REPORT OF ADDITIONAL INVESTIGATION

Port of Tacoma
Former Milwaukee Railyard
Tacoma, Washington

Shaw Project No. 111487

September 2008

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Former Milwaukee Railyard
Tacoma, Washington

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Executive Summary

Additional investigation activities were performed at the former Milwaukee Railyard Site (Site) in Tacoma, Washington, to evaluate the progress of the cleanup actions and compliance with the groundwater cleanup standards established for the Site as part of a Prospective Purchaser Consent Decree (PPCD). The Port of Tacoma entered into the PPCD with the Washington Department of Ecology (Ecology) in 1994 to conduct cleanup actions at the Site associated with historical releases of petroleum and to resolve the potential liability for petroleum hydrocarbons in the soil and groundwater at the Site.

The historical releases of petroleum hydrocarbons were associated with former railyard operations prior to acquisition of the Site by the Port of Tacoma. Site investigation activities performed in the early 1990s identified concentrations of total petroleum hydrocarbons in soil and groundwater and the presence of nonaqueous phase liquids (NAPL). Site demolition activities have removed all potential sources of NAPL from the Site. The hydrocarbons are comprised predominantly of highly weathered diesel fuel with lesser amounts of heavier lube or fuel oils, located in the east-central portion of the Site. The investigations also showed that the NAPL was not migrating to the nearby Milwaukee Waterway (which was subsequently filled, in 1995) or the Sitcum Waterway. Following the initial investigations, a remediation system consisting of 22 NAPL recovery wells was installed during 1997 in accordance with the PPCD, and a total of approximately 63,700 gallons of NAPL has been recovered through 2007. Since 2004, the recovery rate and volume recovered have declined, and the system produces mostly water.

The additional investigation, as approved by Ecology pursuant to a prepared work plan, included three primary tasks:

- Task 1 consisted of groundwater sampling to measure the concentrations of petroleum hydrocarbons and related constituents for comparison to groundwater cleanup standards listed in the PPCD.
- Task 2 consisted of collecting undisturbed soil core samples within the NAPL zone for direct observation and testing of physical properties (e.g., grain-size distribution, porosity, permeability, air/water/NAPL content).
- Task 3 consisted of collecting NAPL samples for chemical and physical characterization.

The results of the additional investigation demonstrate that the remaining residual NAPL is not impacting groundwater at levels above the established cleanup levels. Additionally, potentially hazardous constituents including benzene, toluene, ethyl benzene, and total xylenes; polynuclear aromatic hydrocarbons; naphthalene; and polychlorinated biphenyls were not detected in offsite compliance wells MW-21, MW-22, and MW-23, which are located downgradient or crossgradient (at the point of compliance) from the area where NAPL was previously documented. In addition, measurable NAPL accumulations are now present in only two wells (CW-4 and CW-5) since September 2005.

Gas chromatography (GC) testing of NAPL samples collected from select recovery wells and monitoring wells show that residual NAPL at the Site has undergone extensive biological, chemical, and/or physical alteration resulting from exposure to the natural environment (i.e., weathering). The GC analyses indicate that the remaining NAPL is highly weathered diesel and heavier fuel oils that are immobile under non-pumping conditions and have been depleted of water-soluble hazardous substances. Additionally, the results of soil coring observations and testing demonstrate that the residual NAPL at the Site is predominantly restricted to finer-grained soils, which are less amenable to product removal, and that pore fluids are primarily saturated with water with comparatively small amounts of NAPL (2.9 percent to 8.8 percent). The results also show that NAPL is not extractable from the soil-pore throats at the test boring SC-1 location, but is extractable from the soil-pore throats at the test boring SC-2 location.

The remediation system produces mostly water from the coarser-grained soils when it is operated. Recovery data show that the remediation system recovers less than 0.3 percent NAPL by volume.

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Acronyms and Abbreviations

AGI	Applied Geotechnical, Inc.
API	American Petroleum Institute
bgs	below ground surface
BTEX	benzene, toluene, ethyl benzene, and total xylenes
cP	centipoise
Ecology	Washington Department of Ecology
GC	gas chromatography
gm/ml	gram(s) per milliliter
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
NAPL	nonaqueous phase liquid
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyls
PPCD	prospective purchaser consent decree
Shaw	Shaw Environmental, Inc.
Site	former Milwaukee Railyard site
TechSolv	TechSolv Consulting Group, Inc.
TGI	Torkelson Geochemistry, Inc.
TPH	total petroleum hydrocarbon
UPRR	Union Pacific Railroad
USPCI	United States Pollution Control Inc.
UST	underground storage tank
Work Plan	Additional Studies Work Plan

1.0 Introduction

This report presents the findings and conclusions of additional investigation activities performed at the former Milwaukee Railyard Site in Tacoma, Washington (Site, Figure 1). The Port of Tacoma entered into a Prospective Purchaser Consent Decree (PPCD) with the Washington Department of Ecology (Ecology) in 1994 and conducted cleanup actions at the Site associated with historical releases of petroleum. The objective of this investigation is to evaluate the progress of the cleanup actions and compliance with the groundwater cleanup standards at the points of compliance identified in the PPCD and the associated Cleanup Action Plan.

The objectives and proposed tasks for this investigation were discussed during an August 30, 2007 meeting with the Port of Tacoma, TechSolv Consulting Group, Inc. (TechSolv), Shaw Environmental, Inc. (Shaw), and Ecology. The technical approach was described in a letter from TechSolv to Ecology dated September 9, 2007 (TechSolv, 2007a). TechSolv subsequently prepared an Additional Studies Work Plan (Work Plan), dated October 15, 2007 (TechSolv, 2007b). The Work Plan was approved by Ecology in a comment letter dated October 31, 2007 (Ecology, 2007). The Work Plan and this report were implemented and prepared by Shaw and TechSolv.

1.1 Prospective Purchaser Consent Decree

The purpose of the PPCD is to resolve the potential liability for petroleum hydrocarbons in the soil and groundwater at the Site. The PPCD is also intended to promote the public interest by expediting cleanup activities and site redevelopment.

Cleanup standards for soil and groundwater are identified in the PPCD. The cleanup level for total petroleum hydrocarbons (TPH) in groundwater is based on the protection of adjacent surface waters, and is set at 10 milligrams per liter (mg/L) TPH (for diesel and oil). The cleanup level for TPH in soil was identified as 200 milligrams per kilogram (mg/kg). Alternatively, compliance with the soil cleanup level can be demonstrated empirically by documenting compliance with groundwater cleanup standards. The point of compliance for groundwater is within the nonaqueous phase liquid (NAPL) area, and at the downgradient property boundary. The cleanup actions selected to achieve these cleanup standards included capping the site, installing and operating a groundwater and NAPL recovery system, and monitoring.

1.2 Additional Studies Rationale

The Work Plan was developed to evaluate compliance with the cleanup standards in accordance with the five-year review requirement in the PPCD. Groundwater sampling performed in 2004 showed—with one exception—that TPH concentrations in groundwater were below cleanup levels. The 2004 groundwater sample from well CW-5 (which also contained NAPL) contained TPH (13 mg/L) above the 10 mg/L cleanup level. Samples from the remediation system effluent have also been below the cleanup level for the last 21 sampling events, and below the laboratory detection limit during August 2007. These data suggest that groundwater cleanup standards under the PPCD may have been reached.

A NAPL recovery system was installed during 1997 and operated through 2007, resulting in a decrease in the number of wells with measurable accumulations of NAPL. Figure 2 shows the current Site, locations of monitoring wells, and also depicts when measurable accumulations of NAPL were last observed. While the extent of measurable NAPL appears to have decreased, measurable NAPL remains in wells CW-4 and CW-5. NAPL recovery data show that the system produces relatively little NAPL compared to the total volume of groundwater pumped (less than 0.3 percent by volume), and since 2004 the recovery rate and volume recovered have substantially declined. The NAPL is black in color and highly viscous, suggesting that the NAPL is depleted of water-soluble constituents, with little potential to migrate further or contaminate groundwater or surface water.

Based on the results of the groundwater monitoring and operation of the remediation system, Ecology agreed that additional data were necessary to assess the progress of remedial action and compliance with PPCD cleanup standards. Direct observation methods were also proposed to document NAPL in subsurface soil, so that NAPL accumulations in monitoring wells could be directly compared to NAPL present in the adjacent soil.

1.3 Nature of NAPL in the Subsurface

The behavior of NAPL in the subsurface is discussed below and is presented in greater detail in Appendix A (from the American Petroleum Institute [API] Interactive LNAPL [light nonaqueous phase liquid] Guide, 2004)

A common misconception among remediation practitioners is that NAPL in the subsurface exists as a homogeneous, separate-phase lens of NAPL at the water table. This “pancake” model led to several inaccurate conclusions about the occurrence, mobility, and recoverability of NAPL in the subsurface, including the following:

- The thickness of NAPL measured in a monitoring well is directly proportional to the amount of NAPL in the surrounding soil.
- Soils directly above the water table contain a uniformly high saturation of NAPL.
- If NAPL accumulations are observed in a well, NAPL in the adjacent formation is easily recoverable, and likely to migrate further.

- Soil and NAPL properties were not considered significant limiting factors in determining the mobility of NAPL.

A better model for NAPL in the subsurface considers the coexistence of NAPL, air, and water in the soil-pore throats. The degree of saturation of NAPL in the soil, and its mobility and recoverability, are highly dependent on the physical properties of the soil (e.g., heterogeneity, grain size, porosity, permeability) and NAPL (e.g., viscosity, composition, degree of weathering). In this multiphase model, NAPL partially fills the soil-pore space, and the degree of NAPL saturation decreases with depth until water fills all the pores (Beckett and Huntley, 1998). Though the NAPL saturation varies with depth, some of this NAPL may migrate into an adjacent monitoring well, with NAPL from the more permeable zones in the impacted soil column displacing water in a monitoring well, resulting in NAPL accumulations in the well that have no direct relationship to the amount of NAPL in the adjacent soil (Figure 3).

1.4 Scope of Work

The fieldwork activities and laboratory testing were performed in accordance with the Work Plan and consisted of three primary tasks:

- Task 1 consisted of groundwater sampling to measure the concentrations of petroleum hydrocarbons and related constituents for comparison to groundwater cleanup standards listed in the PPCD.
- Task 2 consisted of collecting undisturbed soil core samples within the NAPL zone for direct observation under regular and ultraviolet light. Selected soil samples were also tested for certain physical properties (e.g., grain-size distribution, porosity, permeability, air/water/NAPL content).
- Task 3 consisted of collecting NAPL samples for chemical and physical characterization. The purpose of the testing was to characterize the nature and degree of weathering of the petroleum hydrocarbons for comparison with previous results, and to measure the physical characteristics of the NAPL (e.g., density, viscosity, surface tension, and interfacial tension).

Ecology’s letter approving the Work Plan contained the following additional requirements:

1. Perform additional groundwater sampling if the extraction system is not operated for more than three months.
2. Evaluate solubility and toxicity as part of the NAPL characterization.
3. Evaluate the potential for downward migration of petroleum compounds to the lower aquifer.

2.0 Background

2.1 Site Description and History

The Site covers approximately 53 acres of industrially-zoned property within the Port of Tacoma (Figure 1). The Site is bordered by East 11th Street on the northwest, Milwaukee Way on the northeast, Lincoln Avenue on the southeast, and Cascade Pole and Lumber Company and the Maersk-Pacific marine terminal on the southwest. The surface topography is essentially even, with about a 5-foot crown near the center of the Site for surface drainage.

The Site was originally a tidal marsh within the Puyallup River delta. The Site was filled with dredged sediment from construction of nearby waterways in approximately 1900. By 1909, the Chicago, Milwaukee, Saint Paul, and Pacific Railroad Company had begun operating the Site as a railyard. The railyard was the West Coast headquarters for train maintenance and repairs. The railyard included maintenance and repair shops, and various other supporting buildings. The Site configuration changed very little between 1918 and 1980. Figure 4 presents a 1969 aerial photograph of the Site with key features noted, and the current monitoring well network added to the photograph. A former river channel west of the Site, shown on the 1969 aerial photograph, was filled in as part of industrialization of the area.

The railyard closed on March 15, 1980, and demolition began thereafter. The Union Pacific Railroad (UPRR) acquired the property in 1981. The Site has undergone redevelopment since the 1980s, including removal of all buildings/structures, underground and above-ground storage tanks and associated piping, and all other appurtenances associated with railyard operations. In 1995, Ecology and the Port of Tacoma entered into the PPCD, and the Port of Tacoma took ownership of the property later that year. A restrictive covenant prohibiting the use of groundwater for domestic purposes was also recorded by the Pierce County Auditor.

The surface water body closest to the Site at the time of the purchase of the UPRR property by the Port of Tacoma in 1995 was the Milwaukee Waterway. The Milwaukee Waterway was subsequently filled with dredged materials from the Sitcum and Blair Waterways, capped, and redeveloped as a marine terminal (the base map for Figure 1 was modified to show the current configuration of the marine terminal). At present, the nearest surface water bodies are the Sitcum Waterway and the Puyallup River.

Redevelopment of the Site was completed by the beginning of 2005. The Site has been capped with asphalt and utilized for vehicle and/or container storage (Figure 2). The Site is fenced in such a way that public access is prohibited and only controlled access is allowed.

2.2 Site Geology and Hydrogeology

The Site comprises hydraulically placed fill overlying fluvial and tidal sediments of the Puyallup River Delta. Prior to development, the entire tideflats area, including the Site, was a tidal marsh. The former tideflat surface can be observed in borings and test pits as a silt layer occurring beneath the overlying hydraulic fill. The geology beneath the Site consists of the following units (starting with the uppermost unit):

- The "*Upper Sand*" comprises 5 to 15 feet of fine- to coarse-grained silty sand (hydraulically placed fill), and typically occurs at grade to 10 feet below ground surface (bgs). The Upper Sand also contains areas of construction debris.
- A small portion of the former City of Tacoma landfill at the southeast end of the Site is present at the same depth as the Upper Sand, which covers the remainder of the Site.
- Beneath the Upper Sand, the "*Upper Silt*" represents the former tidal marsh sediments. This unit may range from a few inches to 4 or 5 feet thick, typically occurring at 10 to 12 feet bgs. The Upper Silt is absent along much of the northeast side of the Site.
- Beneath the Upper Silt, the "*Lower Sand*" comprises 15 to 25 feet of fine- to coarse-grained sand. This sand extends to approximately 30 to 35 feet bgs, and is in direct contact with the Upper Sand in areas where the Upper Silt is absent.
- Beneath the Lower Sand, the "*Lower Silt*" occurs at approximately 30 to 35 feet bgs, and is believed to be continuous beneath the Site and adjacent properties.

Groundwater occurs in the Upper Sand under water table (unconfined) conditions and in the Lower Sand under semiconfined conditions (lower aquifer). The Upper Silt is a significant aquitard where present, and the Lower Silt is an aquitard of Site-wide significance. Groundwater in the Upper and Lower Sands is in hydraulic communication where the Upper Silt is absent.

Groundwater recharge occurs from direct stormwater infiltration. Groundwater flow in the Upper Sand appears to be toward the area where the Upper Silt is absent, or towards the Lincoln Avenue ditch at the southeast end of the Site. The Lower Sand receives recharge from the Upper Sand.

2.3 Previous Investigations

In 1990, investigations performed on behalf of UPRR found NAPL, comprised predominantly of diesel fuel in the east-central portion of the Site along Milwaukee Way (Applied Geotechnology Inc. [AGI], 1990a; AGI, 1990b). In May 1990, a 6,000-gallon underground storage tank (UST), formerly used for storage of Bunker C fuel, was removed. Soils containing bunker oil were removed from the tank pit and piping trenches as an interim cleanup action.

A hydrologic characterization study was completed for the Site in 1993 (United States Pollution Control Inc. [USPCI], 1993). The results of the study identified concentrations of TPH and NAPL in soil and groundwater. Additional potential source areas identified were two former refueling racks; a product pipeline used to carry bunker fuel oil, and later diesel (abandoned in 1995); the round house area; and various USTs (USPCI, 1993). A study conducted in 1993 concluded that NAPL was not migrating to the Milwaukee Waterway (which was subsequently filled in 1995) or the Sitcum Waterway from the Site (AGI, 1993). A feasibility study was completed in 1994 that identified cleanup approaches for the Site (EMCON, 1994).

A remediation system consisting of 22 recovery wells was installed during 1997, and a total of approximately 63,700 gallons of NAPL has since been recovered (Shaw, 2008a). Since 2004, the recovery rate and volume recovered have declined, and the system produces mostly water. Most of the well-heads for the extraction wells are not accessible from the surface as a result of Site grading and paving that occurred after the system was installed. Water elevations and product thickness measurements are made from other monitoring wells, which were completed at ground surface during paving of the Site.

3.0 Results

This section presents the field and laboratory testing results. The field investigation and laboratory testing methods are described in Appendix B.

3.1 Task 1 – Groundwater Monitoring

Groundwater monitoring and sampling was performed in January and March 2008, and reported to Ecology in the January 2008 and April 2008 monthly progress reports (Shaw, 2008b and 2008c). Groundwater elevations and NAPL thicknesses measured in 2008, along with historical data, are presented in Table 1. Figure 2 also shows monitoring wells that have documented NAPL accumulations since 1993 (CW-1, CW-4, CW-5, CW-8, and MW-29). Measurable NAPL accumulations are now present in only two wells (CW-4 and CW-5) since September 2006.

Groundwater elevations and chemical data measured in January and March 2008, and groundwater elevation contours interpreted from these data, are shown in Figures 5 and 6, respectively. Both figures show groundwater generally flowing toward the north-northeast, with a horizontal hydraulic gradient of approximately 0.002 feet per foot. The gradient and flow direction are consistent with groundwater flow maps developed since the early 1990s.

A summary of the groundwater analytical results for samples collected in January and March 2008, along with results for samples collected in August 2004 (CW-4 and CW-5 were not sampled in 2004), are provided in Table 2. The 2004 and 2008 results indicate that diesel- and oil-range TPH were either not detected or detected at concentrations ranging from 0.13 to 13 mg/L. The detected concentrations are below the TPH cleanup level of 10 mg/L established for the Site under the PPCD, with the exception of a single sample result from well CW-5 (January 2008 sample at 13 mg/L as diesel). Additionally, the January and March 2008 data indicate benzene, toluene, ethyl benzene, and total xylenes (BTEX), polynuclear aromatic hydrocarbons (PAHs), naphthalene, and polychlorinated biphenyls (PCBs) were not detected in offsite compliance wells MW-21, MW-22, and MW-23, which are located downgradient or crossgradient from the area where NAPL was previously documented.

3.2 Task 2 -Test Boring and Soil Characterization

Two test borings (SC-1 and SC-2) were advanced to collect soil samples for physical observation and testing in areas with documented NAPL (Figures 2 and 4). Boring SC-1 was drilled near well CW-8, where NAPL was last observed in 2002. Boring SC-2 was drilled near well CW-5, where measurable accumulations of NAPL were present during this investigation. Soil cores were photographed under natural and ultraviolet light by PTS Laboratories in Santa Fe Springs, California, to identify NAPL. Selected soil samples were also tested for physical properties. The methodology for collecting and testing the samples is described in Appendix B. Soil boring logs are presented in Appendix C. Laboratory reports and sample chain-of-custody records are included in Appendix D.

Annotated photographic logs divided into 2-foot intervals for SC-1 are provided in Figures 7 through 11, and for SC-2 in Figures 12 through 15. Photographs of the drilling and soil coring activities are provided in Appendix E.

3.2.1 Test Boring SC-1

Fill was encountered to depths of approximately 5 to 6 feet bgs. The fill material was then underlain by the Upper Sand (consisting generally of brown and gray-brown to gray medium dense, very fine to medium sand with some pebbles and rare gravels, trace fines, and occasional sandy silt or sandy silt zones The Upper Silt was not encountered to the total depth drilled (21 feet bgs).

Grain size testing (Table 3), hydraulic conductivity measurements (Table 4) and capillary pressure curves (Figure 16) are indicative of fine to medium sand material.

The laboratory photographs of the cores (Figures 7 through 11) exhibit fluorescence consistent with the presence of NAPL in finely laminated zones at depths of approximately 8.0 to 8.3, 8.6 to 9.0, and 11 to 12.3 feet bgs (in the photographs, NAPL fluoresces yellowish-green; the intensity of the fluorescence increases with the amount of NAPL present).

Table 5 shows that pore fluid is primarily saturated with water, with comparatively small amounts of NAPL (2.9 percent to 8.8 percent). Table 6 shows that NAPL was not extractable from the soil-pore throats during centrifuging at 1,000 times the acceleration due to gravity.

3.2.2 Test Boring SC-2

The soil profile encountered in Test Boring SC-2 was very similar to SC-1, consisting of fill underlain by the Upper Sand. The Upper Sand consisted generally of fine to medium sand with zones of gravel and coarse-grained sand. The gravel zones decrease with depth and are most abundant to a depth of approximately 12.0 feet bgs. The Upper Silt was not encountered to the total depth drilled (20 feet bgs).

Grain size testing (Table 3), hydraulic conductivity measurements (Table 4) and capillary pressure curves (Figure 16) are consistent with fine to coarse sand.

The laboratory photographs of the cores (Figures 12 through 15) show NAPL from approximately 7.9 feet to the total depth sampled (17 feet bgs). The greatest amount of NAPL (i.e., highest fluorescence) occurs from approximately 15.3 to 17 feet bgs, and is present in the sandy layers and not present in the more permeable gravel interbeds.

Table 5 shows that pore fluid consists primarily of water, except for the samples obtained from a depth interval of 16 to 17 feet bgs where NAPL and water saturations were roughly equivalent. Table 6 suggests that the NAPL is extractable from the soil-pore throats during centrifuging at 1,000 times the acceleration due to gravity.

3.3 Task 3 - NAPL Chemical and Physical Characterization

NAPL and groundwater samples were collected on June 7 and 8, 2007, from five wells (RW2L3, RW5L3, RW2L5, CW-4, and CW-5) and submitted to Torkelson Geochemistry, Inc. (TGI) of Tulsa, Oklahoma, for chemical and physical testing. Geochemical and physical properties test results are summarized on Table 7. TGI’s evaluation report, including all gas chromatograms, is provided in Appendix F.

The TGI results show that NAPL at the Site has undergone biological, chemical, and/or physical alteration resulting from exposure to the natural environment (i.e., weathering). Compositions range from weathered diesel (middle distillate) to weathered heavy lube oil-range petroleum hydrocarbons. A chromatogram representative of the NAPL collected from well RW-2L3 and a chromatogram for an unweathered diesel standard are presented in Figure 17. A summary of the effects of NAPL weathering and chromatogram interpretation is presented below.

Gas chromatography (GC) is a primary method for identifying NAPL constituents. NAPL is injected into the GC, and enters a small-diameter coiled capillary tube. As the sample is heated and travels through the capillary tube, NAPL constituents separate by polarity and boiling point. A chromatogram depicts NAPL constituents as they exit the capillary tubing. The chromatograms identify the relative abundance (as peaks depicted on the y-axis) of the individual compounds, and constituents are identified by retention time (depicted as time beneath a peak on the x-axis). Lighter (lower molecular weight) compounds with shorter retention times appear on the left-hand side of a chromatogram. Heavier (higher molecular weight) compounds have longer retention times and appear on the right-hand side of a chromatogram. There are several “marker” compounds that indicate relative degrees of weathering, particularly in diesel-range hydrocarbons. Selected marker compounds are labeled on the chromatogram in Figure 17.

A chromatogram of non-weathered diesel fuel is characterized by an array of repeating peaks of normal alkanes (i.e., a homologous series of compounds including octane [nC8], nonane [nC9], and decane [nC10]). These compounds characteristically appear as the dominant peaks, and are evenly distributed in the middle range of the diesel standard (Figure 17). These compounds are easily weathered and decrease in relative abundance compared to other compounds with increasing weathering. This decrease in normal alkanes accentuates the relative abundance of other marker compounds that are more persistent (i.e., the isoprenoid compounds, labeled as IP12, IP14, etc.). Two specific marker isoprenoids are pristane and phytane, which are located next to nC17 and nC18 alkane peaks. With increasing weathering, these isoprenoid compounds increase relative to the adjacent normal alkanes (Bruce and Schmidt, 1994). The TGI chromatograms show that all of the NAPL samples are so degraded that the normal alkanes are nearly absent on all the GC chromatograms, and the only dominant identifiable peaks are isoprenoids, particularly pristane and phytane (Figure 17).

TGI's analyses show that the NAPL consists of variable amounts of degraded diesel with some heavier lube-oil range hydrocarbons (see Appendix F). The NAPL sampled from RW-2L3 is primarily degraded diesel, while RW-5L3 contains degraded diesel and heavier lube-oil range hydrocarbons. The remainder of NAPL samples indicated a composition intermediate between RW-2L3 and RW-5L3, and so samples RW-2L3 and RW-5L3 were also tested for density and viscosity (Table 7). The density of the NAPL from RW-2L3 of 0.8803 gram/milliliter (gm/ml) is consistent with weathered diesel (non-degraded diesel has a density of about 0.827 gm/ml; API, 2004). The NAPL sample collected from well RW-5L3 has a density of 0.9498 gm/ml, which is consistent with a heavy lube or fuel oil. The viscosity of the RW2L3 sample (8.34 centipoise [cP]) is comparable to the viscosity of No. 2 fuel oil (4.04 cP), and the viscosity of RW-5L3 (633 cP) is comparable No. 6 fuel oil (Bunker C) and other heavier fuels (122 cP to 3,180 cP) (Beckett and Huntley, 2002).

4.0 Summary and Conclusions

Groundwater sampling and NAPL testing indicate the presence of highly weathered petroleum that has been depleted of water-soluble hazardous constituents. Soil testing results also show that the residual NAPL is typically absent from the pore throats of coarser-grained soil, but is present in finer-grained soils which are less amenable to NAPL removal.

Most of the fluid that is pumped by the remediation system consists of water extracted from coarser-grained soils. Recovery data show that the remediation system recovers less than 0.3 percent NAPL by volume.

The results of groundwater monitoring data collected at the Site show that the groundwater cleanup standards have been met and that the remaining residual NAPL is not impacting groundwater. All of the groundwater samples were either non-detect or below the cleanup levels for petroleum compounds, with the exception of one sample from well CW-5, which was marginally above the cleanup level for TPH in January 2008. BTEX, carcinogenic PAHs, naphthalene, and PCBs were not detected in groundwater samples from offsite compliance wells MW-21, MW-22, and MW-23, which are located downgradient or crossgradient from the area that has historically been affected by NAPL. Since dissolved constituents are generally not partitioning from the NAPL to the groundwater in the area downgradient of or below the NAPL, migration to the deeper aquifer is unlikely.

Shaw recommends sampling wells CW-4 and CW-5 for three consecutive quarters to ascertain compliance with the cleanup standards associated with the PPCD. Recommendations for further work should be based on the results of these additional data.

5.0 References

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Limitations

The services described in this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, expressed or implied, is made. These services were performed consistent with our agreement with our client. This report is solely for the use and information of our client unless otherwise noted. Any reliance on this report by a third party is at such party's sole risk.

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, or the use of separated portions of this report.

