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FINAL - Phase II Remedial Implementation As-built Report

Unocal Edmonds Bulk Fuel Terminal Lower Yard

11720 Unoco Road

Edmonds, Washington 98020

January 18, 2010

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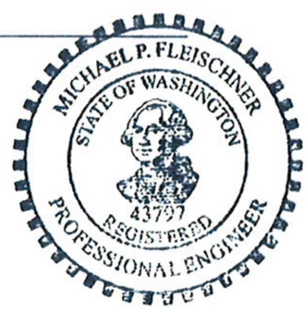

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Unocal Edmonds Bulk Fuel Terminal Lower Yard

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1. Introduction

On behalf of Chevron Environmental Management Company (Chevron), ARCADIS U.S., Inc. (ARCADIS) is pleased to submit this Lower Yard Phase II Remedial Implementation As-Built Report (Report) for remedial activities completed at the Lower Yard of the Former Unocal Edmonds Bulk Fuel Terminal, located at 11720 Unoco Road, Edmonds, Washington (Lower Yard). The site location is shown on **Figure 1**. This report summarizes Phase II remedial work completed in accordance with the requirements of Washington State Agreed Order No. DE 4460 and the *Interim Action Report – Work Plan for 2007 Lower Yard Interim Action, Unocal Edmonds Bulk Fuel Terminal* (SLR 2007a) (the Work Plan). Site layout is shown on **Figure 2**.

2. Background

2.1 Site Description

The Lower Yard occupies approximately 22 acres and lies east-southeast of Burlington Northern Santa Fe Railway (BNSF) property, south of the Edmonds Marsh (also known as the Union Oil Marsh) and a drainage ditch (Willow Creek), and north of the Upper Yard. The site layout is shown on **Figure 2**.

At its nearest point (the southwest corner of the Lower Yard), the Lower Yard boundary is approximately 160 feet from the Puget Sound shoreline. Two detention basins (DB-1 and DB-2) are located along the north and northeast boundaries of the Lower Yard. DB-1 borders Edmonds Marsh and Willow Creek and acts as a retention pond for overflow from DB-2 during storm events. DB-2 serves as a collection area from which site stormwater is discharged into Willow Creek.

Currently, a stormwater system consisting of 12 storm drains 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.

Previous structures in the Lower Yard included petroleum storage and transfer equipment (aboveground storage tanks and piping), two truck loading racks, several office buildings, a railcar loading/unloading station, a stormwater conveyance system including two 10,000-gallon stormwater detention tanks and two 500-gallon vapor recovery tanks, an air-blown asphalt plant, and an asphalt packaging warehouse.

2.2 Site History

Unocal operated the bulk fuel 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 Lower Yard from 1953 to the late 1970s.

In 2001, Unocal conducted an Interim Action in the Lower Yard, removing light non-aqueous phase liquid (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 – Volume 1* (MFA 2002). Additional Interim Actions conducted in 2003 included soil excavations in the Southwest Lower Yard and Detention Basin No.1. The results of the 2003 Interim Action are summarized in *2003 Lower Yard Interim Action As-Built Report – Volume 1* (MFA 2004). Previous excavations are shown on **Figure 2**.

In June 2007, Unocal entered into an Agreed Order with the Washington Department of Ecology (DOE) 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 Lower Yard, removal of LNAPL, extraction of groundwater that is in contact with LNAPL, and removal of soil with arsenic concentrations in excess of the cleanup levels (CULs) within the Southwest Lower Yard. The soil RELs were calculated to provide a concentration that is protective of direct contact. The RELs are believed to be protective of groundwater as well. Groundwater monitoring, to be conducted following soil remediation to the RELs, is expected to provide empirical evidence that RELs are protective of groundwater. Soil CULs and RELs were established in the Work Plan, and are summarized in **Table 1**.

2.3 Geology

Prior to excavation, subsurface materials encountered during 2007-2008 Phase I excavation were silty sands with gravel and sandy silts with gravel. Between 8 to 15 feet below ground surface (bgs), a poorly graded sand formation of very fine to medium sand with fine gravel was encountered, which contained organic material such as beach debris, wood, and seashells. Excavation areas throughout the Lower Yard encountered a native layer approximately 6 to 12 inches thick composed of sandy silt with large amounts of peat, wood debris, and decomposing vegetation. This layer was encountered at depths of 8 to 14 feet bgs and is considered to be representative of the former marsh located at the site.

The current lithology of the Lower Yard consists primarily of backfill material from the 2007-2008 Phase I and Phase II Interim Action work. The fill was placed within excavated areas to a depth of 8 to 12 feet bgs and is composed of very fine to medium sand, trace silt, and coarse gravel. Backfill in the saturated zone (approximately 1 foot above groundwater to the bottom of each excavation) is composed of poorly graded coarse gravels. See Section 5 (Lower Yard Restoration) for complete grain size specifications of backfill material used in the excavations. Top and bottom of gravel backfill elevations are presented on **Figures 3 and 4**, respectively.

3. Lower Yard Interim Action

In July 2007, Union Oil Company of California (Unocal) entered into an Agreed Order (No. DE 4460) with the DOE to conduct an interim remedial action at the Lower Yard (Interim Action).

The purposes of the Interim Action are to reduce potential threats to human health and the environment, to support completion of the feasibility study (FS) for the Lower Yard, and to provide information to design additional cleanup actions, if necessary. In accordance with Washington Administrative Code (WAC) 173-340-430(1), the Interim Action may constitute the cleanup action for the Lower Yard if it is sufficient to comply with WAC 173-340-350 through 173-340-390. If the Interim Action does constitute the cleanup action for the Lower Yard, then the FS will not need to be completed.

The specific requirements of the Interim Action include the following:

- Excavate the soil within the Lower Yard that contains petroleum hydrocarbon concentrations above the CULs or RELs based on direct contact.
- Remove remaining LNAPL beneath the Lower Yard.
- Extract petroleum hydrocarbon-impacted groundwater that is in contact with the LNAPL.
- Excavate arsenic-impacted soil within the Lower Yard that contains concentrations above the soil CUL, based on naturally occurring background concentrations.

- Remove sediment that failed the 2003 toxicity tests in the drainage ditch (Willow Creek) at locations near the Lower Yard's two stormwater outfalls.

- Obtain data necessary to evaluate if remaining soil concentrations are sources of LNAPL on the groundwater table.

- Obtain data necessary to evaluate if remaining soil concentrations will cause exceedance of the groundwater CULs at the groundwater points of compliance (POCs).

- Obtain data necessary to evaluate if petroleum hydrocarbon concentrations in groundwater beneath the Lower Yard will naturally attenuate to below the CULs at the groundwater POCs.

- Obtain data necessary to calculate restoration timeframes to meet the groundwater CULs at the groundwater POCs.

Methods to accomplish the objectives established in the Agreed Order were detailed in the Work Plan. The Work Plan described areas proposed for excavation, and estimated that 64,000 tons (43,642 cubic yards [cy]) of soil should be removed to accomplish the objectives. Once excavation activities were determined to be complete (based on confirmation soil sampling), a network of groundwater monitoring wells was proposed to complete a 2-year groundwater monitoring program. The groundwater data collected during this timeframe would be used to show that LNAPL had been successfully removed and the remaining soil concentrations would not cause continued exceedances of dissolved-phase constituents. If, at the end of the monitoring program, groundwater concentrations were below the applicable CULs at the POCs, and concentrations within the established flow-paths indicated that natural attenuation is occurring at reasonable rates, then the cleanup would be complete. If additional remediation is required after completion of the monitoring program, then an FS will be required.

The detailed scope of work for remedial activities is available in the Work Plan. Due to permitting delays, the proposed scope of work was split into two phases: Phase I and Phase II. Phase I consisted of the bulk of the soil excavation, LNAPL recovery, and groundwater treatment. Sediment removal, creek restoration, and the excavation of inaccessible material remaining from Phase I was conducted as part of Phase II. Phase II excavation volumes are summarized in **Table 2**.

Phase II included the following activities:

- Soil, LNAPL, and debris removal in the areas of planned excavation to meet objectives of the Interim Action;
- Cofferdam installation, de-watering, and sediment removal in Willow Creek;
- Off-site treatment and/or disposal of excavated soil, debris, and LNAPL;
- Treatment of extracted groundwater to facilitate construction activities and to satisfy the temporary construction National Pollutant Discharge Elimination System (NPDES) permit No. WA-0032150-8;
- Replacement of monitoring wells removed during Phase I activities and installation of a monitoring well network for the groundwater monitoring program;
- Site restoration including the post-excavation restoration and re-planting of Willow Creek banks, constructing on-site haul roads, and the removal of the lined stockpile area and temporary on-site water treatment system.

Due to direct connections with navigable water, Willow Creek, including its adjacent wetlands and associated buffers, is considered a waterway of the United States. Therefore, in-water construction in Willow Creek required agency permits. A Joint Aquatic Resources Permit Application was submitted to the United States Army Corps of Engineers (USACOE) Seattle District, and a Nationwide 38 – Cleanup of Hazardous Waste permit from USACOE was received in July 2008. The Hydraulic Project Approval was issued by Washington State Department of Fish and Wildlife on April 24, 2008. As required by the Nationwide 38 permit a professional archeologist was on-site during all ground disturbing activities to monitor for the possible presence of archeological resources. An archeologist from Northwest Archeological Associates Inc. (NWAA) was present on site during excavation activities conducted during Phase II implementation. A full report prepared by NWAA is presented as **Appendix A**.

