27	12.16	-0.11
MW-502	1	85	92	7.74	7.99	0.25
MW-503	1	82	93	7.61	7.34	-0.27
MW-504	1	77	94	7.50	7.04	-0.46
MW-505	1	76	90	7.30	7.06	-0.24
MW-506	1	73	95	7.37	7.07	-0.30
MW-507	1	71	92	7.11	6.95	-0.16
MW-508	1	70	88	6.38	6.99	0.61
MW-509	1	70	84	6.65	7.07	0.42
MW-510	1	64	83	6.40	6.29	-0.11
MW-511	1	87	83	7.67	8.12	0.45
MW-512	1	82	82	7.12	7.05	-0.07
MW-513	1	78	80	6.94	7.06	0.12
MW-514	1	80	79	6.92	7.05	0.13
MW-515	1	74	78	6.66	7.05	0.39

Table 4.
Calibration Targets and Residuals

Unocal Edmonds Bulk Fuel Terminal Lower Yard
11720 Unoco Road
Edmonds, Washington

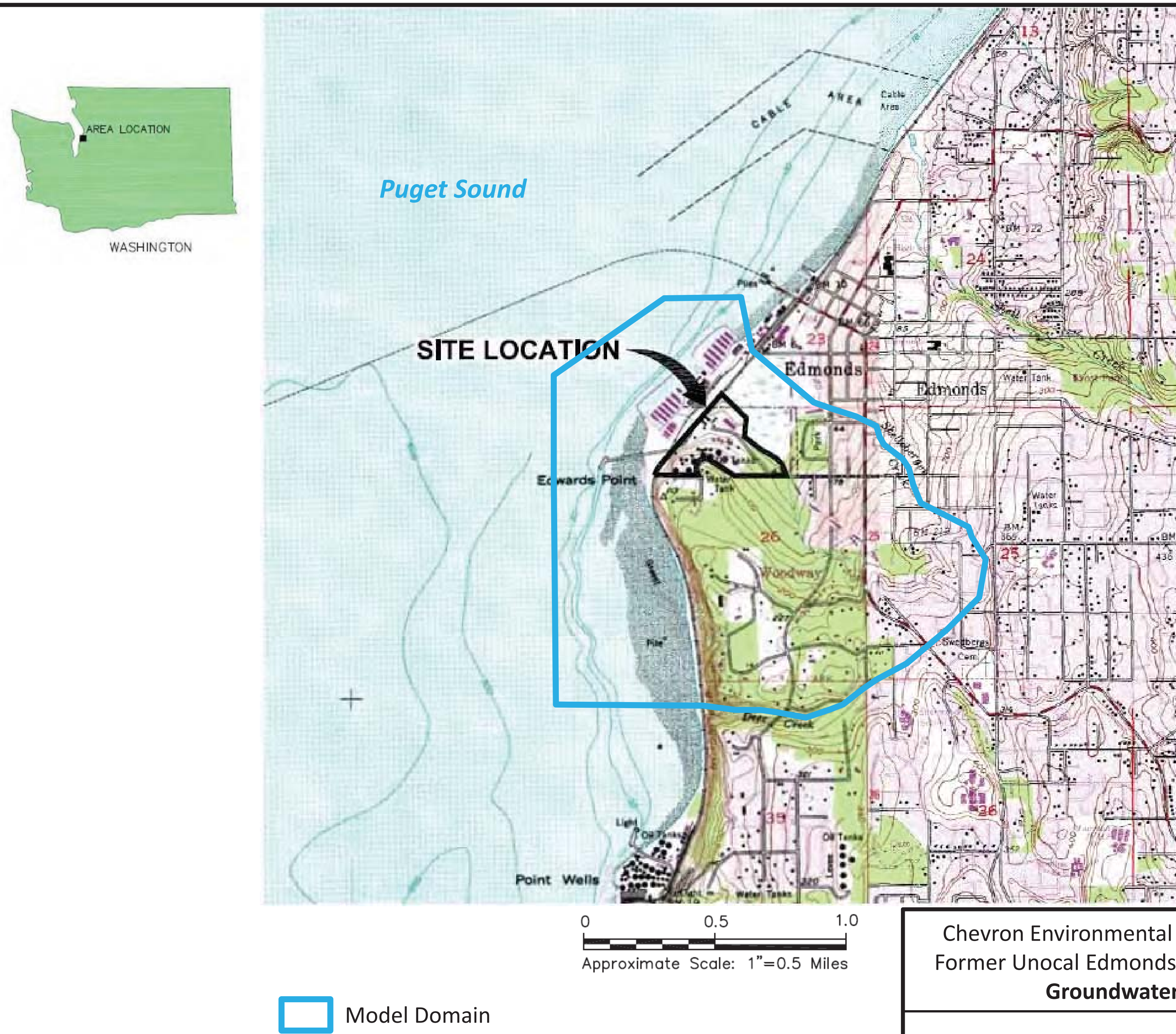
Well ID	Model Layer	Model Row	Model Column	Simulated Heads (ft msl)	Observed Heads (ft msl)	Residual[(1)] (ft)
MW-516	1	76	77	6.62	7.05	0.43
MW-517	1	77	76	6.58	7.04	0.46
MW-518	1	71	76	6.31	6.48	0.17
MW-519	1	87	68	6.25	6.04	-0.21
MW-520	1	85	66	6.24	6.06	-0.18
MW-521	1	87	65	6.25	6.03	-0.22
MW-522	1	83	63	6.13	6.02	-0.11
MW-523	1	86	60	6.05	6.03	-0.02
MW-524	1	93	54	6.17	6.08	-0.09
MW-525	1	84	73	6.39	6.62	0.23
MW-526	1	84	83	7.24	7.99	0.75
MW-527	1	98	117	10.82	10.08	-0.74
MW-528	1	100	121	10.78	10.27	-0.51
MW-529	1	64	82	6.15	5.86	-0.29
MW-530	1	54	91	5.96	5.78	-0.18
MW-531	1	84	71	6.20	5.89	-0.31
MW-532	1	86	73	6.32	6.80	0.48
P-1	1	86	107	11.42	12.82	1.40
P-2	3	88	108	8.78	8.42	-0.36
P-3	1	89	109	12.78	12.10	-0.68
P-4	3	92	113	9.82	8.55	-1.27
P-5	1	93	113	13.13	12.24	-0.89
P-6	1	94	116	11.94	13.12	1.18
P-7	3	94	116	10.34	8.74	-1.60
P-8	3	86	107	8.25	8.35	0.10
P-9	1	73	96	7.39	7.04	-0.35
P-10	1	69	89	6.19	6.93	0.74
P-11	1	69	88	6.33	7.04	0.71
P-12	1	66	84	6.55	6.55	0.00
P-13	1	65	82	6.52	7.32	0.80
P-14	1	64	83	6.38	6.13	-0.25
P-15	1	61	85	6.26	5.95	-0.31
P-16	1	63	87	6.09	6.28	0.19

notes:

(1) Residuals are computed by subtracting observed water levels from simulated water levels.

ft : feet.

ft msl : feet above mean sea level.



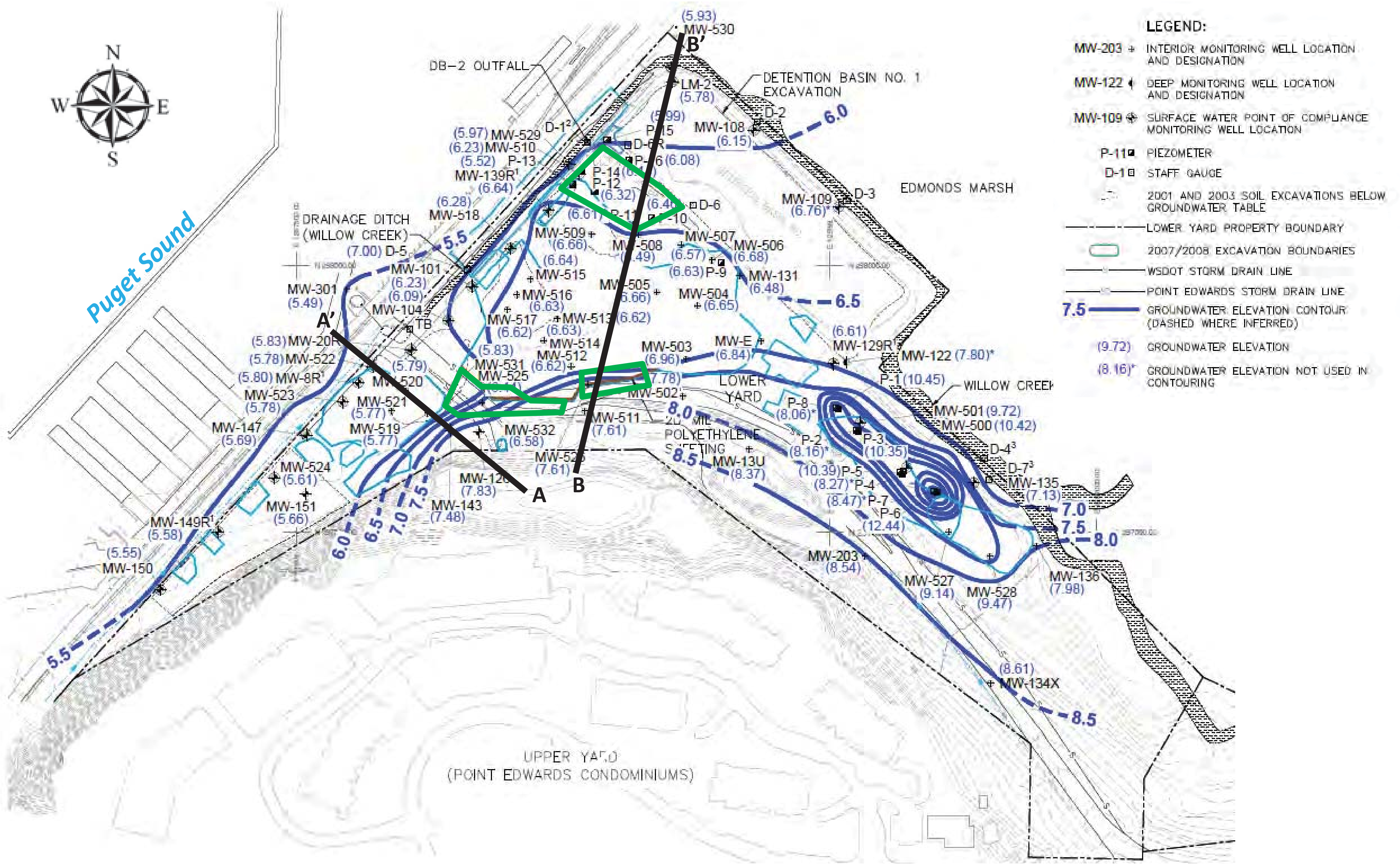
Source: USGS Quads., 7.5 Min. Series (Topographic) – Edmonds East, Wash., and Edmonds West, Wash.

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Site Location

ARCADIS

FIGURE
1



Potential Remediation Area (Approx)

Cross Section Location

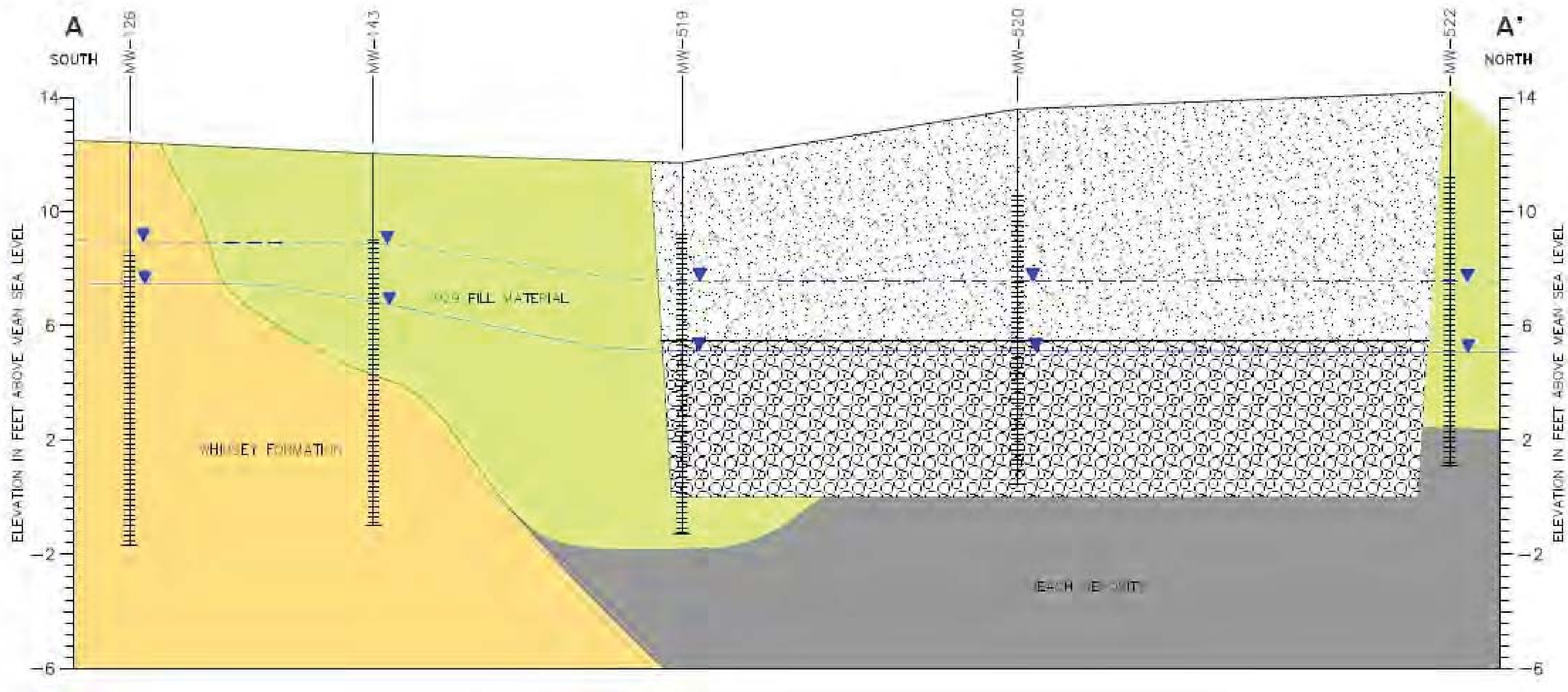
Source: Third Quarter 2013 Groundwater Monitoring Report.

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Site Map with Groundwater Contours, Cross Sections, and Potential Remediation Areas

ARCADIS

FIGURE 2



LEGEND:

- MW-126 — WELL OR BORING ID
- GROUND SURFACE
- HISTORIC HIGH WATER LEVEL
- HISTORIC LOW WATER LEVEL
- LITHOLOGIC CONTACT (DASHED WHERE INFERRED)
- SCREENED INTERVAL
- BOTTOM OF BORING
- 1929 FILL MATERIAL
- BEACH DEPOSITS
- TRANSITIONAL SILT BED
- WHIDBEY FORMATION
- MARSH DEPOSITS
- 2007/2008 FILL (GRAVEL)
- 2007/2008 FILL (SILT, SAND AND GRAVEL)
- (35' SE) — OFFSET DISTANCE FROM CROSS SECTION PROFILE

NOTES:

- HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
- VERTICAL DATUM: N.A.V.D. 88
- UNITS: U.S. SURVEY FEET
- HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).

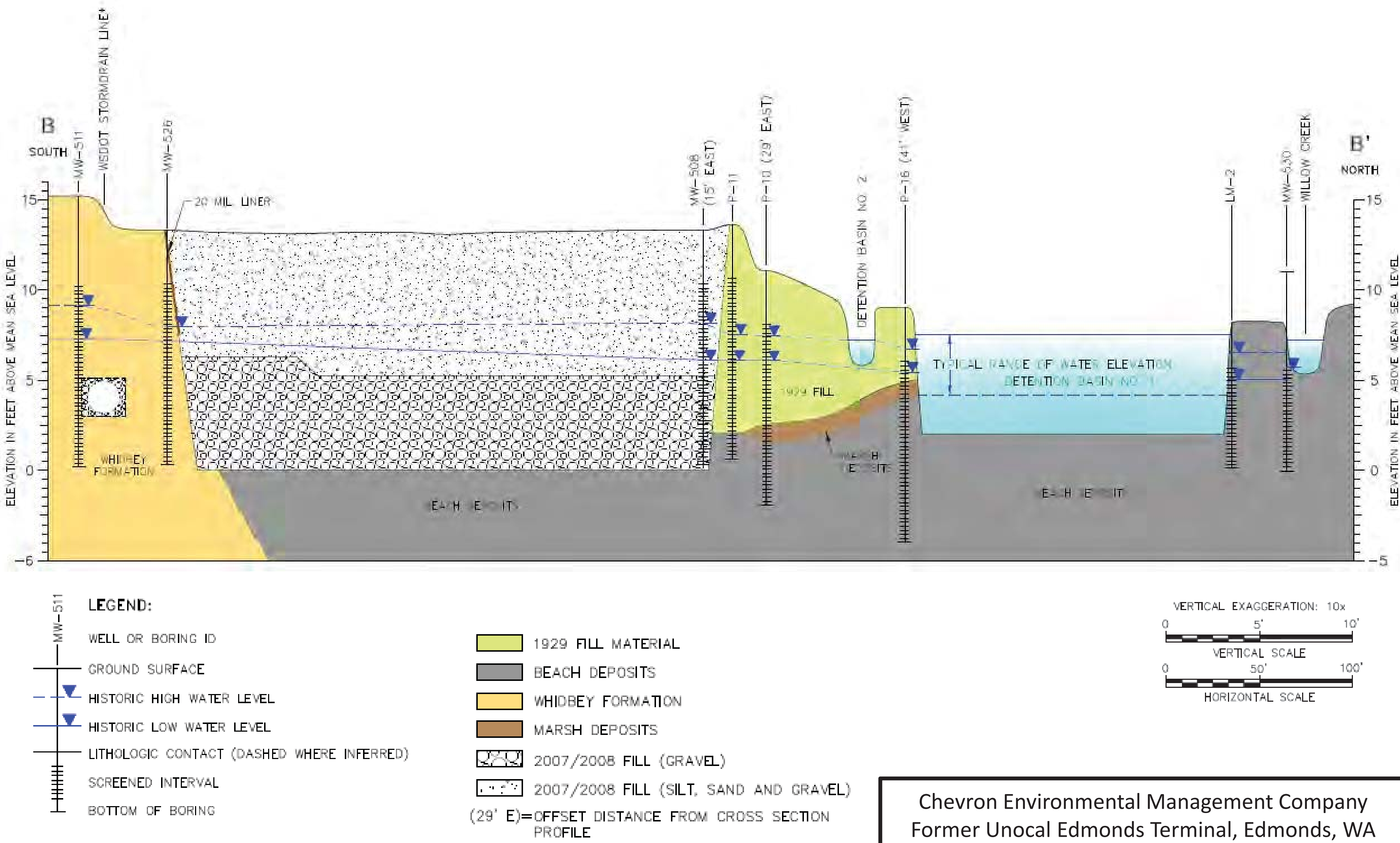
Source: Site Conceptual Model.

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Cross Section A – A'

ARCADIS

FIGURE
3



NOTES:

1. WSDOT STORMDRAIN LINE LOCATION IS APPROXIMATE AND DRAWN TO A NON EXAGGERATED SCALE FOR CLARITY.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
VERTICAL DATUM: N.A.V.D. 88
UNITS: U.S. SURVEY FEET
HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).

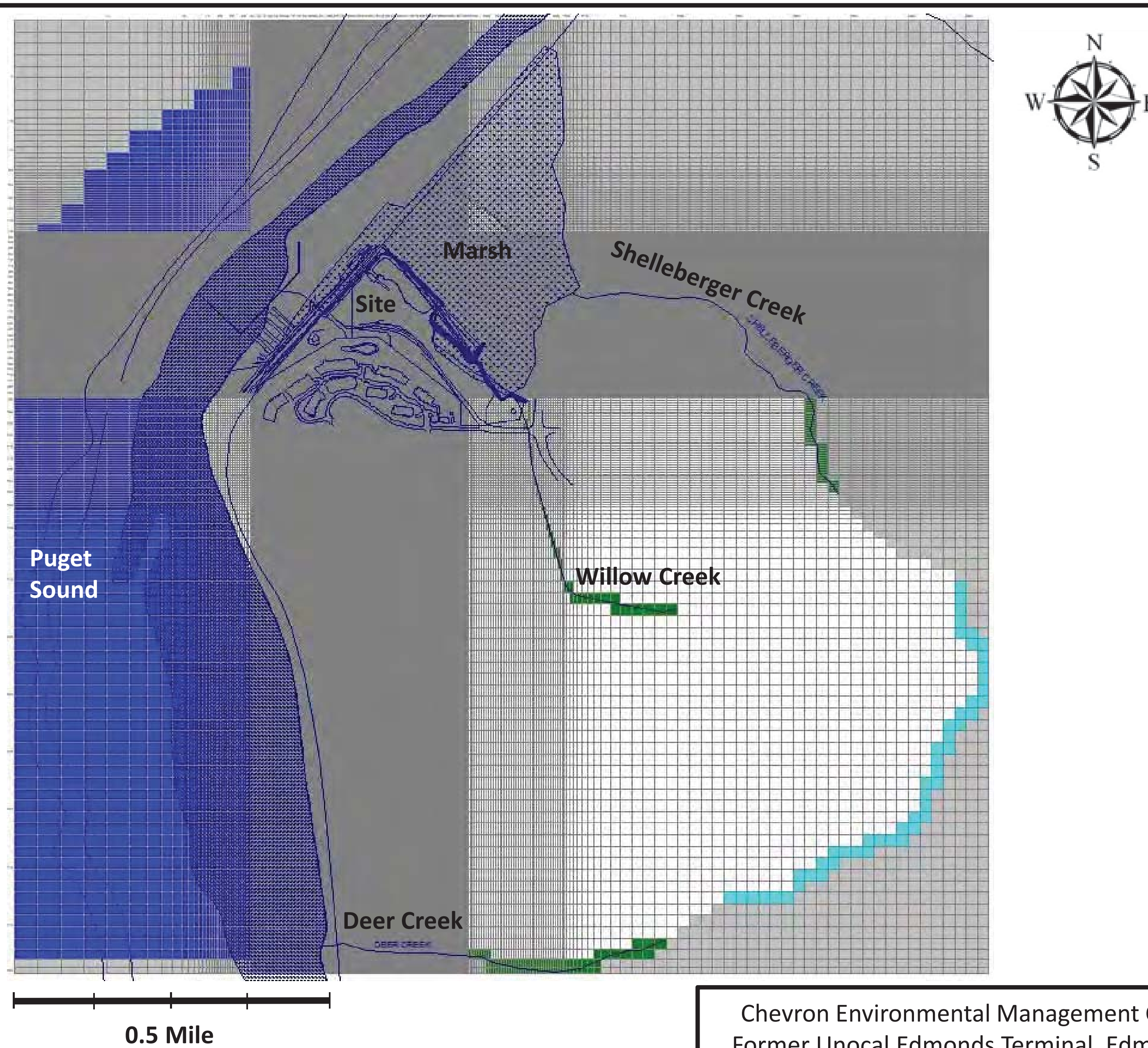
Source: Site Conceptual Model.