Tables

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation^a (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
CW-1	11/28/96	17.81	8.06	NP	9.75
	01/27/97		5.46	0.04	12.39*
	05/22/97		7.30	0.05	10.55*
	10/10/97		8.04	0.08	9.84*
	10/31/97		8.42	0.10	9.48*
	11/07/97		7.86	0.25	10.17*
	01/14/98		6.38	0.07	11.49*
	02/26/98		6.26	0.43	11.93*
	04/02/98		6.68	Film	11.13
	04/30/98		7.52	0.01	10.30*
	06/02/98		7.81	1.58	11.41*
	06/30/98		8.36	0.22	9.65*
	07/23/98		8.65	0.30	9.43*
	08/31/98		9.11	0.45	9.10*
	09/30/98		9.31	0.45	8.90*
	10/29/98		9.40	0.42	8.78*
	11/30/98		6.24	NP	11.57
	12/30/98		5.48	NP	12.33
	01/29/99		5.21	NP	12.60
	02/25/99		5.41	NP	12.40
	03/31/99		6.42	NP	11.39
	04/30/99		7.34	Film	10.47
	06/02/99		7.89	NP	9.92
	06/30/99		8.04	NP	9.77
	07/14/99		8.13	NP	9.68
	08/18/99		8.39	NP	9.42
	09/15/99		8.66	Film	9.15
	10/28/99		9.18	0.08	8.70*
	11/24/99		7.00	NP	10.81
	12/21/99		6.64	NP	11.17
	01/18/00		6.94	0.22	11.07*
	03/01/00		6.56	NP	11.25
	03/30/00		6.88	NP	10.93
	04/26/00		7.58	Film	10.23
	05/31/00		8.02	NP	9.79
	06/29/00		8.16	NP	9.65
	07/25/00		8.38	NP	9.43
	08/15/00		8.59	NP	9.22
	09/12/00		8.84	NP	8.97
	10/17/00		9.24	0.22	8.77*
	11/14/00		8.48	0.03	9.36*
	12/29/00		8.11	0.02	9.72*
	01/19/01		8.01	0.03	9.83*
	02/27/01		7.91	0.01	9.91*
	03/26/01		8.28	0.01	9.54*
	04/30/01		8.06	0.01	9.76*
	05/28/01		7.94	0.01	9.88*
	06/25/01		8.29	0.01	9.53*
	07/23/01		8.46	0.01	9.36*
	08/27/01		9.42	0.01	8.40*
	09/23/01		8.65	0.01	9.17*

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation[a] (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
CW-1, cont.	10/25/01		8.75	0.01	9.07*
	11/29/01		6.30	0.01	11.52*
	12/29/01		6.25	NP	11.56
	01/31/02		6.14	NP	11.67
	02/28/02		6.57	Film	11.24
	03/28/02		6.79	NP	11.02
	04/24/02		7.03	NP	10.78
	05/30/02		7.80	NP	10.01
	06/27/02		8.30	NP	9.51
	07/30/02		8.48	NP	9.33
	08/29/02		8.72	Film	9.09
	09/27/02		8.92	Film	8.89
	10/31/02		9.16	0.01	8.66*
	11/26/02		8.70	0.01	9.12*
	12/26/02		7.52	0.03	10.32*
	01/30/03		6.02	NP	11.79
	02/27/03		6.86	NP	10.95
	03/31/03		6.76	NP	11.05
	04/28/03		7.14	NP	10.67
	05/29/03		7.74	NP	10.07
	06/25/03		8.08	NP	9.73
	07/30/03		8.47	Film	9.34
	08/28/03		8.66	NP	9.15
	09/29/03		8.93	Film	8.88
	10/29/03		7.40	NP	10.41
	11/25/03		7.33	NP	10.48
	01/09/04		6.53	NP	11.28
	01/27/04		6.61	NP	11.20
	02/26/04		6.78	NP	11.03
	03/29/04		7.41	Film	10.40
	04/30/04		7.91	NP	9.90
	05/25/04		8.11	NP	9.70
	06/30/04		8.41	NP	9.40
	07/28/04		8.64	NP	9.17
	08/25/04		8.77	NP	9.04
	09/29/04		8.56	NP	9.25
	10/28/04		8.28	NP	9.53
	11/23/04		8.21	NP	9.60
	12/30/04		7.55	NP	10.26
	01/31/05		7.21	NP	10.60
	02/28/05		7.99	NP	9.82
	03/30/05		7.48	NP	10.33
	04/27/05		7.51	NP	10.30
	05/26/05		6.88	NP	10.93
	06/28/05		7.22	NP	10.59
	07/26/05		8.02	NP	9.79
	09/08/05		8.50	0.01	9.31
	09/30/05		8.71	NP	9.10
	10/28/05		8.48	NP	9.33
	11/30/05		7.85	NP	9.96
	12/28/05		6.85	NP	10.96

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation[a] (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
CW-1, cont.	01/27/06		6.06	Film	11.75
	02/27/06		6.74	NP	11.07
	03/28/06		7.06	NP	10.75
	04/25/06		7.14	NP	10.67
	05/30/06		7.54	NP	10.27
	06/27/06		7.64	NP	10.17
	07/24/06		8.02	NP	9.79
	08/30/06		8.39	NP	9.42
	09/29/06		8.77	NP	9.04
	10/31/06		8.79	NP	9.02
	11/30/06		6.60	NP	11.21
	12/28/06		5.86	NP	11.95
	01/31/07		6.68	NP	11.13
	02/28/07		6.63	NP	11.18
	03/28/07		6.42	NP	11.39
	04/30/07		7.23	NP	10.58
	05/23/07		7.61	NP	10.20
	06/29/07		7.98	NP	9.83
	07/30/07		8.01	NP	9.80
	08/29/07		8.32	NP	9.49
	09/27/07		8.57	NP	9.24
	10/25/07		7.92	NP	9.89
	11/28/07		8.05	NP	9.76
	01/09/08		6.87	NP	10.94
	02/13/08		6.85	NP	10.96
	03/19/08		7.45	NP	10.36
CW-2	02/28/07	20.44	8.61	NP	11.83
	03/28/07		8.27	NP	12.17
	04/30/07		8.87	NP	11.57
	05/23/07		9.28	NP	11.16
	06/29/07		9.82	NP	10.62
	07/30/07		9.95	NP	10.49
	08/29/07		10.23	NP	10.21
	09/27/07		10.53	NP	9.91
	10/25/07		9.97	NP	10.47
	11/28/07		10.00	NP	10.44
	01/09/08		8.95	NP	11.49
	02/13/08		8.58	NP	11.86
	03/19/08		9.26	NP	11.18
CW-3	02/28/07	19.31	6.44	NP	12.87
	03/28/07		6.27	NP	13.04
	04/30/07		7.24	NP	12.07
	05/23/07		7.74	NP	11.57
	06/29/07		8.40	NP	10.91
	07/30/07		8.55	NP	10.76
	08/29/07		8.85	NP	10.46
	09/27/07		9.19	NP	10.12
	10/25/07		8.67	NP	10.64
	11/28/07		8.60	NP	10.71
	01/09/08		7.60	NP	11.71

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation[a] (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
CW-3, cont.	02/13/08		7.30	NP	12.01
	03/19/08		7.91	NP	11.40
CW-4	11/28/96	16.50	8.14	2.28	10.39*
	01/27/97		3.65	0.26	13.08*
	05/22/97		5.71	0.26	11.02*
	10/10/97		6.67	1.06	10.77*
	10/31/97		7.03	0.97	10.33*
	11/07/97		6.00	0.19	10.67*
	01/14/98		4.35	Film	12.15
	02/26/98		5.12	Film	11.38
	04/02/98		5.04	0.23	11.66*
	04/30/98		6.77	0.96	10.58*
	06/02/98		7.67	2.25	10.83*
	06/30/98		—	>0.50	—
	07/23/98		—	>0.50	—
	08/31/98		14.26	7.19	8.64*
	09/30/98		—	>0.50	—
	10/29/98		14.10	6.68	8.35*
	11/30/98		8.11	2.05	10.21*
	12/30/98		5.01	1.32	12.66*
	01/29/99		3.11	1.95	15.13*
	02/25/99		4.80	1.65	13.17*
	03/31/99		6.80	2.35	11.79*
	04/30/99		6.78	1.14	10.73*
	06/02/99		9.35	3.27	10.06*
	06/30/99		—	>5.00	—
	07/14/99		11.70	5.27	9.49*
	08/18/99		14.00	6.70	8.46*
	09/15/99		14.00	6.92	8.66*
	10/28/99		14.70	6.70	7.76*
	11/24/99		5.42	Film	11.08
	12/21/99		5.17	Film	11.33
	01/18/00		5.34	0.25	11.38*
	03/01/00		5.33	0.80	11.88*
	03/30/00		5.50	0.37	11.33*
	04/26/00		8.20	2.40	10.44*
	05/31/00		9.82	3.51	9.80*
	06/29/00		14.10	7.64	9.20*
	07/25/00		14.00	7.05	8.77*
	08/15/00		13.51	6.71	8.96*
	09/12/00		13.60	6.61	8.78*
	10/17/00		13.70	6.06	8.19*
	11/14/00		13.78	6.79	8.76*
	12/29/00		7.65	1.39	10.09*
	01/19/01		9.38	2.89	9.69*
	02/27/01		14.95	8.21	8.86*
	03/26/01		NM	NM	NM
	04/30/01		8.48	1.88	9.69*
	05/28/01		15.45	8.05	8.21*
	06/25/01		7.99	0.91	9.32*

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation[a] (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
CW-4, cont.	07/23/01		7.47	0.28	9.28*
	08/27/01		9.96	0.65	7.12*
	09/23/01		8.56	1.41	9.19*
	10/25/01		7.90	0.11	8.70*
	11/29/01		5.26	0.51	11.69*
	12/29/01		6.85	0.12	9.76*
	01/31/02		7.00	0.90	10.30*
	02/28/02		5.05	0.24	11.66*
	03/28/02		5.90	0.10	10.69*
	04/24/02		7.70	1.80	10.40*
	05/30/02		8.90	0.98	8.47*
	06/27/02		11.00	3.40	8.53*
	07/30/02		7.60	0.08	8.97*
	08/29/02		9.00	0.70	8.12*
	09/27/02		8.26	Film	8.24
	10/31/02		8.75	NP	7.75
	11/26/02		8.31	NP	8.19
	12/26/02		11.14	4.34	9.22*
	01/30/03		6.20	NP	10.30
	02/27/03		7.00	1.00	10.39*
	03/31/03		NM	NM	NM
	04/28/03		8.35	2.20	10.11*
	05/29/03		8.70	1.80	9.40*
	06/25/03		NM	NM	NM
	07/30/03		7.50	0.00	9.00
	08/28/03		8.30	0.50	8.65*
	09/29/03		7.90	0.10	8.69*
	10/29/03		7.01	NP	9.49
	11/25/03		6.88	NP	9.62
	01/09/04		5.20	0.10	11.39*
	01/27/04		5.35	NP	11.15
	02/26/04		7.95	2.81	11.05*
	03/29/04		6.30	Film	10.20
	04/30/04		7.70	Film	8.80
	05/25/04		7.75	Film	8.75
	06/30/04		9.50	1.50	8.34*
	07/28/04		8.20	0.79	9.00*
	08/25/04		NM	NM	NM
	09/29/04		NM	NM	NM
	10/28/04		NM	NM	NM
	11/23/04		8.90	1.80	9.20*
	12/30/04		NM[b,c]	NM[b,c]	NM
	01/31/05		NM[b,c]	NM[b,c]	NM
	02/28/05		NM[b,c]	NM[b,c]	NM
	03/30/05		10.53	0.05	NA[b]
	04/27/05		10.65	0.31	NA[b]
	05/26/05		10.55	0.41	NA[b]
	06/28/05	20.53	10.71	0.35	10.13*
	07/26/05		10.83	1.12	10.70*
	09/08/05		NM[c]	NM[c]	NM[c]
	09/30/05		13.28	2.25	9.25*

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation^a (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
CW-4, cont.	10/28/05		13.48	2.17	8.98*
	11/30/05		13.85	3.13	9.47*
	12/28/05		NM	NM	NM
	01/27/06		NM	NM	NM
	02/27/06		NM	NM	NM
	03/28/06		9.96	1.81	12.18*
	04/25/06		10.18	0.10	10.44*
	05/30/06		10.37	0.09	10.24*
	06/27/06		11.30	0.86	10.00*
	07/24/06		13.23	2.38	9.42*
	08/30/06		12.10	1.01	9.33*
	09/29/06		14.30	2.93	8.84*
	10/31/06		12.54	0.88	8.77*
	11/30/06		9.59	0.01	10.95*
	12/28/06		9.35	0.13	11.30*
	01/31/07		10.02	0.38	10.85*
	02/28/07		9.74	0.06	10.84*
	03/28/07		9.03	0.06	11.55*
	04/30/07		10.29	0.28	10.49*
	05/23/07		10.39	0.16	10.28*
	06/29/07		13.38	2.58	9.45*
	07/30/07		10.25	1.46	11.58*
	08/29/07		11.58	0.67	9.55*
	09/27/07		NM^c	NM^c	NM^c
	10/25/07		13.11	2.25	9.42*
	11/28/07		11.00	1.00	10.42*
	01/09/08		16.15	5.26	9.06*
	02/13/08		10.00	0.35	10.84*
	03/19/08		13.20	3.06	10.05*
CW-5	11/28/96	18.76	8.85	0.71	10.54*
	01/27/97		10.65	5.81	13.28*
	05/22/97		9.00	1.70	11.27*
	10/10/97		7.66	0.01	11.11*
	10/31/97		7.76	0.01	11.01*
	11/07/97		7.78	0.01	10.99*
	01/14/98		6.82	0.05	11.98*
	02/26/98		—	>0.84	—
	04/02/98		7.13	0.51	12.08*
	04/30/98		7.69	0.01	11.08*
	06/02/98		8.42	0.86	11.11*
	06/30/98		—	>0.50	—
	07/23/98		—	>0.50	—
	08/31/98		12.73	3.37	9.03*
	09/30/98		—	>0.50	—
	10/29/98		13.29	3.78	8.83*
	11/30/98		5.35	1.05	14.34*
	12/30/98		5.74	0.70	13.64*
	01/29/99		5.01	0.65	14.33*
	02/25/99		5.70	1.49	14.39*
	03/31/99		7.10	1.54	13.03*

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
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Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation[a] (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
CW-5, cont.	04/30/99		8.20	1.34	11.75*
	06/02/99		8.29	0.78	11.16*
	06/30/99		9.65	0.95	9.96*
	07/14/99		8.32	1.88	12.11*
	08/18/99		9.95	1.13	9.82*
	09/15/99		9.92	0.71	9.47*
	10/28/99		9.89	0.17	9.02*
	11/24/99		9.90	3.09	11.61*
	12/21/99		7.69	0.79	11.77*
	01/18/00		7.80	1.19	12.02*
	03/01/00		7.42	1.24	12.44*
	03/30/00		10.80	3.70	11.25*
	04/26/00		8.30	0.25	10.68*
	05/31/00		10.45	2.01	10.10*
	06/29/00		12.65	4.20	9.85*
	07/25/00		12.70	3.12	8.84*
	08/15/00		11.47	2.02	9.09*
	09/12/00		11.61	1.73	8.69*
	10/17/00		11.65	1.68	8.61*
	11/14/00		9.06	Film	9.70*
	12/29/00		7.84	0.08	10.99*
	01/19/01		9.32	0.91	10.25*
	02/27/01		9.51	1.79	10.84*
	03/26/01		8.99	0.04	9.81*
	04/30/01		7.73	0.12	11.14*
	05/28/01		8.85	1.26	11.03*
	06/25/01		9.24	0.21	9.71*
	07/23/01		9.40	0.07	9.42*
	08/27/01		10.13	1.34	9.82*
	09/23/01		11.90	2.84	9.39*
	10/25/01		11.09	2.86	10.22*
	11/29/01		7.90	1.69	12.36*
	12/29/01		7.59	0.88	11.95*
	01/31/02		7.05	1.44	12.99*
	02/28/02		8.90	2.57	12.15*
	03/28/02		8.10	1.70	12.17*
	04/24/02		7.50	1.15	12.28*
	05/30/02		9.80	2.27	10.98*
	06/27/02		10.91	2.59	10.16*
	07/30/02		10.60	1.85	9.81*
	08/29/02		11.65	2.40	9.25*
	09/27/02		11.95	2.50	9.04*
	10/31/02		12.45	2.67	8.69*
	11/26/02		11.35	2.28	9.44*
	12/26/02		10.23	2.95	11.16*
	01/30/03		7.80	2.04	12.78*
	02/27/03		11.60	4.74	11.38*
	03/31/03		9.80	3.00	11.63*
	04/28/03		10.30	3.18	11.29*
	05/29/03		NM	NM	NM
	06/25/03		10.45	1.00	9.20*

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation[a] (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
CW-5, cont.	07/30/03	19.32	11.80	1.90	8.65*
	08/28/03		11.80	4.53	10.99*
	09/29/03		14.10	4.35	8.53*
	10/29/03		8.57	1.13	11.20*
	11/25/03		8.34	0.95	11.27*
	01/09/04		7.90	1.30	12.02*
	01/27/04		9.76	3.35	11.98*
	02/26/04		7.70	1.05	11.99*
	03/29/04		8.85	1.57	11.31*
	04/30/04		10.30	2.31	10.52*
	05/25/04		10.23	1.63	9.98*
	06/30/04		11.40	2.58	9.66*
	07/28/04		10.70	2.10	9.93*
	08/25/04		9.90	0.85	9.62*
	09/29/04		10.91	1.46	9.15*
	10/28/04		10.20	1.65	10.03*
	11/23/04		10.20	1.60	9.98*
	12/30/04		NM[b,c]	NM[b,c]	NM
	01/31/05		14.30	1.50	NA[b]
	02/28/05		NM[b,c]	NM[b,c]	NM
	03/30/05		12.30	2.92	NA[b]
	04/27/05		9.55	1.16	NA[b]
	05/26/05		9.14	1.10	NA[b]
	06/28/05		9.61	0.94	10.55*
	07/26/05		11.11	0.88	8.99*
	09/08/05		11.42	1.54	9.27*
	09/30/05		11.53	1.55	9.17*
	10/28/05		11.43	1.38	9.12*
	11/30/05		10.15	0.69	9.78*
	12/28/05		8.04	0.19	11.45*
	01/27/06		7.28	0.57	12.55*
	02/27/06		7.85	0.67	12.07*
	03/28/06		8.89	1.35	11.63*
	04/25/06		8.88	1.59	11.86*
	05/30/06		8.45	0.41	11.23*
	06/27/06		8.80	0.44	10.91*
	07/24/06		9.84	0.68	10.09*
	08/30/06		11.80	2.23	9.50*
	09/29/06		10.80	0.85	9.28*
	10/31/06		12.27	0.38	7.39*
	11/30/06		8.13	0.74	11.85*
	12/28/06		7.44	0.72	12.52*
	01/31/07		NA	NA	NA
	02/28/07		NA	NA	NA
	03/28/07		7.81	0.97	12.37*
	04/30/07		NA	NA	NA
	05/23/07		NA	NA	NA
	06/29/07		10.21	0.62	9.66*
	07/30/07		11.51	2.12	9.70*
	08/29/07		10.22	0.64	9.67*
	09/27/07		11.01	0.22	8.51*

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation[a] (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
CW-5, cont.	10/25/07		10.22	0.91	9.91*
	11/28/07		9.25	0.20	10.25*
	01/09/08		10.50	2.45	11.00*
	02/13/08		11.87	4.22	11.21*
	03/19/08		11.47	3.31	10.80*
CW-6	02/28/07	20.52	10.22	NP	10.30
	03/28/07		10.24	NP	10.28
	04/30/07		10.89	NP	9.63
	05/23/07		11.04	NP	9.48
	06/29/07		11.21	NP	9.31
	07/30/07		11.22	NP	9.30
	08/29/07		11.52	NP	9.00
	09/27/07		11.74	NP	8.78
	10/25/07		11.38	NP	9.14
	11/28/07		11.25	NP	9.27
	01/09/08		10.32	NP	10.20
	02/13/08		10.59	NP	9.93
	03/19/08		10.99	NP	9.53
CW-7	02/28/07	19.81	9.02	NP	10.79
	03/28/07		9.04	NP	10.77
	04/30/07		9.54	NP	10.27
	05/23/07		9.72	NP	10.09
	06/29/07		9.83	NP	9.98
	07/30/07		9.90	NP	9.91
	08/29/07		10.16	NP	9.65
	09/27/07		10.41	NP	9.40
	10/25/07		10.11	NP	9.70
	11/28/07		10.00	NP	9.81
	01/09/08		9.15	NP	10.66
	02/13/08		9.38	NP	10.43
	03/19/08		9.74	NP	10.07
CW-8	11/28/96	18.28	8.63	0.12	9.76*
	01/27/97		7.54	2.03	12.55*
	05/22/97		8.60	0.80	10.39*
	10/10/97		8.61	0.14	9.79*
	10/31/97		8.78	0.11	9.60*
	11/07/97		8.30	0.01	9.99*
	01/14/98		7.00	Film	11.28
	02/26/98		7.71	0.03	10.60*
	04/02/98		7.44	0.15	10.97*
	04/30/98		8.96	0.85	10.08*
	06/02/98		8.68	0.32	9.88*
	06/30/98		9.17	0.36	9.43*
	07/23/98		9.38	0.41	9.26*
	08/31/98		9.96	0.67	8.92*
	09/30/98		10.13	0.72	8.79*
	10/29/98		10.40	0.91	8.69*
	11/30/98		6.73	0.20	11.73*
	12/30/98		6.48	0.39	12.15*
	01/29/99		6.27	0.58	12.53*

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation[a] (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
CW-8, cont.	02/25/99		6.50	0.75	12.45*
	03/31/99		7.39	0.68	11.50*
	04/30/99		8.48	0.46	10.21*
	06/02/99		8.68	0.15	9.73*
	06/30/99		8.81	0.13	9.59*
	07/14/99		8.91	0.04	9.41*
	08/18/99		9.20	0.06	9.13*
	09/15/99		9.41	0.03	8.90*
	10/28/99		10.75	0.15	7.66*
	11/24/99		7.83	0.10	10.54*
	12/21/99		7.78	0.57	11.01*
	01/18/00		7.92	0.82	11.09*
	03/01/00		7.79	0.38	10.83*
	03/30/00		8.53	0.74	10.41*
	04/26/00		8.96	0.59	9.85*
	05/31/00		9.20	0.41	9.44*
	06/29/00		8.95	0.10	9.42*
	07/25/00		9.39	0.21	9.08*
	08/15/00		9.61	0.32	8.95*
	09/12/00		9.81	0.40	8.83*
	10/17/00		10.64	1.20	8.71*
	11/14/00		9.88	0.57	8.91*
	12/29/00		8.96	0.09	9.40*
	01/19/01		8.85	0.09	9.51*
	02/27/01		8.82	0.09	9.54*
	03/26/01		9.41	0.15	9.00*
	04/30/01		8.80	0.09	9.56*
	05/28/01		8.70	0.09	9.66*
	06/25/01		8.70	0.09	9.66*
	07/23/01		9.18	0.03	9.13*
	08/27/01		9.20	0.05	9.12*
	09/23/01		9.37	0.08	8.98*
	10/25/01		9.67	0.22	8.81*
	11/29/01		7.21	0.02	11.09*
	12/29/01		6.95	0.03	11.36*
	01/31/02		6.72	NP	11.56
	02/28/02		7.10	0.01	11.19*
	03/28/02		7.35	0.01	10.94*
	04/24/02		7.67	0.02	10.63*
	05/30/02		8.38	NP	9.90
	06/27/02		8.84	NP	9.44
	07/30/02		9.13	0.02	9.17*
	08/29/02		9.42	0.05	8.90*
	09/27/02		9.68	0.10	8.69*
	10/31/02		9.95	0.22	8.53*
	11/26/02		9.53	0.10	8.84*
	12/26/02		8.12	NP	10.16
	01/30/03		6.32	NP	11.96
	02/27/03		7.54	NP	10.74
	03/31/03		7.42	NP	10.86
	04/28/03		7.88	NP	10.40

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation^a (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
CW-8, cont.	05/29/03	19.61	8.63	NP	9.65
	06/25/03		8.97	NP	9.31
	07/30/03		9.20	Film	9.08
	08/28/03		9.31	NP	8.97
	09/29/03		9.55	Film	8.73
	10/29/03		8.12	NP	10.16
	11/25/03		8.17	NP	10.11
	01/09/04		7.51	NP	10.77
	01/27/04		7.29	NP	10.99
	02/26/04		7.51	Film	10.77
	03/29/04		8.20	NP	10.08
	04/30/04		8.72	NP	9.56
	05/25/04		8.82	NP	9.46
	06/30/04		9.00	NP	9.28
	07/28/04		9.12	NP	9.16
	08/25/04		9.24	NP	9.04
	09/29/04		9.18	NP	9.10
	10/28/04		8.80	NP	9.48
	11/23/04		8.95	NP	9.33
	12/30/04		13.05	NP	NA^b
	01/31/05		12.72	Film	NA^b
	02/28/05		10.49	NP	NA^b
	03/30/05		8.98	NP	NA^b
	04/27/05		9.88	NP	NA^b
	05/26/05		9.17	NP	NA^b
	06/28/05		9.55	NP	10.06
	07/26/05		10.22	NP	9.39
	09/08/05		10.66	NP	8.95
	09/30/05		9.73	Film	9.88
	10/28/05		10.67	Film	8.94
	11/30/05		9.99	Film	9.62
	12/28/05		8.72	NP	10.89
	01/27/06		8.16	Film	11.45
	02/27/06		8.91	NP	10.70
	03/28/06		8.94	NP	10.67
	04/25/06		9.33	NP	10.28
	05/30/06		9.59	NP	10.02
	06/27/06		9.97	NP	9.64
	07/24/06		10.19	NP	9.42
	08/30/06		10.56	NP	9.05
	09/29/06		10.86	NP	8.75
	10/31/06		11.02	NP	8.59
	11/30/06		8.95	NP	10.66
	12/28/06		8.34	NP	11.27
	01/31/07		9.07	NP	10.54
	02/28/07		8.79	NP	10.82
	03/28/07		8.23	NP	11.38
	04/30/07		9.51	NP	10.10
	05/23/07		9.68	NP	9.93
	06/29/07		10.19	NP	9.42
	07/30/07		10.21	NP	9.40

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation^a (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
CW-8, cont.	08/29/07		10.46	NP	9.15
	09/27/07		10.71	NP	8.90
	10/25/07		10.21	NP	9.40
	11/28/07		10.21	NP	9.40
	01/09/08		8.51	NP	11.10
	02/13/08		8.89	NP	10.72
	03/19/08		9.58	NP	10.03
CW-9	02/28/07	18.06	9.16	NP	8.90
	03/28/07		9.07	NP	8.99
	04/30/07		9.43	NP	8.63
	05/23/07		9.53	NP	8.53
	06/29/07		9.64	NP	8.42
	07/30/07		9.81	NP	8.25
	08/29/07		9.97	NP	8.09
	09/27/07		10.10	NP	7.96
	10/25/07		9.88	NP	8.18
	11/28/07		9.78	NP	8.28
	01/09/08		9.22	NP	8.84
	02/13/08		9.18	NP	8.88
	03/19/08		9.59	NP	8.47
MW-7	02/28/07	19.85	5.87	NP	13.98
	03/28/07		5.67	NP	14.18
	04/30/07		6.76	NP	13.09
	05/23/07		7.25	NP	12.60
	06/29/07		8.10	NP	11.75
	07/30/07		8.21	NP	11.64
	08/29/07		8.49	NP	11.36
	09/27/07		8.78	NP	11.07
	10/25/07		8.04	NP	11.81
	11/28/07		7.05	NP	12.80
	01/09/08		7.18	NP	12.67
	02/13/08		7.92	NP	11.93
	03/19/08		7.40	NP	12.45
MW-21	02/28/07	17.70	6.78	NP	10.92
	03/28/07		6.64	NP	11.06
	04/30/07		7.63	NP	10.07
	05/23/07		7.84	NP	9.86
	06/29/07		8.15	NP	9.55
	07/30/07		8.18	NP	9.52
	08/29/07		8.44	NP	9.26
	09/27/07		8.69	NP	9.01
	10/25/07		8.16	NP	9.54
	11/28/07		8.16	NP	9.54
	01/09/08		6.94	NP	10.76
	02/13/08		7.18	NP	10.52
	03/19/08		7.92	NP	9.78
MW-22	02/28/07	17.55	6.87	NP	10.68
	03/28/07		6.83	NP	10.72
	04/30/07		7.67	NP	9.88
	05/23/07		7.82	NP	9.73

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation^{a} (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
MW-22, cont.	06/29/07		8.14	NP	9.41
	07/30/07		8.01	NP	9.54
	08/29/07		8.38	NP	9.17
	09/27/07		8.60	NP	8.95
	10/25/07		8.15	NP	9.40
	11/28/07		8.08	NP	9.47
	01/09/08		6.98	NP	10.57
	02/13/08		7.27	NP	10.28
	03/19/08		7.76	NP	9.79
MW-23	02/28/07	17.36	5.53	NP	11.83
	03/28/07		5.26	NP	12.10
	04/30/07		6.45	NP	10.91
	05/23/07		6.84	NP	10.52
	06/29/07		7.41	NP	9.95
	07/30/07		7.50	NP	9.86
	08/29/07		7.69	NP	9.67
	09/27/07		8.14	NP	9.22
	10/25/07		7.36	NP	10.00
	11/28/07		7.33	NP	10.03
	01/09/08		5.92	NP	11.44
	02/13/08		5.91	NP	11.45
	03/19/08		6.91	NP	10.45
MW-29	11/28/96	15.45	NM	NM	NM
	01/27/97		2.25	NP	13.20
	05/22/97		NM	NM	NM
	10/10/97		1.82	0.01	13.64*
	10/31/97		1.25	Film	14.20
	11/07/97		1.21	Film	14.24
	01/14/98		0.26	0.01	15.20*
	02/26/98		0.78	Film	14.67
	04/02/98		1.18	Film	14.27
	04/30/98		1.96	0.01	13.50*
	06/02/98		1.68	Film	13.77
	06/30/98		2.36	0.03	13.12*
	07/23/98		2.64	0.03	12.84*
	08/31/98		3.12	0.01	12.34*
	09/30/98		3.42	0.01	12.04*
	10/29/98		3.42	NP	12.03
	11/30/98		1.09	NP	14.36
	12/30/98		0.61	NP	14.84
	01/29/99		0.00	NP	>15.45
	02/25/99		0.00	NP	>15.45
	03/31/99		0.00	NP	>15.45
	04/30/99		1.08	NP	14.37
	06/02/99		2.02	Film	13.43
	06/30/99		2.26	NP	13.19
	07/14/99		2.51	Film	12.94
	08/18/99		2.85	NP	12.60
	09/15/99		3.18	NP	12.27
	10/28/99		3.42	NP	12.03