3.1 Contractors

Prior to implementing remedial activities in the Lower Yard, subsurface utility locations were marked by Geomarkout Company of Pocatello, Idaho. Soil excavations were completed by Envirocon, Inc. of Missoula, Montana using conventional excavation equipment. Water and soil samples were analyzed at TestAmerica in Bothell, Washington using the procedures identified in the Sampling and Analysis Plan (SAP; SLR 2007b). Removal of LNAPL and some removal of impacted groundwater were conducted by Emerald Services (Emerald) of Seattle, Washington. Excavation limits and sample grid locations were surveyed by OTAK Survey and Mapping of Kirkland, Washington.

Fluids removed from the site were transported by Emerald to their facility in Seattle, Washington for recycling. Petroleum-impacted soil was transported to Cemex (Formerly Rinker Materials), in Everett, Washington, for thermal destruction and recycling. Impacted soil was transported to Cemex by ECTI Trucking of Portland, Oregon.

Imported soil for vadose zone backfill and sediment backfill was provided by Cemex. Gravel used for saturated zone backfill, which was imported by Envirocon Trucking from Green Crow Rock Products in Arlington, Washington, was stockpiled on site at the conclusion of Phase I for use during Phase II. Backfill sources were approved by DOE prior to use. Backfill compaction density testing was conducted by HWA Geosciences Inc. of Lynnwood, Washington.

Drilling activities associated with monitoring well installations and well decommissioning were conducted by Cascade Drilling (Cascade) of Woodinville, Washington.

Activities involving electrical work, such as office trailer installation and pump and/or power line removal and/or replacement, were conducted by a licensed electrician from Veca Electric and Communications (Veca) of Seattle, Washington.

ARCADIS prepared the Construction Specifications, conducted fish removal activities, observed the work completed by Envirocon, and conducted the construction monitoring and sampling. Daily work logs were prepared by Envirocon and are included in **Appendix B**.

3.2 Sampling and Analysis Plan

The Work Plan included a SAP to identify the quality assurance (QA) procedures to be implemented during sampling activities and laboratory analyses, and to ensure that sampling during the Interim Action meets the requirements of Model Toxics Control Act

(MTCA) regulations for SAPs (WAC 173-340-820). The SAP is included as Appendix L of the Work Plan.

As specified in the SAP, a sampling reference grid was established at the Lower Yard at 25-foot intervals. The grid was pre-surveyed and marked prior to the start of excavation activities. Collected soil excavation samples were named in reference to the grid. Using “EX-A1-H-15-15” as an example sample name, the sample naming convention is as follows:

- The label “EX” indicates that the sample was from an excavation
- The excavation name “A1”
- The grid point on which the sample was taken “H-15”
- The depth at which the sample was taken in feet “15”

In excavations completed deeper than 4 feet bgs, samples were collected from the sidewalls of the excavations. Generally in these cases, an “N”, “E”, “S”, or “W” was included with the letters “SW” indicating sidewall: for example “EX-A1-D-17-ESW-5.” This sample was collected from the east sidewall of grid point D-17 at a depth of 5 feet. In some cases, sample locations were over-excavated and re-sampled at the same grid point. In these cases, the sample labels were identical to the initial sample IDs, with the addition of a “(2)” indicating the second sample collected at this location. For example, “EX-A1-D-17-ESW-5(2)” was the sample collected from the east sidewall of grid point D-17 at a depth of 5 feet after the sample location was over-excavated.

Analytical data presented in this report can be located within the DOE Environmental Information Management System (EIMS), under the User Study ID: Unocal02. EIMS is a searchable database and can be accessed through the DOE website (www.ecy.wa.gov). Sample location coordinates are also presented in EIMS using the World Geodetic System. Location coordinates are based on the horizontal datum High Accuracy Reference Network (NAD83 HARN) and the vertical datum North American Vertical Datum 1988 (NAVD88). Analytical and location data for samples collected from temporary locations, such as stockpiles, are not included in EIMS.

The sampling grid, extent of final excavation, and sampling names and locations are shown on **Figure 5**, **Figure 6,** and **Figure 8**. Excavated soil sample analytical data are summarized in **Table 3,** and the analytical reports are included in **Appendix C**.

3.2.1 Soil Analytical Methods

Soil sampling was conducted in accordance with the SAP from an established site sampling grid along the excavation base and sidewalls. Sampling was conducted to confirm that soil exceeding CULs and/or RELs was removed. Samples were submitted for chemical analysis by the following methods:

- Benzene, toluene, ethylbenzene, and total xylenes (BTEX) by Environmental Protection Agency (EPA) method 8021B
- Gasoline-range organics (GRO) by Northwest method NWTPH-Gx
- Diesel-range organics (DRO) and heavy oil range organics (HO) by method NWTPH-Dx
- Soil samples containing detectable concentrations of DRO or HO were also submitted for chemical analysis by carcinogenic polynuclear aromatic hydrocarbons (cPAHs) by EPA method 8270 SIM.

GRO, DRO, and HO were summed to provide a measure of total petroleum hydrocarbons (TPH) which is one of the applicable RELs for the Lower Yard. If one or more TPH constituents were reported at concentrations less than the laboratory detection limit, then one half of the detection limit was used to calculate total TPH. The seven cPAH congener concentrations were adjusted for toxicity according to the method outlined in *Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II Technical Support Document for Describing Available Cancer Potency Factors* (Cal-EPA 2005). If one or more of the congener concentrations was reported at concentrations less than the laboratory detection limit, then one half of the detection limit was used in the adjustment calculations.

3.2.2 Groundwater Analytical Methods

As part of the Phase II activities, groundwater was recovered from the open excavations, as well as water captured between the cofferdams installed in Willow Creek. The recovered water was pumped into the on-site temporary water treatment system and discharged to detention basin DB-2 under the NPDES permit. In compliance with permit requirements, samples were collected weekly for laboratory analysis for the following constituents:

- BTEX by EPA method 8021B
- GRO by Northwest method NWTPH-Gx
- DRO and HO by method NWTPH-Dx

- cPAHs by EPA method 8270 SIM.
- Arsenic and lead by EPA method 200.8
- Turbidity by EPA method 180.1

Analytical data for weekly NPDES sampling are presented in **Table 5**, and laboratory analytical reports are presented in **Appendix D**.

4. Lower Yard Interim Action Results

4.1 Willow Creek Sediment Excavation

As outlined in the Work Plan, contaminated sediment was to be removed from Willow Creek to remediate areas which failed bioassay tests conducted in 2003. The failed bioassay sample locations were located at or near current and historic outfall locations from the site to Willow Creek. The sediment removal included approximately 430 linear feet of sediment from Willow Creek, to a depth of 1 foot bgs (**Figures 6 and 9**). The area which was designated for excavation was delineated by sediment samples on either side of the excavation area which exhibited acceptable toxicity, and therefore no confirmation samples were required.

To access the areas of Willow Creek which were to be excavated, the area between the creek and the detention basins was widened by placing clean imported backfill material in DB-1 and DB-2 of the Lower Yard. Two outfall pumps used to de-water DB-2 into Willow Creek and their associated piping were removed and kept for re-installation upon completion of excavation activities. An access route for haul trucks and excavation equipment was then constructed on the backfill placed in DB-1 and DB-2. Haul routes were constructed using gravel borrow backfill placed on top of washed rock backfill until it matched the surrounding grade. Plastic sheeting with a thickness of 20 thousandths of an inch (20 mil) was placed over the haul road fill in DB-2, and the edges were held in place with sandbags. The access road was approximately 20 feet wide, 150 feet long, and filled in portions of DB-1 and DB-2, as shown on **Figure 9**.

4.1.1 Cofferdam Installation

To contain and de-water the sediment excavation area in Willow Creek, cofferdams were constructed at the north and south ends of the sediment excavation area as shown on **Figure 9**. Prior to cofferdam construction, silt fences were installed across the entire width of the creek bed on the upstream and downstream side of the sediment excavation area to decrease the amount of sediments potentially disturbed and suspended in Willow Creek by construction activities.

Each cofferdam was constructed across the entire width of the excavation area, with the west ends of the cofferdams abutting the toe of the BNSF right-of-way, and the east ends abutting the east creek bank of the Lower Yard. Cofferdams were constructed on top of a geotextile fabric liner laid on the creek bed. Berm import fill was then placed on top of the geotextile material and covered with 30 mil plastic sheeting, which was secured along all edges with sandbags. Berm import fill adhered to the following grain size requirements:

Sieve Size	Berm Import Fill (% Passing)
3 inch	100
2 inch	90-100
1 inch	50-80
½ inch	30-50
⅜ inch	25-40
#4	15-30
#10	10-20
#40	0-10
#200	0-2

A 1-foot layer of quarry spalls was then placed on top of the plastic sheeting. Each cofferdam measured approximately 30 feet long, 15 feet wide at the base, and 12 feet tall. The cofferdams were constructed in accordance with the plans approved by the USACOE. Cofferdam locations are presented on **Figure 9**.