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Cross Section B – B'

ARCADIS

FIGURE
4



Notes:

Total number of grid blocks = 142,280

Smallest grid block = 10’ x 10’ at Site

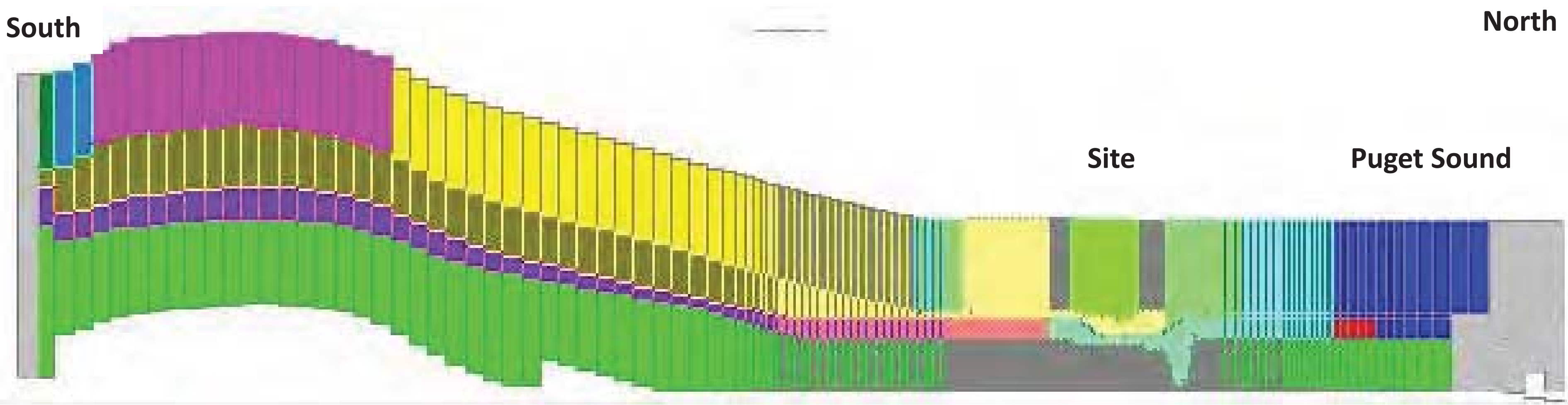
Largest grid blocks = 100’ x 200’ at Model Perimeter

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

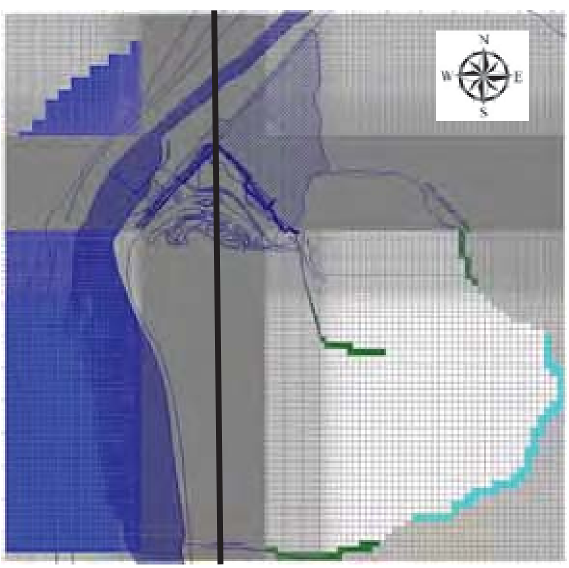
Model Grid

ARCADIS

FIGURE
5



Cross Section Location



Note: Colors Represent Hydraulic Conductivity Values (Feet/Day)

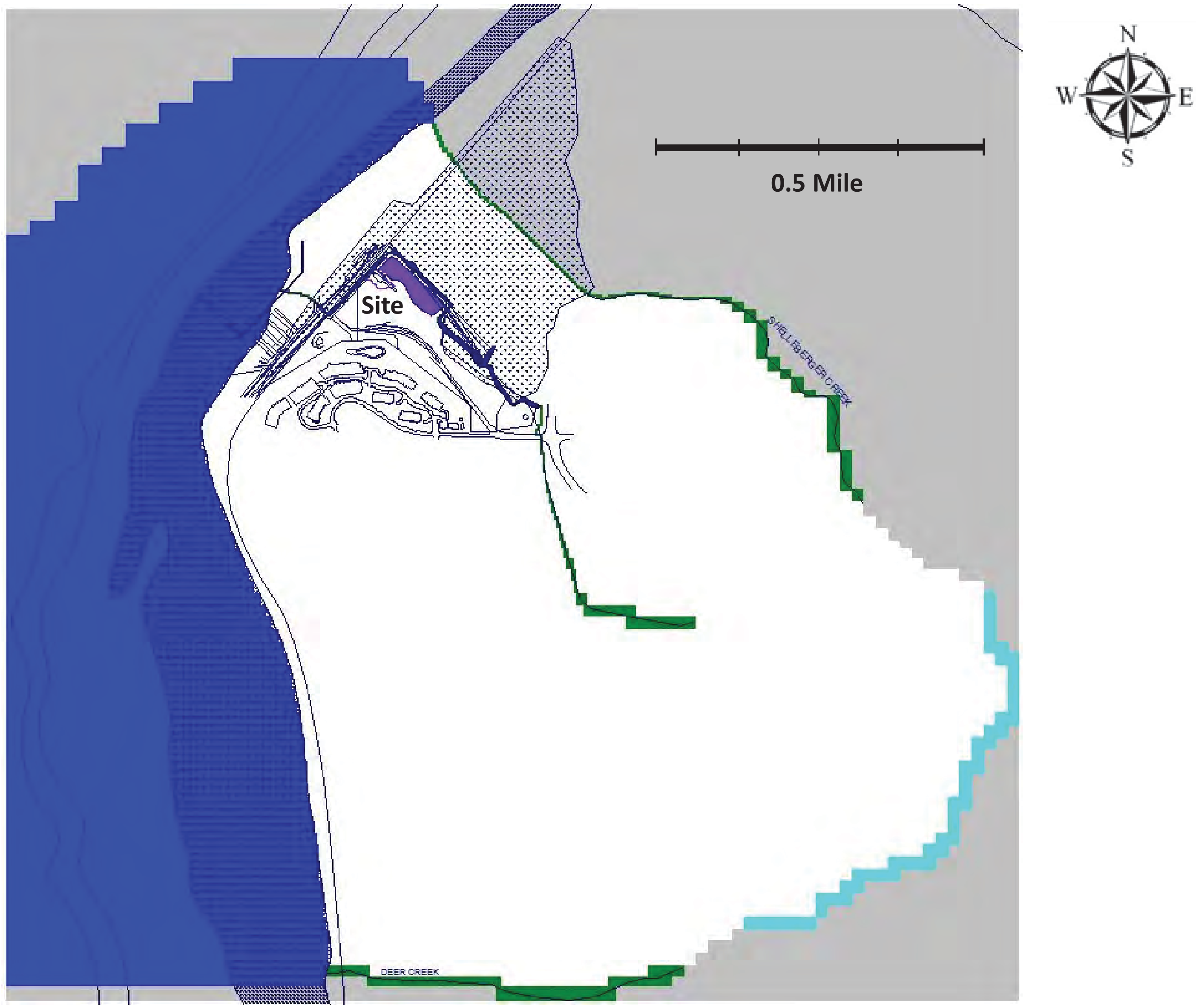
0.75	0.25	0.1
5	0.5	
40	75	
0.75	75	

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Model Layers

ARCADIS

FIGURE 6



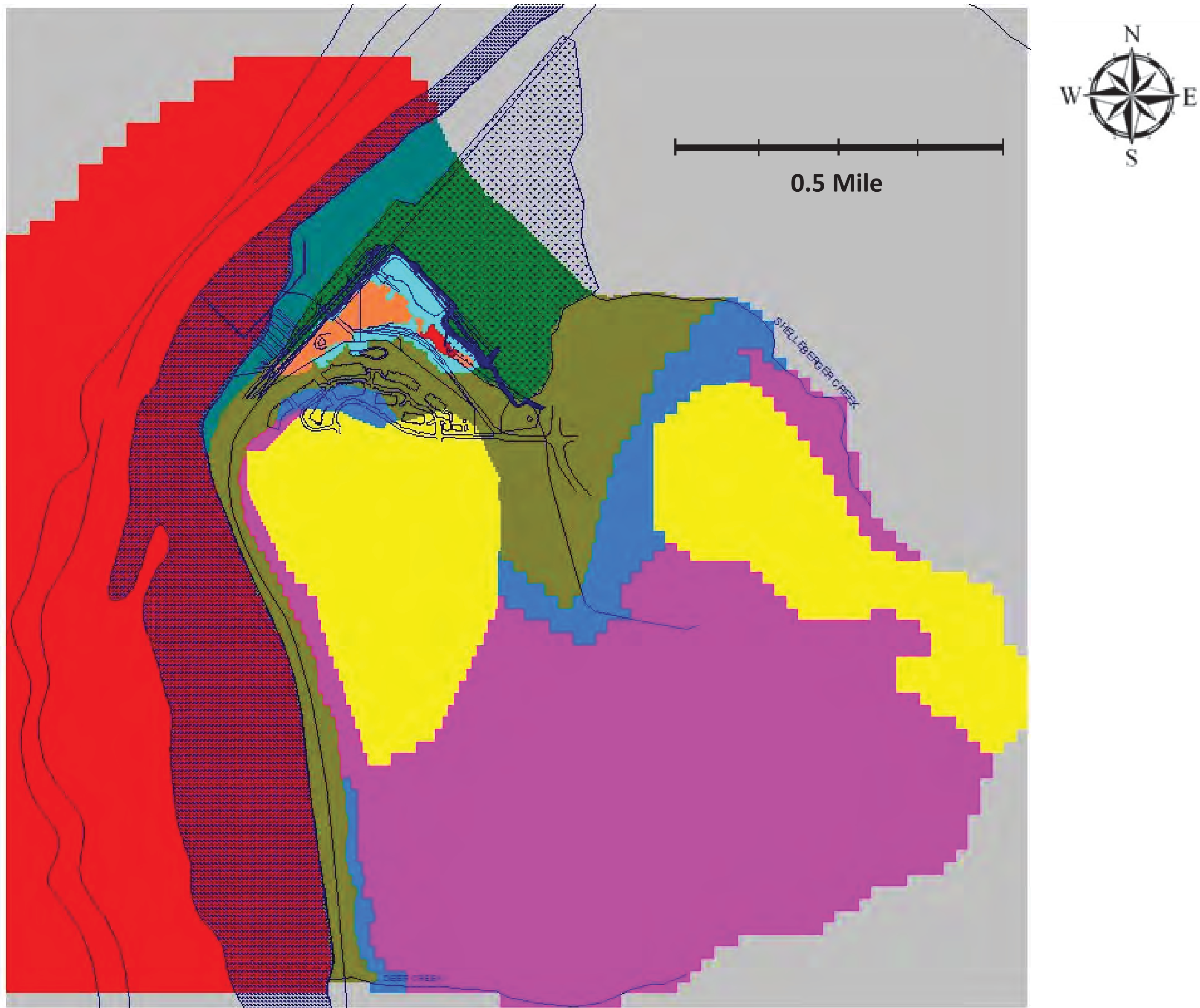
Constant Head Boundary (Puget Sound)
River-Type Boundary
General Head Boundary
Drain
Inactive (No-Flow)

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Boundary Conditions

ARCADIS

FIGURE
7



Hydraulic Conductivity (Feet/Day)

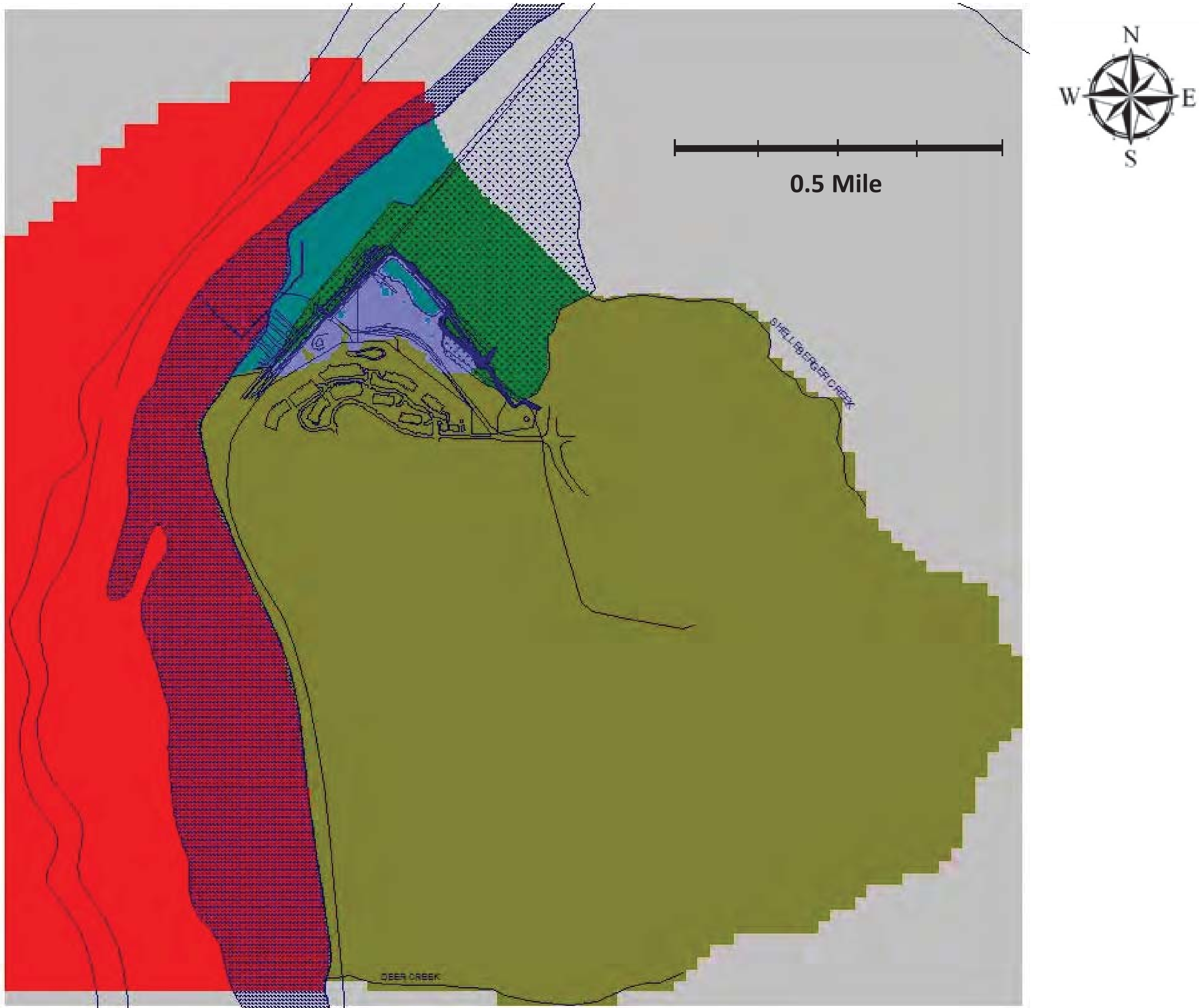
Light blue	0.75	Green	0.25	Dark red	0.1
Teal	5	Yellow	0.5		
Magenta	40	Red	75		
Olive	0.75	Blue	75		

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Hydraulic Conductivity Distribution – Layer 1

ARCADIS

FIGURE 8



Hydraulic Conductivity (Feet/Day)

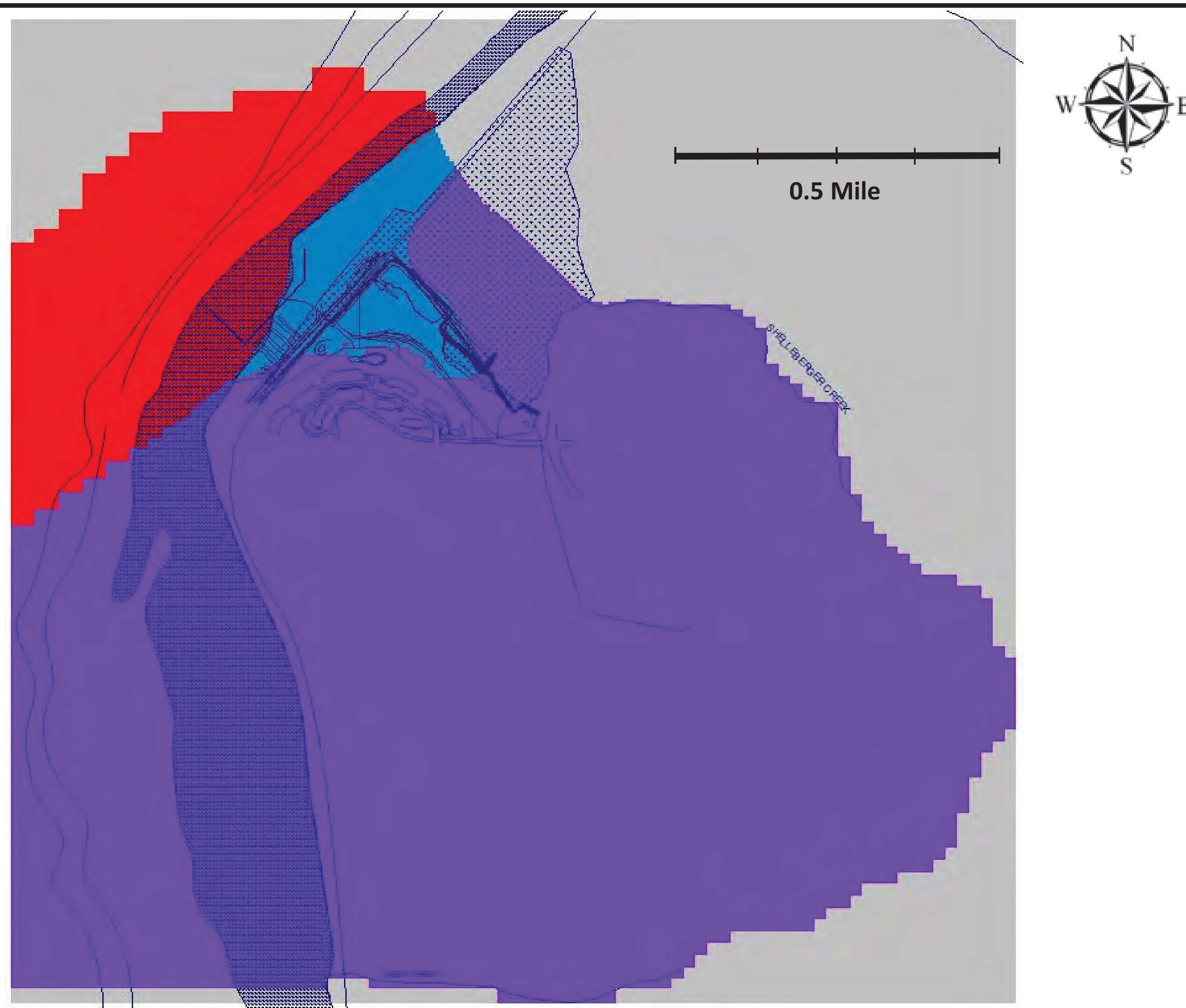
- 5
- 0.75
- 0.25
- 0.85
- 75

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Hydraulic Conductivity Distribution – Layer 2

ARCADIS

FIGURE
9



Hydraulic Conductivity (Feet/Day)

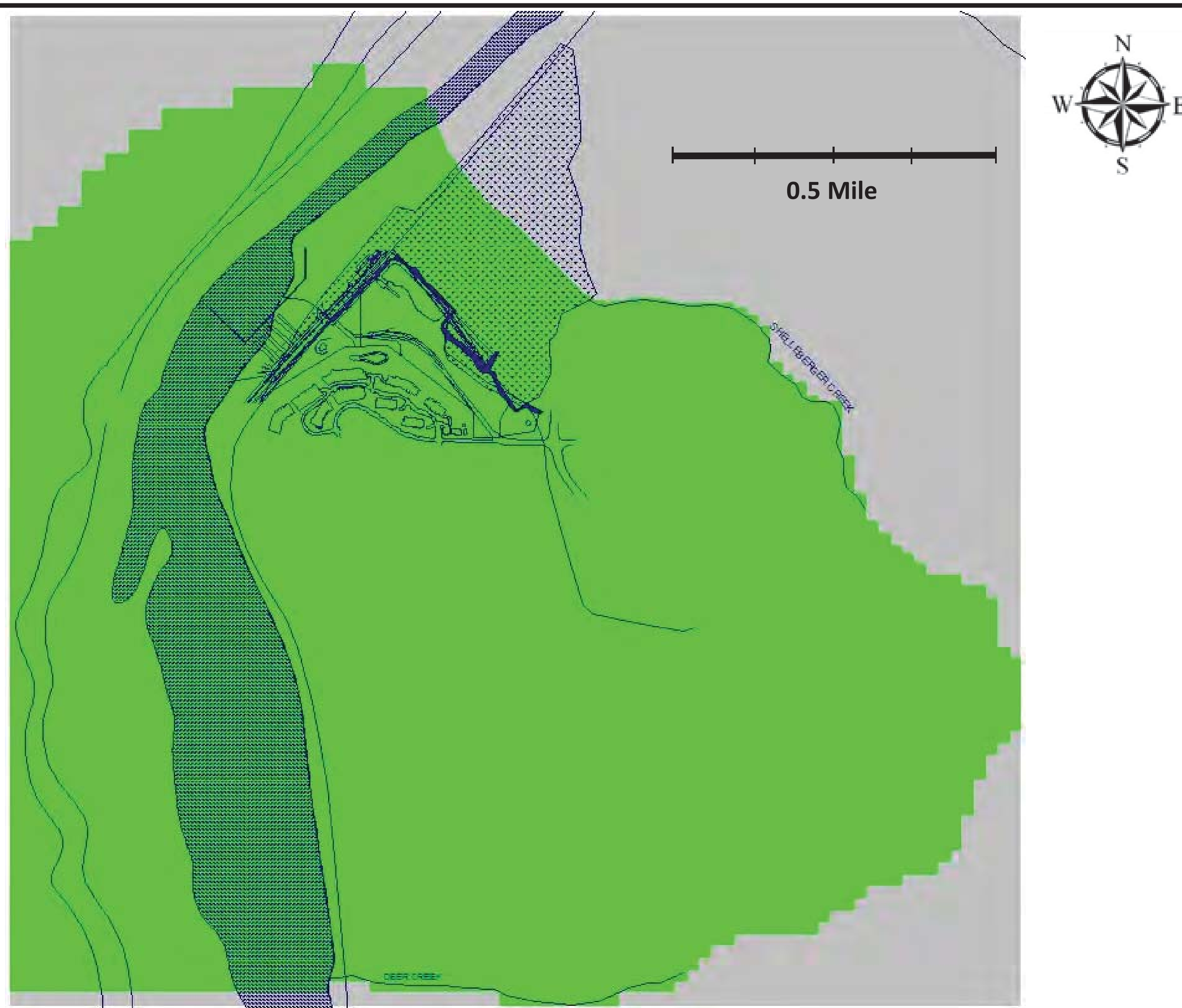
- 1.5
- 75
- 45

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Hydraulic Conductivity Distribution – Layer 3

ARCADIS

FIGURE
10



Hydraulic Conductivity (Feet/Day)