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation[a] (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
MW-29, cont.	11/24/99		1.80	NP	13.65
	12/21/99		0.99	Film	14.46
	01/18/00		1.22	Film	14.23
	03/01/00		0.00	NP	>15.45
	03/30/00		0.41	Film	15.04
	04/26/00		1.21	Film	14.24
	05/31/00		2.18	Film	13.27
	06/29/00		2.56	NP	12.89
	07/25/00		2.80	NP	12.65
	08/15/00		3.06	NP	12.39
	09/12/00		3.10	NP	12.35
	10/17/00		3.22	NP	12.23
	11/14/00		2.78	NP	12.67
	12/29/00		2.61	NP	12.84
	01/19/01		2.79	NP	12.66
	02/27/01		2.42	NP	13.03
	03/26/01		2.26	NP	13.19
	04/30/01		1.80	NP	13.65
	05/28/01		2.71	NP	12.74
	06/25/01		2.69	NP	12.76
	07/23/01		2.98	NP	12.47
	08/27/01		2.97	NP	12.48
	09/23/01		3.51	NP	11.94
	10/25/01		3.29	NP	12.16
	11/29/01		0.73	NP	14.72
	12/29/01		0.21	NP	15.24
	01/31/02		0.27	Film	15.18
	02/28/02		0.60	NP	14.85
	03/28/02		0.48	Sheen	14.97
	04/24/02		1.41	NP	14.04
	05/30/02		2.26	NP	13.19
	06/27/02		2.53	NP	12.92
	07/30/02		2.90	NP	12.55
	08/29/02		3.21	NP	12.24
	09/27/02		3.49	NP	11.96
	10/31/02		3.74	NP	11.71
	11/26/02		3.33	NP	12.12
	12/26/02		2.37	NP	13.08
	01/30/03		0.72	NP	14.73
	02/27/03		1.74	Film	13.71
	03/31/03		1.12	Film	14.33
	04/28/03		1.33	Film	14.12
	05/29/03		2.28	NP	13.17
	06/25/03		2.70	NP	12.75
	07/30/03		3.12	Film	12.33
	08/28/03		3.42	NP	12.03
	09/29/03		3.62	NP	11.83
	10/29/03		2.11	NP	13.34
	11/25/03		1.38	NP	14.07
	01/09/04		0.51	NP	14.94
	01/27/04		0.59	Film	14.86

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation[a] (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
MW-29, cont.	02/26/04	18.01	0.61	Film	14.84
	03/29/04		1.25	Film	14.20
	04/30/04		2.22	0.01	13.23
	05/25/04		2.60	0.02	12.87*
	06/30/04		2.88	NP	12.57
	07/28/04		3.23	NP	12.22
	08/25/04		3.11	NP	12.34
	09/29/04		3.10	Film	12.35
	10/28/04		2.82	NP	12.63
	11/23/04		3.05	NP	12.40
	12/30/04		9.36	NP	NA[b]
	01/31/05		9.06	0.01	NA[b]
	02/28/05		5.36	NP	NA[b]
	03/30/05		4.56	NP	NA[b]
	04/27/05		4.52	NP	NA[b]
	05/26/05		4.39	NP	NA[b]
	06/28/05		5.12	NP	12.89
	07/26/05		5.55	NP	12.46
	09/08/05		6.14	0.01	11.87
	09/30/05		6.30	Film	11.71
	10/28/05		6.38	Heavy Sheen	11.63
	11/30/05		4.98	Film	13.03
	12/28/05		3.92	NP	14.09
	01/27/06		3.61	Film	14.40
	02/27/06		4.22	Sheen	13.79
	03/28/06		4.57	Sheen	13.44
	04/25/06		4.74	NP	13.27
	05/30/06		4.91	NP	13.10
	06/27/06		5.22	Sheen	12.79
	07/24/06		5.54	NP	12.47
	08/30/06		6.00	0.01	12.01
	09/29/06		6.37	0.01	11.64
	10/31/06		6.48	Sheen	11.53
	11/30/06		4.35	NP	13.66
	12/28/06		3.41	NP	14.60
	01/31/07		3.99	NP	14.02
	02/28/07		3.72	NP	14.29
	03/28/07		3.24	NP	14.77
	04/30/07		4.49	NP	13.52
	05/23/07		4.76	NP	13.25
	06/29/07		5.55	Sheen	12.46
	07/30/07		5.60	Sheen	12.41
	08/29/07		5.96	Sheen	12.05
	09/27/07		6.20	Sheen	11.81
	10/25/07		4.32	NP	13.69
	11/28/07		5.50	NP	12.51
	01/09/08		4.45	NP	13.56
	02/13/08		4.55	NP	13.46
	03/19/08		4.89	NP	13.12

Table 1
Groundwater Elevation and NAPL Thickness Monitoring Results
Port of Tacoma Former Milwaukie Railyard Site
Tacoma, WA

Well Number	Date Collected	Top of Casing Elevation^a (feet)	Depth to Groundwater (feet)	Product Thickness (feet)	Groundwater Elevation (feet)
OB-2	02/28/07	18.95	4.63	NP	14.32
	03/28/07		4.53	NP	14.42
	04/30/07		6.05	NP	12.90
	05/23/07		6.52	NP	12.43
	06/29/07		7.12	NP	11.83
	07/30/07		7.23	NP	11.72
	08/29/07		7.67	NP	11.28
	09/27/07		7.95	NP	11.00
	10/25/07		7.33	NP	11.62
	11/28/07		7.13	NP	11.82
	01/09/08		6.57	NP	12.38
	02/13/08		6.27	NP	12.68
	03/19/08		6.81	NP	12.14

Notes:

NA = not available.

NAPL = Nonaqueous phase liquid

NM = depths to groundwater and free product were not measured.

NP = free product was not detected in the well.

--- = not sampled.

* = Groundwater elevation corrected for product thickness by the equation: TOC - (DTW)-[PT x 0.89]; where TOC = top of casing elevation, DTW = depth to groundwater, PT = product thickness, and 0.89 = specific gravity of product.

To minimize table length and still provide seasonal data, this table contains the last 13 months of groundwater monitoring data for wells that have never contained free product.

This table contains all of the monitoring data collected since November 1996 for wells that have contained product.

Observation well OB-N was removed in December 2004 during site development activities.

[a] Top of casing elevations are based on 1997 survey results.

Top of casing elevations for CW-2, CW-6, and CW-7 were resurveyed on January 9, 2004.

Top of casing elevations for CW-2, CW-3, CW-4, CW-5, CW-8, OB-S and MW-29 were resurveyed on June 10, 2005.

b Casing has been altered due to site development work; groundwater elevations are not available.

c Viscosity of product did not allow for accurate measurement of product thickness or groundwater depth.

Table 2
Summary of Goundwater Analytical Results
Port of Tacoma Former Milwaukee Railyard Site
Tacoma, Washington

Well Number	Date Sampled	NWTPH-Dx (Diesel)	NWTPH-Dx (Oil)	Benzene	Toluene	Ethylbenzene	Total Xyenes	Benzo(a)anthracene	Chrysene	Benzo(a)pyrene	Indeno(1,2,3-cd)pyrene	Dibenzo(a,h)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Naphthalene	PCBs^{a}
		TPH (mg/L)		BTEX (µg/L)				*c*-PAHs + Naphthalene (µg/L)								PCBs (µg/L)
CW-1	7/28/04	**2.93**	**2.27**	---	---	---	---	---	---	---	---	---	---	---	---	---
	1/10/08	**0.48**	<0.26	---	---	---	---	---	---	---	---	---	---	---	---	---
	3/20/08	**2.4**	**2.4**	---	---	---	---	---	---	---	---	---	---	---	---	---
CW-2	7/28/04	<0.118	<0.237	---	---	---	---	---	---	---	---	---	---	---	---	---
	1/11/08	<0.13	<0.26	---	---	---	---	---	---	---	---	---	---	---	---	---
	3/20/08	<0.13	<0.26	---	---	---	---	---	---	---	---	---	---	---	---	---
CW-3	7/29/04	<0.12	<0.24	---	---	---	---	---	---	---	---	---	---	---	---	---
	1/11/08	**0.46**	<0.26	---	---	---	---	---	---	---	---	---	---	---	---	---
	3/20/08	**0.23**	<0.25	---	---	---	---	---	---	---	---	---	---	---	---	---
CW-4	1/10/08	**1.9**	**0.62**	---	---	---	---	---	---	---	---	---	---	---	---	---
	3/20/08	**2.3**	**1.2**	---	---	---	---	---	---	---	---	---	---	---	---	---
CW-5	1/10/08	**13**	**2.8**	---	---	---	---	---	---	---	---	---	---	---	---	---
	3/20/08	**4.7**	**2.0**	---	---	---	---	---	---	---	---	---	---	---	---	---
CW-6	7/28/04	<0.119	<0.239	---	---	---	---	---	---	---	---	---	---	---	---	---
	1/11/08	<0.13	<0.26	---	---	---	---	---	---	---	---	---	---	---	---	---
	3/20/08	<0.13	<0.26	---	---	---	---	---	---	---	---	---	---	---	---	---
CW-7	7/28/04	<0.12	<0.241	---	---	---	---	---	---	---	---	---	---	---	---	---
	1/11/08	<0.13	<0.26	---	---	---	---	---	---	---	---	---	---	---	---	---
	3/19/08	<0.13	<0.26	---	---	---	---	---	---	---	---	---	---	---	---	---
CW-8	7/28/04	**8.46**	**1.29**	---	---	---	---	---	---	---	---	---	---	---	---	---
	1/11008	**0.62**	**0.31**	---	---	---	---	---	---	---	---	---	---	---	---	---
	3/20/08	**0.93**	<0.26	---	---	---	---	---	---	---	---	---	---	---	---	---
CW-9	7/28/04	<0.121	<0.242	---	---	---	---	---	---	---	---	---	---	---	---	---
	1/9/08	<0.13	<0.26	---	---	---	---	---	---	---	---	---	---	---	---	---
	3/19/08	<0.13	<0.26	---	---	---	---	---	---	---	---	---	---	---	---	---

Table 2
Summary of Goundwater Analytical Results
Port of Tacoma Former Milwaukee Railyard Site
Tacoma, Washington

		NWTPH-Dx (Diesel)	NWTPH-Dx (Oil)	Benzene	Toluene	Ethylbenzene	Total Xyenes	Benzo(a)anthracene	Chrysene	Benzo(a)pyrene	Indeno(1,2,3-cd)pyrene	Dibenzo(a,h)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Naphthalene	PCBs^a
Well Number	Date Sampled	TPH (mg/L)		BTEX (μg/L)				*c*-PAHs + Naphthalene (μg/L)								PCBs (μg/L)
MW-7	7/29/04	<0.12	<0.239	---	---	---	---	---	---	---	---	---	---	---	---	---
	1/10/08	**0.33**	**0.52**	---	---	---	---	---	---	---	---	---	---	---	---	---
	3/19/08	<0.13	<0.26	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-21	7/29/04	<0.12	<0.24	---	---	---	---	---	---	---	---	---	---	---	---	---
	1/11/08	<0.13	<0.26	<1.0	<1.0	<1.0	<3.0	<0.31	<0.21	<0.21	<0.31	<0.31	<0.42	<0.31	<2.1	<0.53
	3/21/08	<0.13	<0.26	<1.0	<1.0	<1.0	<3.0	<0.30	<0.20	<0.20	<0.30	<0.30	<0.40	<0.30	<2.0	<0.51
MW-22	7/29/04	<0.12	<0.241	---	---	---	---	---	---	---	---	---	---	---	---	---
	1/11/08	**0.13**	<0.26	<1.0	<1.0	<1.0	<3.0	<0.31	<0.20	<0.20	<0.31	<0.31	<0.41	<0.31	<2.0	<0.50
	3/21/08	<0.13	<0.25	<1.0	<1.0	<1.0	<3.0	<0.31	<0.20	<0.20	<0.31	<0.31	<0.41	<0.31	<2.0	<0.50
MW-23	7/28/04	<0.124	<0.248	---	---	---	---	---	---	---	---	---	---	---	---	---
	1/11/08	<0.13	<0.25	<1.0	<1.0	<1.0	<3.0	<0.31	<0.21	<0.21	<0.31	<0.31	<0.42	<0.31	<2.1	<0.50
	3/21/08	<0.13	<0.26	<1.0	<1.0	<1.0	<3.0	<0.31	<0.20	<0.20	<0.31	<0.31	<0.41	0.31	<2.0	<0.50
MW-29	7/29/04	**0.453**	**0.716**	---	---	---	---	---	---	---	---	---	---	---	---	---
	1/10/08	<0.13	<0.25	---	---	---	---	---	---	---	---	---	---	---	---	---
	3/19/08	**0.33**	**0.66**	---	---	---	---	---	---	---	---	---	---	---	---	---

Notes:
BTEX = Benzene, toluene, ethylbenzene, and total xylenes (analyzed by EPA Method 8260B)
c- PAHs = Carcinogenic PAHs (analyzed by EPA Method 8270C)
NWTPH-Dx = Northwest test Method NWTPH-Dx
PAHs = Polynuclear aromatic hydrocarbons
PCBs = Polychlorinated biphenyls (analyzed by EPA Method 8082)
TPH = Total petroleum hydrocarbons (analyzed by Northwest Test Method NWTPH-Dx)
<1.0 = Constituent was not detected at or above the method reporting limit listed.
mg/L = Milligrams per liter (or parts per million)
μg/L = Micrograms per liter (or parts per billion)
--- = Not analyzed

[a] Individual PCB arochlors were not detected at the method reporting limit listed.

Table 3
Soil core Physical Properties Data - Grain Size Analysis
Port of Tacoma Former Milwaukee Railyard Site
Tacoma, Washington

Boring Number	Date Sampled	Sample Depth (feet bgs)	Particle Size Data								
			Mean Grain Size Description[a]	Mean Grain Size (mm)	Particle Size Distribution (% weight)						
					Gravel	Sand Size			Silt	Clay	Silt and Clay
						Coarse	Medium	Fine			
SC-1	6/14/2008	8.9	fine sand	0.335	0.00	0.00	40.06	54.75	3.80	1.39	5.19
SC-1	6/14/2008	11.65	fine sand	0.215	0.00	0.00	15.20	75.59	7.24	1.97	9.21
SC-1	6/14/2008	12.2	fine sand	0.348	0.00	0.00	41.22	53.86	3.67	1.25	4.92
SC-2	6/14/2008	8.7	medium sand	1.061	2.43	27.92	40.33	19.71	b	b	9.61
SC-2	6/14/2008	10.7	coarse sand	0.41	33.14	3.00	13.11	39.43	b	b	11.32
SC-2	6/14/2008	16.1	medium sand	0.504	0.00	0.00	62.03	34.30	2.85	0.81	3.66
SC-2	6/14/2008	16.6	fine sand	0.389	0.00	0.00	45.91	49.51	3.43	1.15	4.58

Notes:
bgs = below ground surface
mm = millimeter

[a] Based on mean from Trask.

[b] Mechanical sieve does not differentiate silt/clay fractions.

Table 4
Soil Core Physical Properties Data - Permeability and Hydraulic Conductivity
Port of Tacoma Former Milwaukee Railyard Site
Tacoma, Washington

					25 psi Confining Stress [a]		
Boring Number	Date Sampled	Soil Core Identification	Sample Depth (feet bgs)	Sample Orientation	Specific Permeability to Air [b] (millidarcy)	Effective Permeability to Water [c, d] (millidarcy)	Hydraulic Conductivity [c, d] (cm/s)
SC-1	6/14/2008	SC-1-10.5'-13.0'	11.8	Horizontal	5,346	2,410	0.00221
SC-2	6/14/2008	SC-2-15.0'-17.5'	15.95	Horizontal	4,841	2,178	0.00198
SC-2	6/14/2008	SC-2-15.0'-17.5'	16.75	Horizontal	6,139	3,858	0.00353

Notes:
bgs = below ground surface
cm/s = centimeters per second
psi = pounds per square inch

[a] Test Methods API 40/EPA 9100.

[b] Specific = no pore fluids in place.

[c] Native state or effective = with as-received pore fluids in place.

[d] Permeability to water and hydraulic conductivity measured at saturated conditions.

Table 5
Soil Core Physical Properties Data - Pore Fluid Saturations
Port of Tacoma Former Milwaukee Railyard Site
Tacoma, Washington

Boring Number	Date Sampled	Soil Core Identification	Sample Depth (feet bgs)	Sample Orientation	Moisture Content [a] (% weight)	Density [b]		Porosity [b, c]		Pore Fluid Saturation [b, d]	
						Bulk (g/cc)	Grain (g/cc)	Total (% Vb)	Air Filled (% Vb)	Water (% Pv)	LNAPL (% Pv)
SC-1	6/14/2008	SC-1-8.0'-10.5'	8.9	Horizontal	25.8	1.49	2.70	44.8	5.7	79.1	8.1
SC-1	6/14/2008	SC-1-10.5'-13.0'	11.65	Horizontal	24.1	1.46	2.69	45.6	9.8	69.6	8.8
SC-1	6/14/2008	SC-1-10.5'-13.0'	12.2	Horizontal	16.0	1.50	2.69	44.3	20.2	51.5	2.9
SC-2	6/14/2008	SC-2-7.5'-10.0'	8.7	Horizontal	67.4	0.82	2.07	60.5	4.7	64.2	28.1
SC-2	6/14/2008	SC-2-10.0'-12.5'	10.7	Horizontal	10.4	2.00	2.70	26.1	4.8	57.0	24.6
SC-2	6/14/2008	SC-2-15.0'-17.5'	16.1	Horizontal	24.2	1.53	2.73	44.0	6.0	40.1	46.3
SC-2	6/14/2008	SC-2-15.0'-17.5'	16.6	Horizontal	27.9	1.46	2.70	45.9	4.0	46.0	45.3

Notes:
bgs = below ground surface
g/cc = grams per cubic centimeter
Pv = pore volume
Vb = bulk volume

[a] Test Methods API RP40/ASTM D2216.

[b] Test Method API RP 40.

[c] Total porosity = no pore fluids in place, all interconnected pore channels. Air filled porisity = pore channels not occupied by pore fluids.

[d] Water = 0.9996 g/cc, SC-1 hydrocarbon = 0.8803 g/cc, SC-2 hydrocarbon = 0.9498 g/cc.

Table 6
Soil Core Physical Properties Data - NAPL Mobility, Initial and Residual Saturations
Port of Tacoma Former Milwaukee Railyard Site
Tacoma, Washington

					Density [a]			Pore Fluid Saturations [b, c] (% Pv)			
								Initial Fluid Saturations		After Centrifuge at 1000xG	
Boring Number	Date Sampled	Soil Core Identification	Sample Depth (feet bgs)	Sample Orientation	Bulk (g/cc)	Grain (g/cc)	Total Porosity [a] (% Vb)	Water (Swi)	LNAPL (Soil)	Water (Srw)	LNAPL (Sor)
SC-1	6/14/2008	SC-1-10.5'-13.0'	11.9	Horizontal	1.53	2.67	42.6	79.7	2.0	11.1	2.0
Note: No visible NAPL produced. Produced water slightly cloudy with strong hydrocarbon odor.											
SC-2	6/14/2008	SC-2-15.0'-17.5'	15.9	Horizontal	1.51	2.68	43.7	63.9	23.9	11.4	9.3
Note: Black NAPL produced. Produced clear water.											
SC-2	6/14/2008	SC-2-15.0'-17.5'	16.9	Horizontal	1.58	2.73	42	48.7	46.1	9.1	15.0
Note: Dark brown NAPL produced. Produced clear water.											

Notes:
1000xG = one thousand times the force of gravity.
bgs = below ground surface
g/cc = grams per cubic centimeter
NAPL = Nonaqueous phase liquid
Pv = pore volume
Soi = Initial NAPL saturation as received prior to centrifuging at 1000xG
Sor = Residual NAPL saturation after centrifuging at 1000xG
Srw = Residual water saturation after centrifuging at 1000xG
Swi = Initial water saturation as received prior to centrifuging at 1000xB
Vb = bulk volume

[a] Test Method API RP40.

[b] Test Method ASTM D425M, Dean-Stark.

[c] Water = 0.9996 g/cc, SC-1 LNAPL = 0.8803 g/cc, SC-2 LNAPL = 0.9498 g/cc.

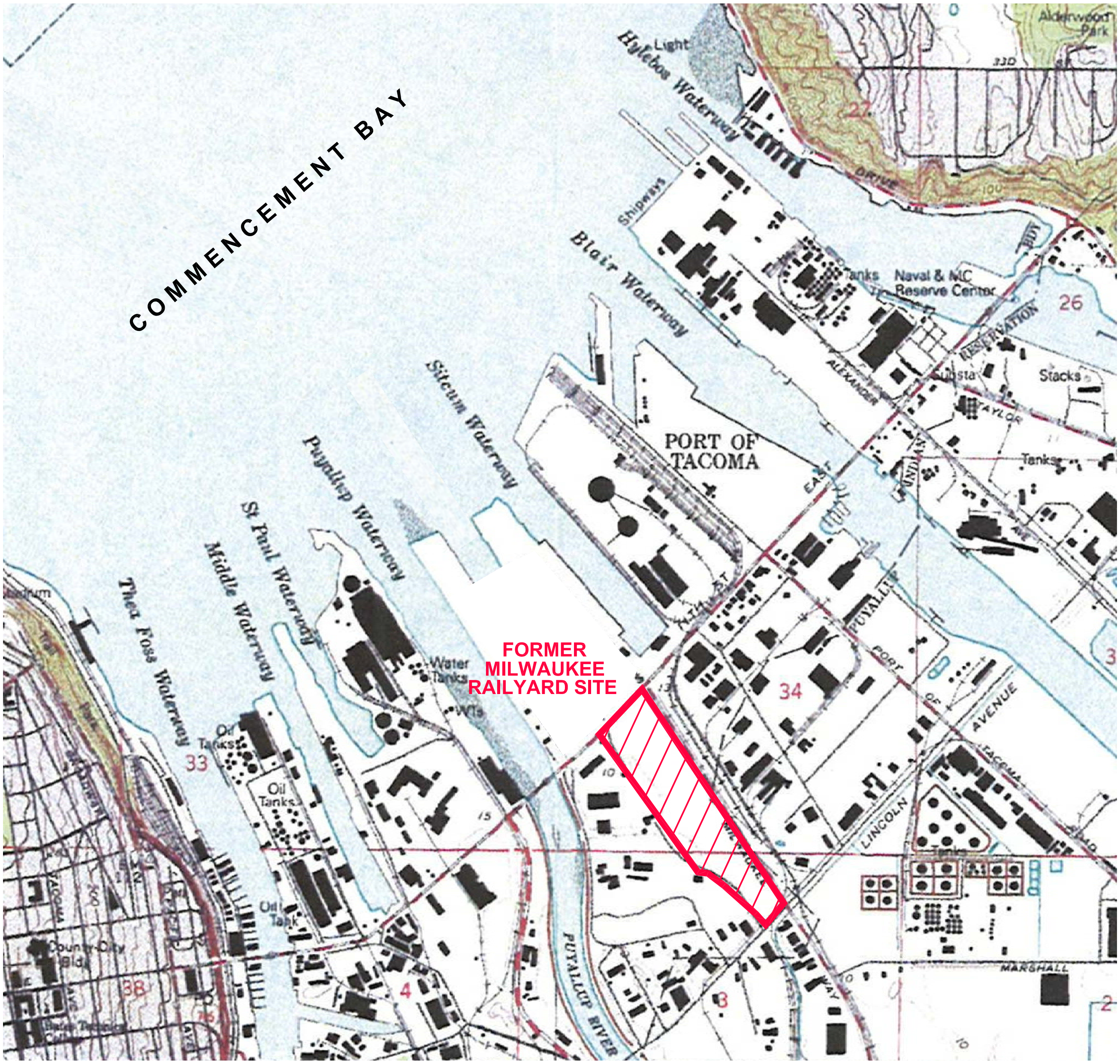
Table 7
NAPL and Groundwater Geochemical and Physical Properties
Port of Tacoma Former Milwaukee Railyard Site
Tacoma, Washington

Well Number	Date Sampled	Geochemical Characterization[a]	Density (gm/ml)	Viscosity (centipoise)	Surface Tension Air/Water (dynes/cm)	Surface Tension NAPL/Water (dynes/cm)	Interfacial Tension Air/NAPL (dynes/cm)	Temperature of Measurements (°F)
CW-4 (NAPL)	6/8/2007	Extremely weathered middle distillate and a heavier material	---	---	---	---	---	---
CW-5 (NAPL)	6/7/2007	Extremely weathered middle distillate and a heavier material	---	---	---	---	---	---
RW-2L3 (NAPL)	6/8/2007	Extremely weathered middle distillate and perhaps a very small amount of heavier material	0.8803	8.34	58.4	7.1	24.6	60
RW-2L5 (NAPL)	6/7/2007	Extremely weathered middle distillate and perhaps a very small amount of heavier material	---	---	---	---	---	---
RW-5L3 (NAPL)	6/7/2007	Extremely weathered middle distillate and a heavier material	0.9498	633.00	56.5	13.7	29.6	60
RW-5L3 (water extract)	6/7/2007	Extremely weathered middle distillate and perhaps a small amount of heavier material	---	---	---	---	---	---

Notes:

°F = degrees fahrenheit
dynes/cm = dynes per centimeter
gm/ml = grams per milliliter
NAPL = nonaqueous phase liquid
--- = not tested

[a] Based on hydrocarbon characterization using gas chromatography (GC) to characterize the composition of petroleum hydrocarbons and the degree of weathering.



MODIFIED FROM U.S.G.S 7.5 MINUTE TOPOGRAPHY MAP,
TACOMA NORTH, WASHINGTON, 1994

NOT TO SCALE

Shaw® Shaw Environmental, Inc.

DATE 8/08
DWN JC
APP DL
REV
PROJECT NO.
130415

FIGURE 1

SITE LOCATION MAP

PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

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LEGEND:

CW-1 ⊕ Compliance Monitoring Well (NAPL Measured Historically)
CW-4 ⊕ Compliance Monitoring Well (NAPL Measured Currently)
CW-4 ⊕ Compliance Monitoring Well (No NAPL Measured Historically)
SC-1 ⊕ Approximate Soil Core Borehole Location Drilled and Sampled by Shaw (February 2008)
RW1L7 Groundwater Recovery Well

NOTE:
Measurable NAPL historically last observed in CW-1 on 9/08/2005; in CW-8 on 11/26/2002; and MW-29 on 9/29/2006.