Three-inch electric bypass pumps were installed at each end of the sediment excavation area to sustain flows consistent with existing tidal fluctuation by conveying Willow Creek surface water upstream and downstream of the cofferdams. Pumps were installed near both the north and south cofferdams with a system of temporary aluminum piping traversing the Lower Yard. This system allowed creek flows to be maintained around the sediment excavation area. An additional 6-inch diesel powered pump was installed at the north cofferdam to handle runoff water collected in Edmonds

Marsh during large storm events. The pump outfalls were fitted with spreader bars, and 6-inch minus quarry spall rock was placed on the creek banks to prevent scouring of the banks. Three-inch gas-powered pumps were used to de-water seepage and runoff water collected in the excavation area. Water removed from the sediment excavation area was treated in the on-site water treatment system. An electric 3-inch pump was installed in DB-2 and connected to the temporary on-site piping system to discharge site stormwater under the Industrial Stormwater General Permit No. SO3-002953C. Discharge water from DB-2 was pumped to the outfall location at the south cofferdam. To protect fish and animal species from pump intake and outfall areas, ¼-inch block nets were installed across the creek bed at the north and south cofferdams, and each pump intake was fitted with a 0.0938-inch wire-woven fish screen.

4.1.2 Fish Collection and Relocation

Prior to de-watering and excavation activities in Willow Creek, ARCADIS fisheries biologists conducted fish collection and relocation activities within the bermed sediment excavation area. Initially, electromagnetic fishing technologies were attempted. One complete pass of the entire sediment excavation area was made with two electrofishing backpack units; however, salinity in the creek water was too high for effective electrofishing. Conductivity readings collected in the creek indicated that electrofishing was unsuitable for this area due to the high salinity of the water. No fish or aquatic organisms were collected via electrofishing methods.

Fish collection was then conducted using seining (netting) techniques. The sediment removal area was divided into three sections (upper, middle, and lower) using ¼-inch fish block nets. Seine nets with ⅛-inch mesh were used to capture fish species by making passes from one end of each section to the other, trapping the fish in the block nets. The fish were then collected, identified, counted, placed in a bucket with creek water and an aerator, and transported to a suitable release site either upstream or downstream of the cofferdams. Care was taken to minimize handling and stress to the fish. At least three, and up to five passes per day of each section of the sediment removal area were conducted over a 2-day period to remove as many fish as possible. Special care was taken to identify any threatened or endangered species, especially salmonids.

Three fish species were identified in the sediment removal area: the three-spined stickleback, prickly sculpin, and starry flounder. No threatened or endangered fish species, including salmonids, or other aquatic organisms, such as mussels, clams, or crustaceans, were observed during the removal effort or during the additional 3 days of oversight provided by an ARCADIS fisheries biologist. In total, approximately 5,565 live fish were relocated (approximately 5,562 sticklebacks, two sculpin, and one flounder). All fish captured and released appeared to be in good condition, with very few (<1%) mortalities.

In comparing the catch totals from the highest first seine net pass, to the lowest last seine net pass in each of the three sections, the catch rate decreased significantly, indicating the majority of fish had been removed during the initial passes. Additionally, due to the high number of fish that were captured, it is unlikely that other fish species were present and went unnoticed during the relocation event. A memo detailing fish relocation activities is provided in **Appendix E**.

4.1.3 Sediment Excavation

Prior to sediment excavation activities, several overhead utility poles with power lines were removed from the sediment excavation area. The power source to the lines was disconnected by the Snohomish County Public Utility District, and Veca dropped and removed the lines. The poles were then removed using a long reach excavator and disposed of as construction debris.

To ensure that the required amounts of material were removed and replaced in Willow Creek, the natural pre-existing topography of the sediment excavation area was surveyed. OTAK Surveying installed a grid of survey markers, consisting of ten rows of wooden stakes across the width of the excavation area. The rows were approximately 50 feet apart. Each wooden stake was marked to show the natural elevation of the topography at that location.

One foot of sediment was scraped from the surface of the entire sediment excavation area, removing approximately 2,000 tons (1,333 cy) of contaminated sediment, as shown on **Figure 10**. The sediment area was excavated beginning at the north cofferdam and ending at the south cofferdam. Excavated sediment was loaded into articulated dump trucks and transported to the lined and bermed impacted soil stockpile. De-watering activities were conducted daily to remove seepage and runoff water collected in the excavation area. Water removed from this area was pumped into the on-site temporary water treatment system for treatment and subsequent discharge at the south cofferdam. Throughout the sediment removal process, the excavation area was surveyed to ensure that at least 1 foot of sediment was being removed.

Upon completion of excavation activities in Willow Creek, a PermeaTex woven slit film geotextile fabric was placed in the creek bed. Sediment excavation backfill material was then placed on top of the geotextile fabric material. Backfill material used in the sediment excavation area was a silt and sand mixture capable of supporting plant growth for restoration, as outlined in the Interim Action Report. The sediment backfill material was compacted using the excavator bucket to prevent erosion or bank sloughing. As backfill material was placed, its topography was surveyed to ensure that the original creek topography was restored. Following backfill and compaction, BioNet was placed over all of the sediment backfill material. BioNet is a biodegradable, woven straw mat material used as an erosion control measure. The mat was placed across the flow of the creek, overlapped at its edges, and held in place against the contours of the creek bank using 10 gauge steel staples.

Upon completion of the sediment excavation and backfill, the creek area was replanted with native inter-tidal plant species in accordance with the Work Plan, the Nationwide 38 permit, and the Hydraulic Project Approval permit, as discussed in Section 5.2.
Cofferdam Removal

The cofferdams were removed after excavation, backfill, planting, and restoration activities were completed on both sides of the creek. The north cofferdam was removed first, and water from Edmonds Marsh was held by the south cofferdam. Prior to the south cofferdam being removed, the flood gate on the culvert into the tidal basin was closed. This allowed for silt disturbed during cofferdam removal to settle and for the water levels on either side of the culvert to equilibrate, minimizing sediment transport and possible erosion when the creek began flowing again. Once water levels were equal on both sides of the culvert, the gate was opened and water began flowing into Willow Creek from the tidal basin.

Material from the cofferdam removal was loaded into haul trucks, transported to the impacted stockpile, and subsequently taken off site for treatment and disposal.

4.2 Soil Excavations

Phase II excavation activities included the completion of excavation areas B1, B8, and B9, which began during Phase I but were postponed due to site constraints and weather conditions. Two additional excavation areas were added to the scope of work after Phase I was completed. These areas are the Railroad Trestle Area and the Former Asphalt Warehouse Area as shown on **Figure 5** and **Figure 8**, respectively.

Excavation activities were conducted in the same manner as Phase I excavations. All contaminated soil was loaded into haul trucks and was taken to the lined and bermed impacted stockpile, where it was loaded into truck and trailers for transport to Cemex for thermal destruction. All other materials encountered during excavation, such as wood, metal, and concrete debris, were removed, segregated, and later transported off site for appropriate disposal. Soil waste manifests are presented in **Appendix F**.

The limits of each excavation were advanced based on analytical results of confirmation soil samples and/or field observations made by ARCADIS staff (visual observation or odor indicating the presence of petroleum products) consistent with the Work Plan. Excavation and soil removal continued until confirmation soil sample analytical results were below site-specific CULs or RELs. If LNAPL was observed leaching into the excavation from the exposed sidewalls, the excavation remained open until LNAPL was removed from the groundwater surface and was not observed re-entering the excavation over a minimum of a 24-hour period.

Sample locations where confirmation soil sample results exceeded one or more of the CULs or RELs were over-excavated to a greater depth or lateral extent and were sampled again. In general, this process continued until confirmation soil samples contained concentrations of TPH, cPAHs, and benzene that were less than site CULs and RELs.

4.2.1 Excavation Area B1

Excavation area B1 is located in the Southeast Lower Yard, bordering Willow Creek and Edmonds Marsh, as shown in **Figure 8**. Excavation of this area was postponed during Phase I activities to avoid excavating in close proximity to Willow Creek and Edmonds Marsh during the wet winter months. Excavation was to be completed during Phase II, when weather conditions were more favorable and water levels in Willow Creek would be controlled.

4.2.1.1 Soil Removal

Approximately 5,000 tons (3,333 cy) of soil was removed from excavation area B1 (**Figure 10**). Soil types encountered in excavation area B1 primarily consisted of silty sands with gravel and sandy silts with gravel. Soil types found on the floor of this excavation were highly organic soils with approximately 50 percent plant and wood matter and 50 percent sandy silt. The excavation reached a final depth of approximately 12 feet bgs, except when joining with the B2 excavation area, where the final depth reached approximately 8 feet bgs. Depths were measured from the concrete base of the well monument of monitoring well MW-136, as topography varied greatly at the eastern boundary of the B1 excavation area.

4.2.1.2 Geophysical Survey

After encountering a steel drum during the initial excavation of area B1 during Phase I excavation activities, and prior to the beginning of excavation activities in area B1 during Phase II, a geophysical survey was conducted in the Southeast Lower Yard. On January 15, 2008, Geomarkout Company of Pocatello, Idaho utilized metal detection, ground penetrating radar (GPR) and electromagnetic technologies to complete a survey of the area in order to determine the extent of debris in the Southeast Lower Yard.