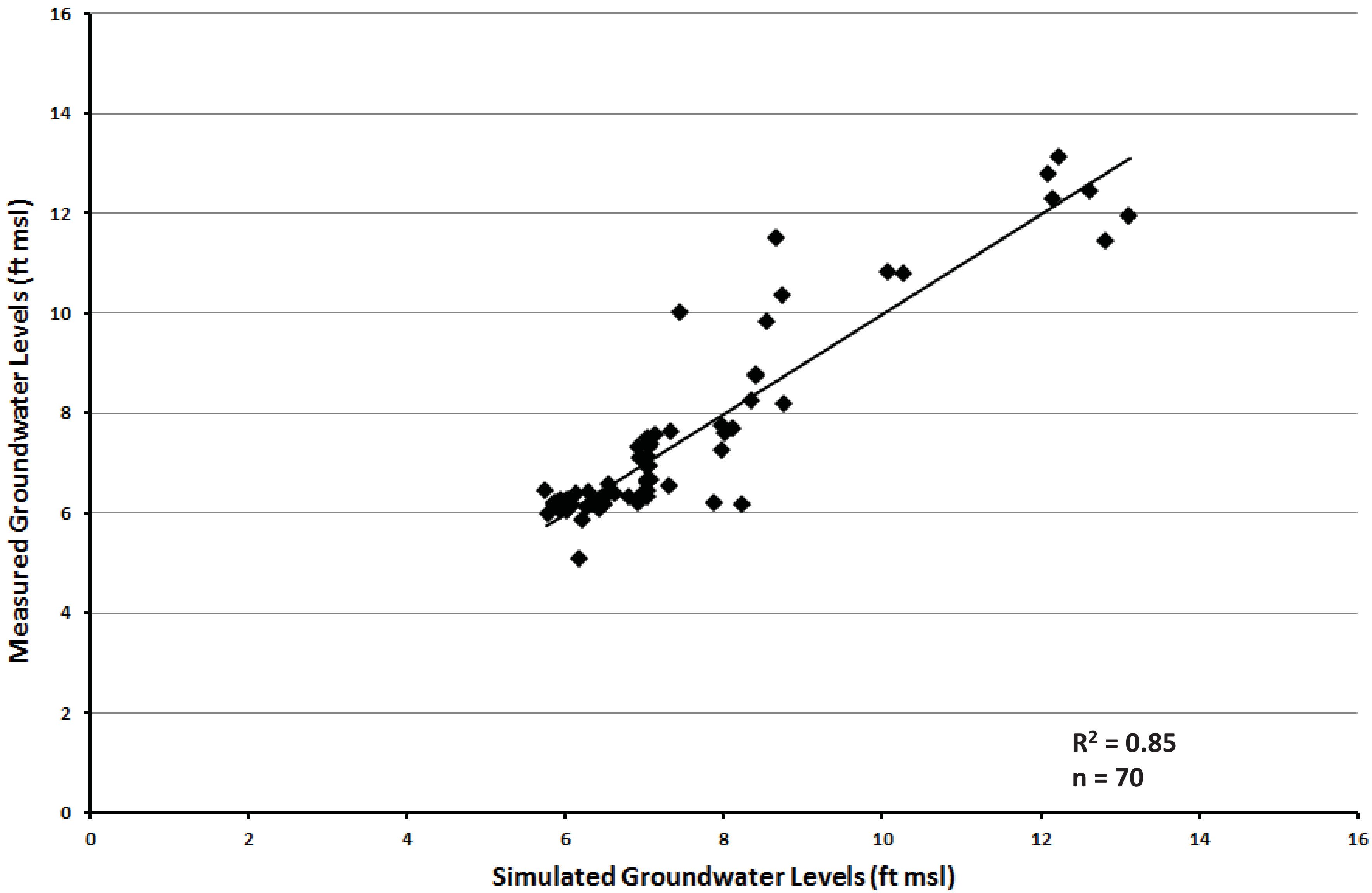
1.5

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Hydraulic Conductivity Distribution – Layer 4

ARCADIS

FIGURE
11

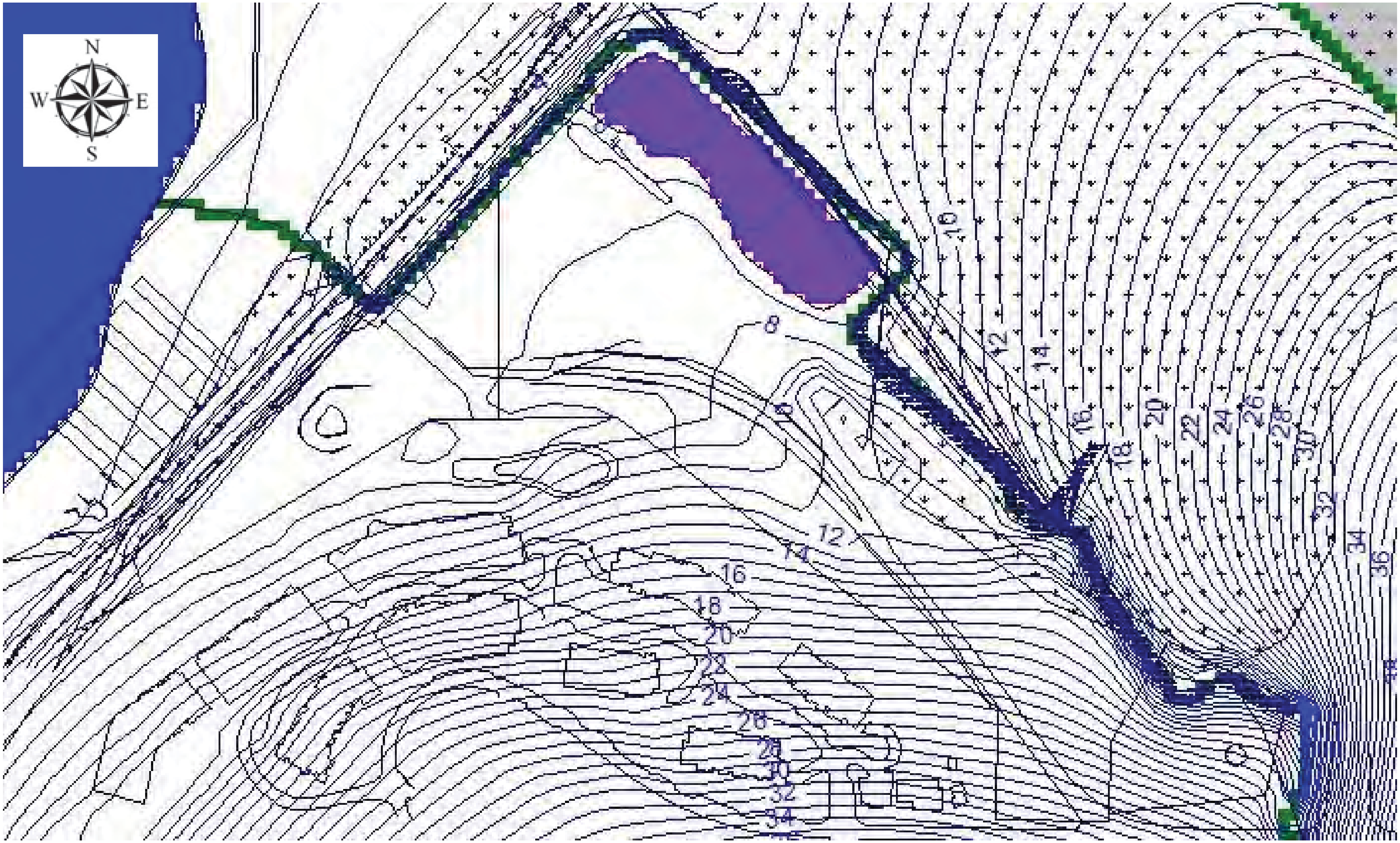


Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Calibration Scatter Plot

ARCADIS

FIGURE
12



Legend

- Puget Sound
- Detention Basin #1
- Creek/River
- Simulated Potentiometric Contour (ft msl)

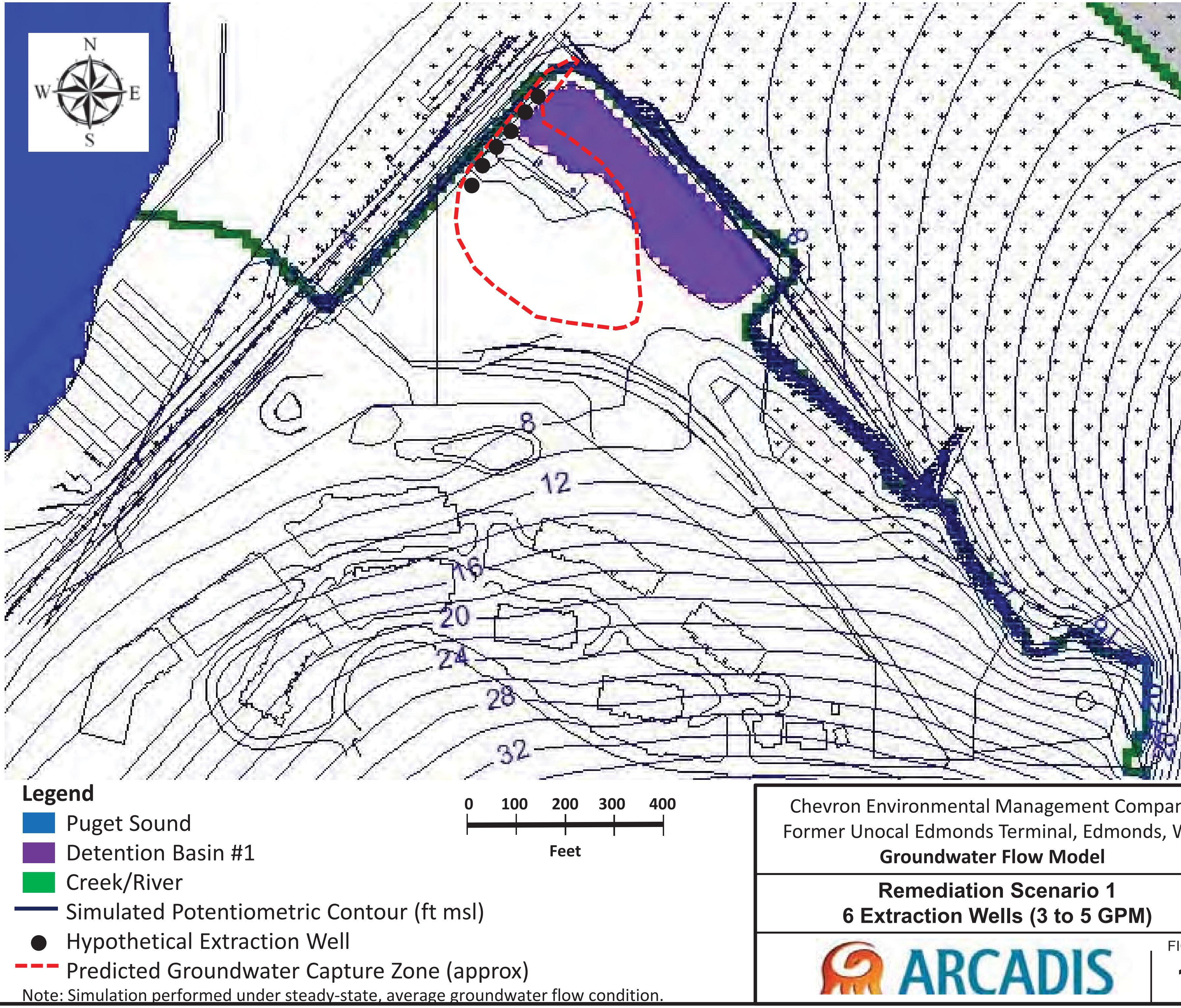
Note: Simulation performed under steady-state, average groundwater flow condition.

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Simulated Potentiometric Surface
Calibrated Condition

ARCADIS

FIGURE
13

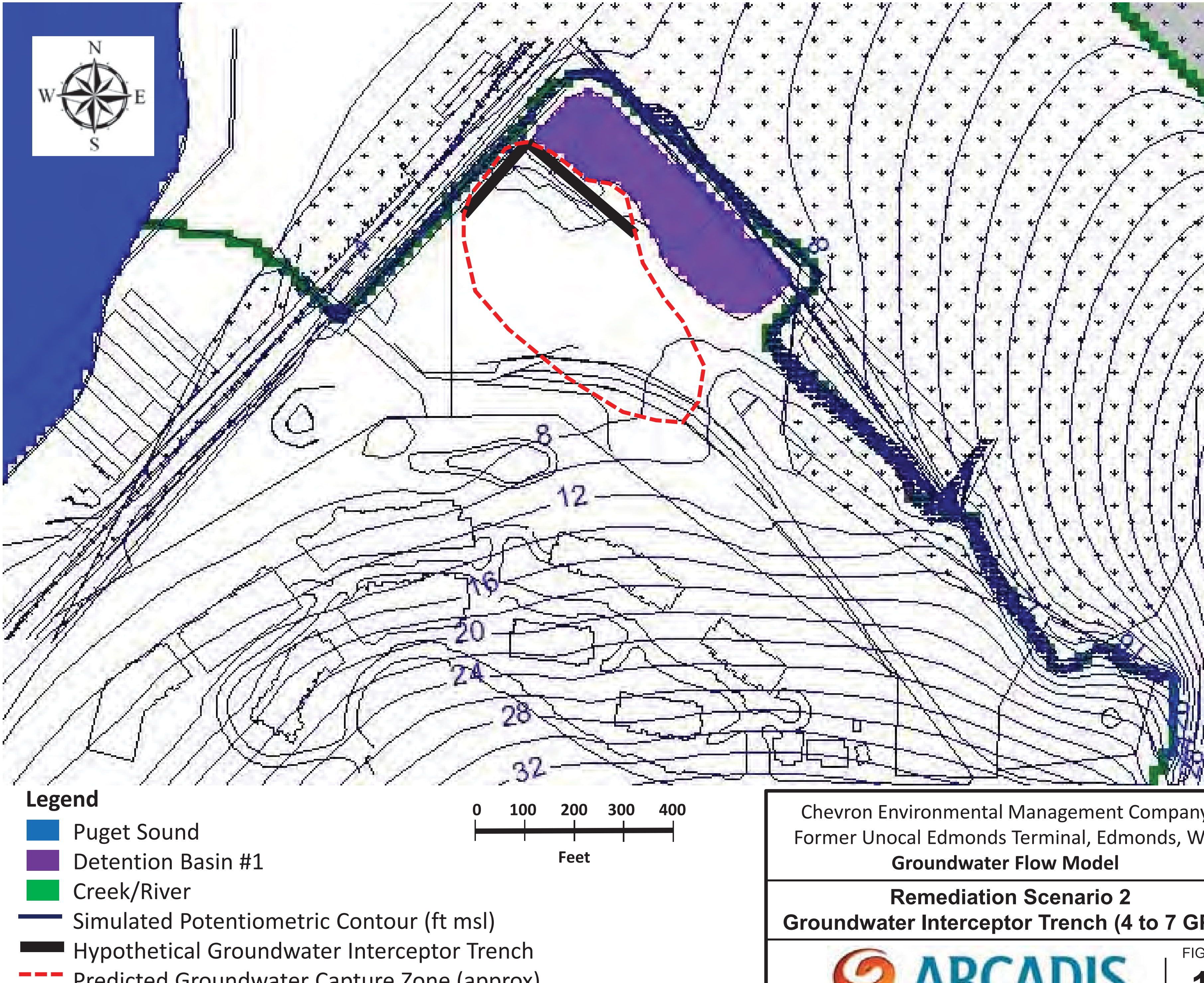


Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Remediation Scenario 1
6 Extraction Wells (3 to 5 GPM)

ARCADIS

FIGURE
14



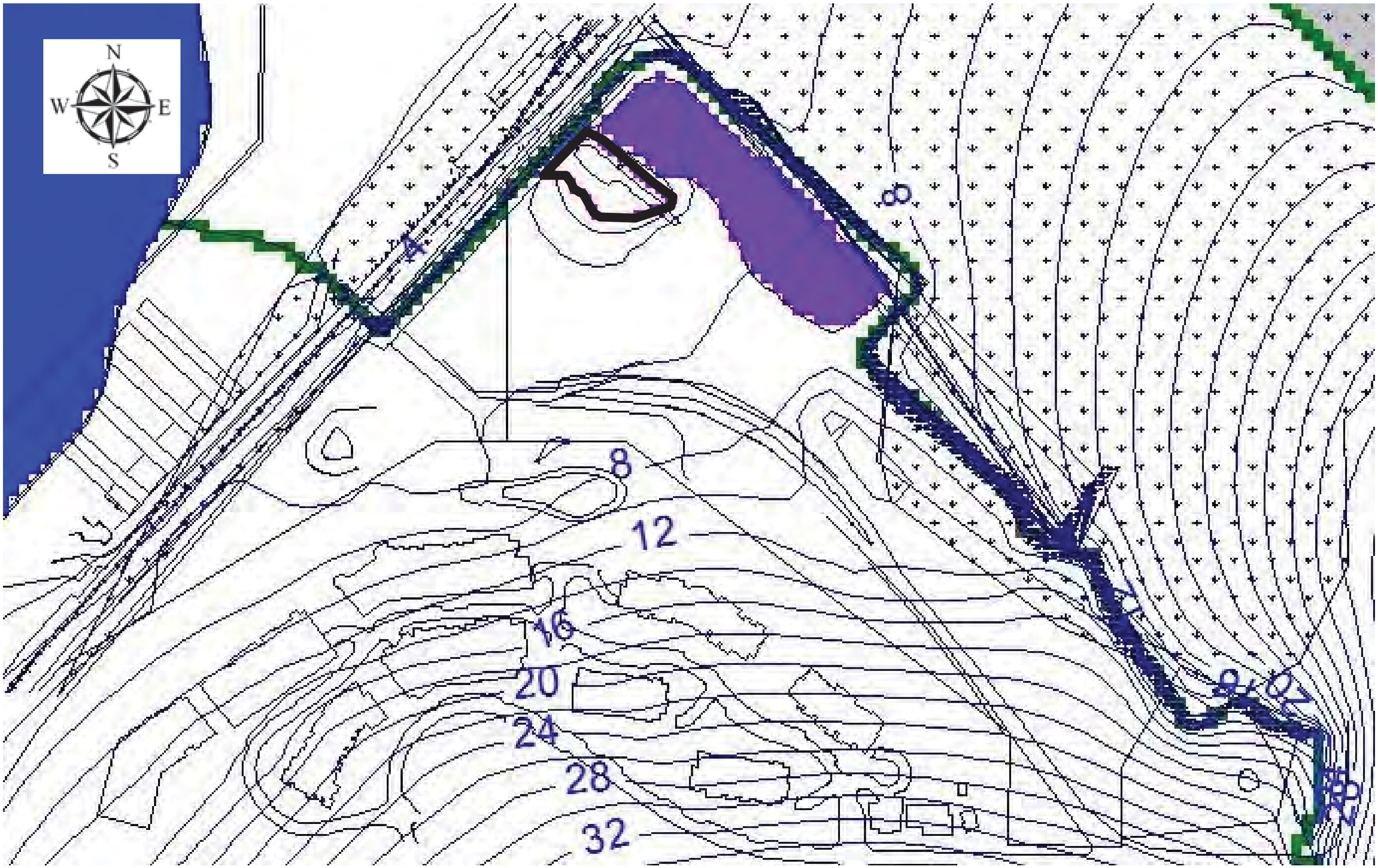
Note: Simulation performed under steady-state, average groundwater flow condition.

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Remediation Scenario 2
Groundwater Interceptor Trench (4 to 7 GPM)

ARCADIS

FIGURE
15



Legend

- Puget Sound
- Detention Basin #1
- Creek/River
- Simulated Potentiometric Contour (ft msl)
- Limits of Soil Excavation (Approx)

0 100 200 300 400
Feet

Note: Simulation performed under steady-state, average groundwater flow condition.

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

Remediation Scenario 3
Soil Excavation Near DB-1 and DB-2

ARCADIS

FIGURE
16

Legend

- Puget Sound
- Detention Basin #1
- Creek/River
- Simulated Potentiometric Contour (ft msl)
- Limits of Soil Excavation (Approx)

0 100 200 300 400

Feet

Note: Simulation performed under steady-state, average groundwater flow condition.

Chevron Environmental Management Company
Former Unocal Edmonds Terminal, Edmonds, WA
Groundwater Flow Model

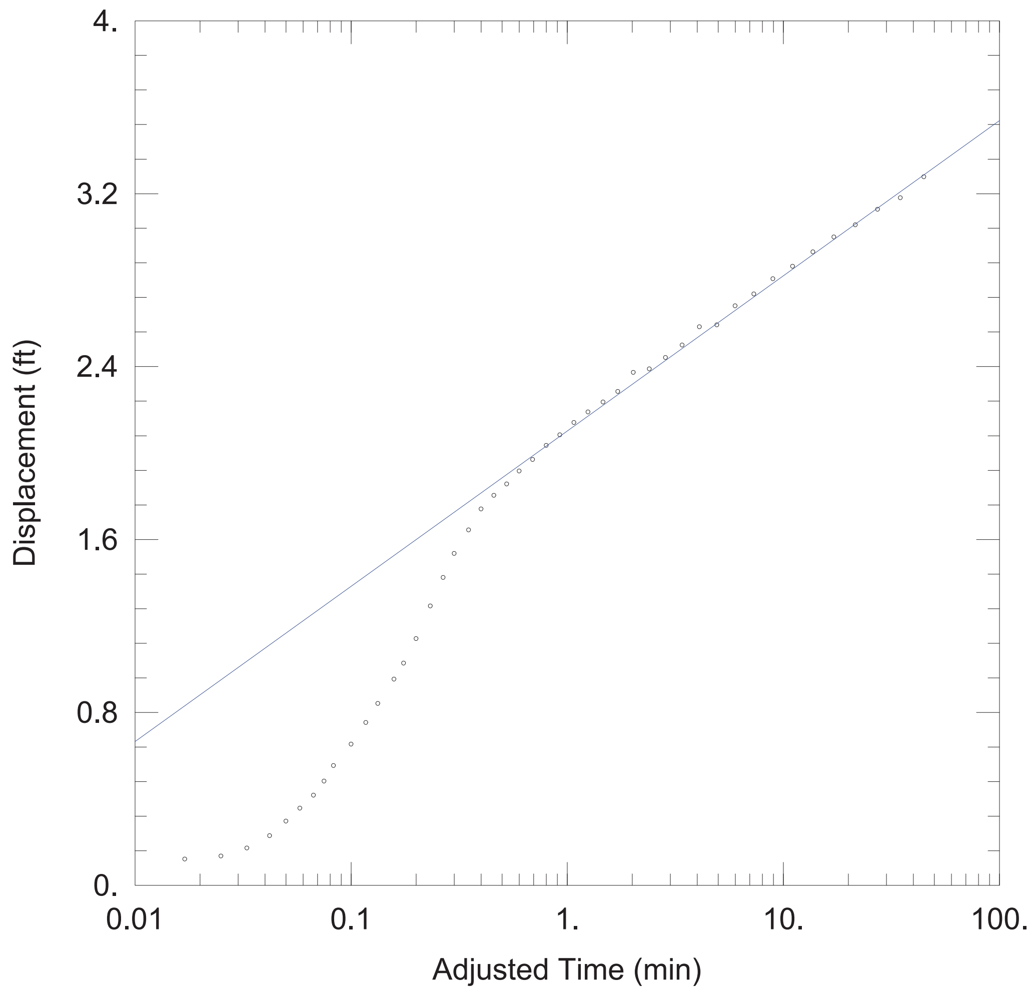
Remediation Scenario 4
Soil Excavation Near Storm Drain

ARCADIS

FIGURE
17

Attachment 1

Constant-Rate Pumping Test Plots



MW-122 CONSTANT-RATE TEST

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-122
Test Date: 3/5/13

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-122	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
◦ MW-122	0	0