N

S C A L E
0 300 600 FEET

REV	DATE	DESCRIPTION	DWN BY	DES BY	CHK BY	APP BY

DATE OF ISSUE 8/08
DWN BY JC
DES BY DL
CHK BY
APP BY

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FIGURE 2
SITE MAP WITH WELL AND SOIL CORE LOCATIONS
PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

PROJECT NO.
111487

1" 1/2" 0" 1"

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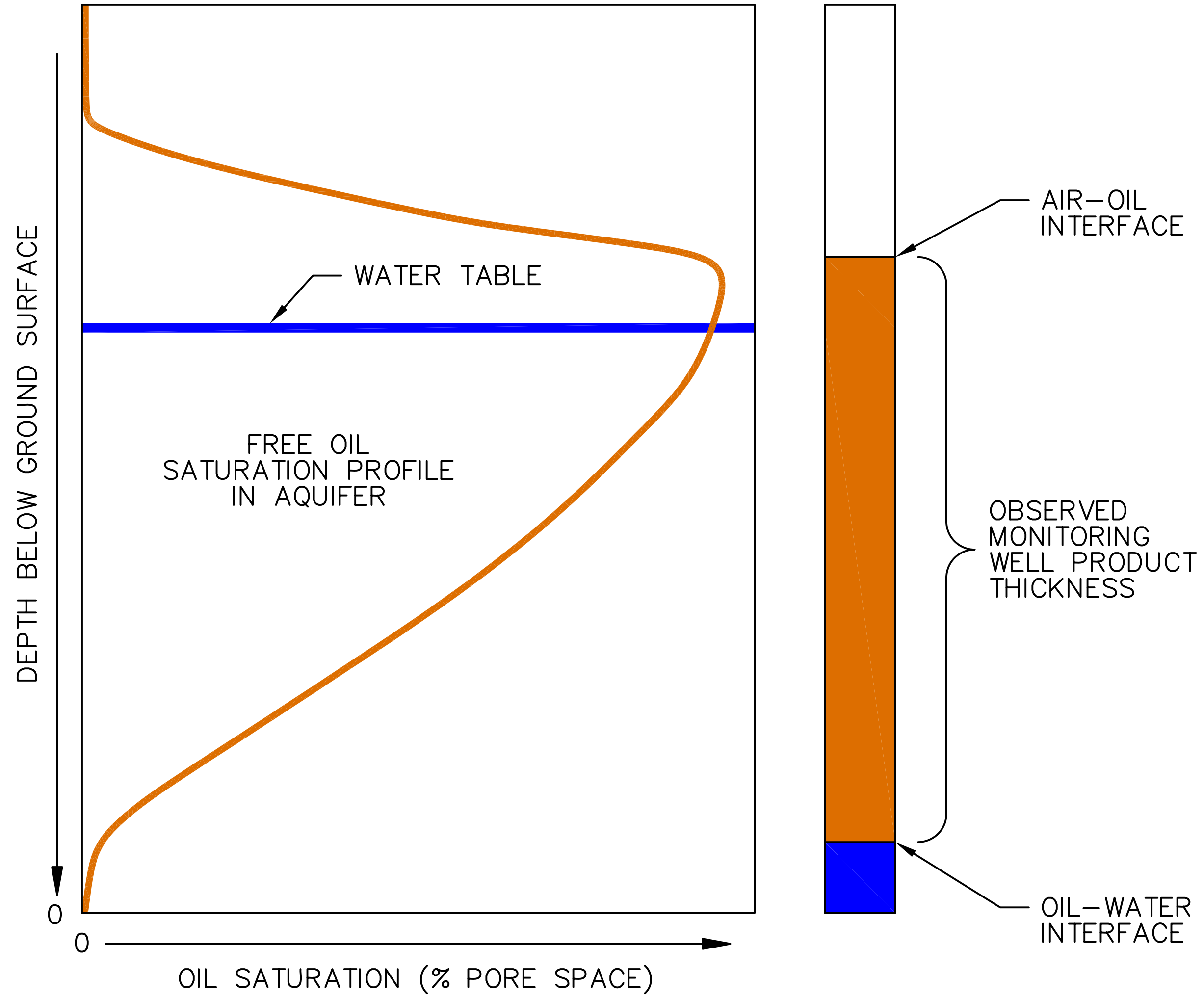

SOURCE: API, 2004, API INTERACTIVE
LNAPL GUIDE, AUGUST 2004

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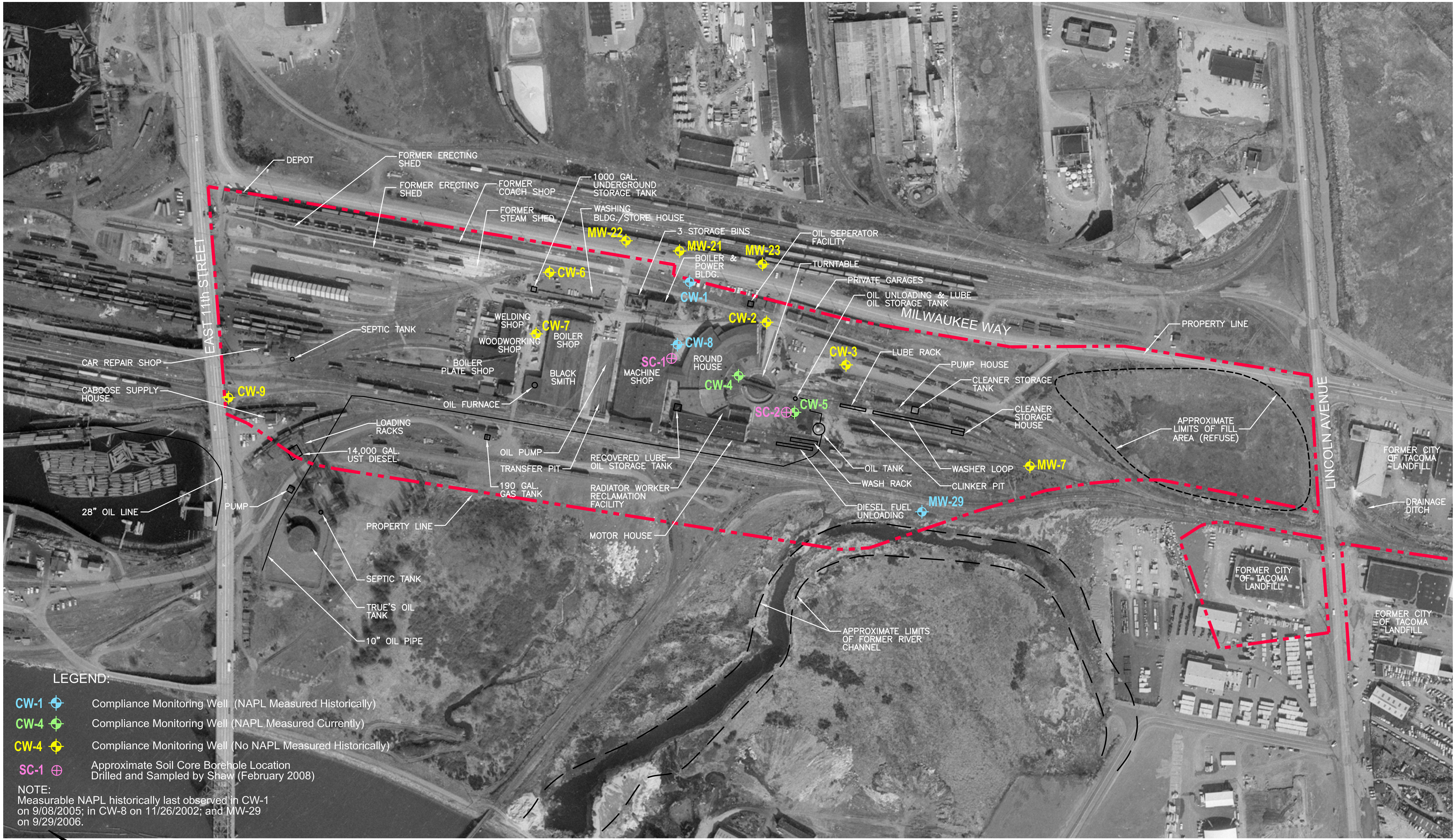
DATE 8/08
DWN JC
APP DL
REV
PROJECT NO.
111487

FIGURE 3
CONCEPTUALIZATION OF NAPL WITHIN A MONITORING WELL

PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

File: N:\Cad\Drawings\Port of Tacoma\August 2008\Figure 3.dwg Layout: layout User: jascha.coddington Sep 04, 2008 – 10:57am



LEGEND:

CW-1 ⊕	Compliance Monitoring Well (NAPL Measured Historically)
CW-4 ⊕	Compliance Monitoring Well (NAPL Measured Currently)
CW-4 ⊕	Compliance Monitoring Well (No NAPL Measured Historically)
SC-1 ⊕	Approximate Soil Core Borehole Location Drilled and Sampled by Shaw (February 2008)

NOTE:
Measurable NAPL historically last observed in CW-1 on 9/08/2005; in CW-8 on 11/26/2002; and MW-29 on 9/29/2006.

SCALE
0 300 600 FEET

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DES BY DL
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APP BY

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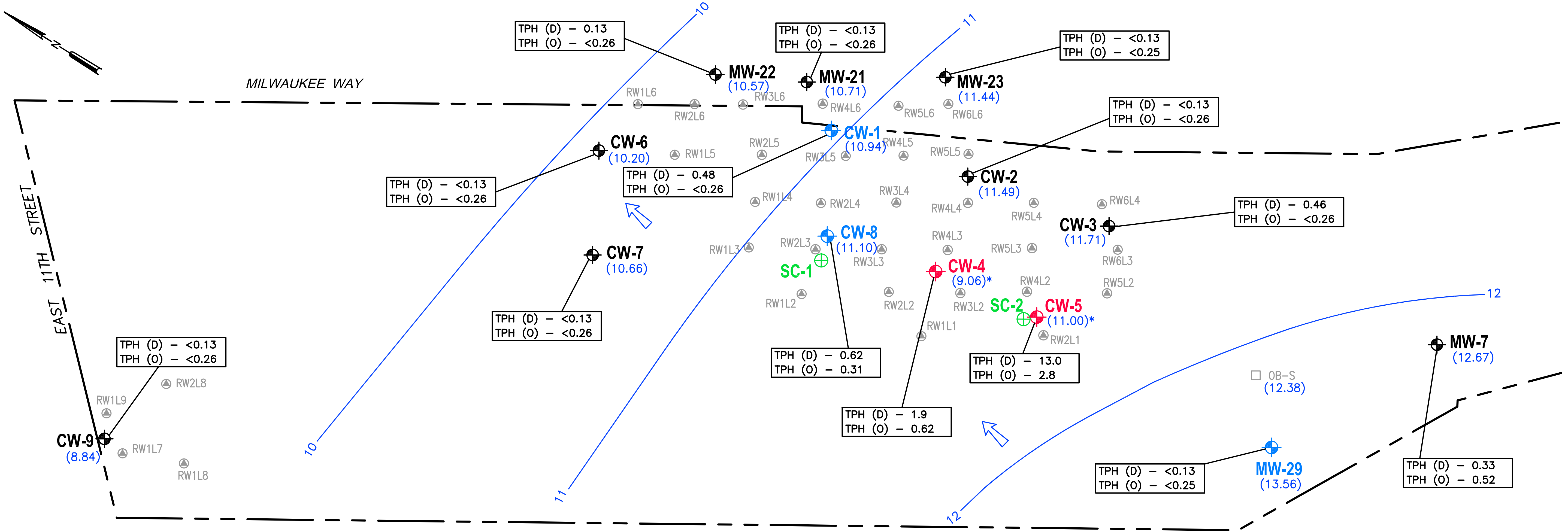
FIGURE 4
1969 SITE MAP WITH HISTORICAL FEATURES
PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

PROJECT NO.
111487



LEGEND:

SC-1 ⊕	Approximate Soil Core Borehole Location Drilled and Sampled by Shaw (February 2008)
CW-1[1] ⊕	Compliance Monitoring Well (NAPL Measured Historically)
CW-4 ⊕	Compliance Monitoring Well (NAPL Measured Currently)
CW-2 ⊕	Compliance Monitoring Well (No NAPL Measured Historically)
⊛ RW1L7	Groundwater Recovery Well
— — — —	Approximate Property Boundary
(10.76)	Groundwater Elevation (Feet Above MSL)
—— 10 ——	Inferred Groundwater Elevation Contour (feet)
⇐	General Groundwater Flow Direction
*	Groundwater Elevation Corrected to Free Product Presence
TPH (D) - 0.33	Diesel-Range Petroleum Hydrocarbon Concentration in milligrams per liter (mg/L)
TPH (O) - 0.52	Oil-Range Petroleum Hydrocarbon Concentration in milligrams per liter (mg/L)
<0.13	Not Detected at or Above the Laboratory Method Reporting Limit Indicated

NAPL THICKNESS TABLE

CW–4	5.26 FT.
CW–5	2.45 FT.

Only wells with measurable product thickness are listed.

NOTE:

Measurable NAPL historically last observed in CW-1 on 9/08/2005; in CW-8 on 11/26/2002; and MW-29 on 9/29/2006.

SCALE
0 200 400 FEET

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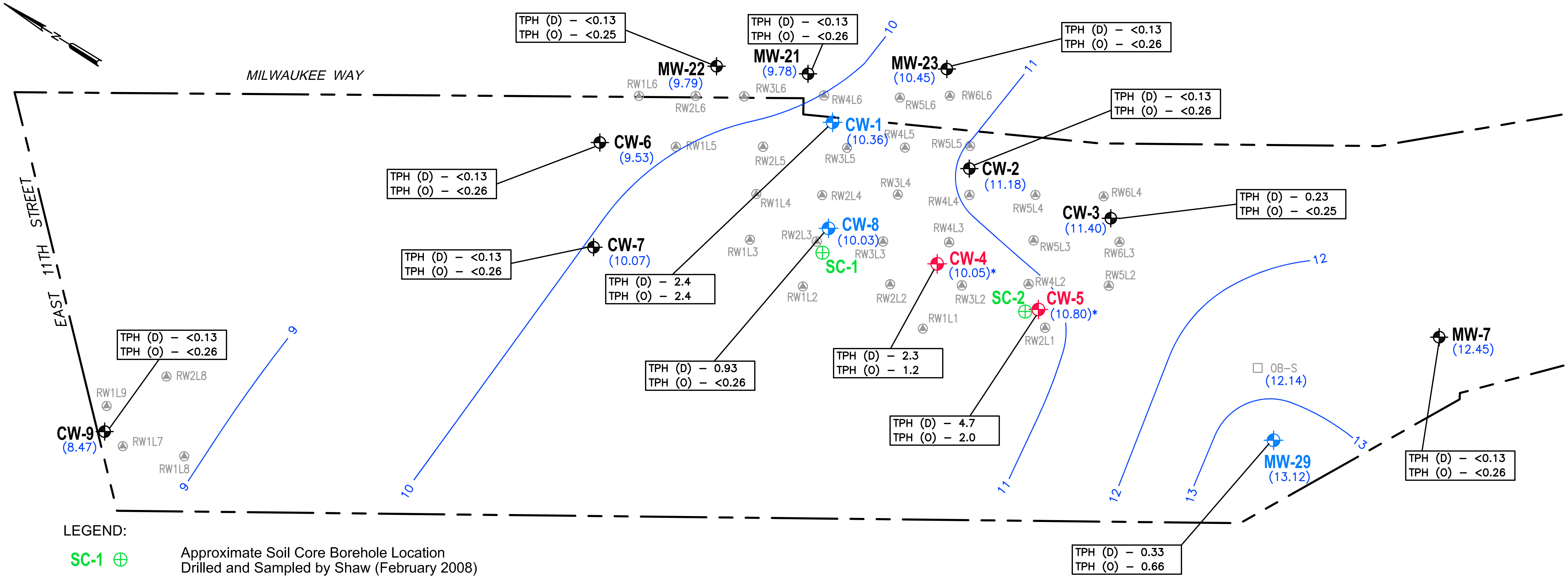
FIGURE 5
GROUNDWATER ELEVATION CONTOUR MAP AND TPH CONCENTRATIONS - JANUARY 2008
PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

PROJECT NO.
111487

1" 1/2" 0" 1"
File: N:\Cad\Drawings\Port of Tacoma\August 2008\Figure 5.dwg Layout: layout User: jascha.coddington Sep 04, 2008 – 11:00am



LEGEND:

SC-1 ⊕	Approximate Soil Core Borehole Location Drilled and Sampled by Shaw (February 2008)
CW-1[1] ⌖	Compliance Monitoring Well (NAPL Measured Historically)
CW-4 ⌖	Compliance Monitoring Well (NAPL Measured Currently)
CW-2 ⌖	Compliance Monitoring Well (No NAPL Measured Historically)
▲ RW1L7	Groundwater Recovery Well
— — — —	Approximate Property Boundary
(10.07)	Groundwater Elevation (Feet Above MSL)
—— 10 ——	Inferred Groundwater Elevation Contour (feet)
⇦	General Groundwater Flow Direction
*	Groundwater Elevation Corrected to Free Product Presence
TPH (D) - 0.33	Diesel-Range Petroleum Hydrocarbon Concentration in milligrams per liter (mg/L)
TPH (O) - 0.52	Oil-Range Petroleum Hydrocarbon Concentration in milligrams per liter (mg/L)
<0.13	Not Detected at or Above the Laboratory Method Reporting Limit Indicated

NAPL THICKNESS TABLE	
CW–4	3.06 FT.
CW–5	3.31 FT.

Only wells with measurable product thickness are listed.

NOTE:

Measurable NAPL historically last observed in CW-1 on 9/08/2005; in CW-8 on 11/26/2002; and MW-29 on 9/29/2006.

S C A L E
0 200 400 FEET

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FIGURE 6
GROUNDWATER ELEVATION CONTOUR MAP
AND TPH CONCENTRATIONS - MARCH 2008
PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

PROJECT NO.
111487

1" 1/2" 0" 1"
File: N:\Cad\Drawings\Port of Tacoma\August 2008\Figure 6.dwg Layout: layout User: jascha.coddington Sep 04, 2008 – 11:01am

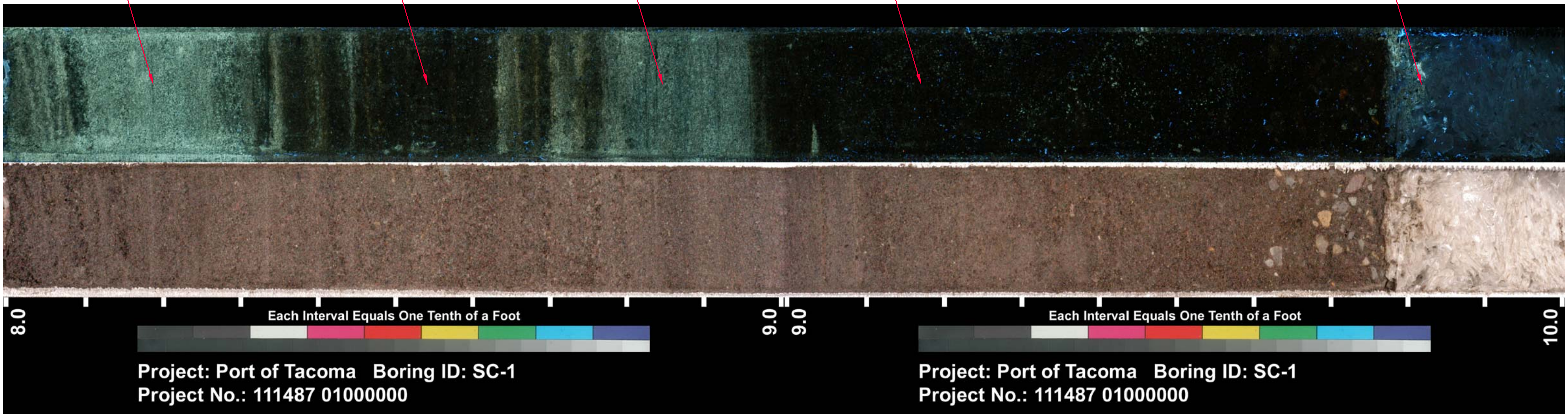
FINE GRAINED SANDS FROM 8.0 TO 8.3 FEET BGS; LIGHT YELLOWISH GREEN UV FLUORESCENCE INDICATES SMALL AMOUNT OF STRATIGRAPHICALLY BOUND NAPL

FINE GRAINED SANDS FROM 8.3 TO 8.6 FEET BGS; LITTLE RESPONSE UNDER UV FLUORESCENCE INDICATES LITTLE IF ANY NAPL

FINE GRAINED SANDS FROM 8.6 TO 9.0 FEET BGS; LIGHT YELLOWISH GREEN UV FLUORESCENCE INDICATES SMALL AMOUNT OF STRATIGRAPHICALLY BOUND NAPL. SAMPLE AT 8.9 FEET BGS SELECTED FOR GRAIN SIZE AND OTHER PHYSICL ANALYSES; WATER AND NAPL SATURATIONS = 79.1% AND 8.1% RESPECTIVELY

FINE GRAINED SANDS FROM 9.0 TO 9.8 FEET BGS; DARK RESPONSE UNDER UV FLUORESCENAL INDICATES NO NAPL (OCCASIONAL GREENISH SPECS ARE FLUORESCENT MINERALS SUCH AS CALCITE) SOME GRAVEL AT 9.6 TO 9.8 FEET BGS

COMMERCIAL SARAN WRAP USED TO PLUG OPEN VOIDS AT END OF CORE



FEET BELOW
GROUND SURFACE

NOTE:
PHOTOGRAPHS DEPICT COLOR (WHITE LIGHT, BOTTOM HALF OF CORE) AND ULTRAVIOLET IMAGES (TOP HALF OF CORE). YELLOWISH GREEN AREAS INDICATE THE PRESENCE OF NAPL. BLUE AREAS INDICATE PRESENCE OF SARAN WRAP USED TO KEEP CORE INTACT

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FIGURE 7
SOIL CORE SC-1, 8.0 - 10.0 FEET LOGS
PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

PROJECT NO.
111487

1" 1/2" 0" 1"

File: N:\Cad\Drawings\Port of Tacoma\August 2008\Core Figures\Figure 7.dwg Layout: layout User: jascha.coddington Sep 04, 2008 - 11:07am

NO RECOVERY FROM 10.0 TO 10.3 FEET BGS

COMMERCIAL SARAN WRAP USED TO PLUG OPEN VOIDS AT END OF CORE

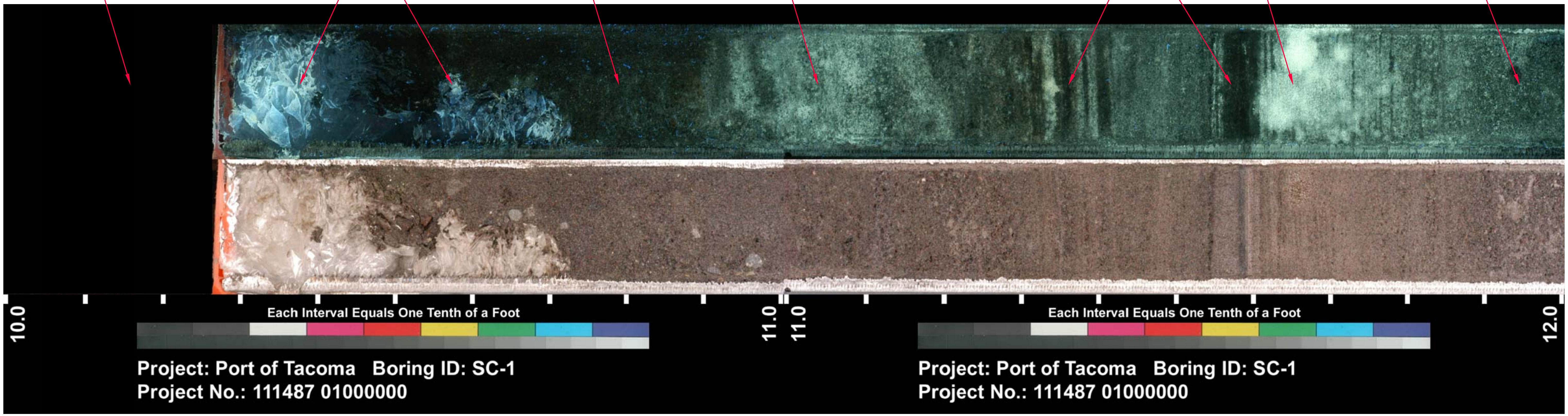
FINE GRAINED SANDS FROM 10.7 TO 11.0 FEET BGS; LITTLE RESPONSE UNDER UV FLUORESCENCE INDICATES LITTLE NAPL

FINE GRAINED SANDS WITH LIGHT YELLOWISH GREEN FLUORESCENCE INDICATES SMALL AMOUNT OF STRATIGRAPHICALLY BOUND NAPL

FINE GRAINED SANDS AT 11.4 AND 11.6 FEET BGS CONTAIN NO FLUORESCENCE OR NAPL

FINE GRAINED SANDS FROM 11.6 TO 11.8 FEET BGS CONTAIN THE HIGHEST LEVELS OF FLUORESCENCE AND THEREFORE NAPL. SAMPLE FROM 11.65 FEET BGS WAS SELECTED FOR GRAIN SIZE AND OTHER PHYSICAL ANALYSES. WATER AND NAPL SATURATIONS = 69.6% AND 8.8%, RESPECTIVELY

FINE GRAINED SANDS CONTAINED FAINT UV FLUORESCENCE INDICATING VERY LITTLE NAPL



FEET BELOW GROUND SURFACE

NOTE:
PHOTOGRAPHS DEPICT COLOR (WHITE LIGHT, BOTTOM HALF OF CORE) AND ULTRAVIOLET IMAGES (TOP HALF OF CORE). YELLOWISH GREEN AREAS INDICATE THE PRESENCE OF NAPL. BLUE AREAS INDICATE PRESENCE OF SARAN WRAP USED TO KEEP CORE INTACT

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APP BY

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FIGURE 8
SOIL CORE SC-1, 10.0 - 12.0 FEET LOGS
PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

PROJECT NO.
111487

File: N:\Cad\Drawings\Port of Tacoma\August 2008\Core Figures\Figure 8.dwg Layout: layout User: jascha.coddington Sep 04, 2008 - 11:08am

1" 1/2" 0" 1"

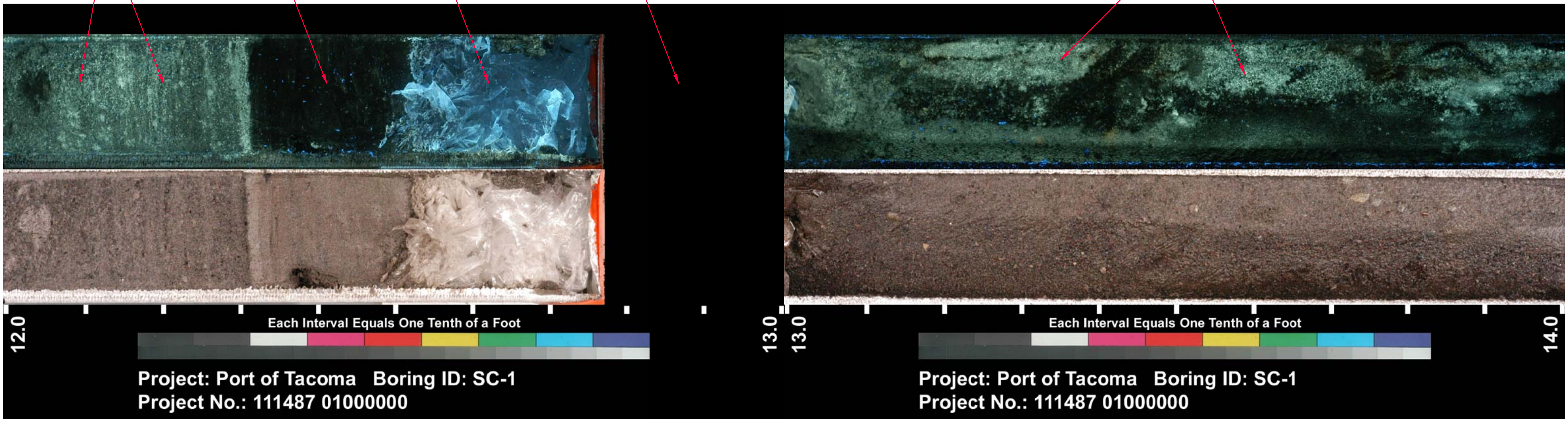
FINE GRAINED SANDS CONTAINED FAINT UV FLUORESCENCE INDICATING VERY LITTLE NAPL. SAMPLE FROM 12.2 FEET BGS WAS SELECTED FOR GRAIN SIZE AND OTHER PHYSICAL ANALYSES. WATER AND NAPL SATURATIONS = 51.5% AND 2.9%, RESPECTIVELY

FINE GRAINED SANDS FROM 12.3 TO 12.5 FEET BGS CONTAIN NO UV FLUORESCENCE AND THEREFORE NO NAPL

COMMERCIAL SARAN WRAP USED TO PLUG OPEN VOIDS AT END OF CORE

NO RECOVERY FROM 12.75 TO 13.0 FEET BGS

FINE GRAINED SANDS WITH LIGHT YELLOWISH GREEN UV FLUORESCENCE INDICATES SMALL AMOUNT OF NAPL. LACK OF STRATIFICATION IN THE SANDS INDICATES "SLOUGH" FROM ABOVE OR HEAVING SANDS



FEET BELOW GROUND SURFACE

NOTE:
PHOTOGRAPHS DEPICT COLOR (WHITE LIGHT, BOTTOM HALF OF CORE) AND ULTRAVIOLET IMAGES (TOP HALF OF CORE). YELLOWISH GREEN AREAS INDICATE THE PRESENCE OF NAPL. BLUE AREAS INDICATE PRESENCE OF SARAN WRAP USED TO KEEP CORE INTACT

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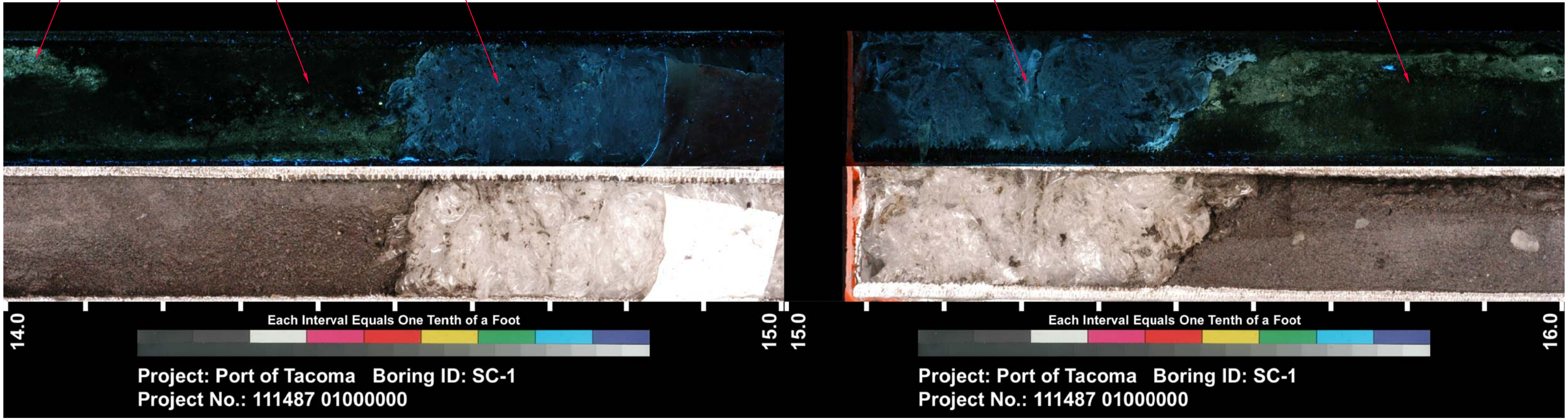
FIGURE 9
SOIL CORE SC-1, 12.0 - 14.0 FEET LOGS
PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

PROJECT NO.
111487

File: N:\Cad\Drawings\Port of Tacoma\August 2008\Core Figures\Figure 9.dwg Layout: layout User: jascha.coddington Sep 04, 2008 - 11:11am



FINE GRAINED SANDS WITH LIGHT YELLOWISH GREEN UV FLUORESCENCE INDICATES SMALL AMOUNT OF NAPL. LACK OF STRATIFICATION IN THE SANDS INDICATES "SLOUGH" FROM ABOVE OR HEAVING SANDS

FINE GRAINED SANDS CONTAINED NO UV FLUORESCENCE INDICATING VERY LITTLE NAPL

COMMERCIAL SARAN WRAP USED TO PLUG OPEN VOIDS AT END OF CORE

COMMERCIAL SARAN WRAP USED TO PLUG OPEN VOIDS AT END OF CORE

FINE GRAINED SANDS CONTAINED NO UV FLUORESCENCE INDICATING VERY LITTLE NAPL; PROBABLE "SLOUGH" FROM ABOVE OR HEAVING SANDS