Results of the geophysical survey indicated the possible presence of metal debris along the edges of the wooded areas of the Southeast Lower Yard, with detections along the eastern perimeter near MW-136, along the southern perimeter to the toe of the slope from lower Unoco Road, and along the northern perimeter approximately 30 to 40 feet from Willow Creek, as shown on **Figure 7**. Possible metal debris was indicated near the edges of what became excavation area B1 and not within the center of the excavation, where they were identified and removed during subsequent excavation activities. This is likely because the capabilities of the technology being used reached to a maximum of 6 to 10 feet bgs, so that the debris closer to the surface around the edge of the excavation area was detected while debris in the center of the excavation area was at depths exceeding the range of the instruments. All areas marked as possible locations of metal debris during the geophysical survey activities were excavated during Phase II excavation activities in area B1.

4.2.1.3 Debris Removal

Excavation area B1 consisted entirely of fill debris, as evidenced by the large amounts of debris encountered. Fill debris in this excavation consisted of various materials. Approximately 18 steel drums and drum remnants were encountered in varying sizes and conditions. Most drums or drum remnants were mangled or broken and coated with a tar-like substance or emulsified asphalt. At the completion of B1 excavation activities, eighteen 65-gallon plastic drum overpacks were filled with damaged drums and scrap metal pieces which were coated with the tar-like substance and/or emulsified asphalt. The tar-like substance and/or emulsified asphalt was sampled, characterized, and disposed of as non-hazardous waste. The overpacks were transported by Emerald Services to Waste Management's transfer facility in Seattle, Washington, for disposal.

Approximately 850 tons of concrete debris, such as pilings, footings, and large broken concrete blocks containing rebar, were removed from the B1 area. Approximately 25 tons of scrap metal, such as steel I beams, sheet metal, and metal wiring, were encountered and removed. Wood debris was also encountered and removed, including wood beams, posts, and other construction materials. The B1 excavation was extended laterally to ensure that all known debris was removed. The B1 excavation was extended vertically until native soil was encountered. Upon completion of excavation activities no debris was visible in the sidewalls or floor of the excavation.

4.2.1.4 Soil Sampling and Over-Excavations

Samples were collected in excavation area B1 on the existing site sampling grid and in accordance with the SAP in the Work Plan (**Figure 8**). Five samples collected from sidewalls in B1 contained concentrations of site Indicator Hazardous Substances (IHSs) which exceeded site CULs and/or RELs. Four confirmation soil samples exceeded the site CULs for total TPH and the site RELs for cPAHs: EX-B1-C-46-4 (4,090 mg/kg TPH, 0.228 mg/kg cPAHs), EX-B1-D-44-NSW-4 (13,600 mg/kg TPH, 0.554 mg/kg cPAHs), EX-B1-E-47-SSW-4 (15,700 mg/kg TPH, 0.756 mg/kg cPAHs), and EX-B1-F-46-4 (12,600 mg/kg TPH, 1.14 mg/kg cPAHs). One confirmation soil sample (EX-B1-F-44-4) exceeded only the site REL for cPAHs with a concentration of 0.212 mg/kg. Over-excavation of the failing confirmation samples is explained below, and confirmation soil sample analytical data are presented in **Table 3**.

The over-excavation of sample grid locations D-44-NSW and C-46 consisted of the removal of approximately one foot of material from the entire height of the sidewall, between grid intersections D-43 and C-47. Upon completion of the over-excavation, confirmation samples EX-B1-D-44-NSW-4(2) and EX-B1-C-46-4(2) were collected. These samples did not contain concentrations of site IHSs exceeding site-specific CULs or RELs.

Approximately 3 feet of material were removed from the sidewall in the area of sample grid intersections F-46 and E-47-SSW before samples were re-collected. Over-excavation of these sample grid locations revealed soil containing LNAPL and wood construction debris. LNAPL leached onto the groundwater surface at the F-46 sample location and was removed via vacuum truck until it was no longer observed over a 24-hour period. Approximately 19 gallons of LNAPL were removed from the groundwater surface in this area. Sidewall material and clean backfill material on the floor of the excavation which came in contact with LNAPL were also removed prior to backfill activities. Over-excavation removed the wood debris and visibly impacted soil until exposed soil did not reveal signs of LNAPL, odors, or visual staining. Samples collected following over-excavation (EX-B1-F-46-4(2) and EX-B1-E-47-SSW-4(2)) did not contain concentrations of IHSs exceeding site-specific CULs or RELs.

Due to a calculation error in the field, sample EX-B1-F-44-4 (0.212 mg/kg cPAHs) was not over-excavated.

4.2.1.5 Phase I Remaining Impacted Soil

The western limit of excavation area B1 extended into excavation area B2, which was completed during Phase I. Sample EX-B2-E-41(2)-5 (0.174 mg/kg cPAHs), collected during the Phase I excavation of B2, exceeded site RELs for cPAHs and was not over-excavated. During Phase I, 20 mil plastic sheeting was placed over the entire sidewall where this exceeding sample was located, and the excavation was backfilled. This sample was subsequently excavated during the Phase II excavation of B1. The plastic sheeting covering the sidewall of the exceeding sample location was excavated in its entirety. The western limit of the B1 excavation was extended into the former B2 excavation area until non-backfill material had been removed to a depth of 8 feet bgs and fill placed following Phase I excavation activities was encountered.

4.2.2 Excavation Area B7

Excavation area B7 is located on the bank of the southwest corner of DB-1. This excavation was not conducted during Phase I because of access constraints due to its location between DB-1 and DB-2 (**Figure 6**). The excavation area was accessed during Phase II while the sediment removal access road was being constructed through DB-2. As mentioned above, and shown on **Figure 9**, the outfall area of DB-2 was backfilled to create access for haul trucks and excavation equipment along the sediment removal area.

In excavation area B7, 250 tons (167 cy) of soil were removed to a maximum depth of 5 feet bgs. A plastic liner from the 2003 DB-1 excavation was encountered and removed at approximately 2 feet bgs. Approximately 2 feet of soil were removed from the bank below the liner. Soil encountered in this area was poorly graded sand with organics. Two confirmation soil samples were initially collected from excavation area B7. Due to time constraints, 20 mil plastic sheeting was placed over the B7 excavation area, and the creek sediment haul road was constructed on top of the sheeting prior to receiving analytical results. Sample EX-B7-B3-4 exceeded the site CUL for TPH with a concentration of 4,050 mg/kg. Subsequently, over-excavation of the B7 area consisted of removing overburden until the 20 mil plastic sheeting was encountered at sample grid intersection B-3. The plastic sheeting, and approximately 1 foot of native material was removed from the B-3 intersection area and a sample was collected at 5 feet bgs. This sample was incorrectly labeled in the field as EX-B7-B-4-5. The correct sample ID should have been EX-B7-B-3-5, as it was collected at the B-3 grid intersection. However, this sample did not contain concentrations of IHSs exceeding the site-specific CULs or RELs. The sample name was not altered in tables or figures to remain consistent with laboratory reports. Excavation soil sample analytical data are presented in **Table 3**.

4.2.3 Excavation Area B8

During Phase I activities, excavation area B8 was suspended due to its proximity to Willow Creek and the overhead utilities along the creek. During Phase I, backfill material from the 2001 Interim Action excavation was encountered on the western sidewall of the B8 excavation and was covered with 20 mil plastic sheeting due to the presence of two samples that were unable to be over-excavated: samples EX-B8-I-4-WSW-4 (4,640 mg/kg TPH, 0.179 mg/kg cPAHs) and EX-B8-H-4-WSW-4 (3,270 mg/kg TPH) exceeded site CULs and/or RELs. Excavation of B8 was completed as part of Phase II (**Figure 6**) during favorable weather conditions and while creek controls were in place in Willow Creek.

Approximately 840 tons (560 cy) of material were removed from excavation area B8 during Phase II (**Figure 9**). The final depth of excavation was approximately 10 feet bgs. Native material encountered was silty sand with gravel and organics. Backfill material from the 2001 excavations, which was not able to be excavated during Phase I, was encountered along the east sidewall of this excavation, consisting of gravel and 6-inch minus quarry spall backfill. During the excavation of B8, LNAPL was observed entering the excavation from the 2001 backfill material on the west sidewall. Excavation area B8 was extended to the east until the entire liner from Phase I, all 2001 Interim Action backfill material and the exceeding sample locations (EX-B8-H-4-WSW-4 and EX-B8-I-4-WSW-4) were removed. All of the 2001 Interim Action excavation backfill was removed and the excavation was left open until LNAPL was no longer observed entering the excavation area. Approximately 111 gallons of LNAPL were recovered from the excavation area and transported to Emerald facilities for recycling. LNAPL was removed from the groundwater surface, and sidewall material which came in contact with LNAPL was removed before excavation activities were completed.

Eight confirmation soil samples were collected from the B8 excavation area. Soil sample EX-B8-I-3-WSW-5 exceeded the site-specific CUL for TPH with a concentration of 5,350 mg/kg, and was over-excavated. The over-excavation at this location consisted of removal of 2 feet of material from the sidewall between grid intersections J-3 and H-3 and collection of another sample. Sample EX-B8-I-3-WSW-5(2) was collected following over-excavation and did not contain concentrations of site IHSs exceeding site CULs or RELs. Excavation soil sample analytical data are presented in **Table 3**.