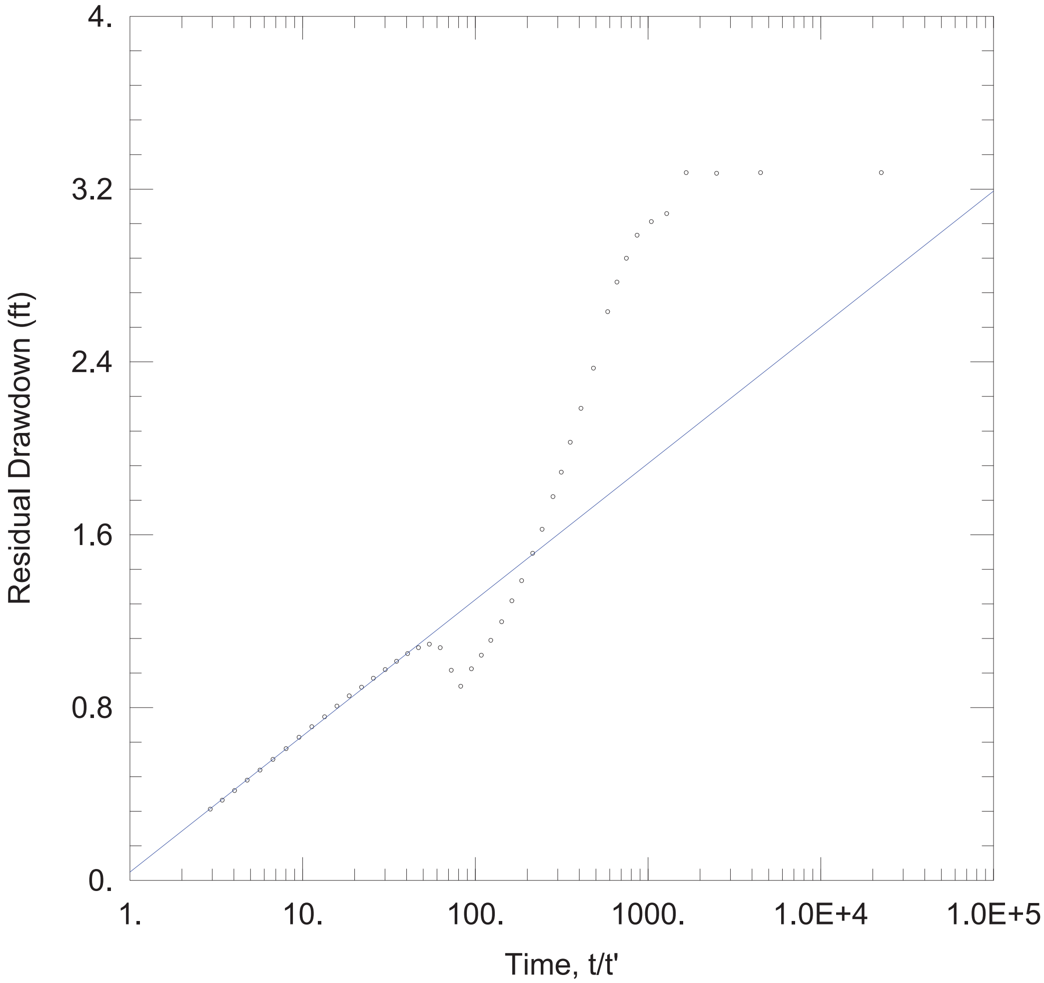
SOLUTION

Aquifer Model: Confined

Solution Method: Cooper-Jacob

T = 165. ft^2/day

S = 0.0028



MW-122 CONSTANT-RATE TEST

PROJECT INFORMATION

Company: ARCADIS
Test Well: MW-122
Test Date: 3/5/13

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-122	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
◦ MW-122	0	0

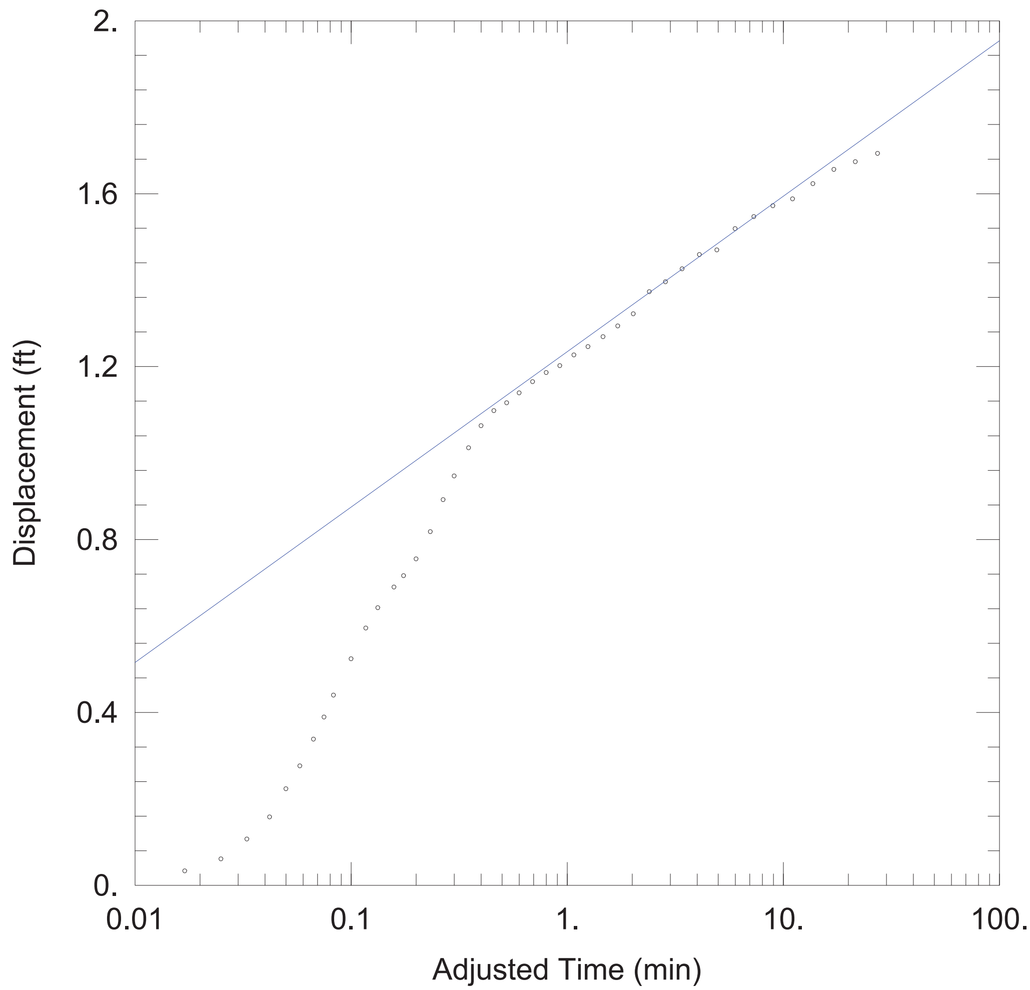
SOLUTION

Aquifer Model: Confined

Solution Method: Theis (Recovery)

T = 188. ft^2/day

S/S' = 0.87



MW-147 CONSTANT-RATE TEST

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-147
Test Date: 3/5/13

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-147	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
◦ MW-147	0	0

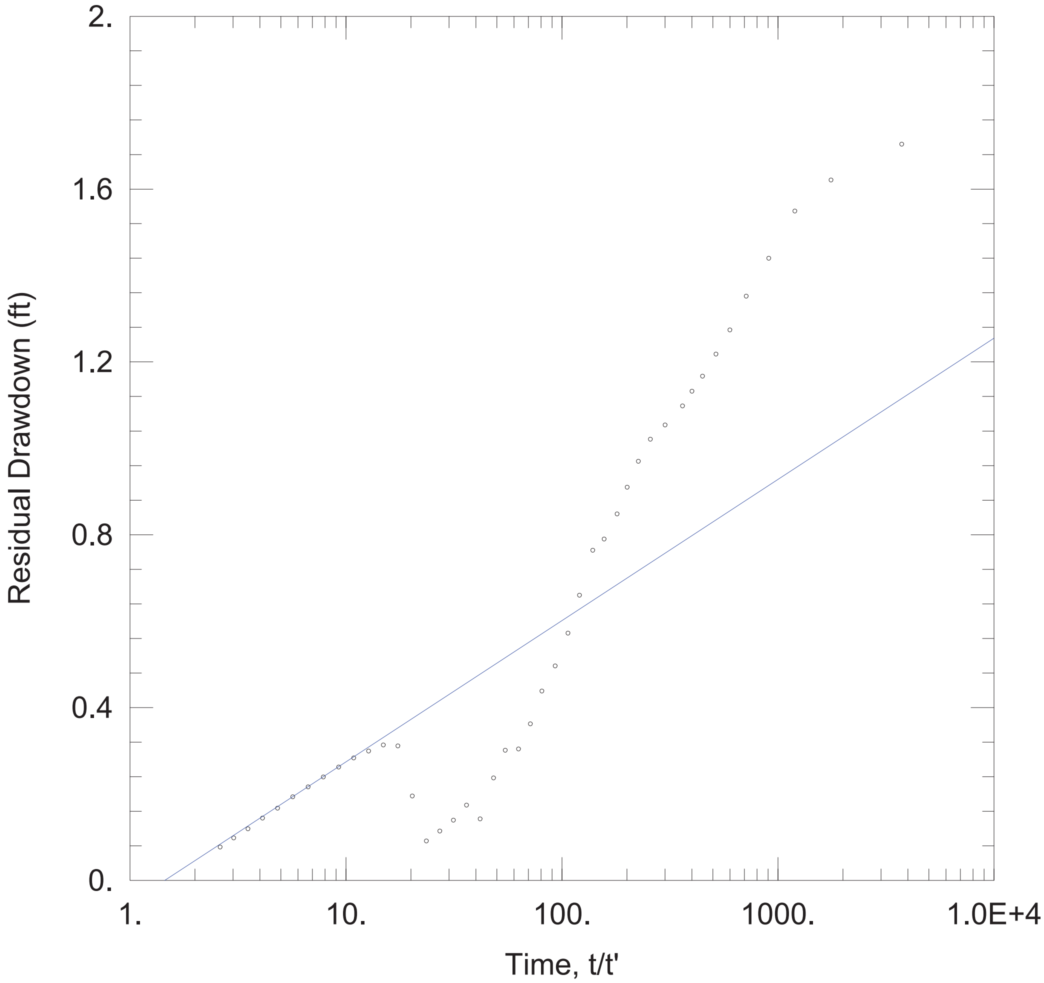
SOLUTION

Aquifer Model: Confined

Solution Method: Cooper-Jacob

T = 360. ft^2/day

S = 0.0019



MW-147 CONSTANT-RATE TEST

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-147
Test Date: 3/5/13

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-147	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
◦ MW-147	0	0

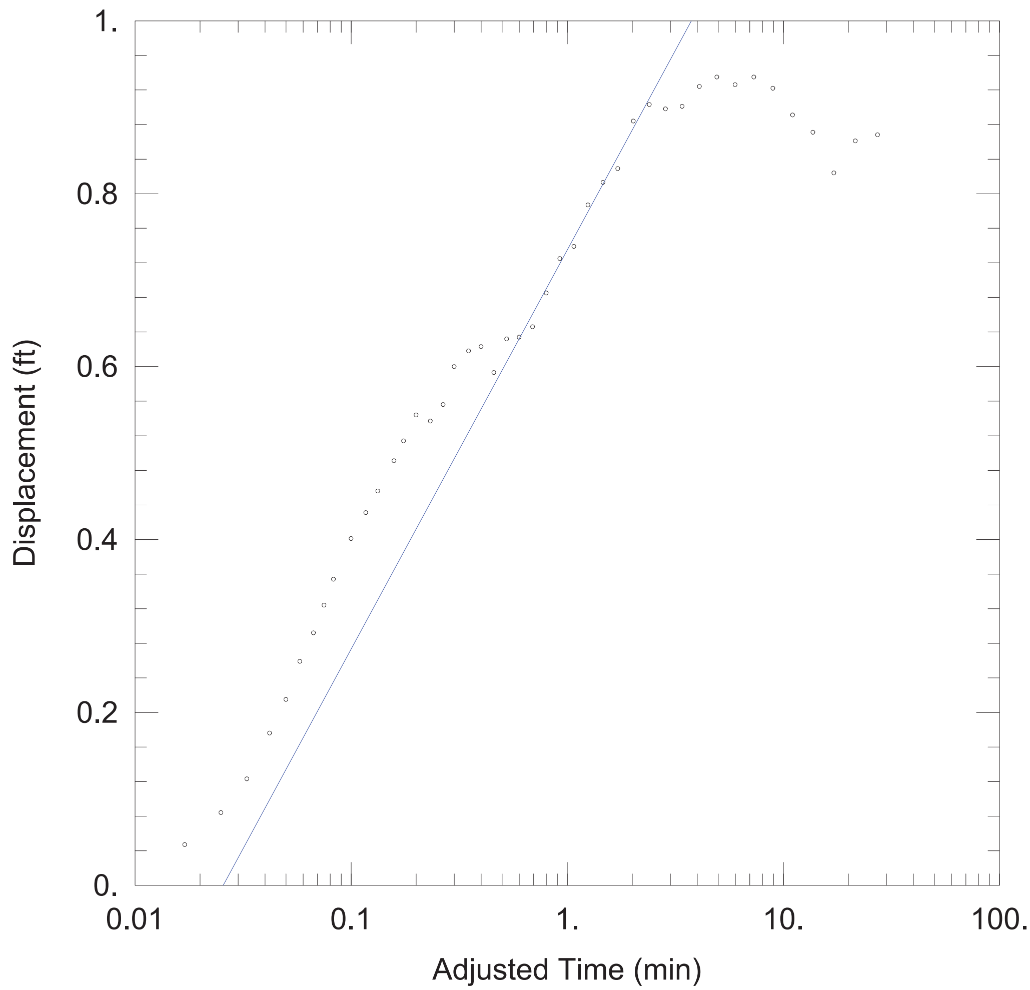
SOLUTION

Aquifer Model: Confined

Solution Method: Theis (Recovery)

T = 396. ft^2/day

S/S' = 1.45



MW-203 CONSTANT-RATE TEST

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-203
Test Date: 3/4/13

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-203	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
◦ MW-203	0	0

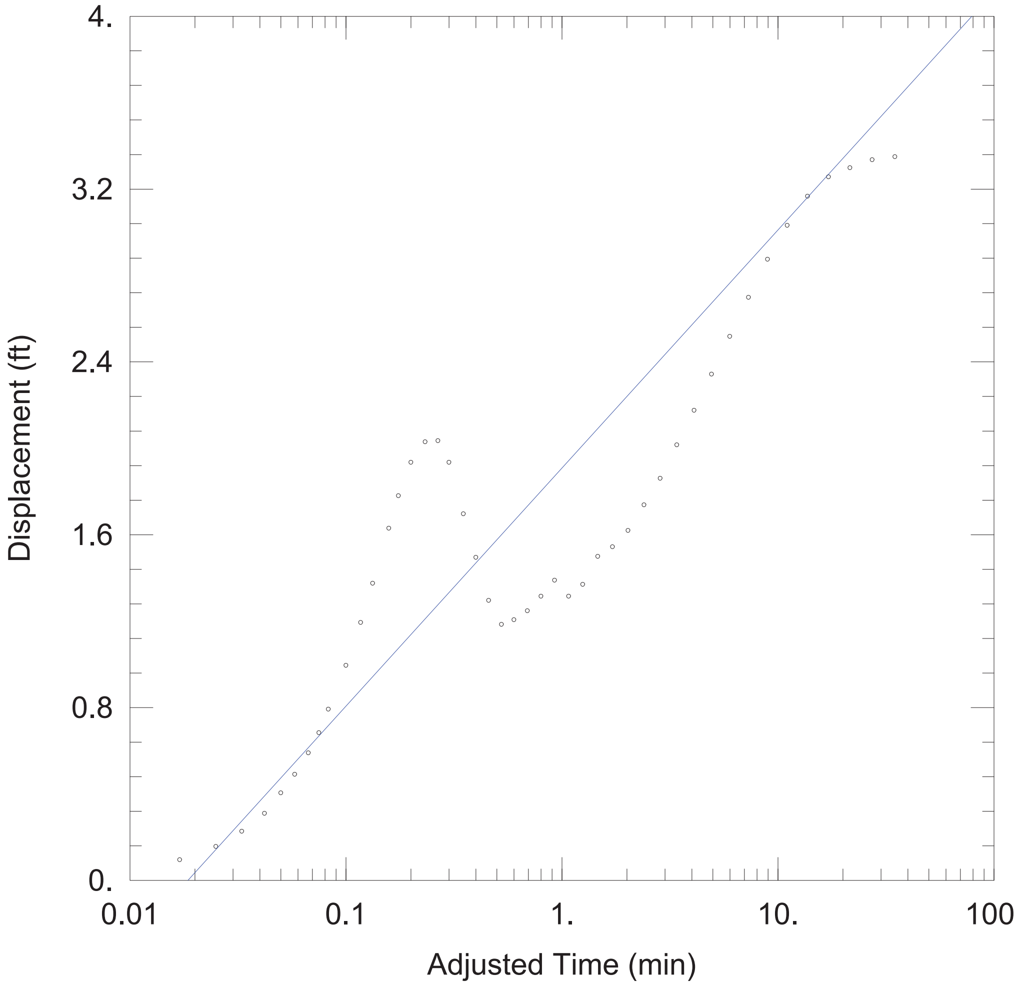
SOLUTION

Aquifer Model: Confined

Solution Method: Cooper-Jacob

T = 191. ft^2/day

S = 0.07



MW-510 CONSTANT-RATE TEST

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-510
Test Date: 3/6/13

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-510	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
◦ MW-510	0	0

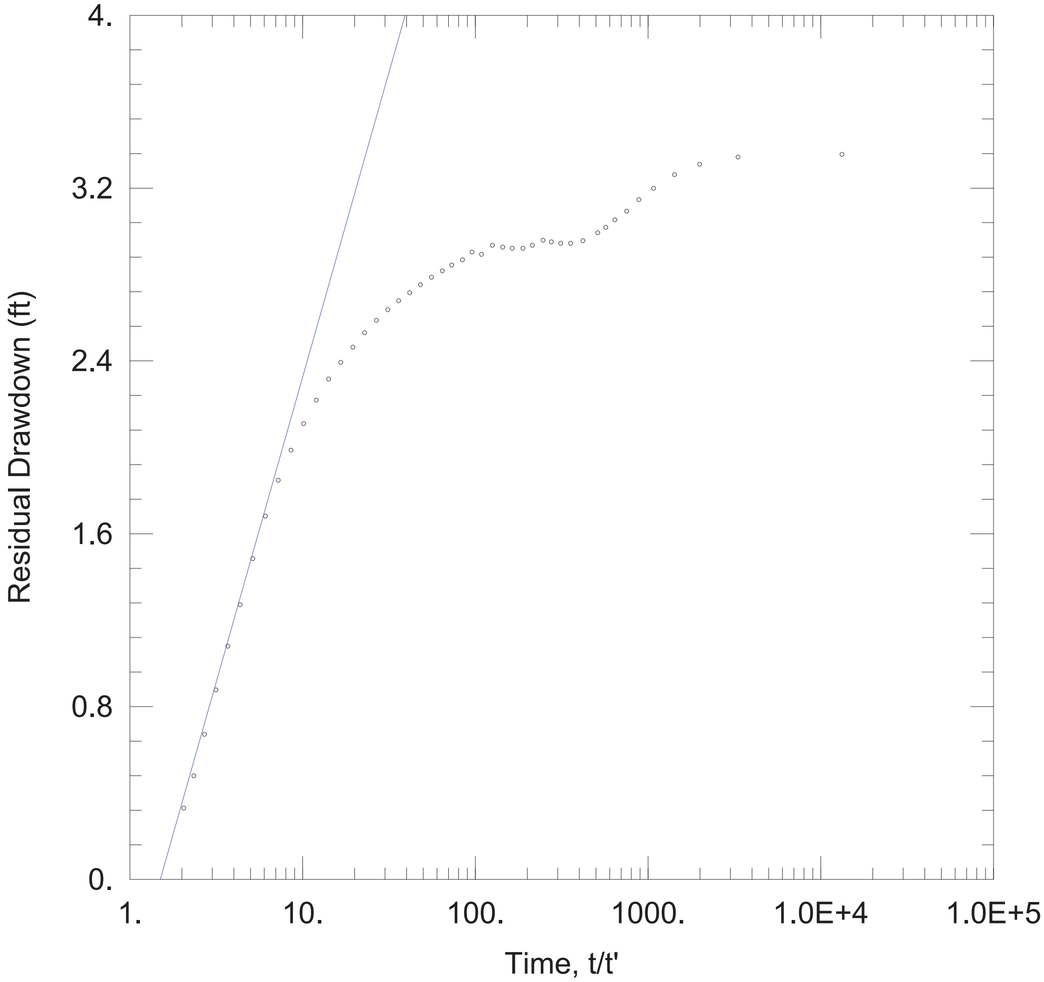
SOLUTION

Aquifer Model: Confined

Solution Method: Cooper-Jacob

T = 6.4 ft^2/day

S = 0.0017



MW-510 CONSTANT-RATE TEST

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-510
Test Date: 3/6/13

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-510	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
◦ MW-510	0	0

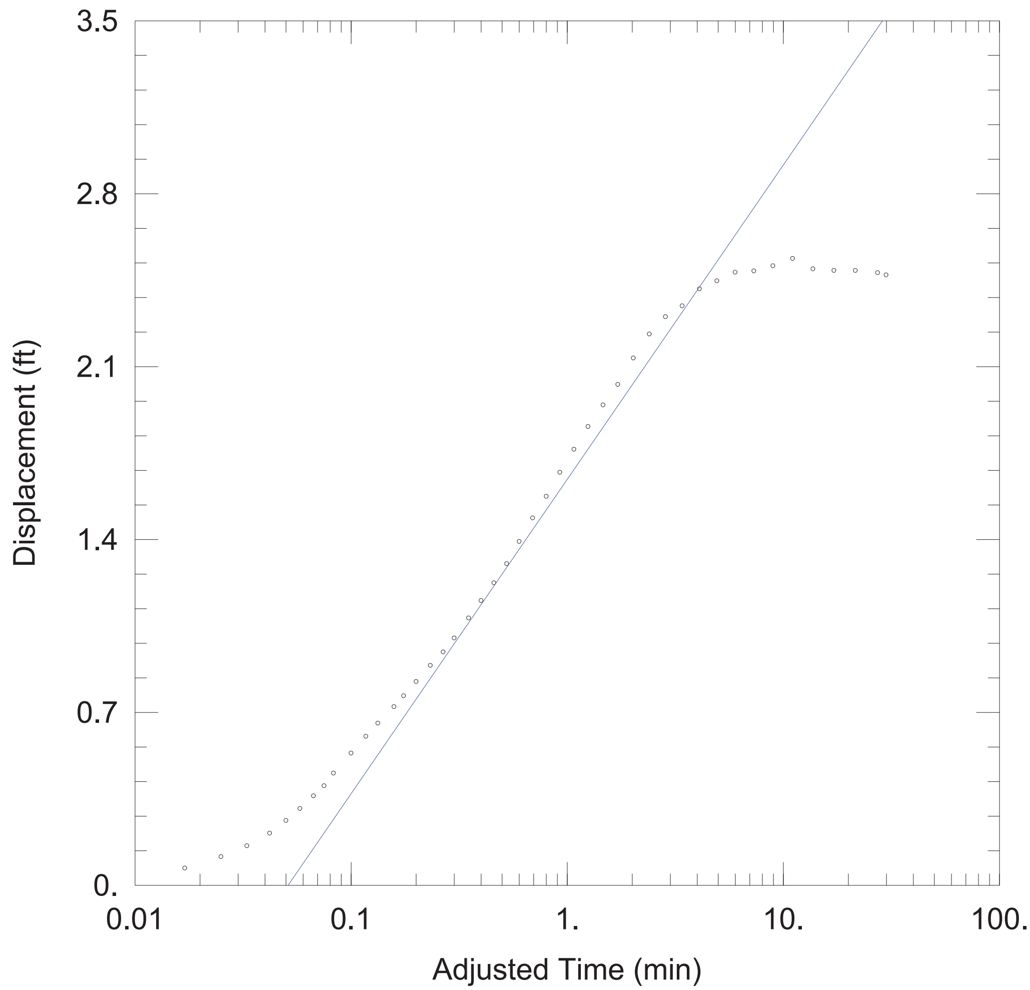
SOLUTION

Aquifer Model: Confined

Solution Method: Theis (Recovery)