FEET BELOW GROUND SURFACE

NOTE:
PHOTOGRAPHS DEPICT COLOR (WHITE LIGHT, BOTTOM HALF OF CORE) AND ULTRAVIOLET IMAGES (TOP HALF OF CORE). YELLOWISH GREEN AREAS INDICATE THE PRESENCE OF NAPL. BLUE AREAS INDICATE PRESENCE OF SARAN WRAP USED TO KEEP CORE INTACT

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FIGURE 10

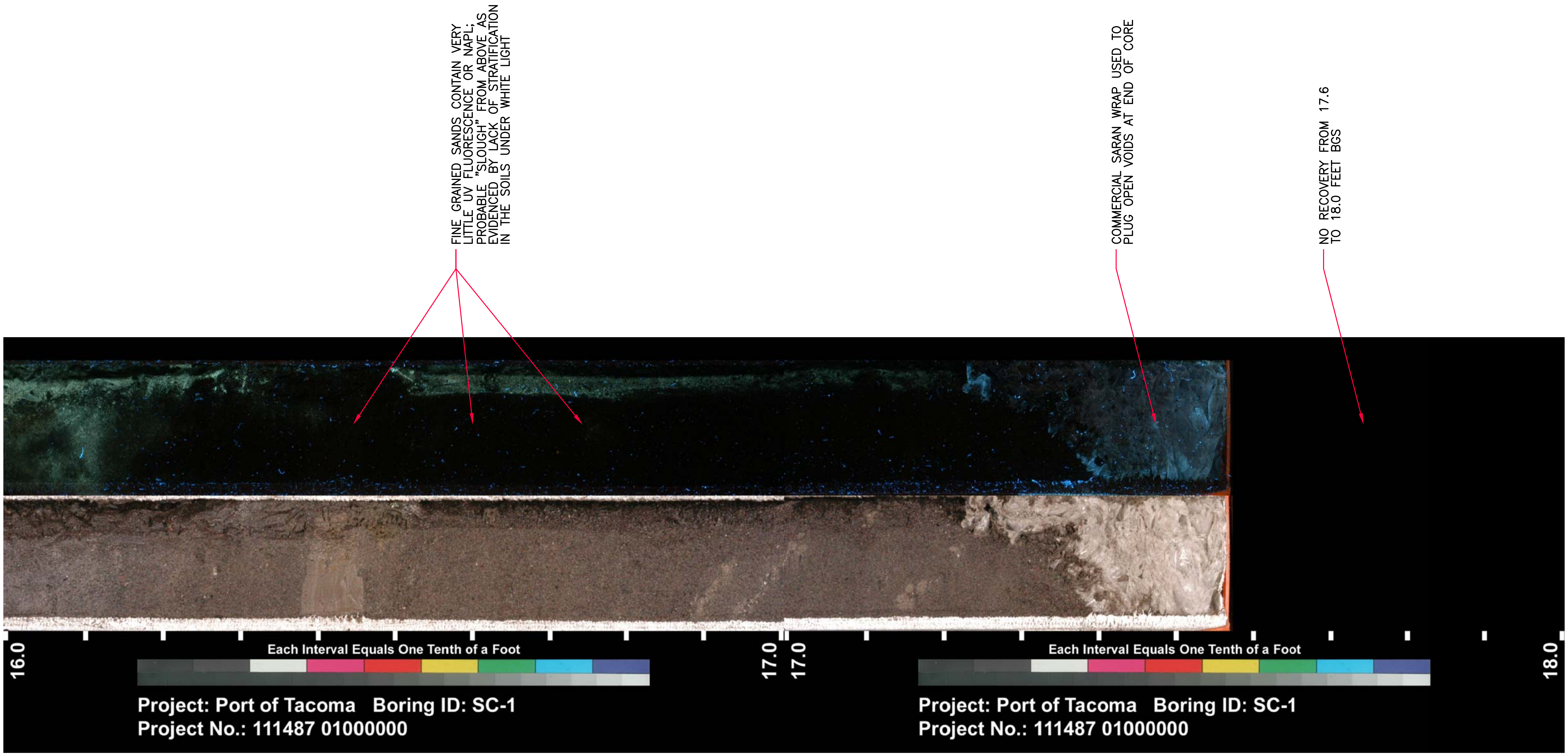
SOIL CORE SC-1, 14.0 - 16.0 FEET LOGS

PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

PROJECT NO.
111487

1" 1/2" 0" 1"

File: N:\Cad\Drawings\Port of Tacoma\August 2008\Core Figures\Figure 10.dwg Layout: layout User: jascha.coddington Sep 04, 2008 - 11:12am



FEET BELOW GROUND SURFACE

NOTE:
PHOTOGRAPHS DEPICT COLOR (WHITE LIGHT, BOTTOM HALF OF CORE) AND ULTRAVIOLET IMAGES (TOP HALF OF CORE). YELLOWISH GREEN AREAS INDICATE THE PRESENCE OF NAPL. BLUE AREAS INDICATE PRESENCE OF SARAN WRAP USED TO KEEP CORE INTACT

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FIGURE 11
SOIL CORE SC-1, 16.0 - 18.0 FEET LOGS
PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

PROJECT NO.
111487

1" 1/2" 0" 1"

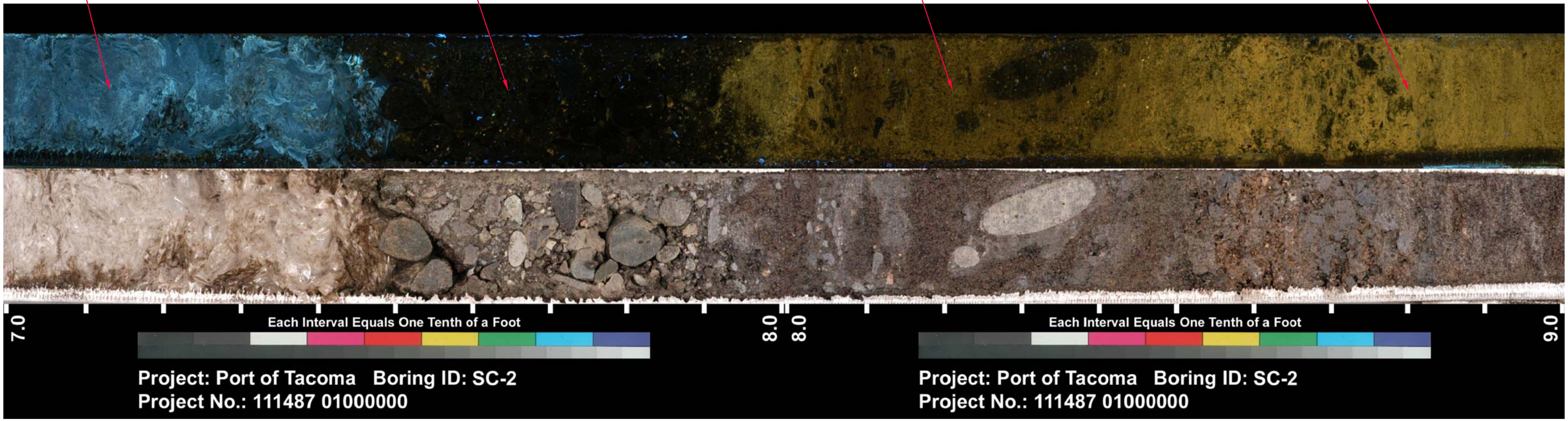
File: N:\Cad\Drawings\Port of Tacoma\August 2008\Core Figures\Figure 11.dwg Layout: layout User: jascha.coddington Sep 04, 2008 – 11:20am

COMMERCIAL SARAN WRAP USED TO PLUG OPEN VOIDS AT END OF CORE

SANDY GRAVEL; LACK OF YELLOWISH GREEN UV FLUORESCENCE INDICATES NO NAPL

GRAVELLY FINE TO MEDIUM GRAINED SANDS; MODERATE UV FLUORESCENCE INDICATES MODERATE NAPL. SAMPLE AT 8.7 FEET BGS SELECTED FOR GRAIN SIZE AND OTHER PHYSICAL ANALYSES. WATER AND NAPL SATURATIONS = 64.2% AND 28.1% RESPECTIVELY

FINE GRAINED SANDS; MODERATE UV FLUORESCENCE INDICATES MODERATE NAPL



FEET BELOW GROUND SURFACE

NOTE:
PHOTOGRAPHS DEPICT COLOR (WHITE LIGHT, BOTTOM HALF OF CORE) AND ULTRAVIOLET IMAGES (TOP HALF OF CORE). YELLOW AREAS INDICATE THE PRESENCE OF NAPL. BLUE AREAS INDICATE PRESENCE OF SARAN WRAP USED TO KEEP CORE INTACT

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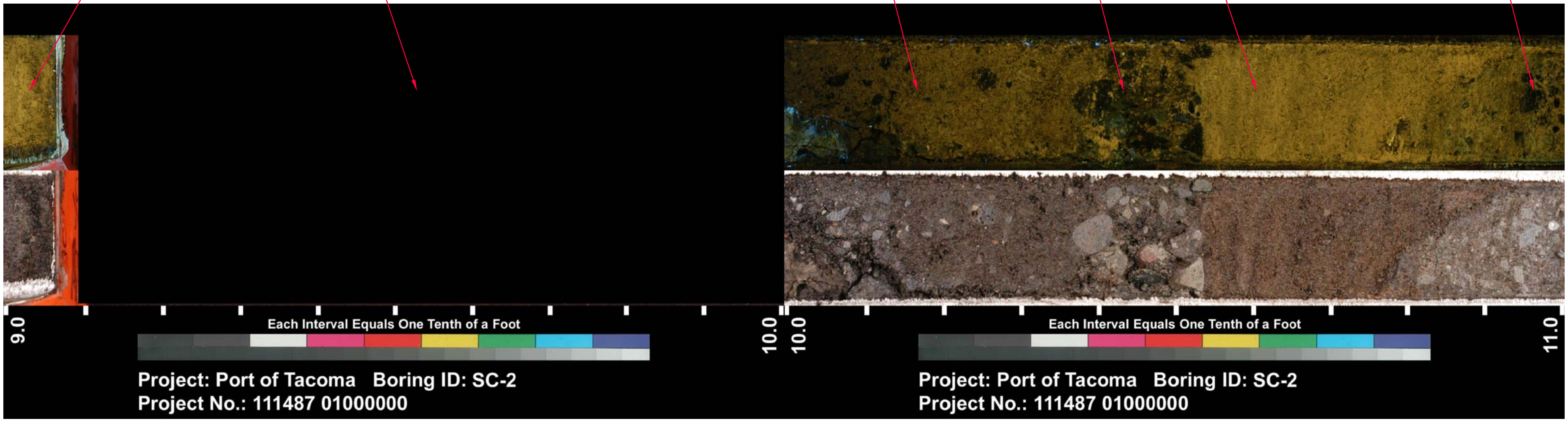
FIGURE 12
SOIL CORE SC-2, 7.0 - 9.0 FEET LOGS
PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

PROJECT NO.
111487

1” 1/2” 0” 1”



FINE GRAINED SANDS; MODERATE UV FLUORESCENCE INDICATES MODERATE NAPL

NO RECOVERY FROM 9.1 TO 10.0 FEET BGS

FINE TO MEDIUM GRAINED SANDS WITH SOME GRAVELS, LIGHT YELLOWISH GREEN FLUORESCENCE INDICATES SMALL OF NAPL

SANDY GRAVELS, LITTLE TO NO FLUORESCENCE OR NAPL

FINE TO COARSE GRAINED SANDS; MODERATE UV FLUORESCENCE INDICATES MODERATE NAPL. SAMPLE AT 10.7 FEET BGS SELECTED FOR GRAIN SIZE AND OTHER PHYSICAL ANALYSES. WATER AND NAPL SATURATIONS = 57.0% AND 24.6% RESPECTIVELY

SANDY GRAVELS, LITTLE TO NO FLUORESCENCE OR NAPL

FEET BELOW GROUND SURFACE

NOTE:
PHOTOGRAPHS DEPICT COLOR (WHITE LIGHT, BOTTOM HALF OF CORE) AND ULTRAVIOLET IMAGES (TOP HALF OF CORE). YELLOW AREAS INDICATE THE PRESENCE OF NAPL. BLUE AREAS INDICATE PRESENCE OF SARAN WRAP USED TO KEEP CORE INTACT

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FIGURE 13
SOIL CORE SC-2, 9.0 - 11.0 FEET LOGS
PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

PROJECT NO.
111487

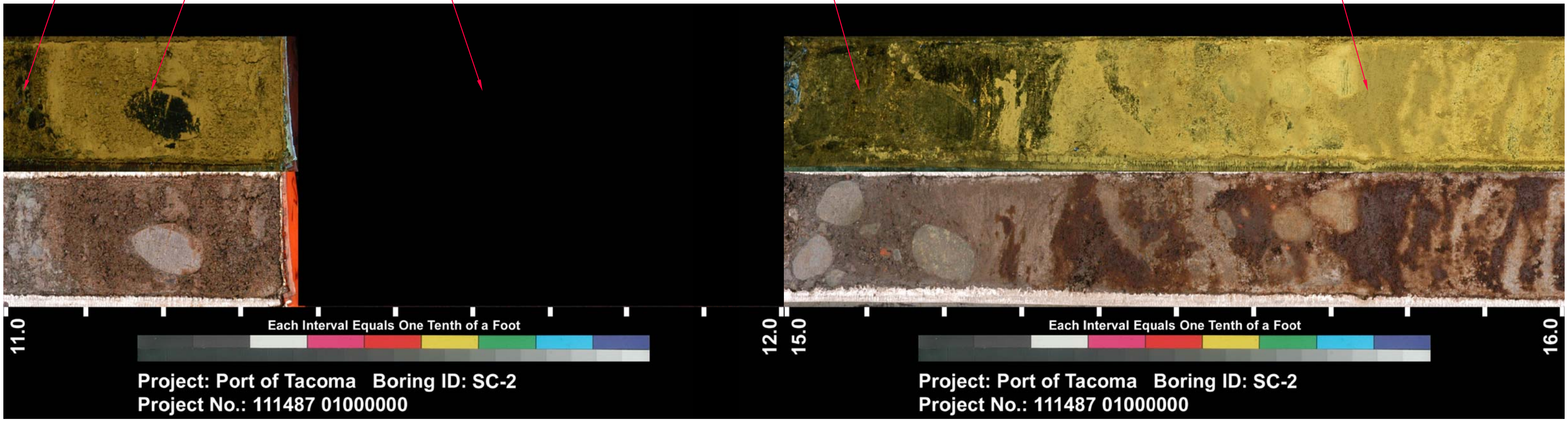
SANDY GRAVELS, LITTLE TO NO FLUORESCENCE OR NAPL

FINE TO MEDIUM GRAINED SANDS; MODERATE FLUORESCENCE INDICATE MODERATE NAPL. (ONE LARGE PEBBLE PRESENT)

NO RECOVERY FROM 11.4 TO 15.0 FEET BGS

SANDY GRAVEL; LITTLE YELLOWISH GREEN UV FLUORESCENCE INDICATES LITTLE NAPL

MEDIUM GRAINED SAND; STRONG UV FLUORESCENCE INDICATES ABUNDANT NAPL. SAMPLE AT 16.1 FEET BGS SELECTED FOR GRAIN SIZE AND OTHER PHYSICAL ANALYSES. WATER AND NAPL SATURATIONS = 40.1% AND 46.3%, RESPECTIVELY



FEET BELOW GROUND SURFACE

NOTE:
PHOTOGRAPHS DEPICT COLOR (WHITE LIGHT, BOTTOM HALF OF CORE) AND ULTRAVIOLET IMAGES (TOP HALF OF CORE). YELLOW AREAS INDICATE THE PRESENCE OF NAPL. BLUE AREAS INDICATE PRESENCE OF SARAN WRAP USED TO KEEP CORE INTACT

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FIGURE 14

SOIL CORE SC-2, 11.0 - 16.0 FEET LOGS

PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

PROJECT NO.
111487

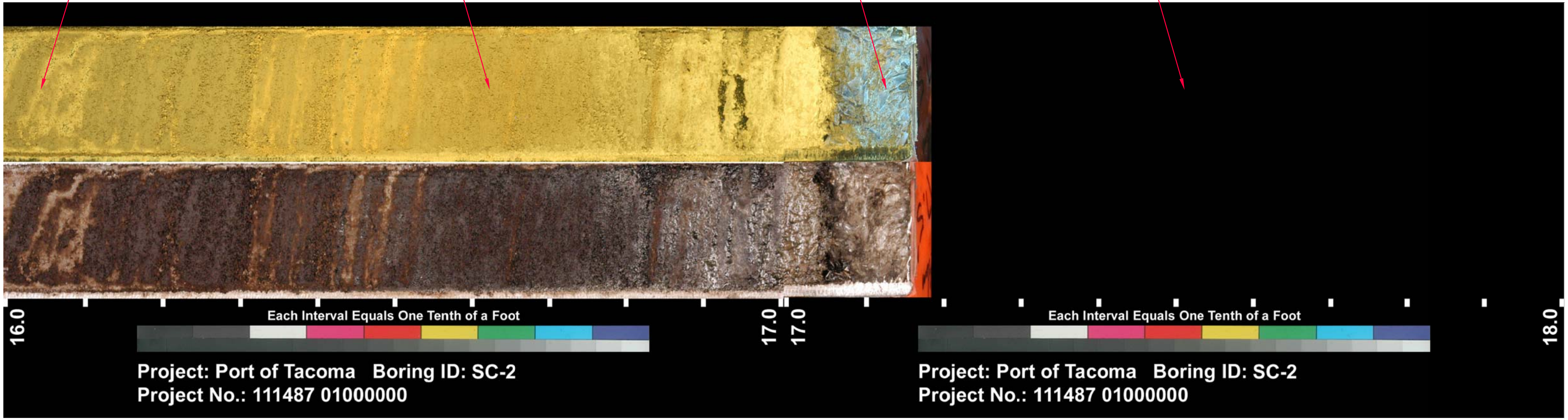
1" 1/2" 0" 1"

MEDIUM GRAINED SAND: STRONG UV FLUORESCENCE INDICATES ABUNDANT NAPL. SAMPLE AT 16.1 FEET BGS SELECTED FOR GRAIN SIZE AND OTHER PHYSICAL ANALYSES. WATER AND NAPL SATURATIONS = 40.1% AND 46.3%, RESPECTIVELY

FINE GRAINED SAND: STRONG UV FLUORESCENCE INDICATES ABUNDANT NAPL. SAMPLE AT 16.6 FEET BGS SELECTED FOR GRAIN SIZE AND OTHER PHYSICAL ANALYSES. WATER AND NAPL SATURATIONS = 46.0% AND 45.3%, RESPECTIVELY

COMMERCIAL SARAN WRAP USED TO PLUG OPEN VOIDS AT END OF CORE

NO RECOVERY FROM 17.2 TO 18.0 FEET BGS



FEET BELOW GROUND SURFACE

NOTE:
PHOTOGRAPHS DEPICT COLOR (WHITE LIGHT, BOTTOM HALF OF CORE) AND ULTRAVIOLET IMAGES (TOP HALF OF CORE). YELLOW AREAS INDICATE THE PRESENCE OF NAPL. BLUE AREAS INDICATE PRESENCE OF SARAN WRAP USED TO KEEP CORE INTACT

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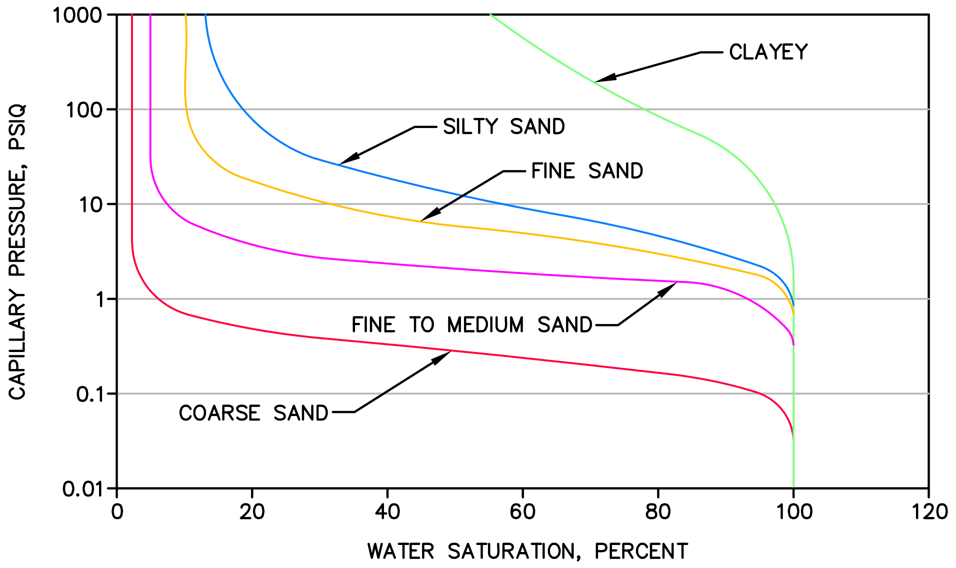
FIGURE 15
SOIL CORE SC-2, 16.0 - 18.0 FEET LOGS
PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

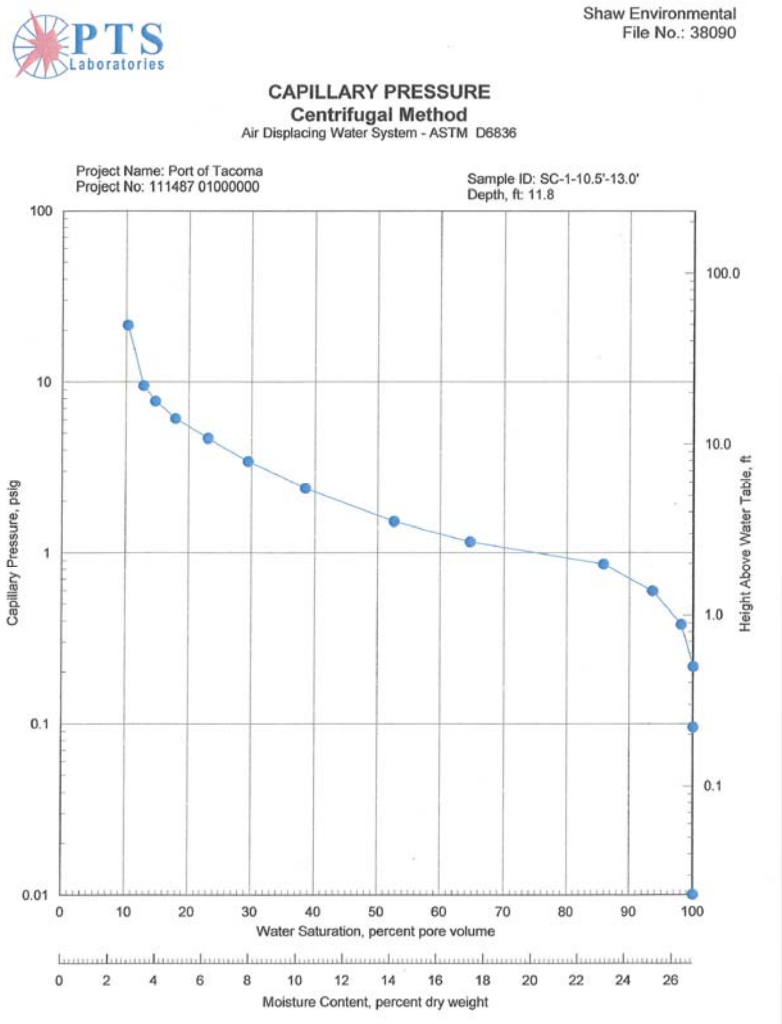
PROJECT NO.
111487

Characteristic Capillary Pressure Curves



SOURCE: ADAPTED FROM BECKETT, G.D. AND HUNTLY, D., EVALUATING HYDROCARBON REMOVAL FROM SOURCE ZONES AND ITS EFFECT ON DISSOLVED PLUME LONGEVITY AND MAGNITUDE, API PUBLICATION NO. 4715, SEPTEMBER 2002

SC-1 @ 11.8 feet BGS



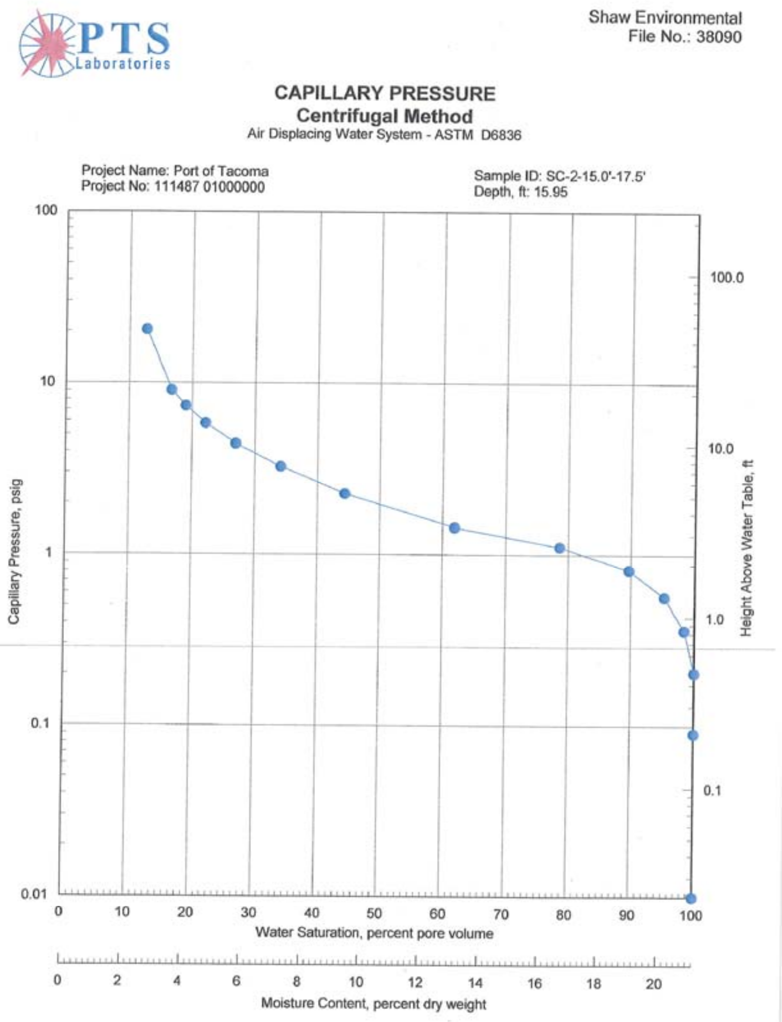
Shaw Environmental
File No.: 38090

CAPILLARY PRESSURE
Centrifugal Method
Air Displacing Water System - ASTM D6836

Project Name: Port of Tacoma
Project No: 111487 01000000

Sample ID: SC-1-10.5'-13.0'
Depth, ft: 11.8

SC-2 @ 15.95 feet BGS



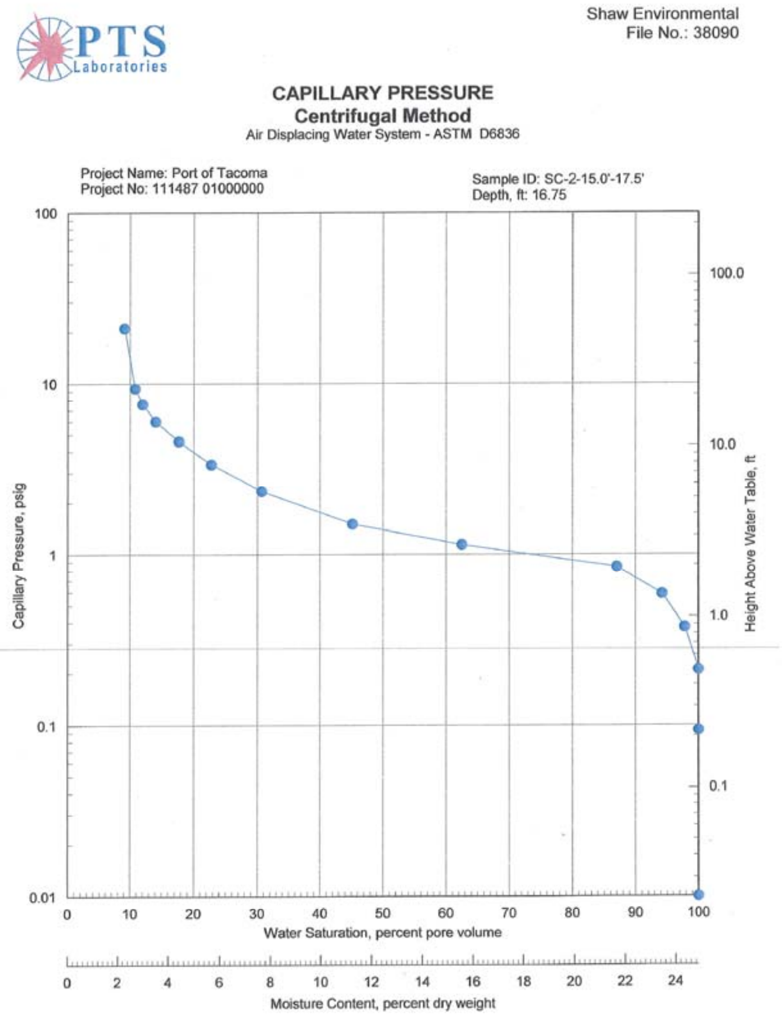
Shaw Environmental
File No.: 38090

CAPILLARY PRESSURE
Centrifugal Method
Air Displacing Water System - ASTM D6836

Project Name: Port of Tacoma
Project No: 111487 01000000

Sample ID: SC-2-15.0'-17.5'
Depth, ft: 15.95

SC-2 @ 16.75 feet BGS



Shaw Environmental
File No.: 38090

CAPILLARY PRESSURE
Centrifugal Method
Air Displacing Water System - ASTM D6836

Project Name: Port of Tacoma
Project No: 111487 01000000

Sample ID: SC-2-15.0'-17.5'
Depth, ft: 16.75

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Shaw Environmental, Inc.