4.2.4 Excavation Area B9

During Phase I activities, excavation area B9 could not be over-excavated any further without extending into Willow Creek (**Figure 6**). During Phase I, the B9 excavation area did not produce any soil samples containing concentrations exceeding site RELs or CULs; however, historical soil sample data from outside of the Phase I B9 excavation area limits warranted further excavation towards Willow Creek. The excavation was postponed during Phase I and completed during Phase II when weather conditions were favorable and controls were in place to mitigate hazards with possible slope failure.

Approximately 1,300 tons (867 cy) of material were removed from the remaining portion of excavation B9 during Phase II activities (**Figure 10**). Soil encountered in the B9 excavation was poorly graded sand with a hydrocarbon-like odor. The limits of the excavation were extended until there were no odors or visible signs of impacted material. The final depth of excavation in this area was approximately 12 feet bgs. The eastern sidewall of excavation B9 extended into Phase I backfill material until non-backfill material had been removed. During the excavation, a small berm of material was left in place to prevent site groundwater from being released into the bermed area of Willow Creek. The top of the berm was approximately 5 feet below ground surface, 4 feet above the groundwater level in the excavation, and 2 feet wide across the top. This berm was the west sidewall of the excavation.

Six confirmation soil samples were collected from excavation area B9 during Phase II activities. No samples contained concentrations of IHSs exceeding site CULs or RELs.

LNAPL was not observed on the groundwater surface or on excavated soils at any time during Phase II excavation activities. Excavation soil sample analytical data are presented in **Table 3**.

4.2.5 Asphalt Warehouse Area Excavation

During site assessment activities completed in June and July of 2008, exploratory soil borings were advanced in the area of the former asphalt warehouse in the Lower Yard. During site assessment activities, soil samples were collected from two boring locations that contained concentrations of IHSs exceeding site-specific CULs and/or RELs. These findings led to the excavation of soil underlying a portion of the former asphalt warehouse area, including the locations of the two borings which contained soil exceeding the site-specific CULs/RELs, as reported in *2008 Additional Site Investigation and Groundwater Monitoring Report* (ARCADIS 2009).

Approximately 4,585 (3,056 cy) tons of material were removed from the Asphalt Warehouse Area during Phase II (**Figure 10**). The excavation was completed to a final depth of approximately 10 feet bgs. Soil types encountered in this excavation consisted of silty sand with gravel. There were no signs of LNAPL, staining, or odors in the excavation at any time. Groundwater was not encountered in the excavation. Samples were collected on the existing site sampling grid and in accordance with the SAP.

Ten confirmation soil samples were collected from this excavation area. Sample EX-AW-F-23-5 contained a TPH concentration of 3,530 mg/kg, exceeding the site REL. The over-excavation of this sample location consisted of the removal of 2 feet of material from the sidewall between grid intersections E-23 and F-24. Grid intersection F-23 was then re-sampled (EX-AW-F-23-5(2)) and did not contain concentrations of IHSs which exceeded site-specific CULs or RELs. Soil sample EX-AW-E-23-5 contained a cPAHs concentration of 0.278 mg/kg, exceeding the site CUL. This sample location was over-excavated, and 2 feet of material was removed between sample grid intersections F-23 and E-24. The area was then re-sampled (EX-AW-E-23-5(2)) and did not contain concentrations of IHSs exceeding site RELs or CULs. Excavation soil sample analytical data are presented in **Table 3**.

4.2.5.1 Stockpiled Soil Analytical Results and Use

During excavation in the Asphalt Warehouse Area, unimpacted overburden soil from the vadose zone (0 to 4 feet bgs) was segregated, stockpiled, and sampled for potential re-use as backfill. The excavated overburden was temporarily placed in two stockpiles on plastic sheeting in the Southeast Lower Yard and was sampled in accordance with the SAP. Each stockpile contained approximately 250 cy of material. Six soil samples were collected from each stockpile for laboratory analysis and analyzed for GRO, DRO, HO, BTEX, and cPAHs. No samples contained analyte concentrations exceeding the CULs or RELs. The highest total TPH concentration of any sample was 356 mg/kg (AWSP2-4). The soil was subsequently used as vadose zone backfill (0 to 4 feet bgs) in the Asphalt Warehouse Excavation Area. This was the only instance of stockpiled overburden material or non-imported backfill material used during Phase II.

Analytical results from the stockpiled soil are summarized in **Table 4**. Analytical and location data for samples collected from temporary locations, such as stockpiles, are not included in the DOE EIMS database.

4.2.6 Railroad Trestle Area Excavation

As part of the Phase I Interim Action, 64 soil borings were advanced in the Southwest Lower Yard in April 2008. Impacted soil was encountered in two of the borings in the southwesternmost corner of the site, in the vicinity of a former piping trestle spanning over the BNSF railway. As part of Phase II, an excavation was conducted in this area to remove TPH exceeding the applicable REL. Analytical data and a full report of Phase I soil boring activities are included in *Phase I Remedial Implementation As-built Report* (ARCADIS 2009).

Approximately 850 (567 cy) tons of impacted material were removed from the Railroad Trestle Area (**Figure 9**). Soil excavation in the Railroad Trestle Area was completed to a depth of 6 feet bgs, and groundwater was not encountered. Soil types encountered were silt and silty sand with organics. No signs of LNAPL, staining, or odors were observed in this excavation at any time. Six confirmation soil samples were collected from this excavation area in accordance with the SAP. No samples contained concentrations of IHSs exceeding site-specific CULs or RELs. Concrete footings from the railroad trestle were encountered and were removed during excavation activities. Excavation soil sample analytical data are presented in **Table 3**.

4.2.7 LNAPL Recovery

During Phase II, moderate amounts of LNAPL were observed on the exposed groundwater in the open excavation areas of B1 and B8. LNAPL recovery was conducted by Emerald Services. LNAPL was skimmed from the groundwater using a 5,000-gallon vacuum truck and various diameter suction hoses. Absorbent pads and booms were also used to collect LNAPL. Skimming operations continued until LNAPL was removed from the groundwater surface and was not observed leaching from excavation sidewalls for a minimum of 24-hours. Any sidewall or backfill material that came in contact with LNAPL was also removed and taken to the impacted soil stockpile. Approximately 131 gallons of LNAPL were recovered during Phase II activities and were transported and recycled at Emerald's facility in Seattle, WA. Bills-of-lading from LNAPL recovery operations are included in **Appendix G**.

Bird deterrents were used as a measure to protect water birds (e.g., ducks and geese) from contacting LNAPL and impacted groundwater in the open excavations. Ropes with brightly colored flagging were strung across open excavations in a criss-cross pattern. Deterrents were used in all excavations with exposed groundwater while work activities were not being completed in the excavation. No birds were observed entering any excavations during Phase II activities.

4.3 Water Treatment and Discharge

The Agreed Order and Work Plan required removal and treatment of groundwater from open excavations. A water treatment system consisting of three-pod sand filtration vessels and dual carbon treatment vessels was used to treat water pumped from the sediment excavation area. The system used during Phase I was left on site and used during Phase II. A summary of the water treatment system and its operation was presented in *Operation, Maintenance, and Monitoring Plan – Temporary Treatment System* (ARCADIS 2007a).

During Phase II, approximately 520,900 gallons of water were treated and discharged into detention basin DB-2 under the NPDES permit. Analytical water samples were collected from the water treatment system once per week if the system was operated at any time during that week. Sample IDs containing "NPDES-MID" were collected from a sampling point between the two carbon filters. Sample IDs containing "NPDES-EFF" were collected at the water treatment system discharge point, prior to discharge into a 21,000-gallon holding tank. Weekly samples were analyzed for GRO, DRO, HO, BTEX, PAHs, arsenic, copper, lead, zinc, turbidity, pH, and hardness. Once laboratory results indicated that the treated water met the stormwater permit requirements, the tank was discharged to DB-2 for final discharge into Willow Creek.

Monthly discharge monitoring reports documenting compliance were submitted to DOE. NPDES sample data are summarized in **Table 5**. NPDES sample laboratory analytical reports are included in **Appendix D**.

5. Lower Yard Restoration

Upon completion, each excavation area was backfilled with clean gravel and soil. Excavated overburden from the Asphalt Warehouse Area was used as backfill above the groundwater table (vadose zone) in the Asphalt Warehouse Excavation Area. Soil analytical results from stockpiled soil are presented in **Table 4**. This was the only instance of non-imported backfill used during Phase II.

Approximately 4,695 tons (3,130 cy) of vadose zone sand backfill was imported from Cemex. The soil imported by Cemex was clean pit-run (un-used sand and gravel material produced by a sand and gravel facility) backfill and came from their facility in Everett, WA. Gravel used for saturated zone backfill had been stockpiled on site at the conclusion of Phase I. Clean sand and gravel that were imported for backfill adhered to the following grain size requirements:

Sieve Size	Vadose Zone Backfill Sand (% Passing)	Saturated Zone Backfill Gravel (% Passing)
1 inch	-	100
¾ inch	-	80 to 100
⅜ inch	-	10 to 40
½ inch	100	0 to 5
#4	90-100	0 to 5
#200	3-12	0 to 2

Backfill was placed in approximately 2-foot lifts and was compacted to a minimum of 90 percent relative compaction (Standard Proctor). Compaction density testing was conducted by HWA Geosciences Inc. of Lynnwood, WA. Compaction testing forms are included in **Appendix H**.