T = 2.5 ft^2/day

S/S' = 1.5



MW-511 CONSTANT-RATE TEST

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-511
Test Date: 3/4/13

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-511	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
◦ MW-511	0	0

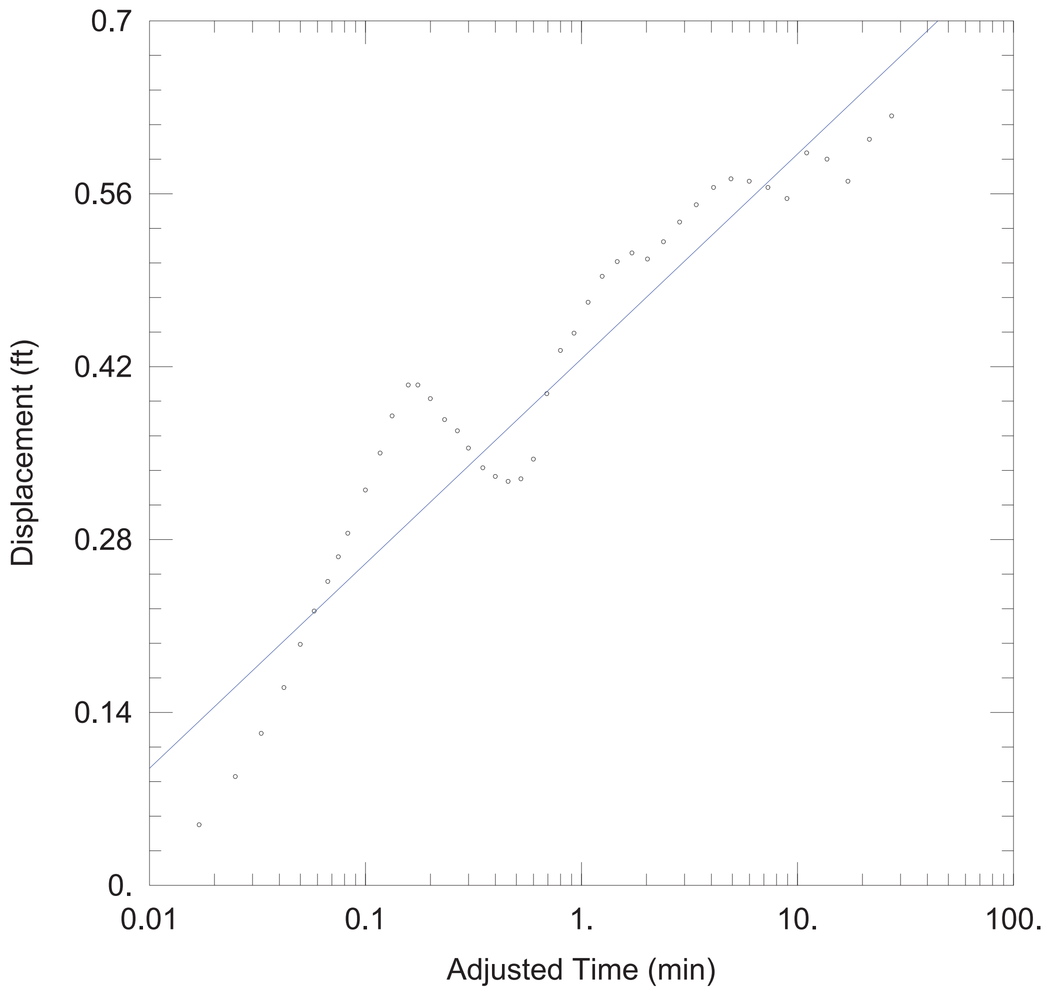
SOLUTION

Aquifer Model: Confined

Solution Method: Cooper-Jacob

T = 97. ft^2/day

S = 0.071



MW-522 CONSTANT-RATE TEST

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-522
Test Date: 3/5/13

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-522	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
◦ MW-522	0	0

SOLUTION

Aquifer Model: Confined

Solution Method: Cooper-Jacob

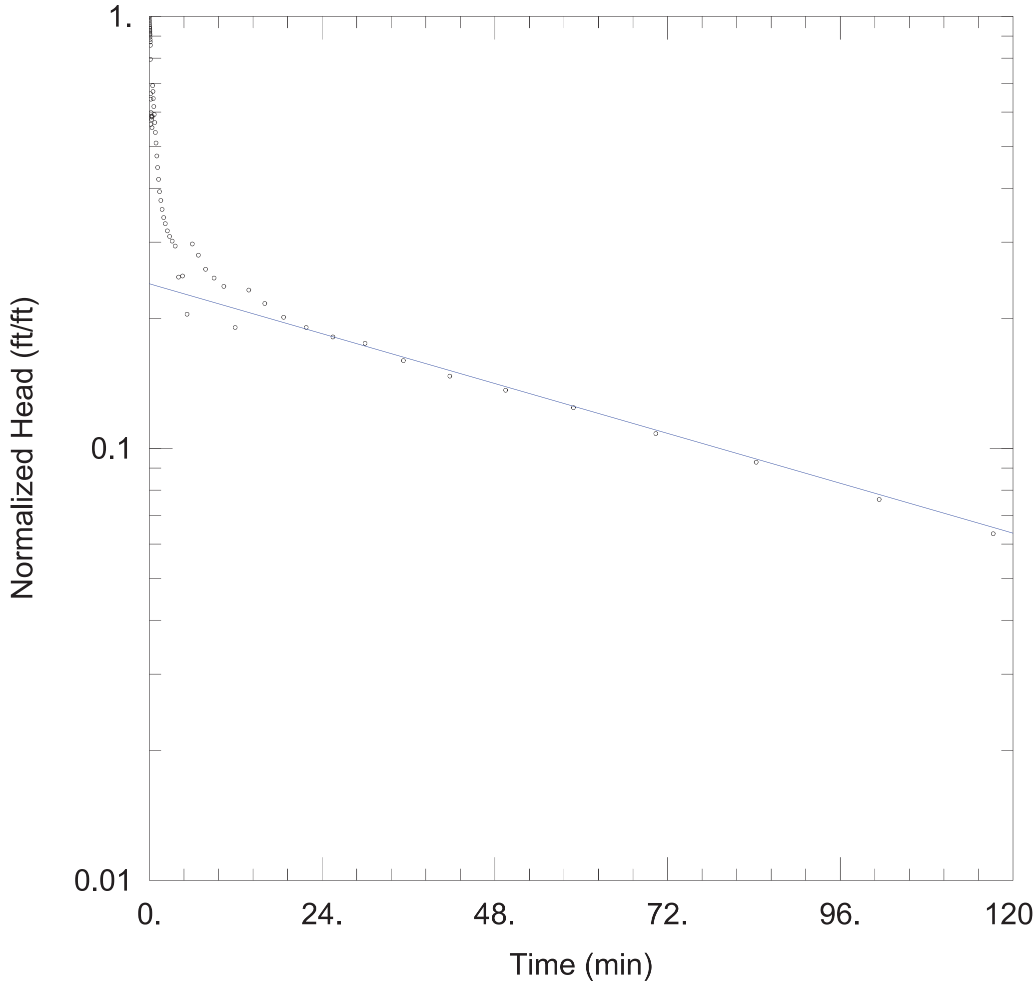
T = 117. ft^2/day

S = 0.0045

ARCADIS

Attachment 2

Slug Test Plots



MW-108 RISING HEAD TEST 1

PROJECT INFORMATION

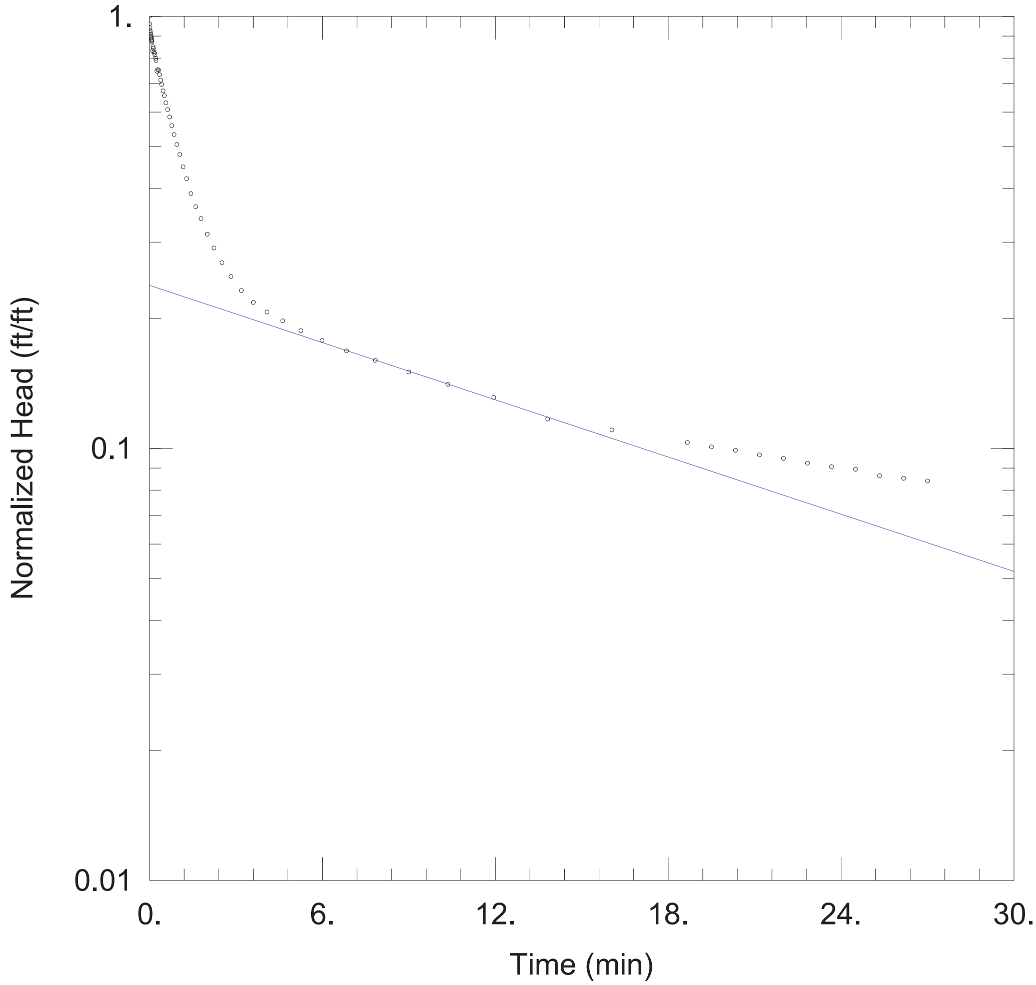
Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-108
Test Date: 3/6/13

WELL DATA (MW-108)

Initial Displacement: 1.498 ft	Static Water Column Height: 9.67 ft
Total Well Penetration Depth: 9.6 ft	Screen Length: 9.6 ft
Casing Radius: 0.0417 ft	Well Radius: 0.17 ft
	Gravel Pack Porosity: 0.35

SOLUTION

Aquifer Model: Unconfined	Solution Method: Bouwer-Rice
K = 0.02 ft/day	y0 = 0.36 ft



MW-109 RISING HEAD TEST 1

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-109
Test Date: 3/7/13

WELL DATA (MW-109)

Initial Displacement: 1.678 ft
Total Well Penetration Depth: 8.09 ft
Casing Radius: 0.0417 ft

Static Water Column Height: 8.22 ft
Screen Length: 8.09 ft
Well Radius: 0.17 ft
Gravel Pack Porosity: 0.35

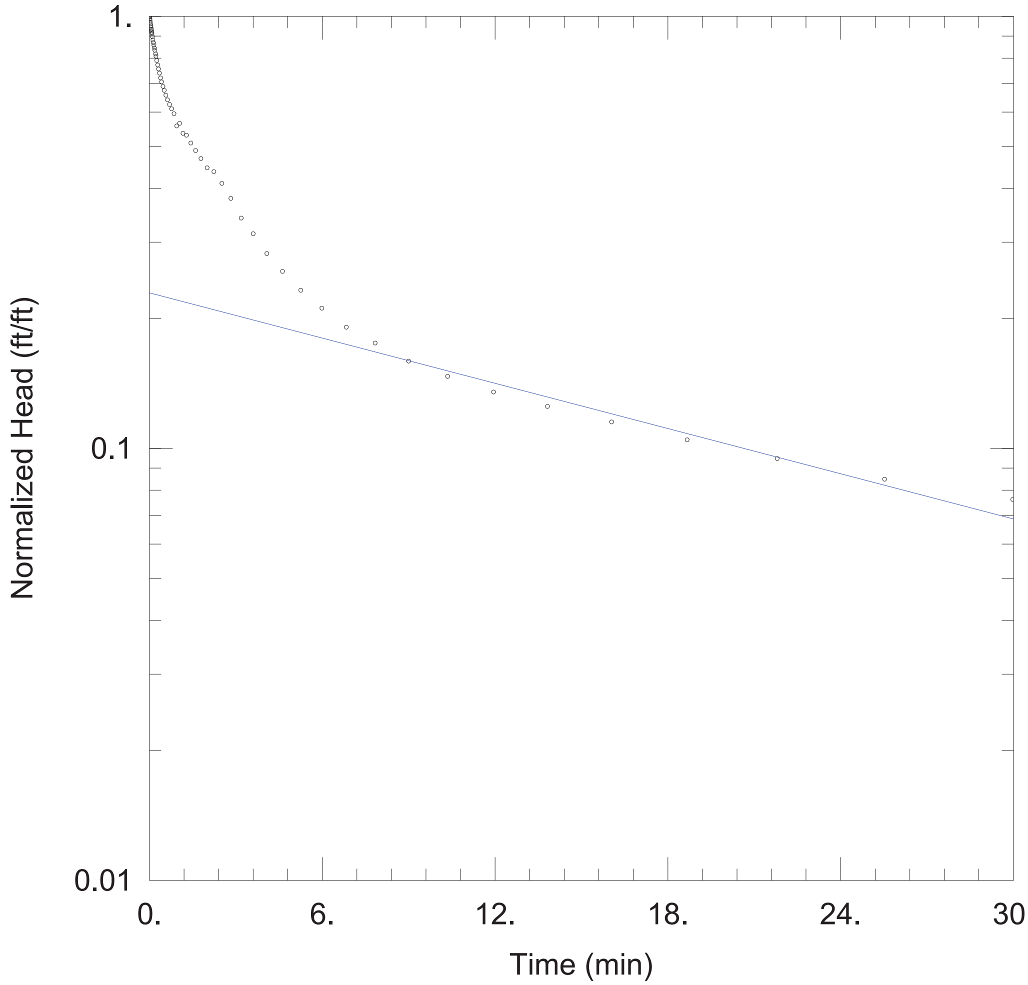
SOLUTION

Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

K = 0.091 ft/day

y0 = 0.4 ft



MW-126 RISING HEAD TEST 1

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-126
Test Date: 3/6/13

WELL DATA (MW-126)

Initial Displacement: 1.616 ft
Total Well Penetration Depth: 9.65 ft
Casing Radius: 0.083 ft

Static Water Column Height: 9.75 ft
Screen Length: 9.65 ft
Well Radius: 0.33 ft
Gravel Pack Porosity: 0.35

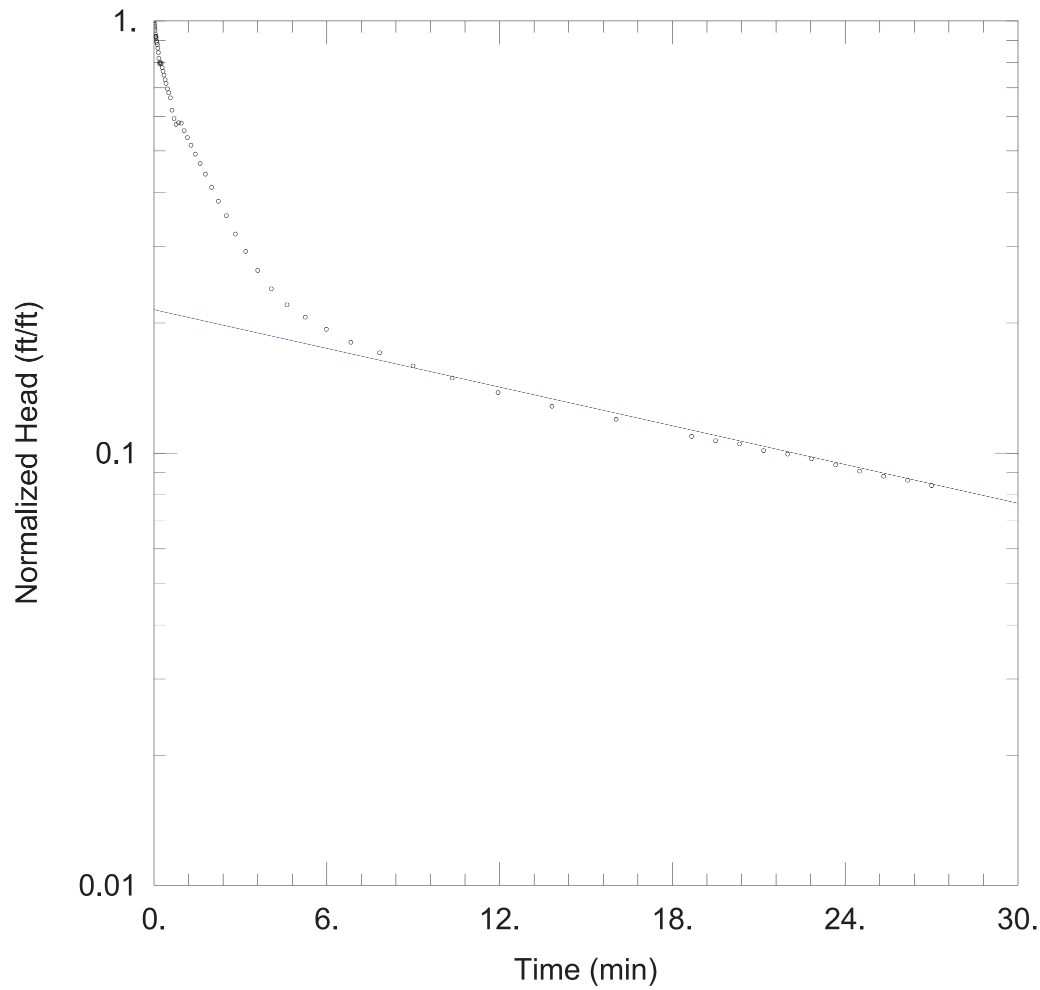
SOLUTION

Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

K = 0.23 ft/day

y0 = 0.37 ft



MW-126 RISING HEAD TEST 2

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-126
Test Date: 3/7/13

WELL DATA (MW-126)

Initial Displacement: 1.63 ft
Total Well Penetration Depth: 9.8 ft
Casing Radius: 0.083 ft

Static Water Column Height: 9.9 ft
Screen Length: 9.8 ft
Well Radius: 0.33 ft
Gravel Pack Porosity: 0.35

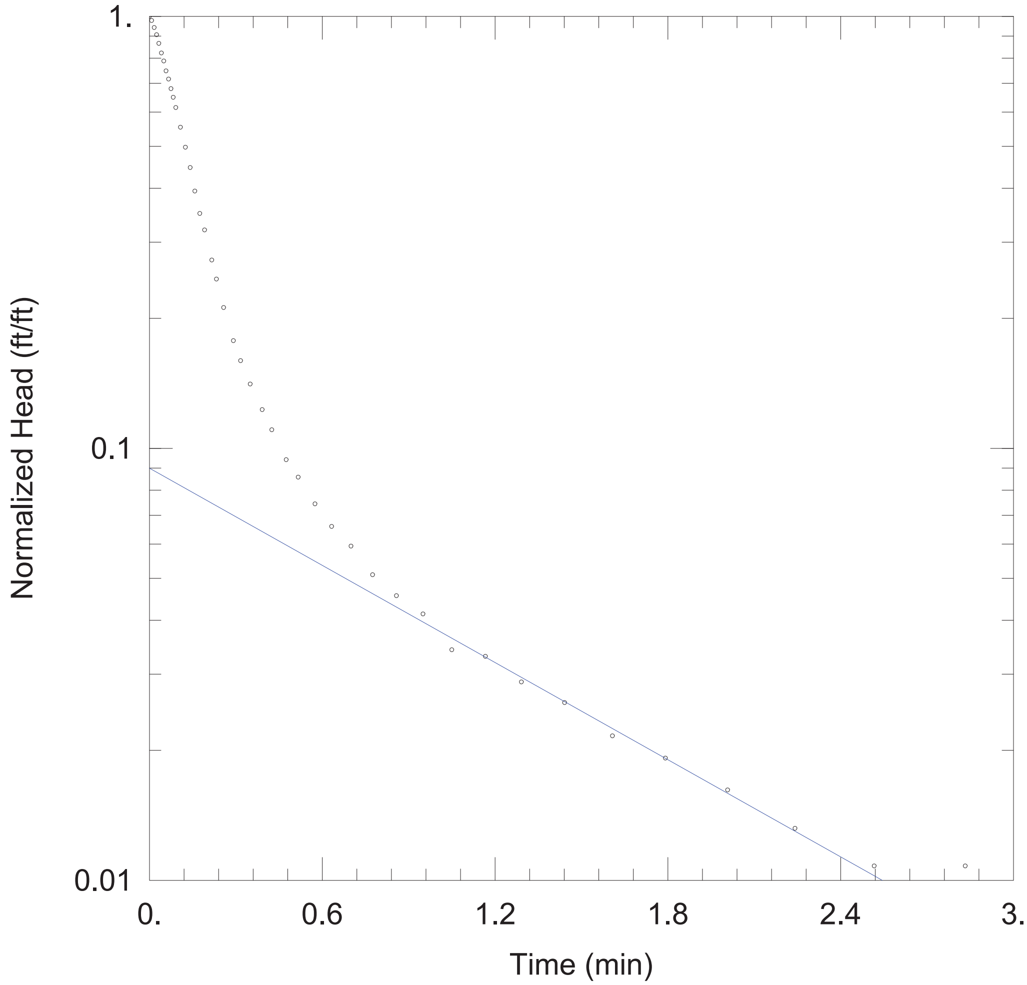
SOLUTION

Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

K = 0.21 ft/day

y0 = 0.35 ft



MW-522 RISING HEAD TEST 1

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-522
Test Date: 3/7/13

WELL DATA (MW-522)

Initial Displacement: 1.668 ft
Total Well Penetration Depth: 4.91 ft
Casing Radius: 0.083 ft

Static Water Column Height: 5.16 ft
Screen Length: 4.91 ft
Well Radius: 0.33 ft
Gravel Pack Porosity: 0.35