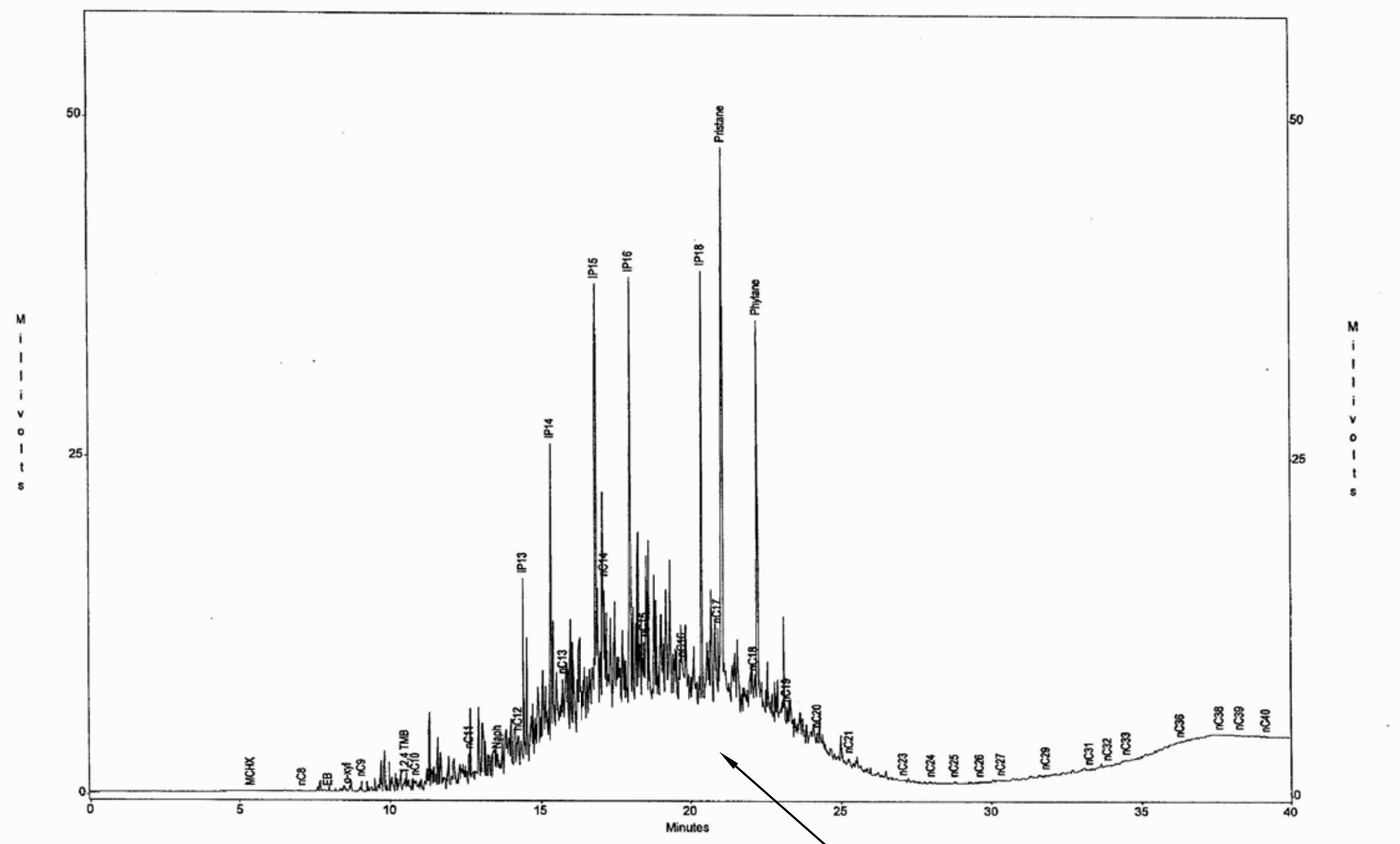
FIGURE 16
CHARACTERISTIC AND SOIL CORE SAMPLE CAPILLARY PRESSURE CURVES
PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

NAPL Sample RW-2L3

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : RW2L3-Product
Acquired : Jun 26, 2007 16:49:41

c:\ezchrom\chrom\07091\rw-2l3 – Channel A



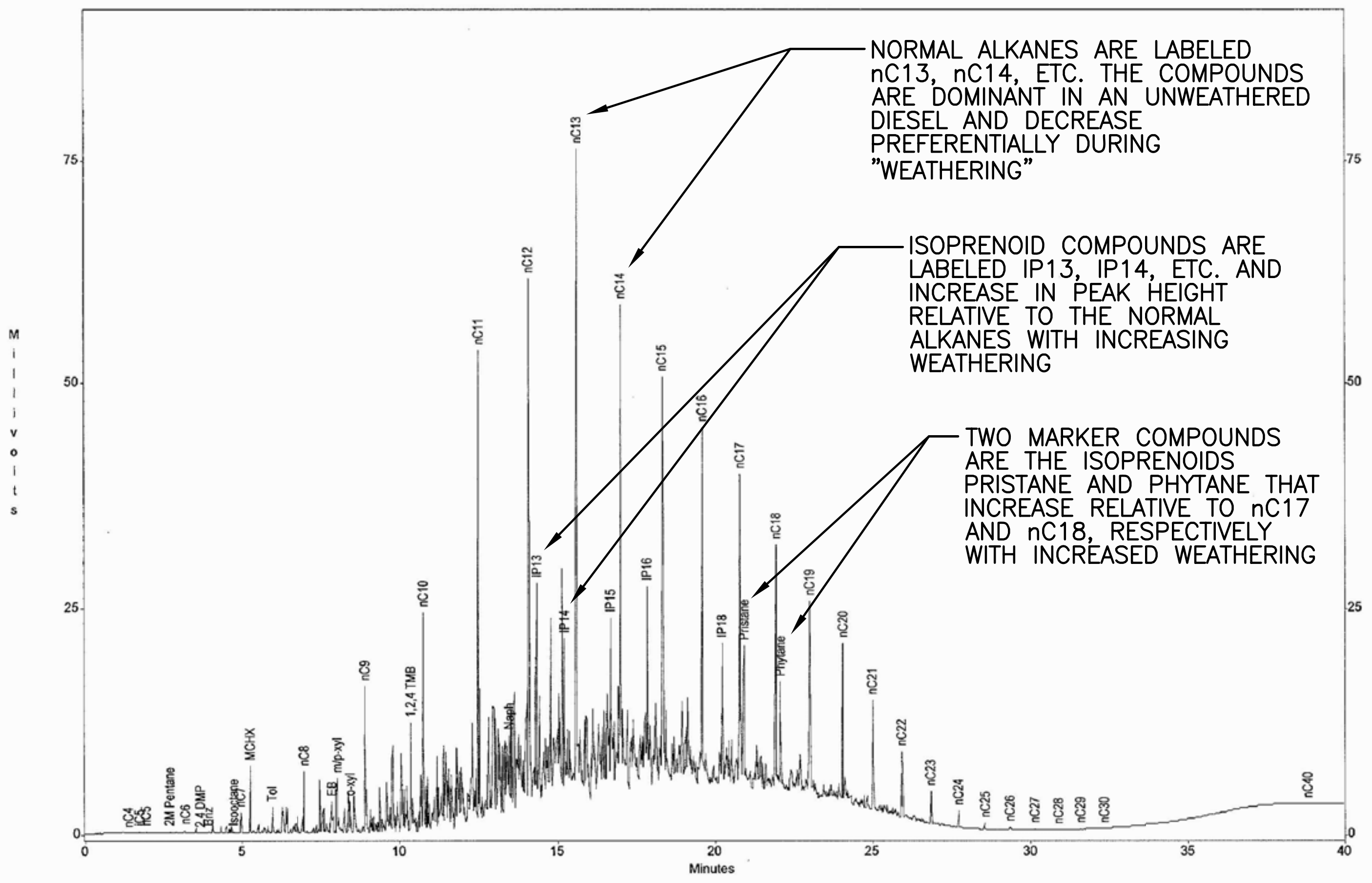
THE "HUMP" AT THE BASELINE IS THOUSANDS OF UNRESOLVABLE COMPOUNDS. THIS HUMP IS ACCENTUATED AS THE MORE DEGRADEABLE NORMAL ALKANES AND EVENTUALLY ISOPRENOIDS DEGRADE

Diesel Standard

Torkelson Geochemistry, Inc.

Sample ID : Diesel
Acquired : Aug 20, 2007 16:18:02

c:\ezchrom\chrom\07133\diesel.2 – Channel A



NORMAL ALKANES ARE LABELED nC13, nC14, ETC. THE COMPOUNDS ARE DOMINANT IN AN UNWEATHERED DIESEL AND DECREASE PREFERENTIALLY DURING "WEATHERING"

ISOPRENOID COMPOUNDS ARE LABELED IP13, IP14, ETC. AND INCREASE IN PEAK HEIGHT RELATIVE TO THE NORMAL ALKANES WITH INCREASING WEATHERING

TWO MARKER COMPOUNDS ARE THE ISOPRENOIDS PRISTANE AND PHYTANE THAT INCREASE RELATIVE TO nC17 AND nC18, RESPECTIVELY WITH INCREASED WEATHERING

REV	DATE	DESCRIPTION	DWN BY	DES BY	CHK BY	APP BY

DATE OF ISSUE 8/08
DWN BY JC
DES BY DL
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Shaw® Shaw Environmental, Inc.

FIGURE 17
GAS CHROMATOGRAM OF NAPL SAMPLE RW-2L3 AND LABORATORY STANDARD FOR DIESEL
PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

PROJECT NO.
111487

1" 1/2" 0" 1"

Appendix A

Behavior of NAPL in the Subsurface

Introduction

A nonaqueous phase liquid results from the physical and chemical differences between liquid hydrocarbon and water, such that a physical interface exists between the two liquids. Hence, nonaqueous phase liquids act as a distinct fluid within the subsurface. Nonaqueous phase liquids, which are commonly referred to by the acronym "NAPL," have typically been divided into two general categories, light and dense. These terms describe the specific gravity or the density of the NAPL with respect to water. Light nonaqueous phase liquids, termed "L"NAPLs, have a specific gravity less than water and dense nonaqueous phase liquids, termed "D"NAPLs, have a specific gravity greater than water. Examples of LNAPLs include most fuels (gasoline, diesel, jet A, heating oil) and lubricants. DNAPLs include chlorinated solvents, creosote based wood-treating oils, coal tar wastes, and pesticides. Although many of the same principles and concerns apply to both LNAPLs and DNAPLs, the focus of this guide is on LNAPLs since these compounds comprise the most common type of contaminants at petroleum retail, storage, distribution and refining sites.

LNAPL contamination poses one of the most significant issues faced by the environmental industry. In particular, LNAPL contamination has typically been perceived as a significant environmental threat by the general public and the regulatory community, and as a result, LNAPL cleanup standards are generally very conservative. Technically, the remediation of LNAPL is difficult because it is significantly influenced by the physical character of the product, the nature of the soil conditions, and the hydrologic setting. LNAPL acts as a source of volatile and dissolved contaminants that may require remediation. Additionally, if sufficient volume exists, LNAPL may migrate posing significant environmental and legal concerns. To effectively manage the various and difficult aspects of LNAPL contamination, one must conceptually and technically understand the sometimes complex issues posed by LNAPL contamination. It is only through this understanding that appropriate management decisions can be made.

The management of LNAPL contaminated sites is a scientific and an engineering challenge. The focus of this primer is to present general fundamental concepts in understanding how subsurface processes and conditions influence the movement and retention of LNAPL in the subsurface. Specifically, these processes require knowledge of chemistry, geology, hydrology, soil science, biology, and engineering. The objective of this primer will be to provide general information on key factors to consider and recognize when managing a LNAPL site. This *NAPL Basics* primer will form the basis of more technical discussions presented in other primers.

LNAPL Movement in the Subsurface

Products typically produced, stored, and distributed include gasoline, middle distillates (diesel, kerosene), and heavy fuel and lubricating oils. These products vary in chemical composition and physical properties. The characteristics of these product types in conjunction with the hydrogeologic conditions at the site and the manner in which the product is released are the primary factors that influence the movement and distribution of LNAPL in the subsurface. When oil is accidentally released at the surface or from an underground pipe or storage tank, oil migrates vertically downward under the force of gravity. When the volume of the release is sufficient, the LNAPL will migrate through the unsaturated zone to the capillary fringe and water table (Figure 1). The increasing water content in the capillary fringe and the effects of buoyancy will impede the vertical movement of the LNAPL near the water table. As a result, the less dense oil will begin to migrate laterally along the water table. In general, the lateral oil migration will preferentially flow with the water table gradient. However, if the rate of downward vertical LNAPL movement from the surface is greater than the lateral migration, the oil will begin to mound vertically and oil flow may become radial. In addition, downward migration into the aquifer will increase displacing water from the aquifer pore space.

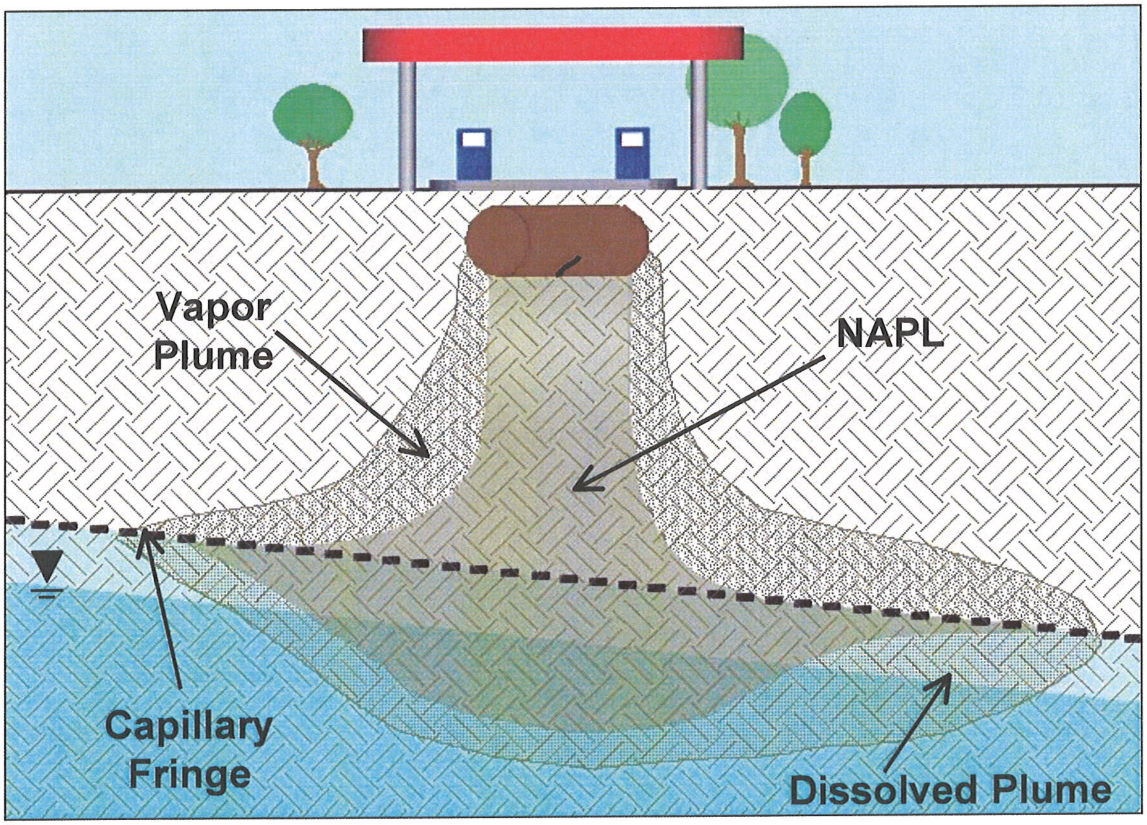

Figure 1. Representation of a LNAPL Release to the Subsurface.

In the aquifer, LNAPL coexists with water in the soil pores. The percentage of LNAPL filling the total pore space is termed the oil saturation. Due to the presence of water in the soil, LNAPL saturations are never 100 percent but may range from as little as 5 percent to over 70 percent (Figure 2). The percent saturation and distribution of LNAPL within the pore network will change over time as oil initially displaces water and is then subsequently displaced as water refills pore spaces when water levels rise.

In the past, a common misconception of the vertical distribution of free product at the water table was based on the idea that LNAPL occurs as a distinct lens in which the drainable pore space is completely saturated with LNAPL. This was often referred to as the "pancake layer" conceptualization (Figure 3). Under the pancake layer paradigm LNAPL saturations are 100 percent. This paradigm predicts large free oil volumes, high mobilities, and large recoverable volumes. Most importantly, the paradigm does not inherently consider soil and product properties as significant. An updated paradigm that is more representative of typical soil capillarity is referred to as the "multiphase" conceptualization, in which LNAPL saturation decreases continuously with depth (Figure 3). In the aquifer, LNAPL coexists in the soil pores with water over a given thickness. An examination of the impacted aquifer indicates that the LNAPL produces a profile with decreasing LNAPL saturation with depth. Specifically, the oil phase will displace the water by pushing into the pore spaces of the upper portions of the profile. With depth, the amount of oil pushing into the pores becomes less and less until at some depth no water is displaced and the pores remain completely filled with water (100 percent water saturation). Field studies have indicated that the multiphase conceptualization provides a good representation for both coarse and fine grained soils.

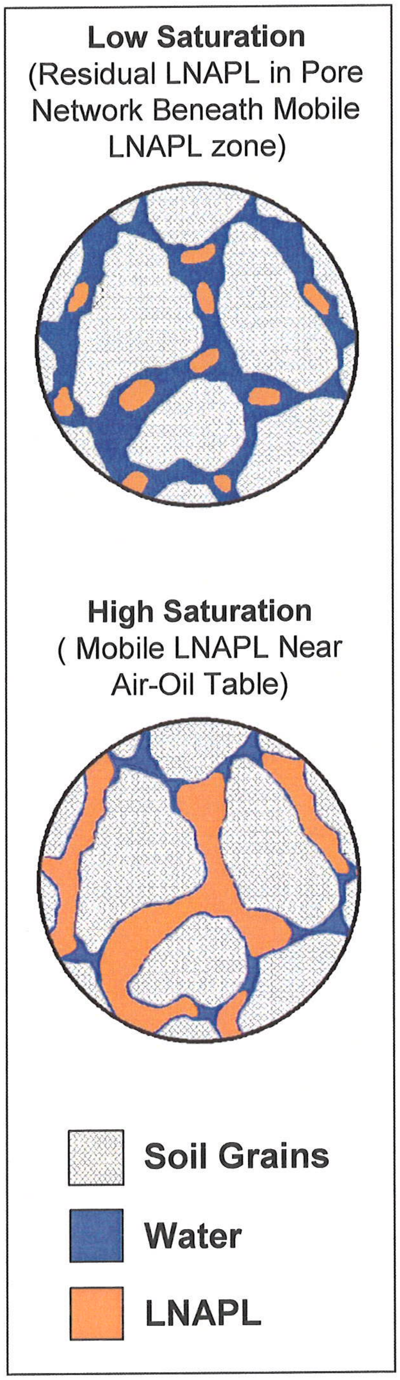

Figure 2. Representation of LNAPL Saturations in the Soil Pore Space.

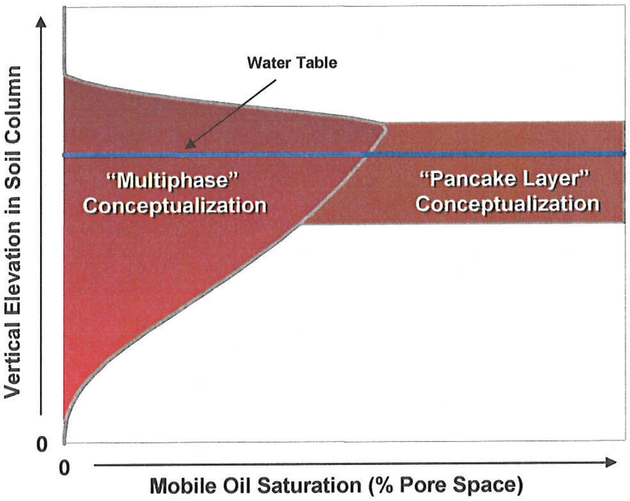

Figure 3. Conceptualization of LNAPL Vertical Distribution in Soil Profile.

When a well penetrates LNAPL saturated soil, oil and water will migrate into the well bore and reach equilibrium relative to the atmospheric conditions. As a result, a distinct layer of oil will develop in the well above the water. The thickness of oil in the well will reflect the thickness of the aquifer in which some amount of mobile oil saturation is present (Figure 4). The upper surface of the oil layer in the well is termed the air-oil interface and the lower surface of the oil is termed the oil-water interface. The actual water potentiometric level cannot be physically measured in the well. This interface must be calculated using the density of the oil (ρ_o), the elevation of the water-oil interface (Z_{ow}), and the LNAPL thickness measured in the well (H_o). The following equation is utilized in determining the theoretical air-water interface (Z_{aw}) in a well containing LNAPL.

$$Z_{aw} = Z_{ow} + (\rho_o H_o) \tag{1}$$

The volume of LNAPL per area of aquifer is primarily dependent upon the properties of the soil and the LNAPL. Since water remains in some of the pore spaces (for some soils, the majority of the pore spaces), the amount of oil in the formation is less than the monitoring well might suggest. In general, for a given observed well product thickness, the mobile LNAPL volume is greater for coarse-grained aquifer material than for soils composed of silt and clay. The importance of grain size is discussed in the primer *Soil Properties*. Similarly, the volume of mobile oil will vary depending on product composition for a given observed well product thickness. The nature and properties of LNAPLs are discussed in the primer *Product Types*.

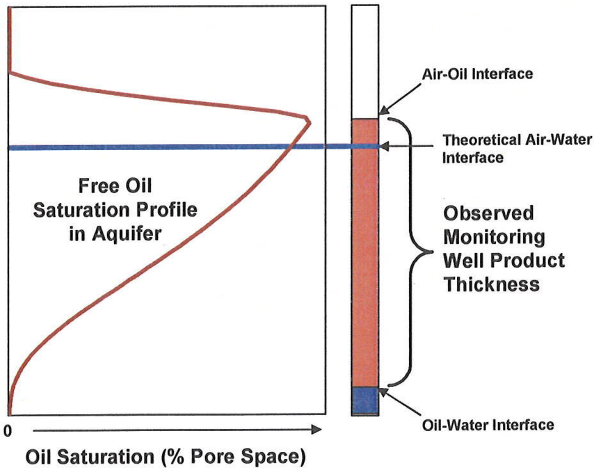

Figure 4. Conceptualization of LNAPL within a Monitoring Well.

Due to capillary forces, some LNAPL is always retained in the soil pores as residual or immobile LNAPL. The remaining "untrapped" LNAPL is mobile and may continue to migrate. As LNAPL moves within the subsurface, the volume of mobile or "free" product continually decreases as LNAPL becomes trapped as isolated droplets within the soil pore network. In particular, it becomes difficult for the oil to coalesce into a consistent plume of any significant thickness. Hence, LNAPL plumes, unless continually supplied from an on-going release, are "spatially self-limiting." This important concept distinguishes LNAPLs from dissolved and vapor plumes that may migrate significant distances.

Other Considerations

The dynamic and heterogeneous character of the subsurface influences LNAPL conditions. For example, slight differences in soil texture may promote preferential pathways within the aquifer, or conversely, may inhibit product migration causing LNAPL to pool as a stratigraphic trap. Similarly, fractures may create anisotropic conditions that cause product to flow in a direction not directly downgradient. In addition, LNAPL is significantly influenced by vertical fluctuations in the water table. These fluctuations enhance the development of residual LNAPL, which in many cases stabilizes the LNAPL movement. The primers on *Water Table Fluctuations* and *Heterogeneous Conditions* discuss how transient and spatial conditions may influence LNAPL migration.

In the subsurface, constituents composing the LNAPL will begin to transfer from the oil phase to the vapor and liquid phases (Figure 1). The transfer of volatile components to the soil air creates a vapor phase in the unsaturated zone above and adjacent to the LNAPL. Similarly, the transfer of soluble components to the water creates a dissolved plume in the saturated zone. The resulting vapor and dissolved plumes may readily migrate away from the LNAPL plume. In many cases, these plumes contain toxic components that may pose human health and environmental risks. As such, an understanding of the mass transfer between the LNAPL and vapor/water phases is important in managing LNAPL plumes. The concepts of dissolution and volatilization are discussed in the primers *Dissolution* and *Volatilization*.

Because LNAPL may act as a continuing source of dissolved and volatile contamination, numerous technologies have been developed to facilitate recovery of both mobile and residual product. The applicability of the technology depends upon site-specific hydrogeologic conditions, the nature and distribution of the LNAPL, and the remedial objectives. Although remediation techniques are continuing to improve, most technologies remain limited in removing LNAPL from the subsurface. In particular, the extraction of residual LNAPL is problematic and retention of approximately 40 to 70 percent of the LNAPL mass within the aquifer may occur. Furthermore, the application and operation of some technologies may increase the retention of LNAPL. As such, the proper selection and appropriate operation of corrective measures is very important and may significantly influence long-term conditions at a site. These concepts are discussed in greater detail in the primer *Remediation Technologies*.

Since the effectiveness of current remedial efforts for residual phase product is limited, LNAPL contaminated sites need to be managed in a different manner. Perspectives of producing rapid clean-ups to background conditions are impracticable and generally not possible. LNAPL contaminated sites must be understood in terms of risk and managed appropriately. Hence, understanding must be gained in terms of LNAPL plume stability and recoverability as well as a source of contaminant mass transfer to the water and vapor phases. It is from this technical basis that LNAPL risk can be determined.

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Appendix B

Field and Laboratory Methods

APPENDIX B

Field and Laboratory Testing Methods

1.0 Introduction

This appendix describes the field and laboratory testing methods implemented for Tasks 1, 2, and 3 of the additional investigation performed at the former Milwaukee Railyard Site in Tacoma, Washington (referred to herein as the Site). The field and laboratory testing methods were performed in accordance with the Additional Studies Work Plan (Work Plan) dated October 15, 2007 (TechSolv, 2007b) that was approved by the Washington State Department of Ecology (Ecology). The locations of boreholes and wells referenced in this appendix are shown in Figure 2 of the report text.

2.0 Task 1 - Groundwater Monitoring

Task 1 consisted of groundwater monitoring. Groundwater analytical testing was performed in accordance with U.S. Environmental Protection Agency (EPA) or Ecology approved test methods.

Field Methods

Groundwater monitoring activities were performed in January and March 2008. Results of the January and March 2008 groundwater monitoring events were previously reported to Ecology in the January 2008 and April 2008 monthly progress reports (Shaw, 2008b and 2008c). The monthly progress reports included the field sampling data sheets (FSDSs) and laboratory analytical data reports; therefore, these documents are not included in this report. Similar field methods were employed for both monitoring events and are briefly described below.

For each groundwater monitoring event, Shaw personnel initially measured the depths to groundwater and any nonaqueous phase liquid (NAPL) in 14 monitoring wells (CW-1 through CW-8, MW-22, MW-21, MW-23, CW-9, MW-7, and MW-29) and piezometer OB-2. An electronic oil-water interface probe was used to collect the measurements.

After measuring the depths to groundwater and NAPL, Shaw personnel collected groundwater samples from the same 14 monitoring wells described above (i.e., CW-1 through CW-8, MW-22, MW-21, MW-23, CW-9, MW-7, and MW-29). Monitoring wells with NAPL (CW-4 and CW-5) were sampled by first removing NAPL from the wells. The following describes the procedures used to remove the NAPL:

- A diaphragm pump (an air compressor and generator were used to supply air to the diaphragm pump) was used to facilitate NAPL removal. Flex hose tubing fitted to the diaphragm pump was lowered into the 2-inch diameter well casing to a depth of approximately 2 to 3 feet below the level of the NAPL-groundwater interface. The wells were purged of NAPL by pumping with the diaphragm pump until NAPL was no longer observed discharging from the tubing (i.e., all of the NAPL encountered was removed from each well). Less than 1 gallon of NAPL was recovered from each well.