The southeast, north, and south portions of the Lower Yard are currently composed of compacted backfill material and surface soil graded toward the stormwater collection system, as well as a network of roads constructed out of clean, imported 2- to 4-inch quarry spalls. Surface soil was covered with hydroseed to prevent erosion. The southwest Lower Yard was covered in 6-inch minus quarry spalls and graded to direct surface water toward the center of the site and into the stormwater system.

Outfall pumps were removed from DB-2 at the beginning of Phase II to construct the sediment haul road along the east bank of Willow Creek. These pumps were kept on site and replaced in DB-2 at the completion of the remedial work. The pumps were reinstalled in the western end of DB-2 and piped into a spreader bar at the outfall area using polyvinyl chloride (PVC) piping. The pumps are set with float switches to discharge water from DB-2 into Willow Creek before the water level reaches the outflow channel into DB-1. Discharge from DB-2 is conducted in accordance with the Industrial Stormwater General Permit No. SO3-002953C.

5.1 Willow Creek Restoration

Due to the nature of work conducted in Willow Creek, impacts to the creek's natural ecosystems were unavoidable. Backfill of the creek to pre-construction elevations and planting of the channel banks and flood plain with native riparian plant species was included as part of the excavation plan as mitigation for these impacts. Approximately 900 tons of sediment backfill material were imported by Cemex which met the specifications presented below as outlined in the project plan and approved by DOE and the USACOE:

Sieve Size	Sediment Excavation Import Backfill (% Passing)
1 inch	-
¾ inch	-
⅜ inch	-
½ inch	100
#4	100
#40	80-90
#200	30-50

Creek topography was matched to pre-construction conditions by using survey stakes as mentioned in Section 4.1. BioNet, a biodegradable, woven-fiber matting, was placed over the backfill in the excavated areas of the creek sediment removal area.

The mat was laid perpendicular to the creek flow, and the sections were overlapped at the edges. BioNet was held in place with 10 gauge staples placed on 3-foot centers and along each edge. This stapling pattern tightly secured the net to the creek channel, flood plain, banks, and contours, preventing erosion from creek flow and flooding events. Minimal amounts of washed rock gravel backfill were placed on the BioNet in the creek channel in areas that were inaccessible for stapling. The small layer of washed rock held the BioNet to the channel bed sufficiently to prevent the creek flow from lifting and scouring under the BioNet.

5.2 Planting

Before the sediment excavation, Willow Creek was dominated by invasive herbs and shrubs and provided diminished wildlife habitat and ecosystem function. The restoration of the site was designed to improve conditions along the affected reach of the creek by eliminating the invasive species and replanting with native plant species to increase ecosystem functions. The total acreage marked for restoration was 0.33 acre. The Willow Creek As-Built and Monitoring Report is included as **Appendix I** and **Figure 11**.

Although there was no soil disturbance in the BNSF right-of-way (so replanting was not necessary), planting occurred on both sides of Willow Creek. At the request of BNSF, tree and shrub species were eliminated from the planting plan for the BNSF side of the creek due to its proximity to the railway right-of-way. Native estuarine wetlands species were planted in the floodplain areas of the creek according to the planting plan in the project manual. The floodplain comprises 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.

All plants were planted under the supervision of an ARCADIS wetland biologist prior to cofferdam removal. The plantings were installed through cuts made in the BioNet, at a density and pattern designated by the wetland biologist, into imported mulch material mixed with fertilizer and the root bases were covered in mulch. The plants were watered by hand for approximately 1 week until regular precipitation began in October 2008.

Maintenance monitoring of the plants in Willow Creek will continue until the restoration planting goals of reestablishing a riparian wetland community and ensuring a survival rate of 75 percent of planted species have been met. Maintenance monitoring consists of semi-monthly site visits and visual plant inspections.

5.3 Water Treatment System Removal

Upon completion of the cofferdam removal, the on-site bypass pumping system was removed from the site. All pumps and associated piping were dismantled, cleaned, and returned to Baker Tanks. The temporary on-site water treatment system was also dismantled, cleaned, and returned to Baker Tanks. Emerald Services cleaned the sand pods, carbon vessels, and tanks using pressure washers and vacuum trucks. Each component of the water treatment system was cleaned to Baker Tanks' specifications and was subsequently taken off site and returned to Baker. Waste water, sludge, sand, and carbon associated with the water treatment system cleaning and dismantling were collected via vacuum truck and taken to Emerald's Seattle facility for recycling or treatment.

The containment berm surrounding the water treatment system was also removed. The clean fill material used to construct the berm was used for site grading, and the containment area liner was washed and returned to Baker Tanks.

5.4 Impacted Stockpile Removal and Sampling

Upon completion of Phase II excavation activities, the impacted soil stockpile area and containment were excavated and removed. The contents of the entire stockpile and containment area was loaded into ECTI trucks and hauled to Cemex with the impacted excavated material. As the final remains of the impacted material were loaded out, the berm and liner of the impacted stockpile were also removed to a depth of approximately 2 feet bgs. Soil samples were collected in the impacted stockpile area on the existing site sampling grid and in accordance with the SAP, as shown on **Figure 8**. These samples were collected to ensure that there was no leaking or cross-contamination of the clean backfill material on which the stockpile area was constructed. Soil analytical data are presented on **Table 3**.

Sixteen soil samples were collected from the impacted stockpile area. No samples collected from this area exceeded site-specific CULs or RELs with the exception of sample ISP-G-19-2, which contained a cPAHs concentration of 0.306 mg/kg. This grid intersection was over-excavated approximately 1 foot and re-sampled. The re-sample ISP-G-19-2(2) did not contain concentrations of IHSs in excess of RELs or CULs.

6. Remaining Impacted Soil

Soil samples from Phase II remedial activities that contained concentrations of site IHSs exceeding site-specific CULs or RELs have been over-excavated and re-sampled, confirming the removal of impacted soil. There are two exceptions resulting from the Phase II work:

- One sample in the B1 excavation area that exceeded the site CUL for cPAHs was not over-excavated (EX-B1-F-44-4, 0.212 mg/kg cPAHs).
- One sample collected during the installation of monitoring well MW-129R at 7 feet bgs exceeded the site REL for TPH (MW129R-7.0, 3,010 mg/kg TPH).

A table of soil samples collected during Phase II activities that exceeded site CULs and/or RELs is presented below. The exceeded site IHS(s) and the sample collected after over-excavation of the exceeding sample location are also included. Analytical data are presented in **Table 3**.

Soil samples with CUL/REL exceedence	Exceeding IHS	Over-excavation sample (no exceedence)
EX-AW-E-23-5	cPAH	EX-AW-E-23-5(2)
EX-AW-F-23-5	TPH	EX-AW-F-23-5(2)
EX-B1-C-46-4	TPH, cPAH	EX-B1-C-46-4(2)
EX-B1-D-44-NSW-4	TPH, cPAH	EX-B1-D-44-NSW-4(2)
EX-B1-E-47-SSW-4	TPH, cPAH	EX-B1-E-47-SSW-4(2)
EX-B1-F-44-4	cPAH	--
EX-B1-F-46-4	TPH	EX-B1-F-47-4(2)*
EX-B7-B3-4	TPH	EX-B7-B-4-5**
EX-B8-I-3-WSW-5	TPH	EX-B8-I-3-WSW-5(2)
ISP-G-19-2	cPAH	ISP-G-19-2(2)
MW129R-7.0	TPH	--

* Sample incorrectly labeled in the field. Correct label should read EX-B1-F-46-4(2), as the sample was collected at grid intersection F-46.
** Sample incorrectly labeled in the field. Correct label should read EX-B7-B-3-5, as the sample was collected at grid intersection B-3.

7. Groundwater Monitoring

In accordance with the Agreed Order, a groundwater monitoring program was implemented following the completion of Phase I and II of the Interim Action excavation activities. The purpose of the monitoring program is to evaluate if remaining on-site soil concentrations will cause exceedance of CULs at points of compliance and to understand if remaining hydrocarbon concentrations in groundwater will naturally attenuate to below the groundwater CULs before reaching the POCs.

The sampling program consists of collecting groundwater samples from 40 on-site wells, sampled on a semi-monthly basis for 24 months, which began in October 2008[1]. Of these 40 wells, 19 wells are POCs for monitoring groundwater quality conditions along the perimeter of the site. Twenty-one wells are located in three on-site groundwater flow paths for monitoring groundwater quality and parameters, indicating the possible biodegradation of dissolved-phase hydrocarbon constituents. The flow paths are generally triangle-shaped with the wide end of the triangle being downgradient. The groundwater sampling from the wells within the flow paths will provide the data to use DOE Data Analysis Tool Package A (Modules 1, 2, and 3) (SLR 2007a). The sampling results (IHS concentrations) and the groundwater monitoring data from the wells within the flow paths are planned to be used in Module 1 to evaluate if the plume is shrinking, expanding, or stable. Eight on-site wells and one off-site well (MW-151, MW-125, MW-122, MW-131, MW-E, MW-13U, MW-203, MW-134X, and MW-301) are not part of the sampling program, but are gauged for groundwater elevations during monitoring events. Groundwater flow paths and well locations are shown on **Figure 12**.