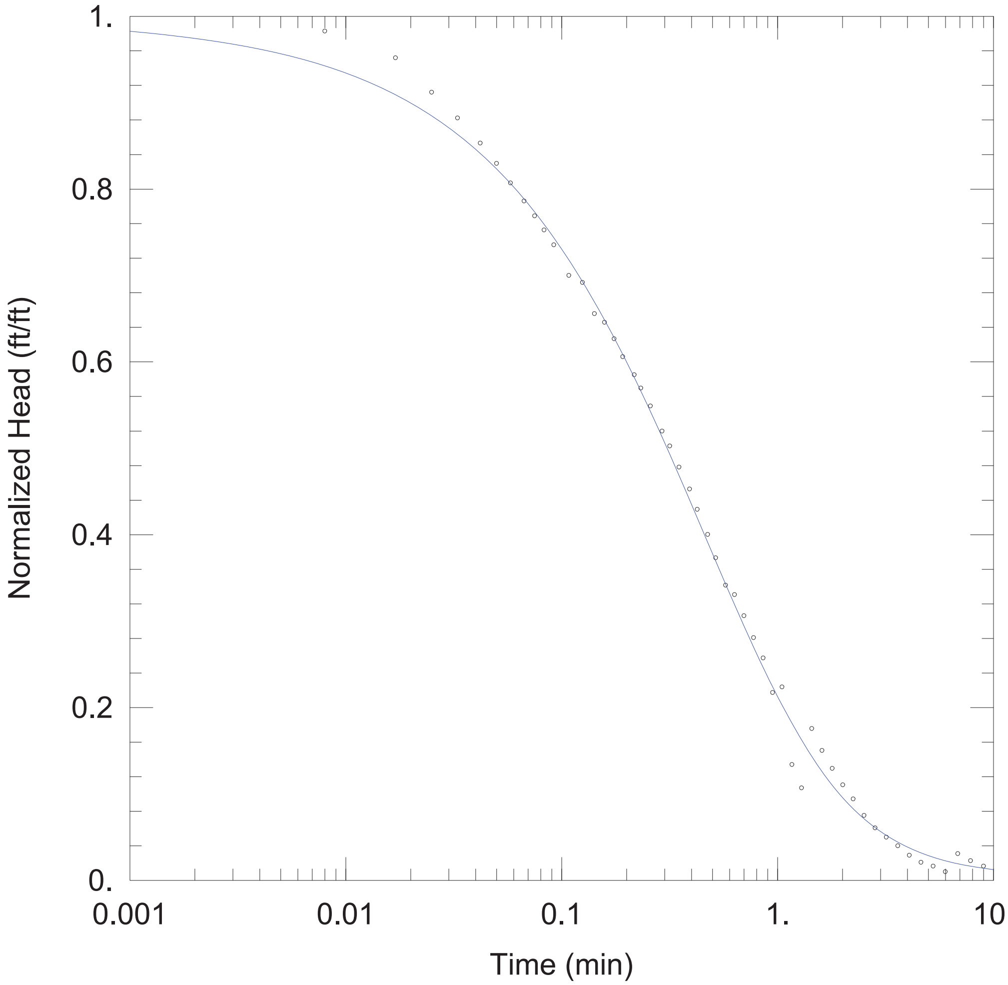
SOLUTION

Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

K = 17.3 ft/day

y0 = 0.15 ft



MW-530 RISING HEAD TEST 2

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-530
Test Date: 3/7/13

WELL DATA (MW-530)

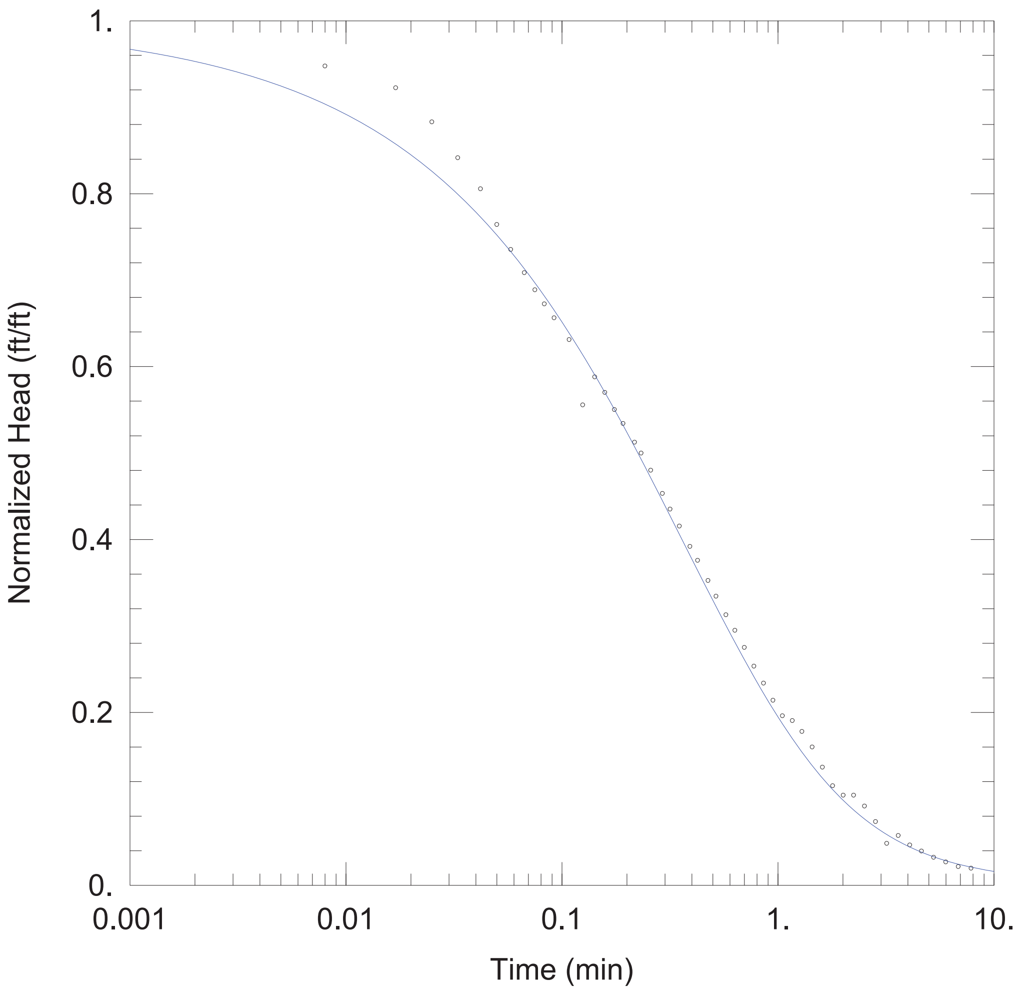
Initial Displacement: 1.104 ft
Total Well Penetration Depth: 6.56 ft
Casing Radius: 0.0417 ft

Static Water Column Height: 6.59 ft
Screen Length: 5. ft
Well Radius: 0.08 ft

SOLUTION

Aquifer Model: Confined
$T = 5.9\ ft^2/day$

Solution Method: Cooper-Bredehoeft-Papadopulos
S = 0.0053



MW-530 RISING HEAD TEST 3

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: MW-530
Test Date: 3/7/13

WELL DATA (MW-530)

Initial Displacement: 1.287 ft
Total Well Penetration Depth: 6.56 ft
Casing Radius: 0.0417 ft

Static Water Column Height: 6.59 ft
Screen Length: 5. ft
Well Radius: 0.083 ft

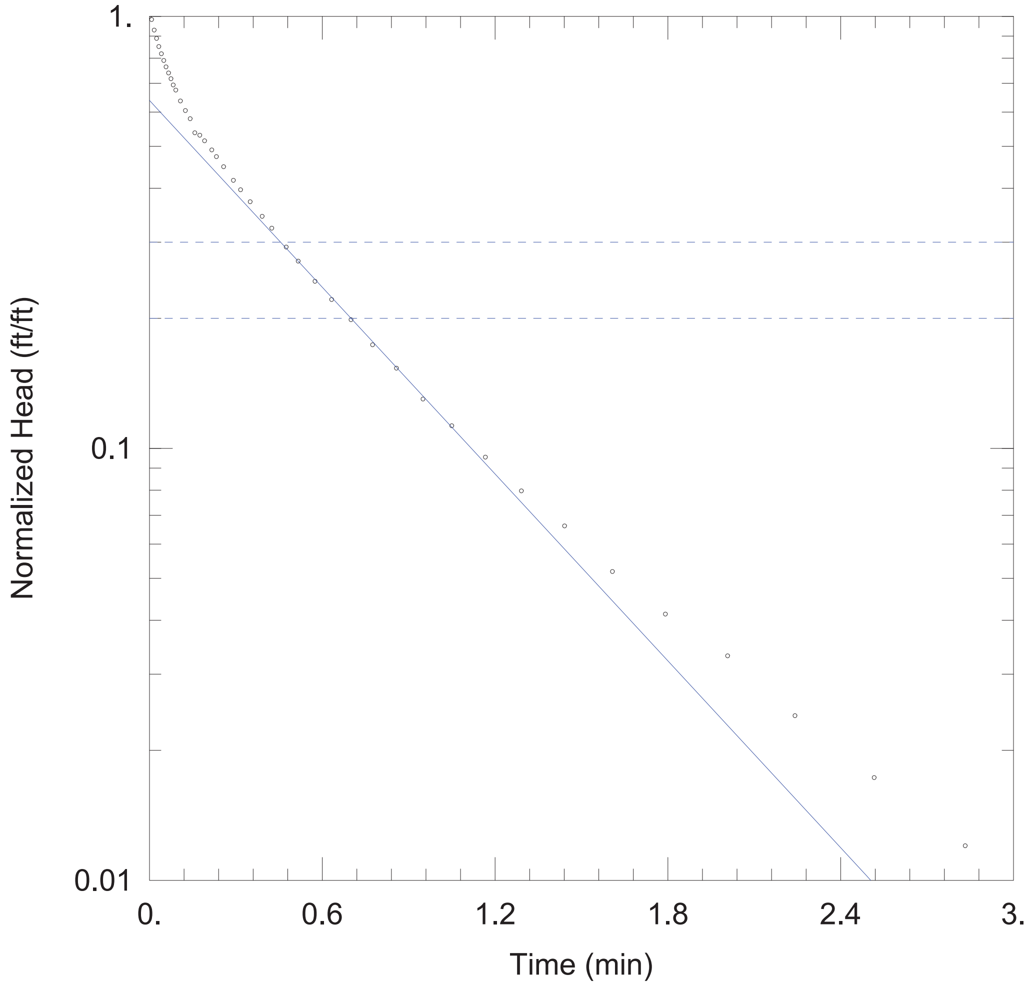
SOLUTION

Aquifer Model: Confined

$T = 4.4$ ft^2/day

Solution Method: Cooper-Bredehoeft-Papadopulos

$S = 0.029$



P-16 RISING HEAD TEST 1

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: P-16
Test Date: 3/6/13

WELL DATA (P-16)

Initial Displacement: 1.331 ft
Total Well Penetration Depth: 10.56 ft
Casing Radius: 0.0417 ft

Static Water Column Height: 10.71 ft
Screen Length: 10. ft
Well Radius: 0.13 ft
Gravel Pack Porosity: 0.35

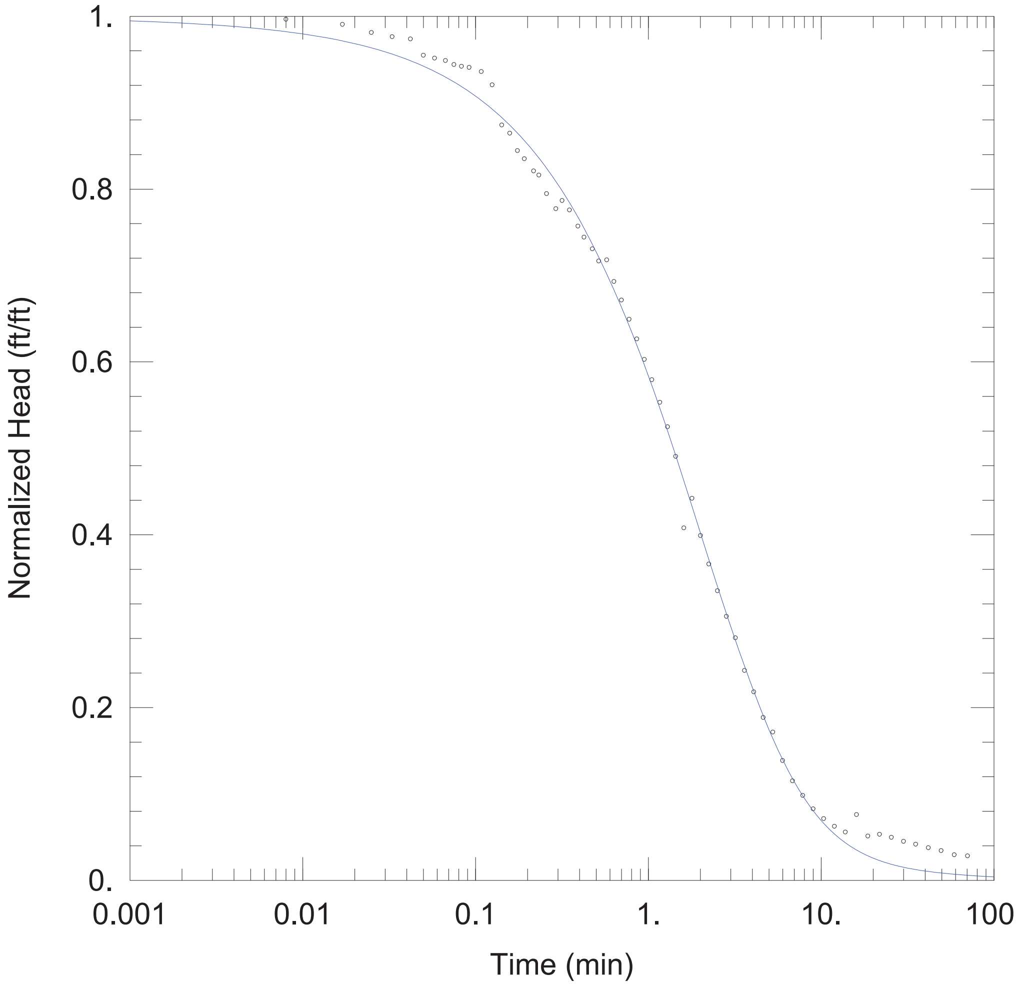
SOLUTION

Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

K = 0.85 ft/day

y0 = 0.85 ft



P-4 RISING HEAD TEST 1

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: P-4
Test Date: 3/7/13

WELL DATA (P-4)

Initial Displacement: 1.486 ft
Total Well Penetration Depth: 15. ft
Casing Radius: 0.0417 ft

Static Water Column Height: 14.55 ft
Screen Length: 5. ft
Well Radius: 0.33 ft

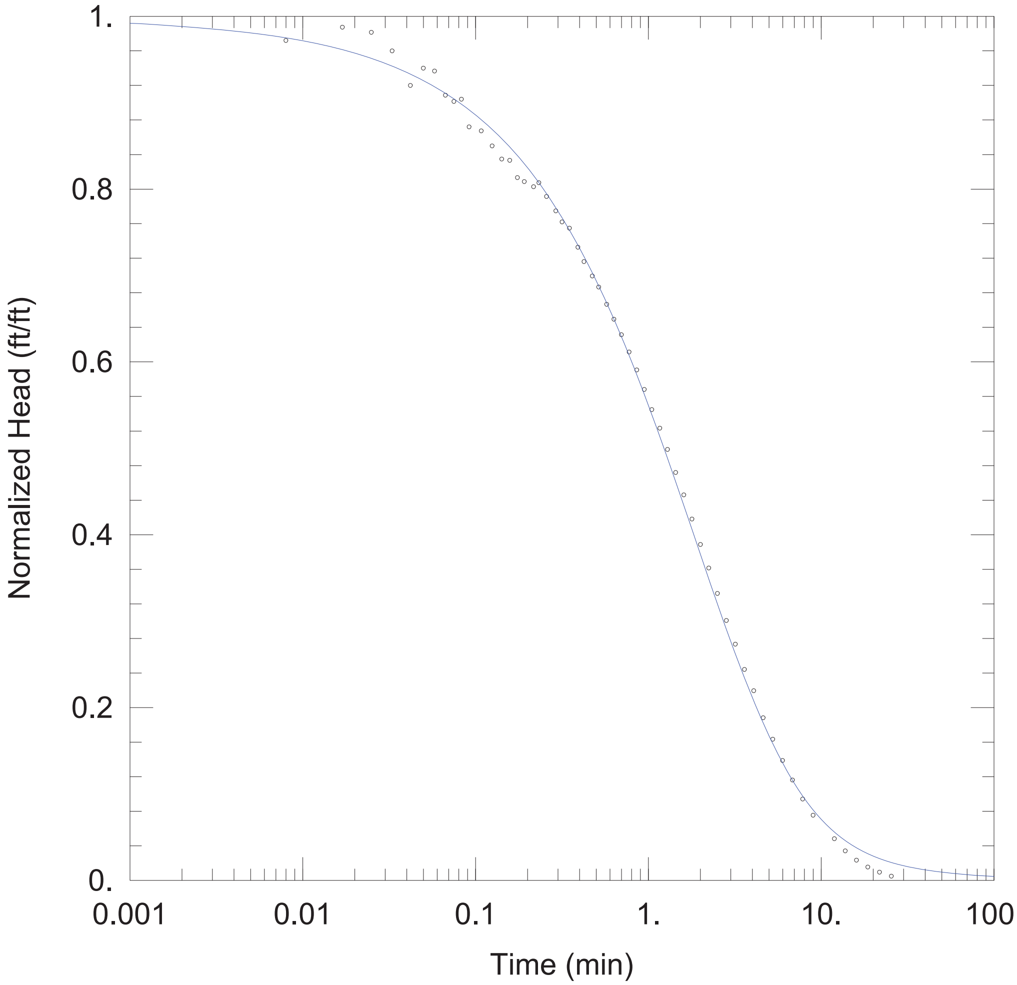
SOLUTION

Aquifer Model: Confined

Solution Method: Cooper-Bredehoeft-Papadopulos

T = 1.7 ft^2/day

S = 0.0001



P-8 RISING HEAD TEST 1

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: P-8
Test Date: 3/7/13

WELL DATA (P-8)

Initial Displacement: 1.5 ft
Total Well Penetration Depth: 17.51 ft
Casing Radius: 0.0417 ft

Static Water Column Height: 16.89 ft
Screen Length: 5. ft
Well Radius: 0.33 ft

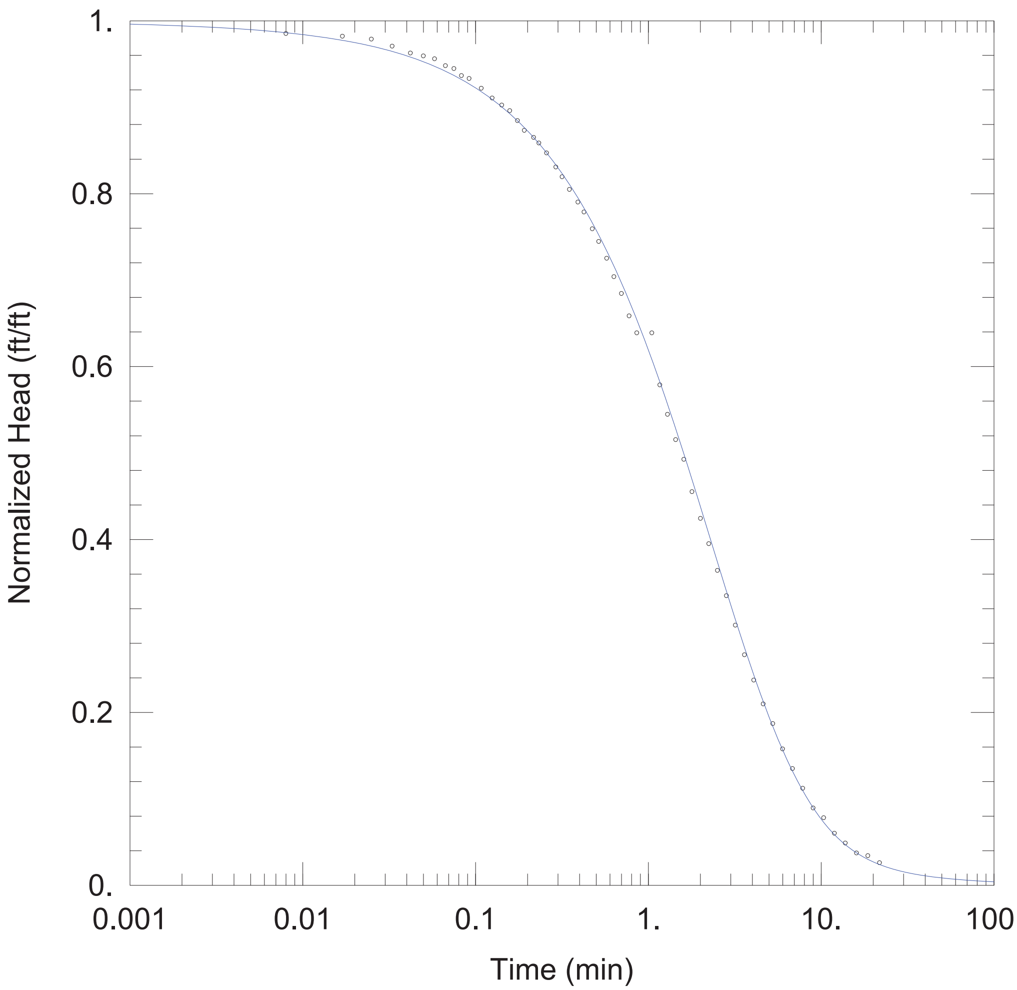
SOLUTION

Aquifer Model: Confined

T = 1.5 ft^2/day

Solution Method: Cooper-Bredehoeft-Papadopulos

S = 0.00029



P-8 RISING HEAD TEST 2

PROJECT INFORMATION

Company: ARCADIS
Client: CHEVRON
Location: EDMONDS, WASHINGTON
Test Well: P-8
Test Date: 3/7/13

WELL DATA (P-8)

Initial Displacement: 0.615 ft
Total Well Penetration Depth: 17.51 ft
Casing Radius: 0.0417 ft

Static Water Column Height: 16.89 ft
Screen Length: 5. ft
Well Radius: 0.33 ft

SOLUTION

Aquifer Model: Confined
$T = 1.7\ ft^2/day$

Solution Method: Cooper-Bredehoeft-Papadopulos
S = 4.9E-5

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Attachment 3

Memorandum: Analysis of Site Geologic Data Using Mining Visualization Software (MVS)

ARCADIS

ARCADIS U.S., Inc.
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Suite 200
Lakewood
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Tel 303 231 9115
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MEMO

To:
Scott Zorn

Copies:
Eric Rogoff
Jim Bognar
Project File

From:
Dave Lipson, Loren North, Rob Porsche

Date:
December 12, 2013

ARCADIS Project No.:
B0045362

Subject:
Analysis of Site Geologic Data Using Mining Visualization Software (MVS)
Chevron Environmental Management Company
Former Unocal Edmonds Bulk Fuel Terminal, Edmonds, Washington

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Introduction

ARCADIS utilized the Mining Visualization System (MVS) software to analyze and visualize geologic data from the Former Unocal Edmonds Bulk Fuel Terminal located in Edmonds, Washington (Site) and support development of the Site groundwater flow model which is being used to assist with feasibility screening of potential remedial alternatives (Figures A-1 and A-2). MVS was developed by C-Tech Development Corporation to efficiently manage, analyze, and help visualize large and complex geologic datasets such as the data from the Site. MVS can import and then use multiple types of digital information such as aerial photographs, topographic maps, digital elevation models, geographic information system (GIS) data, geologic data, water level data, analytical data, AutoCAD drawings, computer model output, data from other subsurface tools [*e.g.*, CPT, MIP, TarGOST, geophysical logs). The software can organize these various data types, analyze them in terms of spatial and volumetric relationships, and clearly display the results in a graphical format. MVS is known throughout the environmental industries for its ability to visualize the most challenging site conceptual models and complex datasets.

Methods

The following data types were imported into a Site-specific MVS model:

- Aerial photograph (source: Google Earth Pro, image date 10-1-2009);

- GIS and CAD drawings of site boundaries, historical excavations, roads, and other site features;
- Geologic data from soil boring and monitoring well construction logs; and
- Digital topographic data from the United States Geologic Survey (USGS).

After all of the data were entered, statistical Kriging methods were used to interpolate the geologic data and estimate the three-dimensional extent and distribution of the various soil layers at the Site. There are five different soil layers present at the Site that were included in the construction and calibration of the Site groundwater flow model and, by extension, analysis of potential remediation scenarios involving groundwater extraction. The five different Site soil layers include:

1. *2008 Fill*. The 2007-2008 Interim Action excavations were backfilled to 6 to 12 inches above the observed groundwater table in the open excavations with poorly graded coarse gravel (⅜ to 1 inch) with little to no fines. Backfill material above the coarse gravel to ground surface was a mixture of very fine to medium sand, trace silt, and fine to medium gravel materials.