- A 1-inch-diameter, polyvinyl chloride (PVC) pipe fitted with a PVC end cap was then quickly lowered into the well casing to approximately 2 to 3 feet above the bottom of the well casing before any NAPL could re-enter back into the well casing. The PVC pipe was held in place using a clamp. Approximately 0.5 gallon of deionized water was poured into the PVC pipe to create a positive head in the pipe. A ½-inch diameter, PVC rod was then used to push the end cap off of the PVC pipe (the end cap was attached to a string and removed from the well after sampling was completed).
- Groundwater purging and sampling was facilitated using the 1-inch-diameter PVC pipe and a peristaltic pump. At least three casing volumes of groundwater were purged from the monitoring wells well prior to additional purging and sampling using low-flow sampling procedures as described below.

The monitoring wells were purged and sampled using a peristaltic pump fitted with new, disposable polyethylene tubing replaced for each well. Low-flow purging and sampling techniques were used. The discharge stream was directed into a flow-through cell during well purging for direct measurement of field parameters including temperature, pH, specific conductance, dissolved oxygen (DO), and oxidation-reduction potential (redox). After field parameter measurements stabilized, the pumping rate was reduced and the discharge tubing was disconnected from the flow-through cell. Groundwater samples were then collected directly into laboratory-supplied sampling containers.

Testing Methods

The groundwater samples were submitted under chain-of-custody to TestAmerica in Tacoma, Washington, for analytical testing. All samples were analyzed for diesel- and oil-range TPH by Northwest Test Method NWTPH-Dx using silica gel cleanup before testing. Samples collected from offsite compliance wells MW-21, MW-22, and MW-23 were also analyzed for Ecology-recommended parameters related to diesel-range organics and heavy oils as specified in Table 830-1 of the MTCA cleanup regulations. The parameters analyzed included benzene, toluene, ethylbenzene, and total xylenes (BTEX) by EPA Method 8260B, carcinogenic polynuclear aromatic hydrocarbons (PAHs) and naphthalene by EPA Method 8270C, and polychlorinated biphenyls (PCBs) by EPA Method 8082.

3.0 Task 2 – Test Boring and Soil Characterization

Task 2 consisted of collecting NAPL and undisturbed soil core samples within the NAPL zone for physical characterization. The characterization methodology was conducted in accordance with NAPL guidance provided by the American Petroleum Institute (API, Interactive NAPL Guide Release 2.0.4, and supporting API document *Methods for Determining Inputs to Environmental Petroleum Hydrocarbon Mobility and Recovery Models* [Sale, 2001]). Soil core physical testing was performed in accordance API and ASTM test methods.

Field Methods

On February 14, 2008, two boreholes (SC-1 and SC-2) were advanced to collect soil cores in the NAPL impacted area using a CME-75, hollow-stem auger drill rig operated by Cascade Drilling of Woodinville, Washington. At each borehole location, Cascade Drilling utilized an air knife vacuum excavation system to remove soil to a depth of 5 feet bgs to prevent the potential for damage to possible subsurface utilities. Initially, a pilot borehole was drilled at each location to collect soil samples for visual observation and logging purposes, and to determine the target depths of cores to be sent to the laboratory for physical analyses. The pilot boreholes for SC-1 and SC-2 were advanced to total depths of 21 and 20 feet below ground surface (bgs), respectively. Soil samples were collected continuously in 18-inch long split spoon samplers. Sample blow counts were recorded every 6 inches for qualitative assessment of soil density. Soils were classified according to the Unified Soil Classification System. Logs of the pilot boreholes are provided in Appendix C. Photographs of the sampling activities are provided in Appendix F.

Upon completion of each pilot borehole, a second borehole was advanced within 10 to 15 feet of the pilot boreholes to collect undisturbed soil cores from the NAPL zone (based on observations from the pilot boreholes) for laboratory testing. The coring depths were selected to include the first depth interval where evidence of NAPL was encountered, and to ensure coring from above and below the water table.

Soil core borehole SC-1 was sampled from 8 to 18 feet bgs, and soil core borehole SC-2 was sampled from 5 to 20 feet bgs. An Osterberg fixed-piston sampler was used to enhance sample recovery due to the loose, granular nature of the subsurface soils, and because it prevents soil from entering the sample tube before the sampling depth is reached. The Osterberg sampler contains an activated fixed piston contained in an outer thin-walled, 2.5-foot-long, Shelby Tube sampler. The sampler assembly was lowered to the desired depth, and then the inner sampler piston was withdrawn while the outer thin-walled tube was forced into the sample interval for undisturbed soil collection. The method develops suction within the Shelby Tube sampler thereby minimizing the potential for soil loss through the open end of the sampler.

Soil core sampling using the Osterberg sampler did not allow for sample observation or logging in the field because the sampler was immediately sealed for shipment to the laboratory. Geologic logging of the cores was subsequently possible based on the core photographs and laboratory testing results. Records of the soil core recovery are provided in the borehole logs.

Sample recoveries from ranged from 60 to 85 percent for individual sample intervals. Core recovery was mostly complete in borehole SC-1. SC-2 had no recovery from sample intervals 5.0 to 7.5 feet, 9.1 to 10.0, 11.4 to 15.0 feet, and 17.5 to 20 feet bgs. Some of the poor recovery was due to sampler damage by occasional gravels and boulders within the formation (see Photos 2 and 3, Appendix E), and due to the inherent loose and granular nature of the soils.

Soil core handling and preservation were performed in accordance with recommendations by the testing laboratory (PTS Laboratories) and guidance described by the American Petroleum Institute (Sale, 2001) specifically for collection and handling of soil cores for NAPL investigation. Portions of the Shelby Tube that did not retain the soil cores were filled with commercially available Saran wrap to minimize core movement (and does not interact with the NAPL). Plastic end caps (provided with the Shelby Tubes) were then placed over the ends of the tubes and taped securely to the tubes. The soil cores were labeled with the sampler number, depth interval, arrows to show top and bottom, and were immediately placed in coolers frozen with dry ice so that migration of NAPL or groundwater within the cores was minimized and fluid saturation was preserved. The samples remained frozen with dry ice during storage and transportation to the laboratory.

Testing Methods

The soil cores were submitted under chain-of-custody to PTS Laboratories in Santa Fe Springs, California, for physical testing. The soil cores were tested to evaluate the porous media physical parameters that affect NAPL distribution and recoverability from the subsurface. The testing methods were conducted in accordance with ASTM and API methods specified in *Methods for Determining Inputs to Environmental Petroleum Hydrocarbon Mobility and Recovery Models* (Sale, 2001).

Soil core physical testing was performed in a phased and iterative approach. Initially, the cores were photographed using standard white light and also ultraviolet light to record NAPL fluorescence and visually assess NAPL distribution. Based on assessment of the core photographs (as discussed in the following sections), discreet soil samples were selected from core borehole SC-1 at 8.9, 11.65, and 12.2 feet bgs, and from core borehole SC-2 at 8.7, 10.7, 16.1, and 16.6 feet bgs) for testing of grain size analysis and pore fluid saturation properties. The testing included the following parameters:

- Grain (particle) size analysis by ASTM Method D422/D4464M
- Moisture content by API RP Method 40 and ASTM Method D42216
- Bulk and grain density, total and air-filled porosity, and water and NAPL pore fluid saturations by APR RP Method 40.

Results of the pore fluid saturation testing were used to select additional samples for testing of air/water drainage capillarity properties and NAPL mobility properties. Composite sample intervals were then collected from core borehole SC-1 at 11.7 to 11.9 feet bgs, and from core borehole SC-2 at 15.9 to 16.1 and 16.7 to 16.9 feet bgs. The testing included the following parameters:

- Intrinsic Permaeability (Water): Includes specific permeability to water (intrinsic permeability) and hydraulic conductivity, by API RP40 and ASTM D5084.
- Intrinsic Permeability (NAPL): Includes specific permeability to NAPL (intrinsic permeability), by API RP40.
- Drainage Capillary Pressure Data (centrifugal method; air/water). Includes initial and residual fluid saturations, final water production vs. capillary pressure, effective (total) porosity, bulk density, air permeability and hydraulic conductivity, by API 40, ASTM D425M, and EPA 9100.
- NAPL Mobility (centrifugal method): Apply centrifugal force of 1000 times gravity for one hour to demonstrate product mobility. Includes initial and residual pore fluid saturations, porosity and bulk density, by ASTM D425.

A copy of the laboratory test data prepared by PTS Laboratories (excluding soil core photographs), and a copy of the chain-of-custody form, are provided in Appendix D.

4.0 Task 3 - NAPL Chemical and Physical Characterization

Task 3 consisted of collecting light nonaqueous phase liquid (NAPL) and groundwater samples for chemical and/or physical characterization. Chemical testing (hydrocarbon fingerprinting analysis) was performed by capillary gas chromatography (GC) methods, and physical testing was performed in accordance with American Society for Testing and Materials [ASTM] methods.

Field Methods

NAPL samples were collected on June 7 and 8, 2007, from five recovery or compliance wells (RW2L3, RW5L3, RW2L5, CW-4, and CW-5). The samples were collected using a peristaltic pump. NAPL was pumped directly into laboratory-supplied containers that were immediately placed in coolers chilled with ice. The samples remained chilled with ice during storage and transportation to the laboratory. Groundwater samples were also collected concurrently from these wells and submitted to the laboratory testing for physical analyses (e.g., NAPL/water interfacial tension); however, only selected groundwater samples were analyzed.

Testing Methods

The NAPL and groundwater samples were submitted under chain-of-custody to Torkelson Geochemistry, Inc. of Tulsa, Oklahoma, for chemical testing. The NAPL samples were initially analyzed for hydrocarbon characterization using capillary GC to characterize the range in composition of petroleum hydrocarbons that are present and the degree of weathering. These data were then used to select NAPL samples (and the associated groundwater samples) from two recovery wells, RW2L3 and RW5L3, for physical testing. The samples from these wells were selected for analyses based on the GC results that indicated they represented end-members in the range of NAPL compositions (i.e., diesel and heavy lube oil-range hydrocarbons). The NAPL physical tests included the following:

- NAPL Density (ASTM Method 4052)
- NAPL Viscosity (Brookfield DV-II instrumentation)
- Surface Tension of Air/Water (ASTM Method D971)
- Surface Tension of Air/NAPL (ASTM Method D971)
- Interfacial Tension of NAPL/Water (ASTM Method D971)

One of the groundwater samples, collected from RW-5L3, was also analyzed by GC to evaluate the potential for the NAPL to partition to groundwater.

A copy of the NAPL evaluation report, including the GC chromatograms and NAPL physical properties test data, prepared by Torkelson Geochemistry, Inc., and a copy of the chain-of-custody form, are provided Appendix F.

Appendix C

Borehole Logs for SC-1 and SC-2

Drilling Log

Soil Boring

SC-1 (Pilot Borehole)

Page: 1 of 1

Project *Former Milwaukee RR Site* Owner *Port of Tacoma*

Location *Tacoma, Washington* Proj. No. *111487*

Surface Elev. *NA* Total Hole Depth *21.0 ft.* North ______ East ______

Top of Casing *NA* Water Level Initial ∇ *9.5 ft.* Static *NA* Diameter ______

Screen: Dia *NA* Length *NA* Type/Size *NA*

Casing: Dia *NA* Length *NA* Type *NA*

Fill Material *Bentonite Chips* Rig/Core *CME-75*

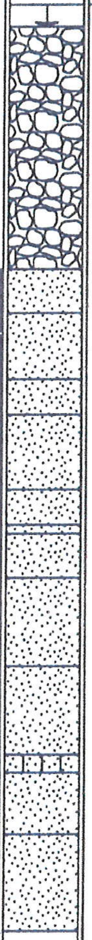
Drill Co. *Cascade Drilling* Method *Hollow Stem Auger*

Driller ______ Log By *David Lamadrid (Shaw)* Date *2/14/08* Permit # *NA*

Checked By ______ License No. ______

COMMENTS

Used 18-inch-long, stainless steel Dames and Moore split-spoon sampler. Depth to groundwater and LNAPL measured at 10.00 and 9.65 feet below top of casing, repectively, in nearby well CW-4 on 2/13/08.



Depth (ft.)	PID (ppm)	Sample ID % Recovery	Blow Count Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Geologic Descriptions are Based on the USCS.
0						Utilized Air Knife to 6' below ground surface for utility clearance. @ 0-0.5' : Asphalt @ 0.5-6' : FILL, gravelly sand with some fines (SW), some cobbles to 3-inch diameter, some concrete chucnks, very wet in upper 2' to 3'.
2						
4						
6		PH-1-1 95%	6 14 16		SP SP	UPPER SAND, Very fine to medium sand (SP), brown, moist , medium dense, trace fines, predominantly very fine grained, some pebbles, rare gravel to 1-inch diameter, no hydrocarbon odor.
8		PH-1-2 100%	10 14 18		SP	@ 7' : Becomes gray-brown, faint hydrocarbon odor. @ 8.5' : 1/2-inch thick lens of slightly silty fine sand (SM)
∇ 10		PH-1-3 100%	6 7 9		SP	@ 9.3' : Same as at 7', becomes wet then quickly saturated with depth, strong hydrocarbon odor, grades to brown-gray.
		PH-1-4 100%	10 12 14		SP	Hydrocarbon odor decreases with depth (moderate odor).
12		PH-1-5 100%	6 6 9		SP SP SP	@ 11.8' : 1-inch thick sandy silt lens. @ 12' : Becomes loose to medium dense. Rare pebbles, still predominantly very fine sand but greater precentage of fine and medium sand.
14		PH-1-6 100%	9 6 4			
16		PH-1-7 100%	7 7 13		SP	Sheen on saturated soil, becomes medium dense.
18		PH-1-8 100%	7 7 9		SM SP	@ 17-17.4' : Slightly silty, very fine to fine sand (SM), brown-gray, saturated silt approximately 10 to 15 percent. @ 17.4' : Very find to medium sand (SP), gray-brown, saturated, medium dense, trace fines, some pebbles.
		PH-1-9 100%	9 9 9		SP	@ 18.8' Sharp contact with very fine to fine sand (SP), gray, saturated, medium dense, no fines, trace to some medium grained sand, becomes slightly finer grained with depth.
20		PH-1-10 100%	9 10 11		SP	Total depth = 21 feet bgs; Groundwater encountered at approx. 9.5' bgs. Backfilled with bentonite chips.
22						
24						

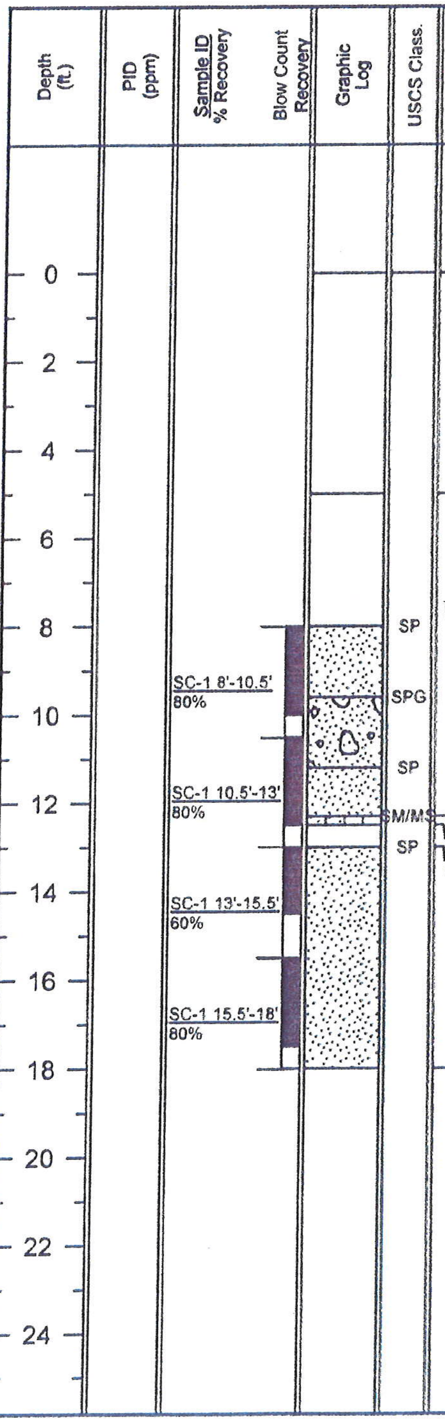
Drilling Log

Soil Boring

SC-1
(Soil Core Borehole)
Page: 1 of 1

Project Former Milwaukee RR Site
Owner Port of Tacoma
Location Tacoma, Washington
Proj. No. 111487
Surface Elev. NA
Total Hole Depth 18.0 ft.
North
East
Top of Casing NA
Water Level Initial NA
Static NA
Diameter
Screen: Dia NA
Length NA
Type/Size NA
Casing: Dia NA
Length NA
Type NA
Fill Material Bentonite Chips
Rig/Core CME-75
Drill Co. Cascade Drilling
Method Hollow Stem Auger
Driller
Log By David Lamadrid (Shaw)
Date 2/14/08
Permit # NA
Checked By
License No.

COMMENTS
SC-1 (Pilot Borehole) drilled adjacent to SC-1 (Core Borehole). Use Osterberg Shelby Tube system to collect soil croes. Core borehole log based on soil core photograph interpretation and grain size analysis.



Description

(Color, Texture, Structure)
Geologic Descriptions are Based on the USCS.

Air Knife Excavation to 5 feet below ground surface.

Auger drill out to 8 feet below ground surface.

UPPER SAND

@ 8' : Fine to medium sand (SP), gray, wet, trace to 10 percent fines, fine laminae, minor to moderate LNAPL from 8.0' to 8.3', 8.6', to 9.0' and 11.0' to 12.3'.

@ 9.6' : scattered pebbles and gravels.

Some layers with apparent fine to coarse sand (SW, 11.2' to 11.3', 11.9' to 12.1')

12.3' - 12.5' : Apparent silty fine sand or fine sandy silt layer.

@12.5' - 13.0' : No recovery

@13' : fine to medium sand (SP), gray, wet, scattered pebbles and gravels, stratification not apparent, minor LNAPL at 13.0' to 14.0', and 15.5' to 16.2', potential sloughing soils based on lack of stratification.

Total Depth = 18'
Backfilled with bentonite chips

Drilling Log

Shaw

SC-2

Soil Boring (Pilot Borehole)

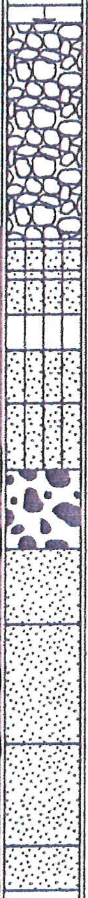
Page: 1 of 1

Project *Former Milwaukee RR Site* Owner *Port of Tacoma*
Location *Tacoma, Washington* Proj. No. *111487*
Surface Elev. *NA* Total Hole Depth *20.0 ft.* North ____ East ____
Top of Casing *NA* Water Level Initial *NA* Static *NA* Diameter ____
Screen: Dia *NA* Length *NA* Type/Size *NA*
Casing: Dia *NA* Length *NA* Type *NA*
Fill Material *Bentonite Chips* Rig/Core *CME-75*
Drill Co. *Cascade Drilling* Method *Hollow Stem Auger*
Driller ____ Log By *David Lamadrid (Shaw)* Date *2/14/08* Permit # *NA*
Checked By ____ License No. ____

COMMENTS
Used 18-inch-long, stainless steel Dames and Moore split-spoon sampler. Depth to groundwater and LNAPL measured at 11.87 and 7.65 feet below top of casing, repectively, in nearby well CW-5 on 2/13/08.

Depth (ft.)	PID (ppm)	Sample ID % Recovery	Blow Count Recovery	USCS Class.
0				
2				
4				
6		PH-2-1 100%	4 6 6	SM SM SM SM
		PH-2-2 100%	4 7 7	ML SM
8		PH-2-3 100%	7 8 12	SM
10		PH-2-4 35%	9 8 9	GW
12		PH-2-5 55%	7 7 8	SP
14		PH-2-6 100%	7 5 9	SP
		PH-2-7 65%	9 12 16	
16		PH-2-8 65%	5 7 7	SP
18		PH-2-9 100%	8 9 11	
		PH-2-10 85%	7 9 9	SP SP
20				
22				
24				

Graphic Log



Description

(Color, Texture, Structure)

Geologic Descriptions are Based on the USCS.

Utilized Air Knife to 5' below ground surface for utility clearance.

@ 0-0.4' : Asphalt

@ 0.4-5.3' : FILL, slightly silty sand (SM), fine to medium sand, brown, moist, some gravels, some cobbles to 8-inch diameter, rare wood chunks.

@ 5.3' : 1.5-inch thick lens of wood chip debris.

@ 5.5' : UPPER SAND, slightly silty, fine to medium sand (SM), brown-gray, wet, loose to medium dense, silt 5 to 15 percent, strong hydrocarbon odor.

@ 6' : 1.5" thick sandy gravel layer, wet, sheen

@ 6.2' : Same as 5.5', minor gravel to 1-inch diameter, slightly more silt increasing with depth.

@ 7' : Slightly sandy silt (ML), green-gray, wet, loose to medium dense, abundant fine gravel, fine sand 5-15 percent, strong hydrocarbon odor.

@ 7.8' : Slightly silty, very fine to medium sand (SM), brown-gray, wet, silt 5 to 15 percent, predominantly fine grained sand, some rounded fine gravel, strong hydrocarbon odor.

@ 9' : silt increases to 10 to 20 percent, abundant LNAPL residue, some gravel.

@10.5' : Fine to coarse sandy gravel (GW), gray, saturated, medium dense, rounded gravel to 1-inch daimeter some fines, abundant LNAPL/sheen, rare wood chunks.

@ 12.3' : Very fine to medium sand (SP), saturated, gray, medium dense, trace fines, moderate LNAPL residue.

Slightly more silt with depth.

@ 16.7' : trace fines, pockets of LNAPL.

@ 19' : moderate LNAPL residue.

Total depth = 20' bgs; LNAPL encountered at approximately 9' bgs. Backfilled with bentonite chips.

Drilling Log

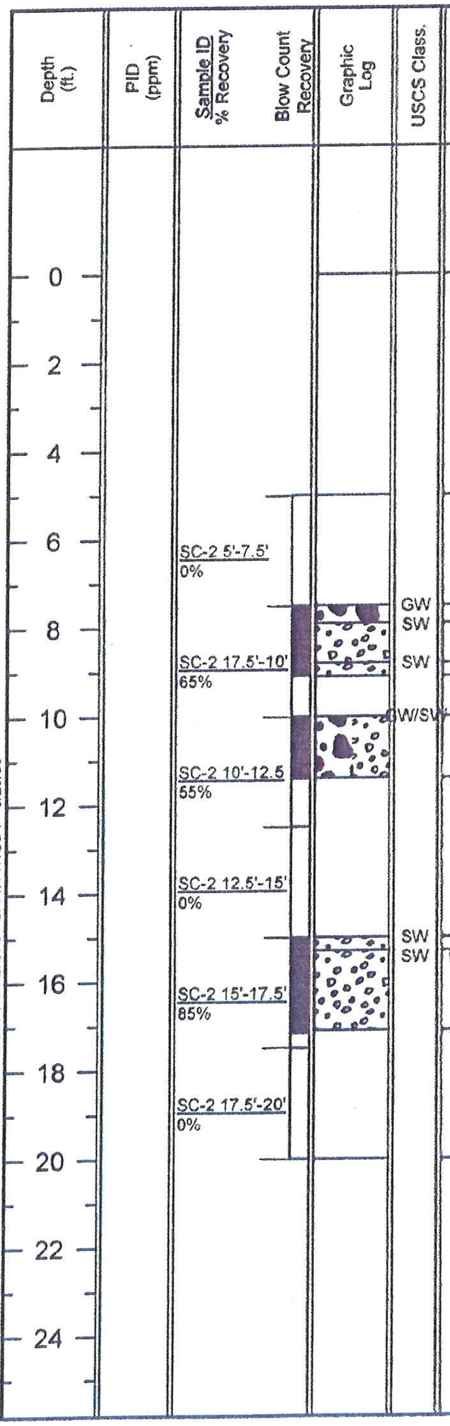
Soil Boring

SC-2
(Soil Core Borehole)

Page: 1 of 1

Project Former Milwaukee RR Site
Owner Port of Tacoma
Location Tacoma, Washington
Proj. No. 111487
Surface Elev. NA
Total Hole Depth 20.0 ft.
North
East
Top of Casing NA
Water Level Initial NA
Static NA
Diameter
Screen: Dia NA
Length NA
Type/Size NA
Casing: Dia NA
Length NA
Type NA
Fill Material Bentonite Chips
Rig/Core CME-75
Drill Co. Cascade Drilling
Method Hollow Stem Auger
Driller
Log By David Lamadrid (Shaw)
Date 2/14/08
Permit # NA
Checked By
License No.

COMMENTS
SC-1 (Pilot Borehole) drilled adjacent to SC-1 (Core Borehole) for lithology. Use Osterberg Shelby Tube system to collect soil croes. Core borehole log based on soil core photograph interpretation and grain size analysis.



Sample ID	% Recovery
SC-2 5'-7.5'	0%
SC-2 17.5'-10'	65%
SC-2 10'-12.5	55%
SC-2 12.5'-15'	0%
SC-2 15'-17.5'	85%
SC-2 17.5'-20'	0%

USCS Class.: GW, SW, SW, GW/SW, SW, SW

Description
(Color, Texture, Structure)
Geologic Descriptions are Based on the USCS.

Air Knife Excavation to 5 feet below ground surface.

@ 5' - 7.5' : No Recovery

@7.5' : UPPER SAND, Fine to coarse sandy gravel (GW), wet, no LNAPL.

@ 7.9' : Fine to coarse sand (SW), wet, 5 to 10 percent fines, few gravels up to 1.5 inch diameter, minor LNAPL.

@ 8.8' : Fine to medium sand, wet, trace fines, no gravel, minor LNAPL.

@ 9.1' - 10.0' : No recovery

@10' : Interbedded sandy gravel (GW) and gravelly sand (SW), beds up to 3" thick, wet, little or no LNAPL in gravel layers, moderate LNAPL in sandy layers.

@11.4' - 15.0' : No reccovery

@15' : Fine to coarse sand (SW) wet, some gravels up to 1.5 inch diameter, very minor LNAPL.

@15.3' : Fine to medium sand (SW), wet, minor pebbles or gravels decreasing with depth, trace fines, abundant LNAPL.

@17.1' - 20' : No recovery

Total Depth = 20'
Backfilled with bentonite chips

Appendix D

PTS Laboratories Soil Core Test Data

PTS Laboratories

May 20, 2008

David Lamadrid
Shaw Environmental
10300 S.W. Nimbus Avenue, Suite B
Portland, Oregon 97223

Re: PTS File No: 38090
Port of Tacoma
111487 01000000

Dear Mr. Lamadrid:

Please find enclosed report for Physical Properties analyses conducted upon cores received from your Port of Tacoma; 111487 01000000 project. All analyses were performed by applicable ASTM, EPA, or API methodologies. An electronic version of the report has previously been sent to your attention via the internet. The samples are currently in storage and will be retained for thirty days past completion of testing at no charge. Please note that the samples will be disposed of at that time. You may contact me regarding storage, disposal, or return of the samples.

PTS Laboratories appreciates the opportunity to be of service. If you have any questions or require additional information, please give me a call at (562) 907-3607.

Sincerely,
PTS Laboratories

Michael Mark Brady

Michael Mark Brady, P.G.
Project Manager

Encl.

8100 Secura Way -- Santa Fe Springs, CA 90670
Phone 562.907.3607 Fax 562.907.3610
www.ptslabs.com

PTS Laboratories

Project Name: Port of Tacoma
Project Number: 111487 01000000

PTS File No: 38090
Client: Shaw Environmental

TEST PROGRAM

CORE ID	Depth ft.	Core Recovery ft.	Slab and Core Photo	Pore Fluid Saturation Package	Grain Size Anal.	A/W Drng. Capillarity Pkg.	Free Product Mobility	Calculate VG Params.	Fluid Properties Package	Notes
Hor. 1.5"		Plugs:	1/4:3/4	Hor. 1.5"	Grab	Hor. 1"	Hor. 1.5"	Calc.	Bulk Fluid	Keep core frozen
SC-1-8'-10.5'	8-10.5	1.8	2	8.9	X					
SC-1-10.5'-13.0'	10.5-13	2	3	11.65, 12.2	X, X	11.7-11.9	11.7-11.9			
SC-1-13.0'-15.5'	13-15.5	1.5	2							
SC-1-15.5'-18.0'	15.5-18	1.9	3							
SC-2-7.5'-10.0'	7.5-10	1.55	3	8.7	X					
SC-2-10.0'-12.5'	10-12.5	1.35	2	10.7	X					
SC-2-15.0'-17.5'	15-17.5	2.05	3	16.1, 16.6	X, X	15.9-16.1, 16.7-16.9	15.9-16.1, 16.7-16.9			
TOTALS:	7 cores	12.15	18	7	7	3	3	0	0	

Laboratory Test Program Notes

Copy Larry Roberts/TechSolv Consulting on all project communication per D. Lamadrid/Shaw Environmental.
Sample locations to be selected by Shaw Environmental and TechSolv personnel from core photography.
Take Grain Size Analysis samples from adjacent to Pore Fluid Saturation Pkg. sample locations.
Take Free Product Mobility from adjacent to A/W Drng. Capillarity Pkg. sample locations.