Groundwater CULs for the site have been established based on the protection of surface water. The groundwater CULs are as follows:

- benzene: 51 micrograms per liter (µg/L)
- total cPAHs: 0.018 µg/L (adjusted for toxicity)
- total TPH (eastern side of site): 506 µg/L

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[1] This comment describes the initial sampling program as described in the Interim Action Report. Chevron Proposed changes to the program in December 2009.

- total TPH (western side of site): 706 µg/L

At the completion of the 2-year monitoring program, statistical analysis will be utilized in conjunction with additional evaluation in order to determine the final cleanup action.

Groundwater monitoring data for the October and December 2008 monitoring events are presented in the *2008 Additional Site Investigation and Groundwater Monitoring Report* (ARCADIS 2009).

7.1 Monitoring Well Abandonment and Installation

7.1.1 Monitoring Well Abandonment

Monitoring well MW-129 was abandoned prior to Phase II excavation activities as a contingency for the Asphalt Warehouse Excavation extending to its location. The well was abandoned in place with hydrated bentonite chips by Cascade, pursuant to *Minimum Standards for Construction and Maintenance of Wells* (WAC 173-160-310). MW-129 was subsequently removed in its entirety using excavation equipment during remedial implementation activities, and was replaced upon completion of Phase II activities.

7.1.2 Monitoring Well Installation

From October 8 to October 14, 2008, ARCADIS supervised the installation of 29 on-site monitoring wells (**Figure 12**). Twenty of the monitoring wells are located within three designated groundwater flow paths as outlined in the Agreed Order. Five of the wells (MW-500, MW-501, MW-510, MW-518, and MW-524) are POC wells, and four of the wells (MW-8R, MW-129R, MW-139R, and MW-149R) are replacements for POC wells abandoned and removed during Phase I and Phase II remedial activities. The replacement wells include monitoring well MW-8R, which is both a groundwater flow path well and a POC well. Monitoring well MW-509, which was installed in the northern portion of the Lower Yard, is not included in any groundwater flow path, but is included in the groundwater monitoring and sampling program.

Wells were installed with a hollow-stem auger drill rig. Borings drilled for monitoring well installation were 8 inches in diameter. The well borings were completed to 13 feet bgs with the exceptions of MW-129R, MW-149R, MW-518, and MW-524, which were completed to 13.5 feet bgs, and MW-511, which was completed to 15 feet bgs. The monitoring wells were installed to a depth of 13 feet bgs, with 10 feet of screen, except for MW-518 and MW-511. Monitoring well MW-511 was installed to a depth of 15 feet bgs with screen from 5 to 15 feet bgs due to its location and slightly higher ground surface elevation on Upper Unoco Road. Monitoring well MW-518 was installed to a depth of 13.5 feet bgs with screen from 3.5 to 13.5 feet bgs due to the boring being advanced past the desired depth of 13.0 feet bgs. The monitoring well casings are 2.0-inch-diameter schedule 40 PVC with 0.01-inch factory-slotted screens. Filter packs were installed using 10/20 or #2/12 silica sand extending up to 1 foot above the top of the well screen. On top of the sand pack is a bentonite and concrete seal at least 1 foot thick. Traffic rated flush-mount well monuments with locking well caps were installed flush with the ground surface.

Soil samples from wells installed in clean backfilled excavation areas were not collected for analytical testing. These wells are monitoring wells MW-8R, MW-139R, MW-149R, MW-503 through MW-509, MW-512 through MW-521, MW-523, and MW-524. During the installation of these wells, cuttings were logged to ensure backfill material was encountered, and split spoon samples were advanced between 6 and 7 feet bgs and again at the completion of the boring, to confirm that the wells were installed in clean backfill material and below the water table. Monitoring well installation boring logs are presented in **Appendix J**.

7.1.3 Monitoring Well Soil Sampling and Surveying

Monitoring wells MW-129R, MW-502, MW-510, and MW-511 were installed in native, non-excavated soil. Soil samples for analytical analysis were collected from these borings in accordance with the SAP and were analyzed for GRO, DRO, HO, BTEX, and cPAHs. One sample collected during the installation of MW-129R contained concentrations of TPH exceeding the site-specific REL. At 7.0 feet bgs, a sample was collected from this boring that exceeded the site-specific TPH REL of 2,975 mg/kg, with a concentration of 3,010 mg/kg. Monitoring wells MW-500 and MW-501 were installed partly (7.5 feet bgs to 13.0 feet bgs) in native non-excavated soils, but no samples were collected for analytical analysis due to low photoionization detector (PID) headspace readings and no observable signs of impact. Laboratory data for soil samples collected during monitoring well installation are presented in **Table 6**.

OTAK Surveying surveyed the new and existing monitoring well locations relative to existing site features and NAD 83/98 horizontal datum. OTAK also measured top-of-casing well elevation to the nearest 0.01 ft for all new and existing wells. Monitoring well location data are available in the DOE EIM database.

7.1.4 Monitoring Well Development

Well development activities were conducted using an Emerald Services vacuum truck and 1½-inch stinger attachment. Vacuum was applied to each well for at least 15 minutes while the stinger was moved up and down the screen interval to ensure a minimum of 10 well volumes were removed. Prior to and during vacuum operations, well screens were surged with a 2-inch surge block. Wells installed in October 2008 were developed in this manner, as well as existing site wells that are part of the site groundwater monitoring program. Groundwater collected during well development was transported to Emerald Services facility for recycling.

On December 5, 2008, wells MW-104, MW-500, MW-501, MW-502, MW-510, MW-514, and MW-518 were re-developed due to poor water production. During this re-development, the water column in each well was surged for at least 5 minutes using a disposable bailer. Each well was then vacuumed with an Emerald vacuum truck for at least 30 minutes using a 1½-inch stinger moving up and down the well screen interval. Groundwater collected during this event was transported to the Emerald Services facility for recycling.

8. Statistical Analysis and Overall Site Status

Comparisons of Phase II confirmation soil sampling data to the RELs established for cPAHs and TPH were based on MTCA *Statistical Guidance for Ecology Site Managers* (Ecology 1992) (MTCA Guidance). The methods and approaches described in the MTCA Guidance reflect WAC 173-340-740 regarding the comparisons of observed soil concentrations to a criterion. Table 13 of the MTCA Guidance provides a flowchart summarizing the methods relevant to soil. This table provides the decision process for selecting the appropriate methods and shows that guidance was used as a starting point for the analyses conducted herein. The methods and results are described below.

8.1.1 Data Sets

Of the 82 samples collected and analyzed for cPAHs and TPH in Phase II, only those data associated with soil remaining after the Phase II excavation were included in the analyses. This choice was based on the rationale that samples collected from soil that was subsequently excavated no longer represent the site. Excavations conducted in Phase II removed soil from locations associated with nine of the confirmation samples, for a resulting data set of 73 samples. Of these remaining 73 samples, one sample exceeded a criterion (EX-B1-F-44-4 with a cPAH concentration of 0.21 mg/kg).

8.1.2 Methods

MTCA requires that, for comparisons to chronic cleanup criteria, the 95 percent upper confidence limit of the population mean (95 UCL) must be less than the specified criterion (WAC 173-340-740[7][c][iv][B]). WAC specifies that the calculation be based on an assumption that the data are lognormally distributed. In the event that the data are not lognormally distributed, WAC specifies that the data be tested for normality and the UCL calculation based on the determination that the data are from *either* a normal or lognormal distribution (WAC 173-340-740[7][d][i][B]). A variety of methods are specified in WAC to be "used to determine whether the data are lognormally or normally distributed…" In addition, MTCA provides methods to calculate the 95 UCL in the case of either distributional assumption. However, MTCA does not provide methods to calculate the 95 UCL in the case where neither distributional assumption is met.

MTCA has the additional requirements that no single sample yields a concentration greater than two times the soil cleanup criterion (WAC 173-340-740[7][e][i]) and less than 10 percent of the samples yield concentrations exceeding the criterion (WAC 173-340-740[7][e][ii]). For the requirement that no sample exceeds twice the criterion, MTCA provides for an adjustment to control the false positive error rate, but only when the criterion is based on a distribution of background concentrations.

The EPA and others have conducted a substantial amount of research in recent years into the statistical characterization of environmental data (EPA 2007b). A software package (ProUCL) developed by the EPA for the calculation of statistical tests relevant to the comparison of environmental data to criteria or background data (EPA 2007a) was used to calculate the 95 UCL. The methods implemented by ProUCL represent the current state of the practice for the calculation of 95 UCLs.

ProUCL uses the Anderson-Darling and Kolmogorov-Smirnov test statistics for comparison of the observed data to normal and gamma distributions and the Lilliefors test for comparison to the lognormal distribution. These distribution goodness-of-fit tests may be performed on data sets containing samples whose concentrations are reported at their detection or reporting limit (i.e., "non-detects"). ProUCL provides a full suite of methods for the treatment of these non-detects, and these methods were employed to control the influence of non-detects on the distribution tests.