2. *1929 Fill*. This 1929 fill consists of silty sands with gravel and sandy silts with gravel. During the 2007-2008 Interim Action excavations, subsurface materials encountered from ground surface to a depth of 8 to 15 feet below ground surface (bgs) were mostly fill material placed circa 1929 or later, during the creation of the Lower Yard facility.

3. *Marsh Deposits*. In many areas of the Lower Yard, beneath the 1929 Fill, there is a layer ranging from 1 foot to 15 feet thick composed of silt and sandy silt with large amounts of organic matter such as peat, and wood debris. This layer is encountered at depths ranging from 8 to 14 feet bgs, directly below the 1929 Fill material, and is interpreted to be representative of the former marsh horizon beneath the Lower Yard. This layer is typically demarcated by a 6 to 12 inch thick layer of decomposing vegetation.

4. *Beach Deposits*. Below the 1929 Fill and Marsh Deposits, a poorly graded sand formation of very fine to medium sand with fine gravel is present, containing organic material such as driftwood and seashells. This layer is interpreted to be representative of the former beach environment in the area prior to creation of the Lower Yard.

5. *Whidbey Formation*. This material is a poorly graded sand layer consisting of very fine to medium sand with fine gravel and is distinct from the overlying materials in the Lower Yard. It is present to the maximum explored depth of 41.8 feet bgs by Unocal. This unit contains interbedded sand with silt, and interbedded silt and sandy silt are also present. The interbeds range in thickness from less than 1 inch to several feet, and appear to be laterally discontinuous. This unit is interpreted to be alluvium, and is likely part of the Whidbey Formation.

Kriging is a spatial averaging technique that uses a linear combination of weights at known data points to estimate data values at unknown locations. Kriging uses a variogram (a.k.a. semivariogram) which is a representation of the spatial and data differences between some or all possible "pairs" of points in the measured data set. The variogram then describes the weighting factors that will be applied for the interpolation. Unlike other estimation procedures, kriging provides a measure of the error and associated confidence in the estimates.

For the Site, the traditional MVS modeling method of using geologic data alone to delineate the extent and distribution of the soil layers was supplemented with additional information. To expand on the geologic data, observations made during the recent remedial excavations were utilized to create points that defined both their surficial and sloped excavated extents, assuming all the replaced material was modern fill. This method allowed the kriging algorithm to better define the related excavation contacts while minimally impacting the distribution of historic and natural materials in the boring logs.

The final model was detail checked against existing geologic cross sections and the geologic contact elevations from the boring logs.

Results

Results of the MVS geologic data modeling were used to create a three-dimensional framework of the various soil types that was used to support development and calibration of the Site groundwater flow model. The groundwater flow model is a three-dimensional model that incorporates soil heterogeneities based on MVS analysis. The groundwater flow model is discussed elsewhere in the report.

Results of MVS geologic model are presented as graphical visualizations of the distribution and extent of the five Site soil layers on Figures A-3 through A-14.

Figure A-3 shows the Site plan in the MVS model and includes an aerial photograph, the Site groundwater monitoring well network, Detention Basin 1, Detention Basin 2, Willow Creek, and the historical remedial soil excavation areas.

Figure A-4 shows the Site monitoring well network from an oblique angle, and indicates the various soil layers identified at the monitoring wells.

Figure A-5 shows a map of the interpreted extent and distribution of the soil layers encountered at the Site. It is notable that not all of the soil layers can be seen in this view, because some soil layers exist beneath other soil layers. Because of this, the following figures show individual soil layers.

Figure A-6 shows a map of the interpreted extent and distribution of natural soil layer at the Site, including the marsh deposits, beach deposits, and Whidbey formation. As shown, marsh deposits fringe the surface water features at the Site (i.e., Willow Creek and the detention basins) and also exist within the marshlands. Furthermore, this view shows marsh deposits atop beach deposits, with both soil layers underlain by the Whidbey formation.

Figure A-7 shows a map of the interpreted extent and distribution of the fill layers at the Site, including the 2008 fill, 2008 fill gravel, and 1929 fill.

Figure A-8 shows a map of the interpreted extent and distribution of only the 2008 fill.

Figure A-9 shows a map of the interpreted extent and distribution of only the 1929 fill.

Figure A-10 shows a map of the interpreted extent and distribution of only the marsh deposits.

Figure A-11 shows a map of the interpreted extent and distribution of only the beach deposits.

Figure A-12 shows a geologic cross section extending north to south through the Site to show the vertical relationships between the various soil layers. As shown, the fill layers site atop the marsh deposits and, in some areas, they sit atop beach deposits. The Whidbey formation underlies the entire Site.

Figure A-13 shows a close-up geologic cross section extending northwest to southeast through the potential remediation areas. This view shows the vertical relationships between the various soil layers in this area. As shown, the potential remediation areas are limited to fill types, and are underlain by marsh and beach deposits.

MVS Model Domain

MODFLOW Model Domain

Source: USGS Quads., 7.5 Min. Series (Topographic) – Edmonds East, Wash., and Edmonds West, Wash.

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MVS Analysis

Site Location

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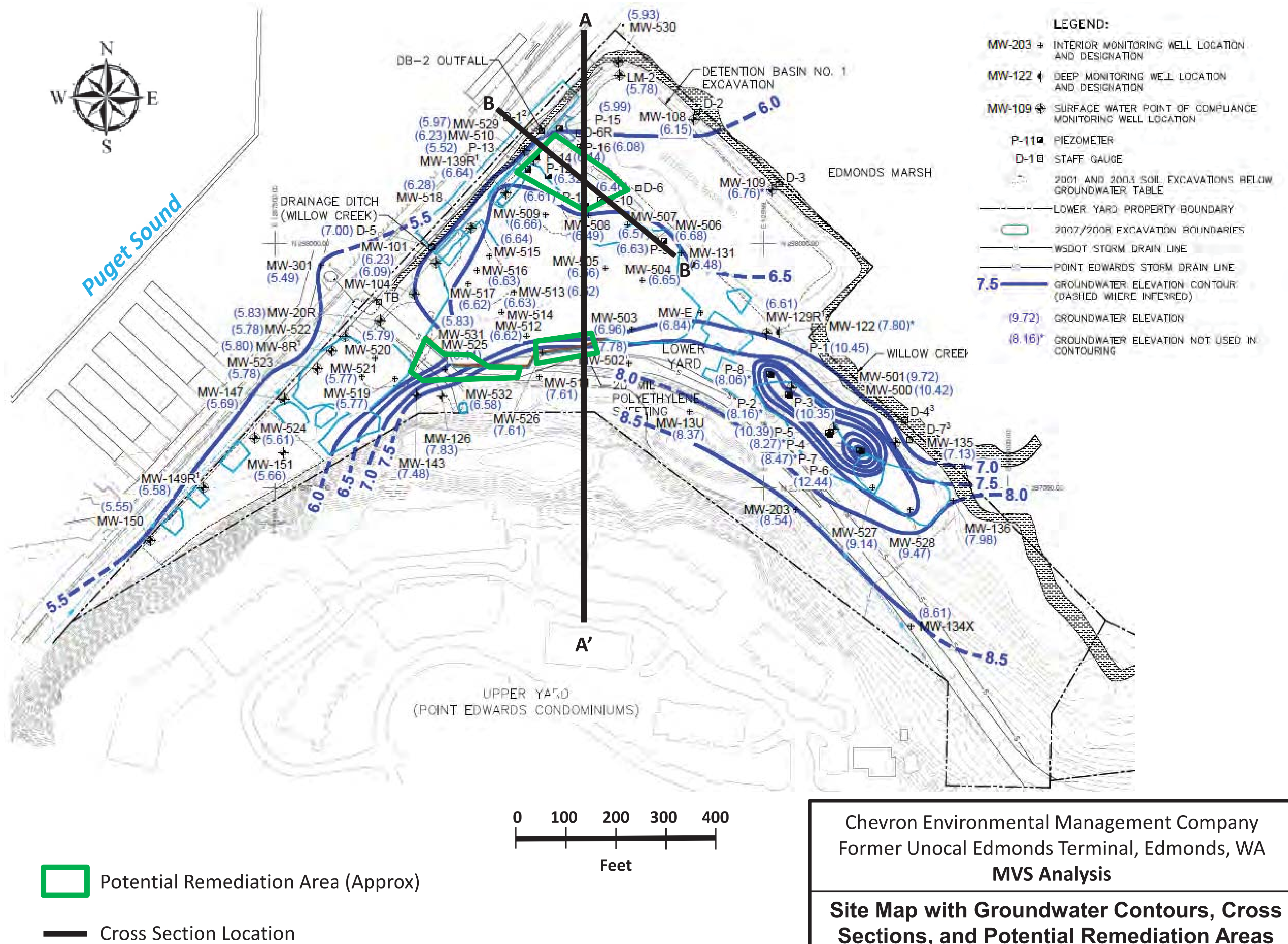
FIGURE
A-1



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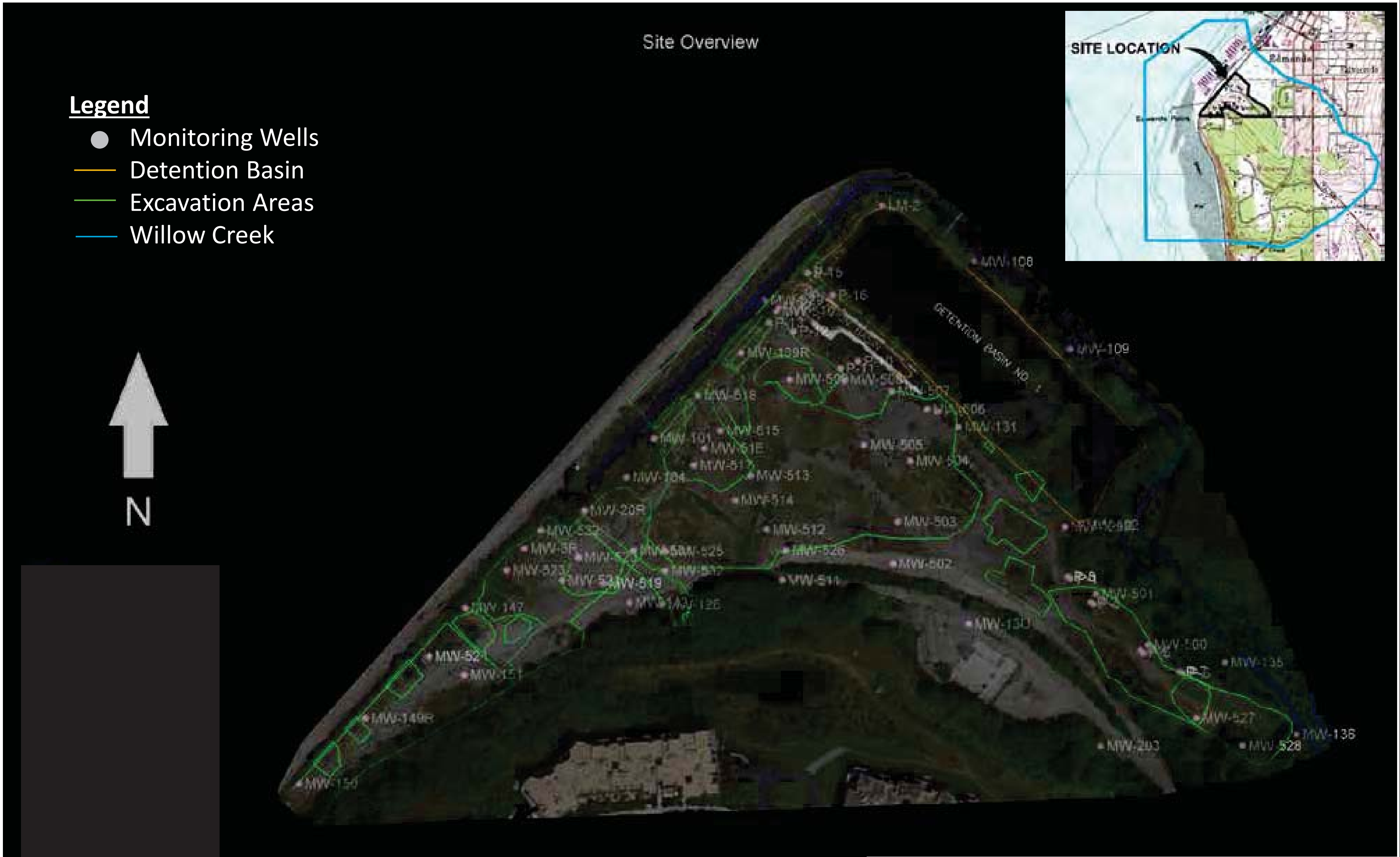
MVS Analysis

Site Map with Groundwater Contours, Cross Sections, and Potential Remediation Areas

ARCADIS

FIGURE **A-2**

Source: Third Quarter 2013 Groundwater Monitoring Report.



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Site Plan

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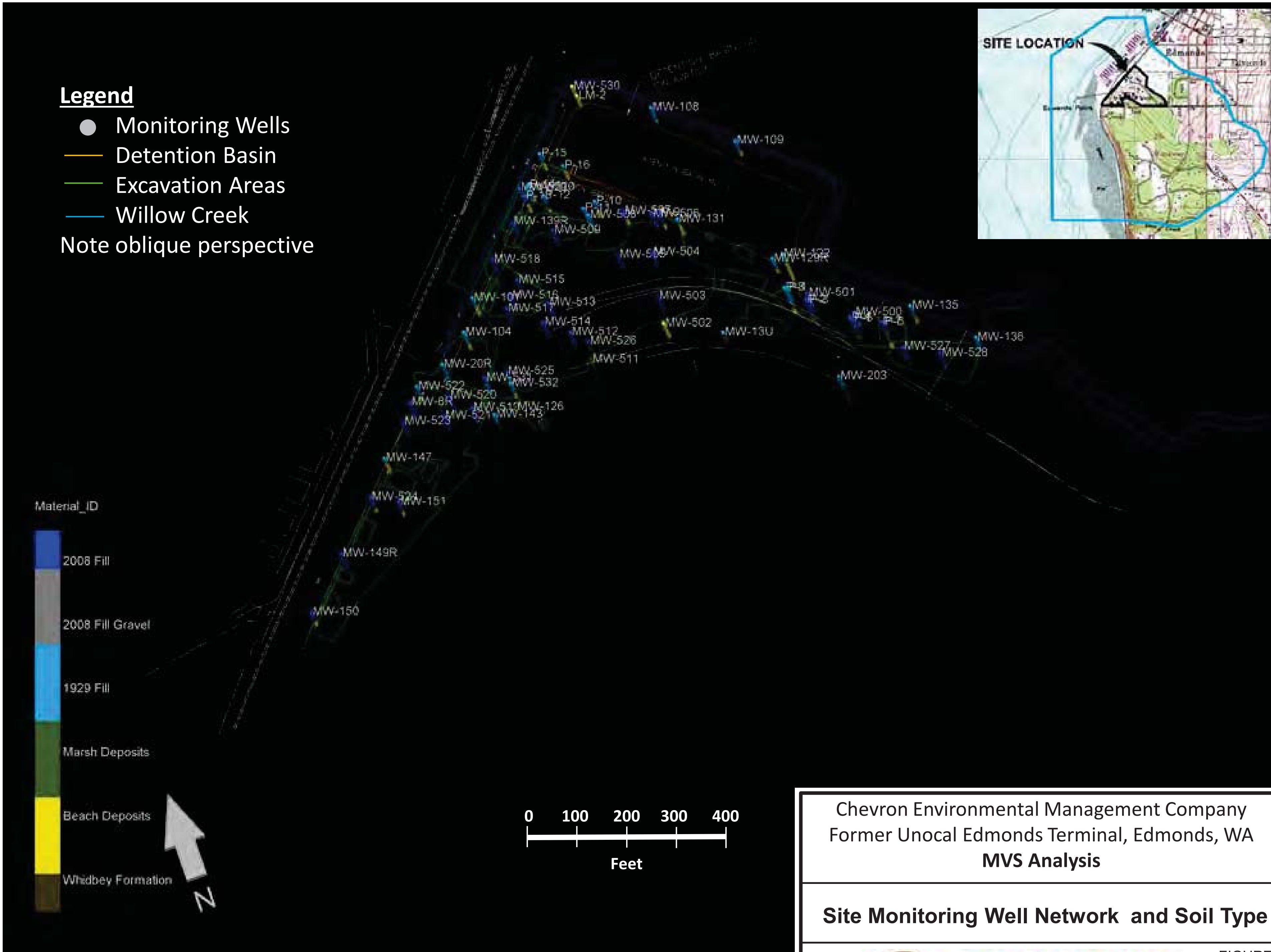
FIGURE
A-3



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Site Monitoring Well Network and Soil Type

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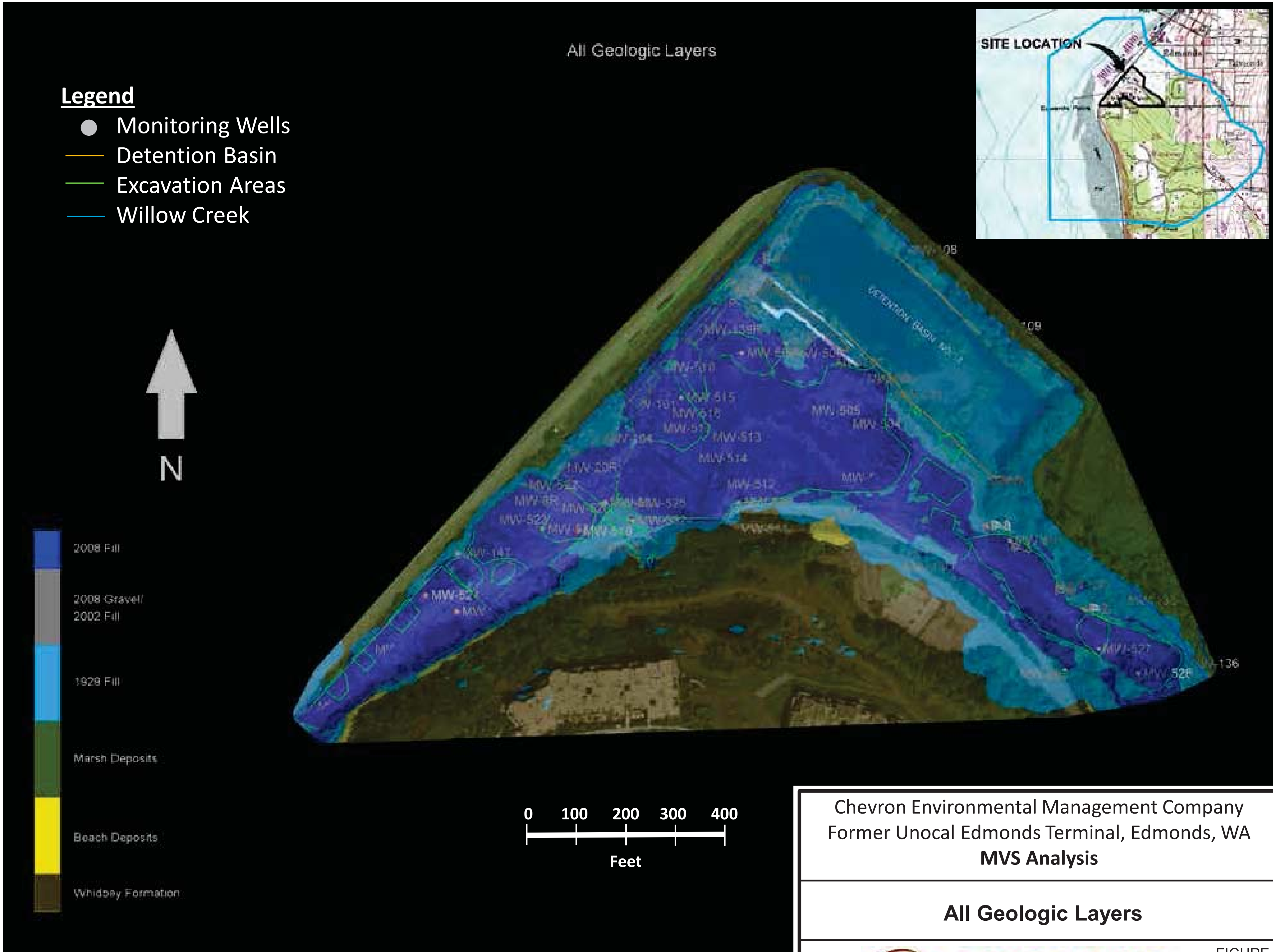
FIGURE **A-4**



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All Geologic Layers

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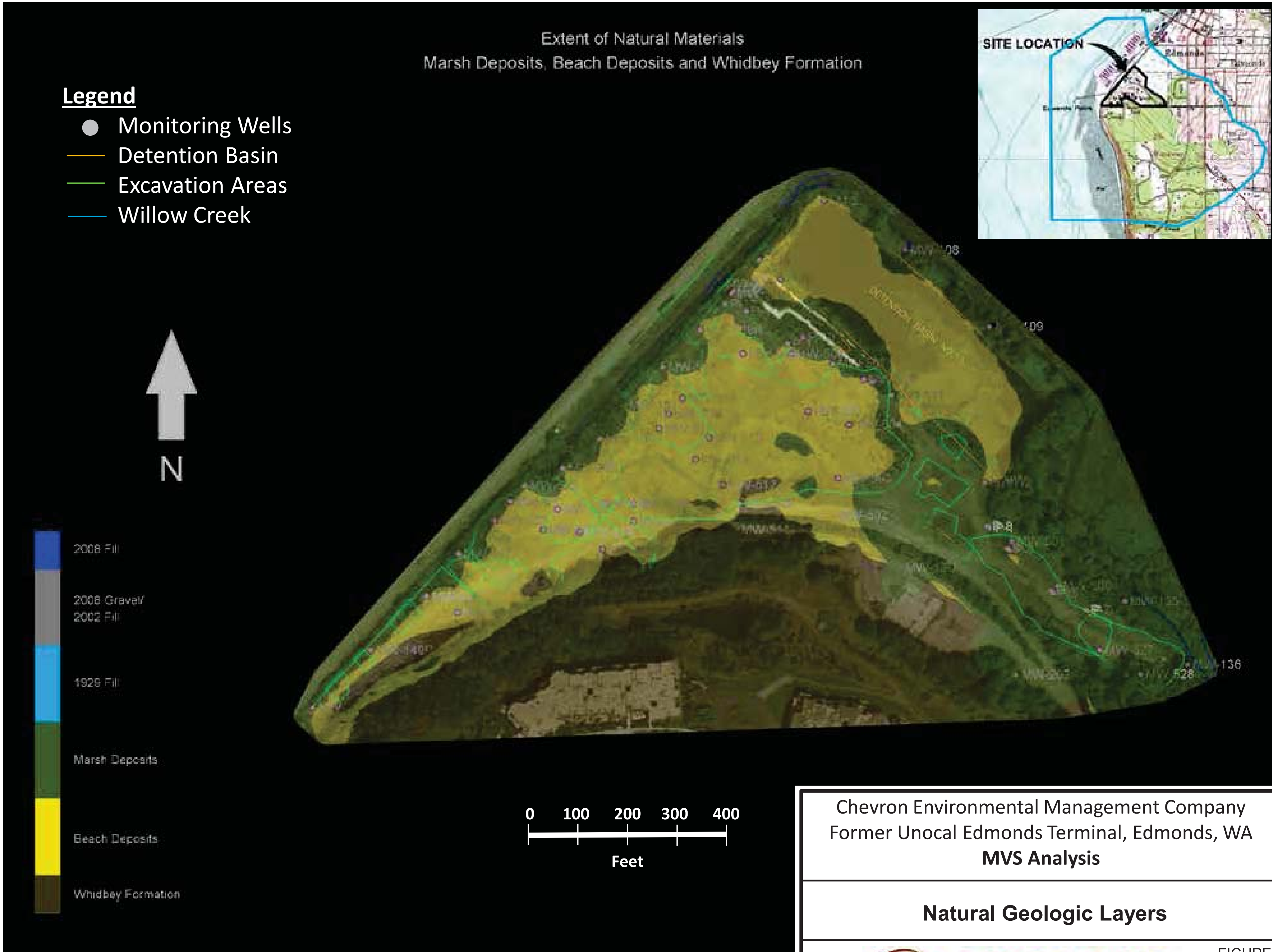
FIGURE
A-5



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Natural Geologic Layers

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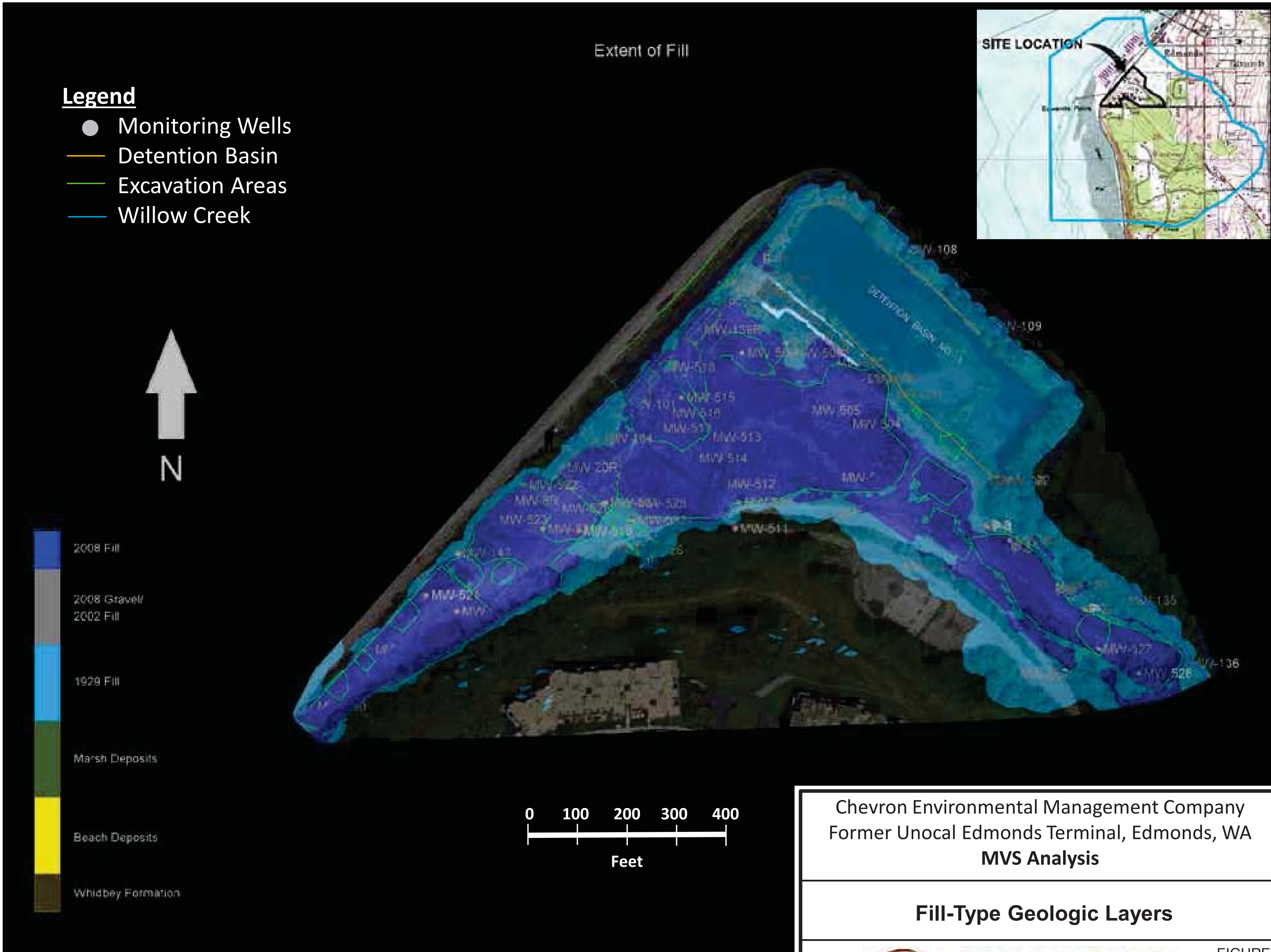
FIGURE
A-6



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Fill-Type Geologic Layers

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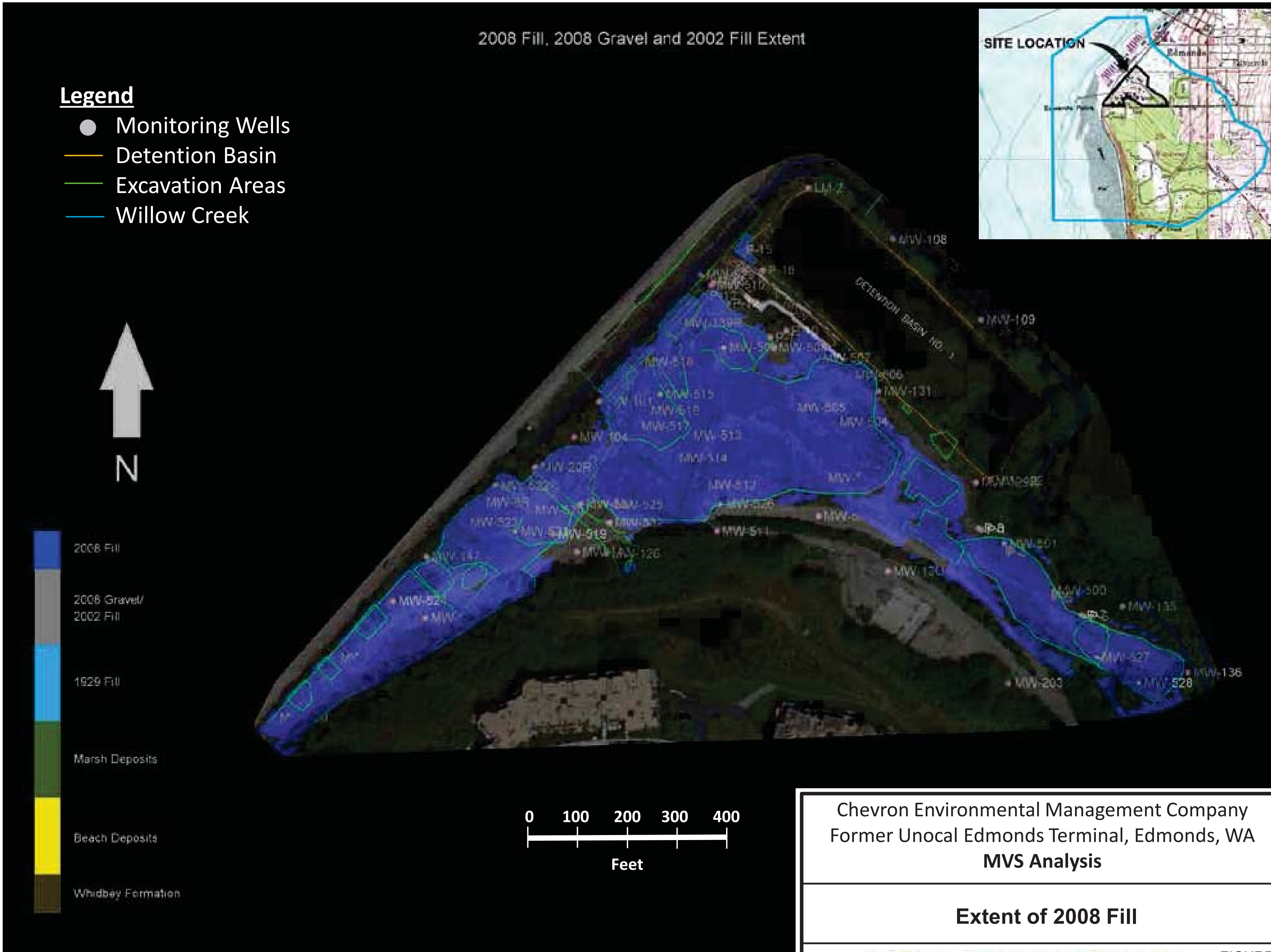
FIGURE
A-7



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Extent of 2008 Fill

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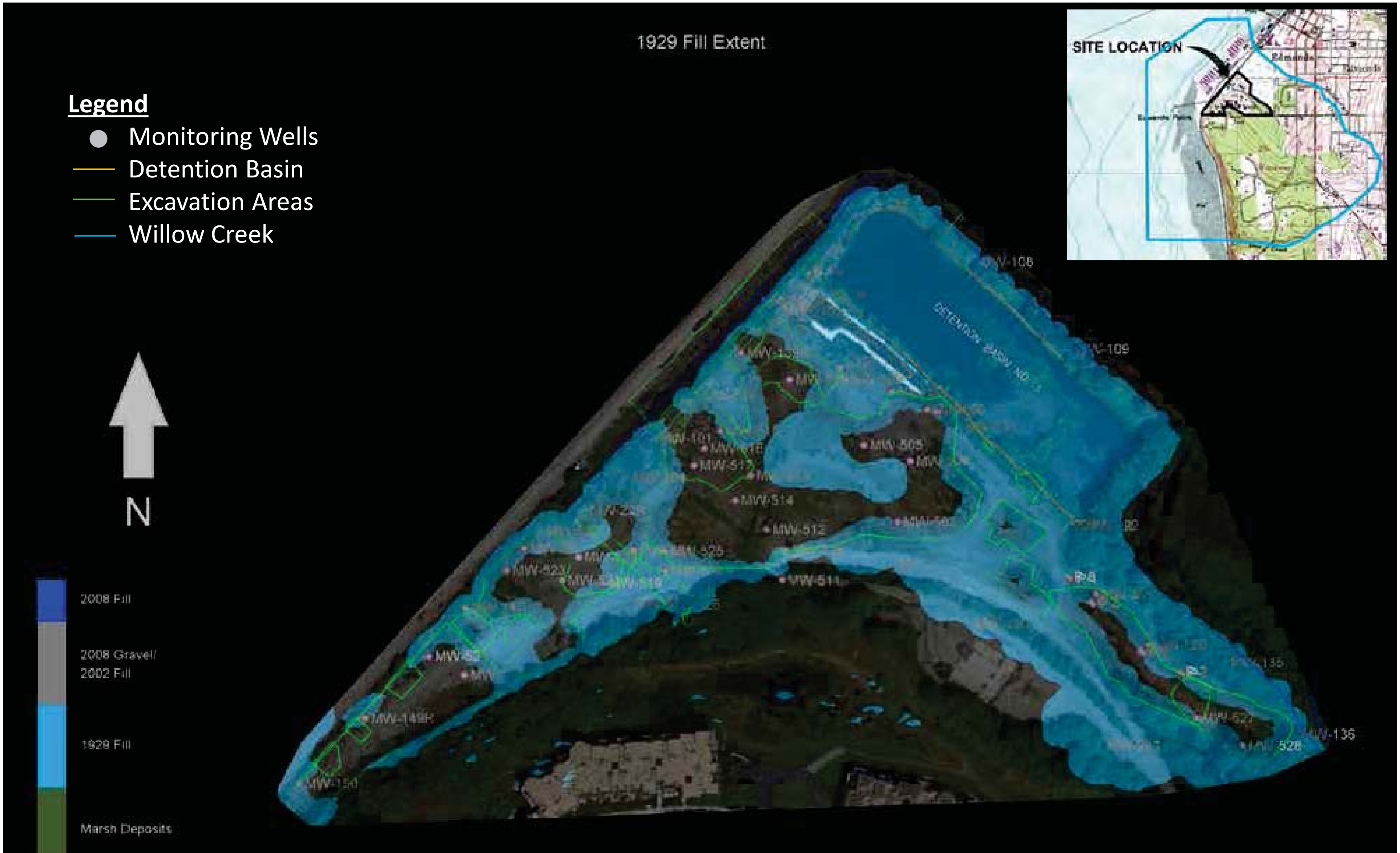
FIGURE
A-8



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Extent of 1929 Fill

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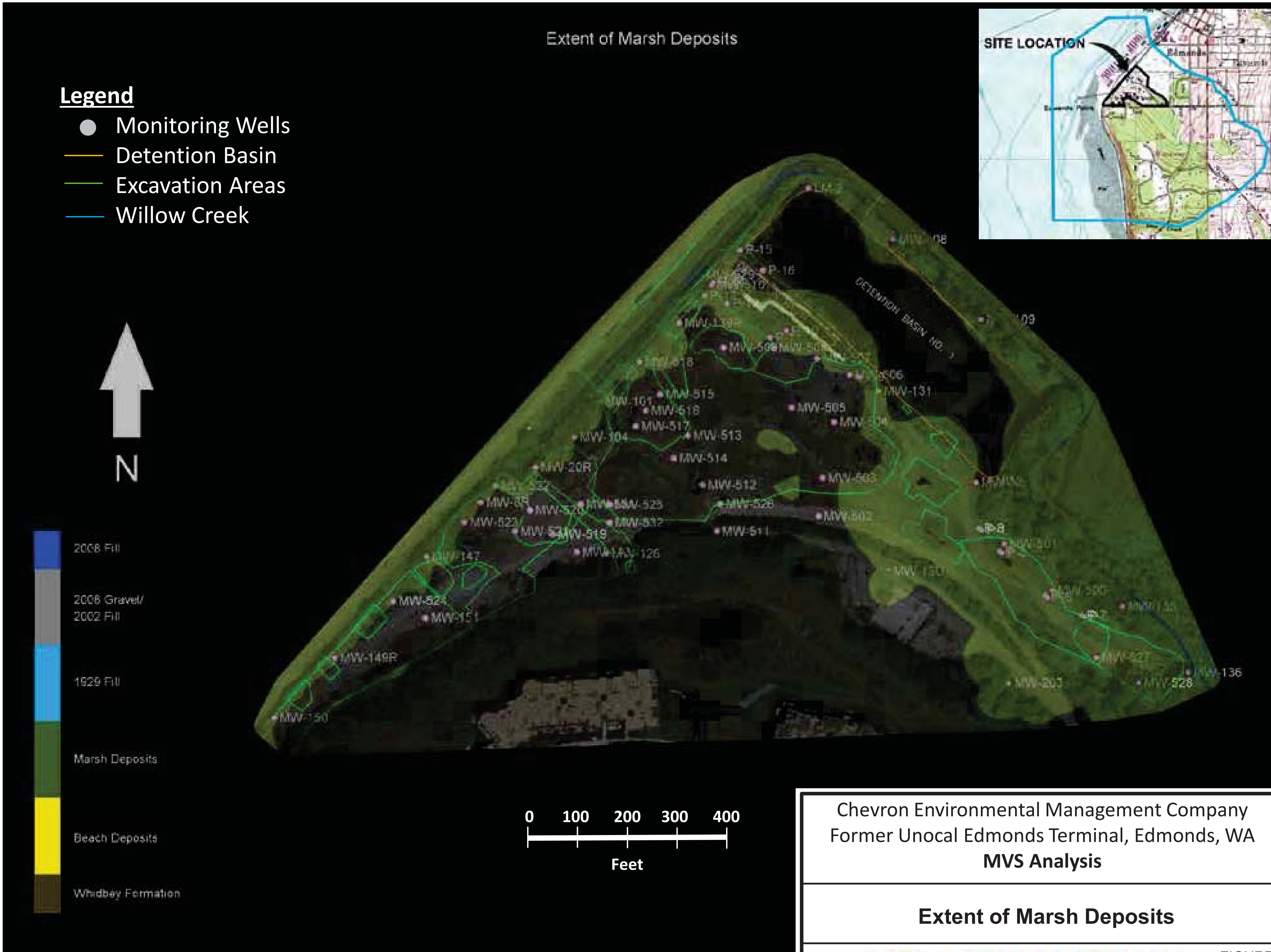
FIGURE
A-9



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Extent of Marsh Deposits

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FIGURE
A-10

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Extent of Beach Deposits

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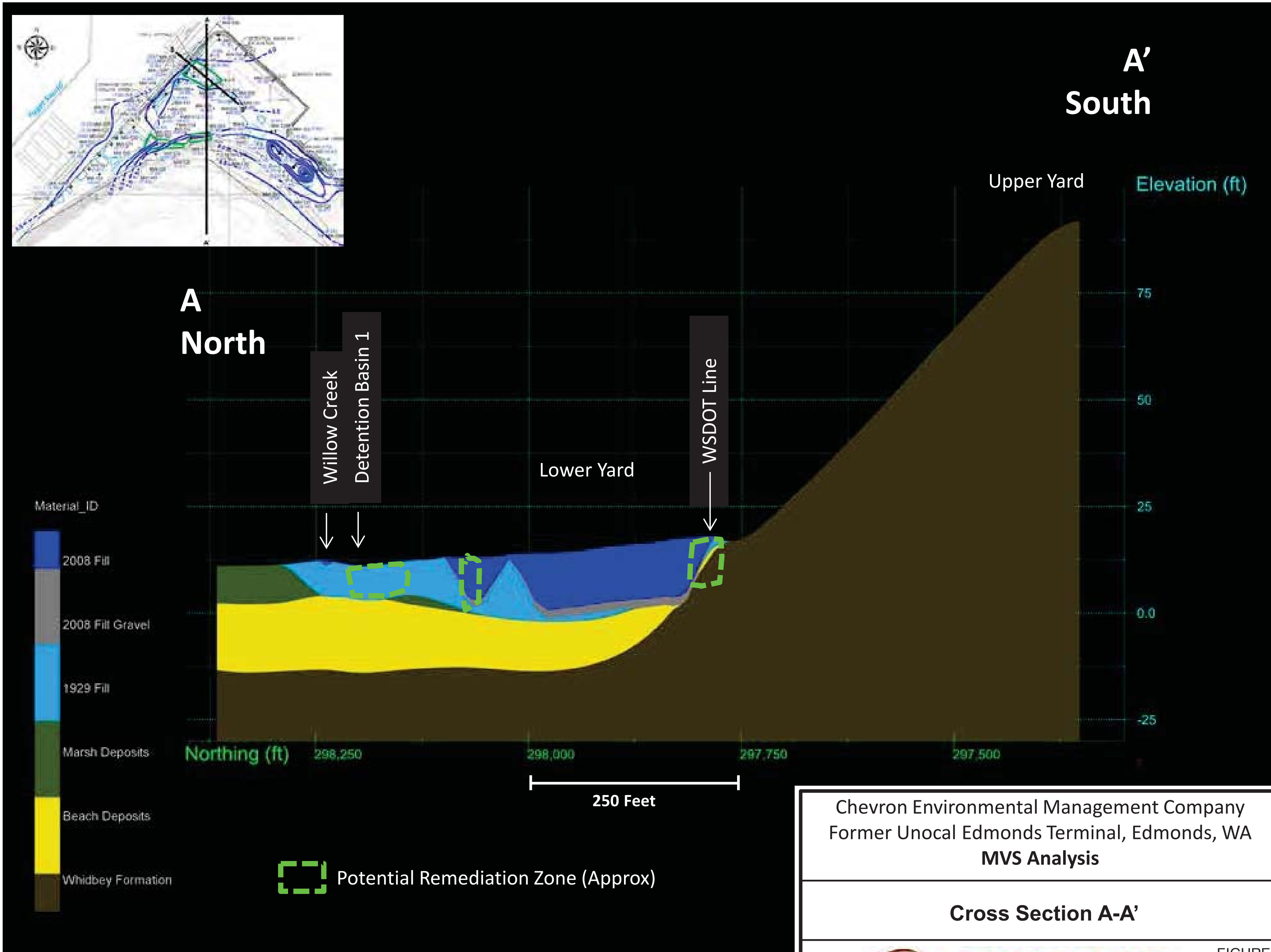
FIGURE
A-11



Note: Elevation in ft msl.

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Cross Section A-A’

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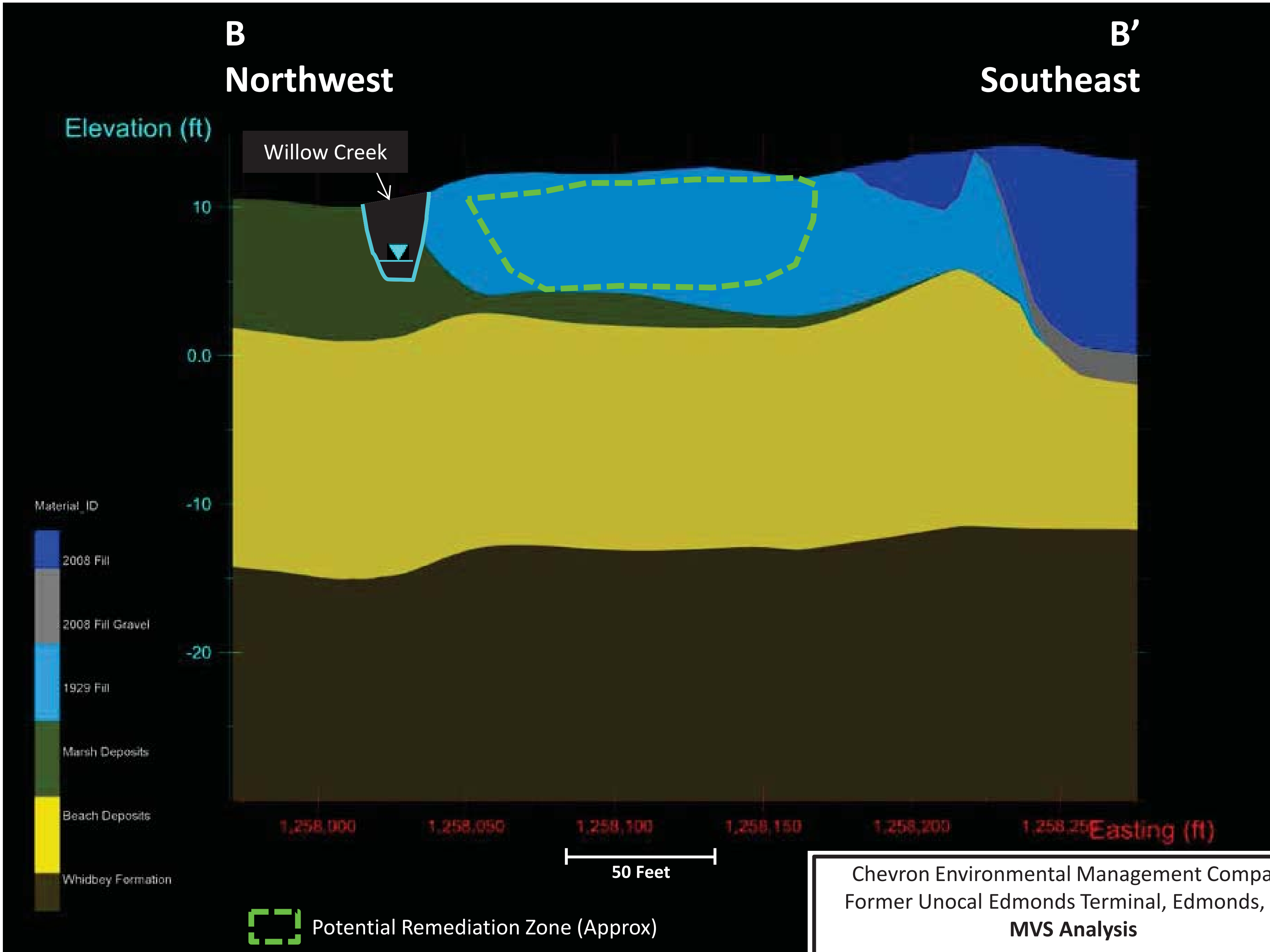
FIGURE
A-12



Note: Elevation in ft msl.

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MVS Analysis

Cross Section B-B’

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FIGURE
A-13