ProUCL provides for several approaches to calculating the 95 UCL depending on whether the data are determined to be samples from a normal, lognormal, or gamma distribution, or from an undefined distribution, in approaches reflecting the guidance of EPA 2007b. Specifically, a nonparametric approach based on the theorem of Chebyshev's inequality was used when the distribution of sample data could not be determined to be either normally or lognormally distributed, whether that distribution was determined to likely be from a gamma distribution or undefined. EPA guidance notes, "The Chebyshev's inequality can be used to obtain a reasonably conservative but stable estimate of the UCL of the mean…" (EPA 2007b). We note here for emphasis that by "conservative" the EPA guidance means that the UCL based on Chebyshev's inequality will tend to be higher than UCLs calculated using distributional assumptions; therefore, if a 95 UCL based on Chebyshev's inequality is less than a given criterion, our confidence that the true mean is less than the UCL is at least equal to – and perhaps greater than – 95 percent.

The requirement that no more than 10 percent of the data exceed the cleanup criterion was tested by the equivalent comparison of the 90th percentile of observed data to the criterion. If this statistic is less than the cleanup criterion, the requirement is satisfied. The 90th percentile of the sample data was calculated using SYSTAT (SYSTAT 2007).

8.1.3 Results

The distributional tests identified the cPAHs and TPH concentration data sets in samples remaining after Phase II excavation as being statistically undefined in nature. Based on these tests, the 95 UCL estimates were calculated using the nonparametric approach described above. The MTCA test results for cPAHs and TPH, the full array of goodness-of-fit tests, and 95 UCL estimates from ProUCL are provided in their entirety in **Appendix K**.

The results may be summarized as follows:

- For both cPAHs and TPH, the 95 UCL estimates are below the cleanup criteria.
- For both cPAHs and TPH, less than 10 percent of the observations exceed the cleanup criteria.
- For both cPAHs and TPH, no observation is greater than two times the cleanup criteria.

The Phase II data sets are in compliance with the established cleanup criteria.

9. Data Validation

As outlined in the *Sampling and Analysis Plan* (SAP) (SLR, 2007b), the laboratory submitted summary data and quality assurance information to permit independent and conclusive determination of data quality. The determination of data quality was performed using the Laboratory Data Validation Guidelines for Evaluating Inorganic Analyses (USEPA, 1994a) and the Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses (USEPA, 1994b), as guidelines for data review.

Laboratory deliverable requirements for the chemical analyses included the information outlined below:

- A cover letter for each sample batch that includes a summary of any quality control, sample, shipment, or analytical problems, and documentation of all internal decisions. Problems were outlined and final solutions documented. A copy of the signed chain of custody form for each batch of samples was included in the narrative packet.

- Sample concentrations reported on standard data sheets in proper units and the appropriate number of significant figures. For undetected values, the lower limit of detection for each compound was reported separately for each sample. Dates of sample extraction, preparation and analysis were included.

- A method blank summary.

- Surrogate percent recovery was calculated and reported.

- Duplicate sample analytical results.

- Matrix spike/matrix spike duplicate percent recoveries, spike level, and relative percent difference.

- A list of the detection limits calculated for the laboratory instruments for all compounds.

Sample holding times were calculated by comparing the date of sample collection (shown on the chain of custody form) with the date of sample analysis. ARCADIS completed a full data quality review of laboratory deliverables, and completed separate Data Validation Reports, which are attached as **Appendix L**. Based on the ARCADIS review of laboratory reports, the overall system performance was acceptable, and the overall data quality was within the guidelines specified in the SAP (SLR, 2007b). No data were marked as unusable.

10. Summary

From July to October 2008, approximately 2,000 tons (1,333 cy) of wet contaminated sediment were removed from Willow Creek as part of Phase II of the Interim Action. Approximately 900 tons (1,350 cy) of dry clean backfill material and 4,749 native species plants were used to restore the creek to pre-construction conditions. 14,825 tons (9,883 cy) of petroleum impacted soil and approximately 131 gallons of LNAPL were removed from the Lower Yard. Also, 18 crushed drums and drum remnants, 850 tons of concrete, and 25 tons of metal debris were removed from the site. Approximately 4,695 tons (3,130 cy) of vadose zone sand backfill and the remaining stockpile of saturated zone gravel backfill were used on site. The temporary on-site water treatment system treated approximately 520,900 gallons of water for discharge into Willow Creek.

Prior to the excavation of Willow Creek, cofferdams and bypass pumps were installed to control and divert the flow of the creek. Fish recovery was conducted in the creek excavation area once the berms were installed and prior to sediment removal activities; approximately 5,565 fish were relocated from the excavation area. Willow Creek was restored to its pre-construction condition by backfilling the creek channel and banks to their original topography and re-planting the area with native vegetation.

Impacted soil was successfully removed from the Lower Yard excavation areas B1, B7, B8, B9, the Asphalt Warehouse Area, and the Former Railroad Trestle Area. Excavation in areas B1, B7, B8, and B9 began during Phase I and was completed during Phase II. The Asphalt Warehouse Area and Former Railroad Trestle excavations were initiated and completed during Phase II.

During Phase II, 82 confirmation soil samples were collected. Locations yielding samples which exceeded CULs or RELs were over-excavated and re-sampled until concentrations of IHSs were confirmed to be less than site RELs or CULs. One sample location with exceeding concentrations of cPAHs was not over-excavated. In accordance with the Work Plan, no confirmation soil samples were collected from the sediment excavation area. Overburden material from the Asphalt Warehouse Excavation was stockpiled, sampled, and subsequently used as vadose zone backfill material in the Asphalt Warehouse Excavation Area. This was the only instance of non-imported backfill being used during Phase II; the overburden material was sampled and reused in accordance with the SAP (SLR, 2007b).

Twenty-nine monitoring wells were installed on site after Phase II activities were completed. A total of six soil samples were collected from those wells installed in native, non-backfill material. One of the soil samples collected from the installation of MW-129R exceeded the site REL for cPAHs. Monitoring wells were developed, and in some cases re-developed, and surveyed prior to groundwater monitoring events.

The project has now entered the monitoring phase of remedial action. Groundwater samples are being collected from the on-site network of monitoring wells every other month, and the monitoring is expected to continue for 2 years beginning October 2008. Statistical analysis of groundwater analytical data collected during this monitoring period will be used to evaluate if the remaining soil concentrations will cause an exceedance of groundwater CULs at POCs.

Temporary site features and designated areas were removed from the Lower Yard upon completion of Phase II. Office trailers, on-site temporary storage units, the temporary on-site water treatment system, and the lined and bermed impacted soil stockpile and containment area were also removed. Cofferdams and bypass pumps were removed from Willow Creek upon the completion of excavation, backfill, and restoration activities. The site is now compacted backfill material graded toward the site stormwater drainage system.

The groundwater monitoring program will continue as scheduled at the Lower Yard, and reporting will be conducted on an annual basis. Results from year one will be presented in a report submitted in January 2010, and results from year two will be presented in a report submitted in January 2011.

References

ARCADIS. 2007a. *Operation, Maintenance, and Monitoring Plan – Temporary Treatment System.* ARCADIS, BBLES, Inc. August, 2007.

ARCADIS. 2007b. *Proposed Modification of Sampling and Analysis Plan– Import Soil Stockpile*. ARCADIS, BBLES, Inc. September, 2007.

ARCADIS. 2008. *Evaluation of Lower Yard Phase I Data and Work Plan for Additional Site Investigation*. ARCADIS U.S., Inc. July, 2008.

ARCADIS. 2009. 2008 Additional Site Investigation and Groundwater Monitoring Report. ARCADIS U.S., Inc. March, 2009.

California Environmental Protection Agency (Cal-EPA). 2005. *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 Environmental Protection Agency. May 2005.

MFA. 2002. *Lower Yard Interim Action Report – Volume 1*. November 30, 2002. Maul, Foster & Alongi, Inc.

MFA. 2004. Draft 2003 Lower Yard interim Action As-Built Report, Unocal Edmonds Terminal. February 26, 2004. Maul, Foster & Alongi, Inc.

SYSTAT. 2007. SYSTAT Statistics. SYSTAT Software, Inc. San Jose, CA.

SLR. 2007a. *Interim Action Report - Work Plan for 2007 Lower Yard Interim Action, Unocal Edmonds Bulk Fuel Terminal*. June 25, 2007. SLR International Corporation.

SLR. 2007b. *Sampling and Analysis Plan*. July 5, 2007. SLR International Corporation.

U.S. Environmental Protection Agency (EPA). 2007a. *ProUCL Version 4.0 User Guide*. Office of Research and Development. EPA/600/R-07/038. April.

EPA. 2007b. *ProUCL Version 4.0 Technical Guide*. Office of Research and Development. EPA/600/R-07/041. April.

Washington Department of Ecology (Ecology). 1992. *Statistical Guidance for Ecology Site Managers*. Washington State Department of Ecology: Toxics Cleanup Program. Publication 92-54.

ARCADIS

Appendix A

Northwest Archeologists Inc.
Monitoring report

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Appendix B

Envirocon Daily Work Logs

Available on Attached CD

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Appendix C

Soil Sample Laboratory Analytical Reports and Chain-of-Custody

Available on Attached CD

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Appendix D

NPDES Sample Analytical Reports
and Chain-of-Custody

Available on Attached CD

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Appendix E

Fish Relocation Summary

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Appendix F

Soil Waste Manifests

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Appendix G

LNAPL Bills-of-Lading

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Appendix H

Compaction Testing Reports

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Appendix I

Willow Creek As-built and Monitoring Report

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Appendix J

Monitoring Well Installation Boring Logs

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Appendix K

Statistical Analysis

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Appendix L

Data Validation Reports

Available on Attached CD