PTS Laboratories
ENVIRONMENTAL SERVICES

CHAIN OF CUSTODY RECORD

PAGE 1 OF 1

COMPANY
Shaw Environmental

ADDRESS / CITY / ZIP CODE
10300 SW Nimbus Ave, Ste. B, Portland, Oregon

PROJECT MANAGER
David Lamadrid

PROJECT NAME
Port of Tacoma

PHONE NUMBER
(503) 603-1067

PROJECT NUMBER
111487 01000000

FAX NUMBER
(503) 603-1001

SITE LOCATION
Former Milwaukee Railyard Site

SAMPLER SIGNATURE

PO#

TURNAROUND TIME
24 HOURS ☐ 48 HOURS ☐ 72 HOURS ☐ 5 DAYS ☐ NORMAL ☐
OTHER: ______

SAMPLE INTEGRITY (CHECK):
INTACT ____ ON ICE ____

PTS QUOTE NO.

PTS FILE:
38090

ANALYSIS REQUEST

SAMPLE ID NUMBER	DATE	TIME	DEPTH, FT	NUMBER OF SAMPLES	SOIL PROPERTIES PACKAGE	HYDRAULIC CONDUCTIVITY PACKAGE	PORE FLUID SATURATIONS PACKAGE	TCEQ/TNRCC PROPERTIES PACKAGE	CAPILLARITY PACKAGE	FLUID PROPERTIES PACKAGE	PHOTOLOG: CORE PHOTOGRAPHY	MOISTURE CONTENT, ASTM D2216	POROSITY: TOTAL, API RP40	POROSITY: EFFECTIVE, ASTM D425M	SPECIFIC GRAVITY, ASTM D854	BULK DENSITY (DRY), API RP40 or ASTM D2937	AIR PERMEABILITY, API RP40	HYDRAULIC CONDUCTIVITY, EPA9100, API RP40, D5084	GRAIN SIZE DISTRIBUTION, ASTM D422/4464M	TOC: WALKLEY-BLACK	ATTERBERG LIMITS, ASTM D4318					COMMENTS
√ SC-1- 8.0-10.5'	1/14/08	1245	8.0-10.5																							Coordinate Testing with Larry Roberts
√ SC-1-10.5'-13.0'	1/14/08	1250	10.5-13.0																							of TechSolv
√ SC-1-13.0'-15.5'	1/14/08	1255	13.0-15.5																							~~503~~ (425) 402-8277
√ SC-1-15.5'-18.0'	1/14/08	1305	15.5-18.0																							

1. RELINQUISHED BY	2. RECEIVED BY	3. RELINQUISHED BY	4. RECEIVED BY
David Lamadrid David Lamadrid			
COMPANY Shaw Environmental	COMPANY PTS	COMPANY	COMPANY
DATE 1/15/08 TIME 11:00	DATE 2-16-08 TIME 0940	DATE TIME	DATE TIME

PTS Laboratories
ENVIRONMENTAL SERVICES

CHAIN OF CUSTODY RECORD

PAGE 1 OF 1

COMPANY: Shaw Environmental
ADDRESS: 10300 SW Nimbus Avenue, CITY: Portland, ZIP CODE: 97223
PROJECT MANAGER: David Lamadrid
PHONE NUMBER: (503) 603-1067
PROJECT NAME: Port of Tacoma
FAX NUMBER: (503) 603-1001
PROJECT NUMBER: 111487 01000000
SITE LOCATION: Former Milwaukee Railyard site
SAMPLER SIGNATURE: David Lam

PO#:

TURNAROUND TIME
24 HOURS ☐ 5 DAYS ☐
48 HOURS ☐ NORMAL ☐
72 HOURS ☐
OTHER: ____

SAMPLE INTEGRITY (CHECK):
INTACT ____ ON ICE ____

PTS QUOTE NO.

PTS FILE: 38090

ANALYSIS REQUEST

	SAMPLE ID NUMBER	DATE	TIME	DEPTH, FT	NUMBER OF SAMPLES	SOIL PROPERTIES PACKAGE	HYDRAULIC CONDUCTIVITY PACKAGE	PORE FLUID SATURATIONS PACKAGE	TCEQ/TNRCC PROPERTIES PACKAGE	CAPILLARITY PACKAGE	FLUID PROPERTIES PACKAGE	PHOTOLOG: CORE PHOTOGRAPHY	MOISTURE CONTENT, ASTM D2216	POROSITY: TOTAL, API RP40	POROSITY: EFFECTIVE, ASTM D425M	SPECIFIC GRAVITY, ASTM D854	BULK DENSITY (DRY), API RP40 or ASTM D2937	AIR PERMEABILITY, API RP40	HYDRAULIC CONDUCTIVITY, EPA9100, API RP40, D5084	GRAIN SIZE DISTRIBUTION, ASTM D422/4464M	TOC: WALKLEY-BLACK	ATTERBERG LIMITS, ASTM D4318					COMMENTS
✓	SC-2-7.5'-10.0'	1/14/08	1500	7.5'-10.0'																							coordinate testing
✓	SC-2-10.0'-12.5'	1/14/08	1505	10.0'-12.5'																							with Larry Roberts
✓	SC-2-15.0'-17.5'	1/14/08	1515	15.0'-17.5'																							of Tech Solu
																											(425)402-8277

1. RELINQUISHED BY: David Lamadrid David L
COMPANY: Shaw Environmental
DATE: ~~1/14~~ 1/15/08 TIME: 11:00

2. RECEIVED BY:
COMPANY: PTS
DATE: 2-16-08 TIME: 0940

3. RELINQUISHED BY
COMPANY
DATE TIME

4. RECEIVED BY
COMPANY
DATE TIME

D.Z

PTS Laboratories, Inc. • 8100 Secura Way • Santa Fe Springs, CA 90670 • Phone (562) 907-3607 • Fax (562) 907-3610
PTS GeoLabs, Inc. • 4342 W. 12th St. • Houston, TX 77055 • Phone (713) 680-2291 • Fax (713) 680-0763

PTS File No: 38090
Client: Shaw Environmental

PTS Laboratories

PHYSICAL PROPERTIES DATA - PORE FLUID SATURATIONS

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000

		METHODS:	API RP 40 / ASTM D2216	API RP 40		API RP 40		API RP 40	
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	MOISTURE CONTENT, % weight	DENSITY		POROSITY, %Vb (2)		PORE FLUID SATURATIONS, % Pv (3)	
				BULK, g/cc	GRAIN, g/cc	TOTAL	AIR FILLED	WATER	NAPL
SC-1-8-10.5	8.9	H	25.8	1.49	2.70	44.8	5.7	79.1	8.1
SC-1-10.5-13.0	11.65	H	24.1	1.46	2.69	45.6	9.8	69.6	8.8
SC-1-10.5-13.0	12.2	H	16.0	1.50	2.69	44.3	20.2	51.5	2.9
SC-2-7.5-10.0	8.7	H	67.4	0.82	2.07	60.5	4.7	64.2	28.1
SC-2-10.0-12.5	10.7	H	10.4	2.00	2.70	26.1	4.8	57.0	24.6
SC-2-15.0-17.5	16.1	H	24.2	1.53	2.73	44.0	6.0	40.1	46.3
SC-2-15.0-17.5	16.6	H	27.9	1.46	2.70	45.9	4.0	46.0	45.3

(1) Sample Orientation: H = horizontal; V = vertical (2) Total Porosity = no pore fluids in place; all interconnected pore channels; Air Filled = pore channels not occupied by pore fluids (3) Water = 0.9996 g/cc, SC-1 Hydrocarbon = 0.8803 g/cc, SC-2 Hydrocarbon = 0.9498 g/cc; Vb = Bulk Volume, cc; Pv = Pore Volume, cc; ND = Not Detected

PTS File No: 38090
Client: Shaw Environmental

PHYSICAL PROPERTIES DATA - AIR/WATER CAPILLARY PRESSURE

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000

		METHODS:	API RP 40 / ASTM D2216	API RP 40		API RP 40		API RP 40	
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	MOISTURE CONTENT, % weight	DENSITY		POROSITY, %Vb (2)		PORE FLUID SATURATIONS, % Pv (3)	
				BULK, g/cc	GRAIN, g/cc	TOTAL	AIR FILLED	WATER	NAPL
SC-1-10.5'-13.0'	11.8	H	24.8	1.46	2.67	45.4	8.5	68.4	13.0
SC-2-15.0'-17.5'	15.95	H	20.9	1.66	2.79	40.6	5.1	60.2	27.3
SC-2-15.0'-17.5'	16.75	H	26.7	1.47	2.68	45.2	4.6	38.5	51.2

PHYSICAL PROPERTIES DATA - AIR/WATER CAPILLARY PRESSURE

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000

		METHODS:	**API RP 40 / ASTM D2216**	**API RP 40**		**API RP 40**		**API RP 40**	
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	MOISTURE CONTENT, % weight	DENSITY		POROSITY, %Vb (2)		PORE FLUID SATURATIONS, % Pv (3)	
				BULK, g/cc	GRAIN, g/cc	TOTAL	AIR FILLED	WATER	NAPL

(1) Sample Orientation: H = horizontal; V = vertical (2) Total Porosity = no pore fluids in place; all interconnected pore channels; Air Filled = pore channels not occupied by pore fluids (3) Water = 0.9996 g/cc, SC-1 Hydrocarbon = 0.8803 g/cc, SC-2 Hydrocarbon = 0.9498 g/cc; Vb = Bulk Volume, cc; Pv = Pore Volume, cc; ND = Not Detected

PTS File No: 38090
Client: Shaw Environmental

PERMEABILITY DATA

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000

		METHODS:	**API RP 40; EPA 9100**		
			25 PSI CONFINING STRESS		
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	SPECIFIC (2) PERMEABILITY TO AIR millidarcy	EFFECTIVE (3,4) PERMEABILITY TO WATER, millidarcy	HYDRAULIC CONDUCTIVITY (3,4), cm/s
SC-1-10.5'-13.0'	11.8	H	5346	2410	2.21E-03
SC-2-15.0'-17.5'	15.95	H	4841	2178	1.98E-03
SC-2-15.0'-17.5'	16.75	H	6139	3858	3.53E-03

PERMEABILITY DATA

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000

METHODS: **API RP 40; EPA 9100**

			25 PSI CONFINING STRESS		
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	SPECIFIC (2) PERMEABILITY TO AIR millidarcy	EFFECTIVE (3,4) PERMEABILITY TO WATER, millidarcy	HYDRAULIC CONDUCTIVITY (3,4), cm/s

(1) Sample Orientation: H = horizontal; V = vertical (2) Specific = No pore fluids in place (3) Native State or Effective = With as-received pore fluids in place (4) Permeability to water and hydraulic conductivity measured at saturated conditions

PTS File No: 38090
Client: Shaw Environmental

PTS Laboratories

FREE PRODUCT MOBILITY: INITIAL AND RESIDUAL SATURATIONS

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000

		METHODS:	API RP 40		API RP 40	ASTM D425M, DEAN-STARK			
						PORE FLUID SATURATIONS, % Pv			
		SAMPLE	DENSITY		TOTAL	Initial Fluid Saturations		After Centrifuge at 1000xG	
SAMPLE ID.	DEPTH, ft.	ORIENTATION (1)	BULK, g/cc	GRAIN, g/cc	POROSITY, %Vb	WATER (Swi) SATURATION	NAPL (Soi) SATURATION	WATER (Srw) SATURATION	NAPL (Sor) SATURATION
SC-1-10.5'-13.0'	11.9	H	1.53	2.67	42.6	79.7	2.0	11.1	2.0
	NOTE:	**No visible NAPL produced. Produced water slightly cloudy with strong hydrocarbon odor.**							
SC-2-15.0'-17.5'	15.9	H	1.51	2.68	43.7	63.9	23.9	11.4	9.3
	NOTE:	**Black DNAPL produced. Produced water clear.**							
SC-2-15.0'-17.5'	16.9	H	1.58	2.73	42.0	48.7	46.1	9.1	15.0
	NOTE:	**Dark brown DNAPL produced. Produced water clear.**							

N/A = Not Analyzed. Vb = Bulk Volume, Pv = Pore Volume. (1) H = horizontal, V = vertical
Soi = Initial NAPL Saturation as received prior to centrifuging at 1000xG, Swi = Initial Water Saturation as received prior to centrifuging at 1000xG
Sor = Residual NAPL Saturation after centrifuging at 1000xG, Srw = Residual Water Saturation after centrifuging at 1000xG

FREE PRODUCT MOBILITY: INITIAL AND RESIDUAL SATURATIONS

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000

		METHODS:	**API RP 40**		**API RP 40**	**ASTM D425M, DEAN-STARK**			
						PORE FLUID SATURATIONS, % Pv			
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	DENSITY		TOTAL POROSITY, %Vb	Initial Fluid Saturations		After Centrifuge at 1000xG	
			BULK, g/cc	GRAIN, g/cc		WATER (Swi) SATURATION	NAPL (Soi) SATURATION	WATER (Srw) SATURATION	NAPL (Sor) SATURATION

Water =0.9996 g/cc, SC-1 NAPL = 0.8803 g/cc, SC-2 NAPL = 0.9498 g/cc.

PTS File No: 38090
Client: Shaw Environmental

PHYSICAL PROPERTIES DATA - AIR/WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000

Capillary Pressure		Height Above Water Table, ft	Sample ID	
			SC-1 (10.5'-13.0') at 11.8 ft.	
psi	cm water		Saturation, % pore volume	Moisture, % dry weight
0.000	0.00	0.000	100.0	26.9
0.095	6.68	0.220	100.0	26.9
0.214	15.0	0.495	100.0	26.9
0.380	26.7	0.880	98.1	26.4
0.594	41.8	1.37	93.6	25.2
0.855	60.1	1.98	85.9	23.1
1.16	81.8	2.69	64.7	17.4
1.52	107	3.52	52.6	14.2
2.38	167	5.50	38.5	10.4
3.42	241	7.92	29.5	7.9
4.66	327	10.8	23.1	6.2
6.08	428	14.1	17.9	4.8
7.70	541	17.8	14.7	4.0
9.50	668	22.0	12.8	3.5
21.4	1503	49.5	10.3	2.8

Shaw Environmental
File No.: 38090

CAPILLARY PRESSURE
Centrifugal Method
Air Displacing Water System - ASTM D6836

Project Name: Port of Tacoma
Project No: 111487 01000000

Sample ID: SC-1-10.5'-13.0'
Depth, ft: 11.8

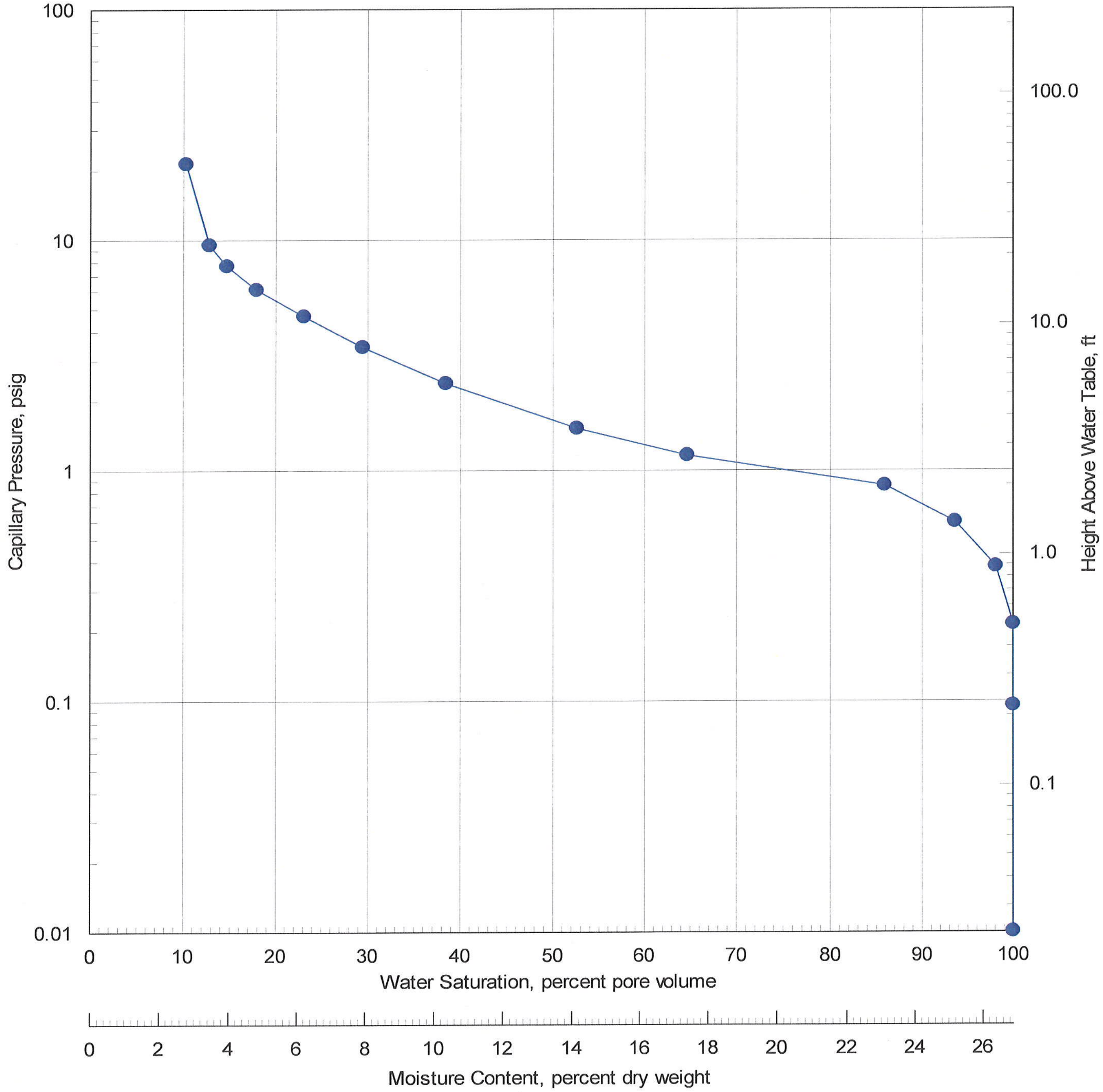


TABLE 1

SOIL MOISTURE RETENTION CURVE FITTING FOR QUANTIFYING THE HYDRAULIC FUNCTIONS OF UNSATURATED SOILS

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000
SAMPLE ID: SC-1 (10.5'-13.0') at 11.8 ft.

van Genuchten Parameters	
alpha (1/cm)	1.160E-02
n	2.602
residual water	0.095
total water	1.000
m	0.616
Water Perm (mD)	2410
Air Perm (mD)	5346
R^2	0.99491

Notes: alpha, n, and residual saturation are capillary parameters defined by the following equation (van Genuchten, 1980), with m = 1-1/n, S = water saturation, and h = capillary head (cm):

$$S_r + [(S_s - S_r)/(1+(\alpha h)^n)^m]$$

Laboratory Measured Data

Capillary Head (cm)	**SC-1 (10.5'-13.0') at 11.8 ft.** Volumetric Moisture	Predicted Moisture by Curve Fit	RPD (%)
0.00	1.000	1.000	0.00%
6.68	1.000	0.999	-0.07%
15.03	1.000	0.994	-0.59%
26.72	0.981	0.975	-0.64%
41.76	0.936	0.925	-1.20%
60.13	0.859	0.833	-2.98%
81.84	0.647	0.710	9.64%
106.89	0.526	0.580	10.43%
167.02	0.385	0.379	-1.59%
240.51	0.295	0.263	-10.85%
327.36	0.231	0.200	-13.43%
427.57	0.179	0.164	-8.66%
541.15	0.147	0.142	-3.36%
668.08	0.128	0.129	0.58%
1503.19	0.103	0.104	1.68%

TABLE 2

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000
SAMPLE ID: SC-1 (10.5'-13.0') at 11.8 ft.

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

Capillary Head (cm)	(van Genuchten, 1980) Volumetric Moisture	(Mualem, 1976) Effective Water Perm.	(Mualem, 1976) Effective Air Perm.
0.001	1.000	2.41E+03	2.46E-19
0.02	1.000	2.41E+03	1.78E-13
0.04	1.000	2.41E+03	4.05E-12
0.05	1.000	2.41E+03	1.11E-11
0.08	1.000	2.41E+03	9.18E-11
0.09	1.000	2.41E+03	1.56E-10
1	1.000	2.41E+03	8.02E-06
1.2	1.000	2.40E+03	1.82E-05
1.3	1.000	2.40E+03	2.61E-05
1.5	1.000	2.40E+03	4.98E-05
2	1.000	2.40E+03	1.82E-04
3	1.000	2.39E+03	1.13E-03
5	1.000	2.36E+03	1.13E-02
7	0.999	2.32E+03	5.13E-02
9	0.998	2.28E+03	1.59E-01
11	0.997	2.23E+03	3.91E-01
15	0.994	2.12E+03	1.56E+00
20	0.988	1.96E+03	5.61E+00
25	0.978	1.78E+03	1.49E+01
30	0.966	1.60E+03	3.26E+01
35	0.950	1.41E+03	6.23E+01
40	0.932	1.23E+03	1.07E+02
45	0.911	1.06E+03	1.70E+02
50	0.887	9.07E+02	2.53E+02
60	0.834	6.42E+02	4.78E+02
70	0.777	4.42E+02	7.74E+02
75	0.749	3.65E+02	9.41E+02
80	0.720	3.00E+02	1.12E+03
85	0.692	2.46E+02	1.30E+03
90	0.665	2.02E+02	1.48E+03
95	0.639	1.66E+02	1.66E+03
100	0.613	1.36E+02	1.85E+03
120	0.524	6.32E+01	2.51E+03
140	0.452	3.07E+01	3.06E+03
160	0.395	1.57E+01	3.49E+03
180	0.351	8.43E+00	3.82E+03
200	0.315	4.76E+00	4.08E+03
220	0.287	2.80E+00	4.28E+03
240	0.263	1.72E+00	4.44E+03
260	0.244	1.09E+00	4.57E+03

TABLE 2

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000
SAMPLE ID: SC-1 (10.5'-13.0') at 11.8 ft.

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

Capillary Head (cm)	(van Genuchten, 1980) Volumetric Moisture	(Mualem, 1976) Effective Water Perm.	(Mualem, 1976) Effective Air Perm.
280	0.228	7.09E-01	4.67E+03
300	0.215	4.75E-01	4.75E+03
320	0.204	3.26E-01	4.82E+03
340	0.194	2.29E-01	4.88E+03
360	0.185	1.63E-01	4.92E+03
380	0.178	1.19E-01	4.97E+03
400	0.172	8.78E-02	5.00E+03
420	0.166	6.57E-02	5.03E+03
440	0.161	4.99E-02	5.06E+03
460	0.156	3.83E-02	5.08E+03
480	0.152	2.98E-02	5.10E+03
500	0.149	2.33E-02	5.12E+03
550	0.141	1.32E-02	5.16E+03
600	0.135	7.87E-03	5.18E+03
650	0.130	4.88E-03	5.21E+03
700	0.127	3.13E-03	5.22E+03
750	0.123	2.07E-03	5.24E+03
800	0.120	1.41E-03	5.25E+03
850	0.118	9.79E-04	5.26E+03
900	0.116	6.95E-04	5.27E+03
950	0.114	5.03E-04	5.28E+03
1000	0.113	3.70E-04	5.28E+03
1050	0.111	2.76E-04	5.29E+03
1100	0.110	2.09E-04	5.29E+03
1150	0.109	1.60E-04	5.30E+03
1200	0.108	1.24E-04	5.30E+03
1250	0.107	9.69E-05	5.30E+03
1300	0.107	7.66E-05	5.31E+03
1350	0.106	6.11E-05	5.31E+03
1400	0.105	4.91E-05	5.31E+03
1450	0.105	3.98E-05	5.31E+03
1500	0.104	3.25E-05	5.31E+03
1550	0.104	2.67E-05	5.32E+03
1600	0.103	2.20E-05	5.32E+03
1650	0.103	1.83E-05	5.32E+03
1700	0.103	1.53E-05	5.32E+03
1750	0.102	1.29E-05	5.32E+03
1800	0.102	1.09E-05	5.32E+03
1850	0.102	9.22E-06	5.32E+03
1900	0.101	7.85E-06	5.33E+03

TABLE 2

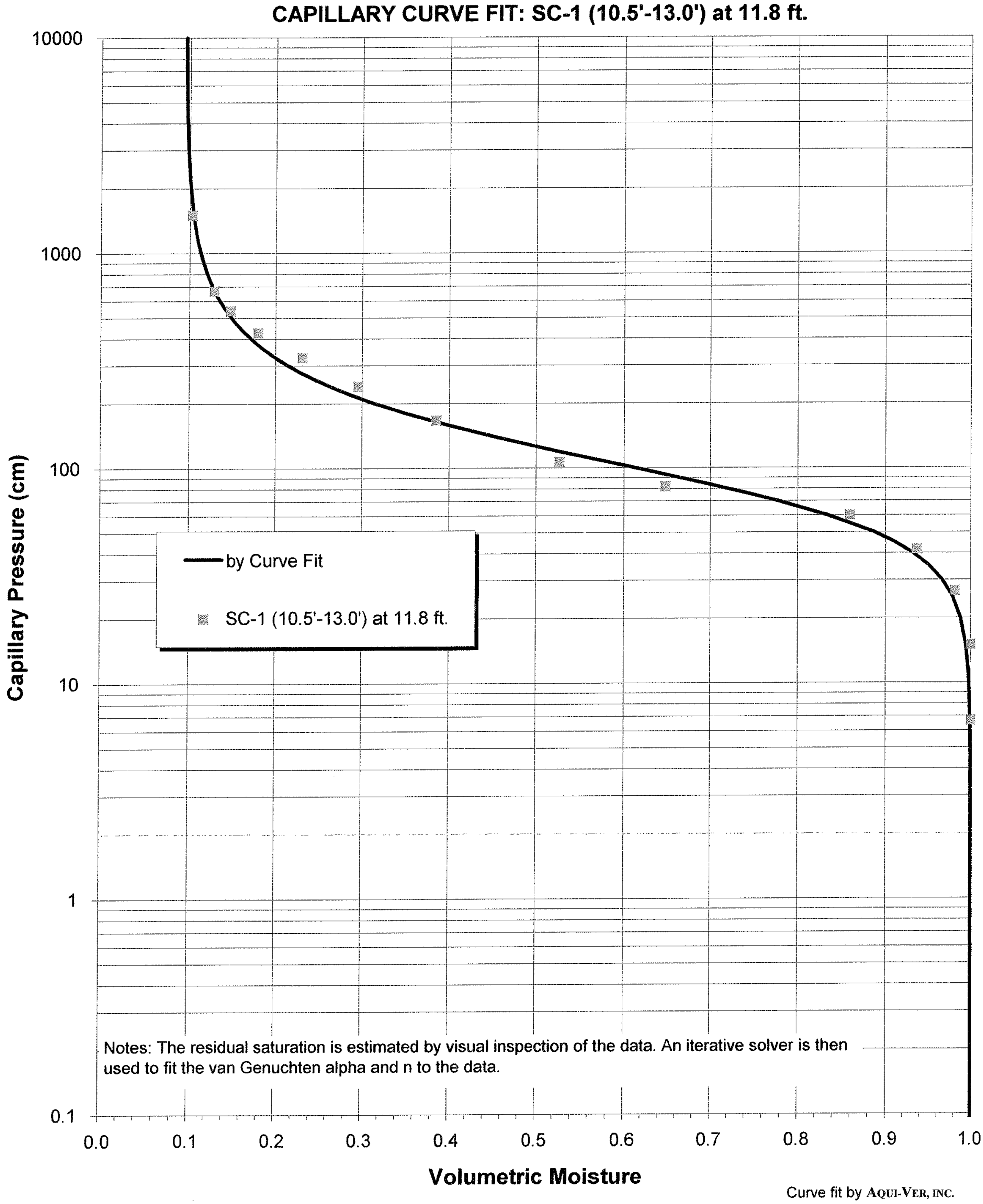
FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000
SAMPLE ID: SC-1 (10.5'-13.0') at 11.8 ft.

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

Capillary Head (cm)	(van Genuchten, 1980) Volumetric Moisture	(Mualem, 1976) Effective Water Perm.	(Mualem, 1976) Effective Air Perm.
1950	0.101	6.72E-06	5.33E+03
2000	0.101	5.77E-06	5.33E+03
2200	0.100	3.26E-06	5.33E+03
2400	0.099	1.93E-06	5.33E+03
2600	0.099	1.19E-06	5.33E+03
2800	0.098	7.66E-07	5.34E+03
3000	0.098	5.06E-07	5.34E+03
3200	0.098	3.43E-07	5.34E+03
3400	0.098	2.39E-07	5.34E+03
3600	0.097	1.69E-07	5.34E+03
3800	0.097	1.22E-07	5.34E+03
4000	0.097	9.00E-08	5.34E+03
4200	0.097	6.71E-08	5.34E+03
4400	0.097	5.08E-08	5.34E+03
4600	0.097	3.89E-08	5.34E+03
4800	0.096	3.01E-08	5.34E+03
5000	0.096	2.36E-08	5.34E+03
5200	0.096	1.86E-08	5.34E+03
5400	0.096	1.48E-08	5.34E+03
5600	0.096	1.19E-08	5.34E+03
5800	0.096	9.66E-09	5.34E+03
6000	0.096	7.88E-09	5.34E+03
6500	0.096	4.88E-09	5.34E+03
7000	0.096	3.12E-09	5.34E+03
7500	0.096	2.06E-09	5.34E+03
8000	0.096	1.40E-09	5.34E+03
8500	0.096	9.74E-10	5.34E+03
9000	0.096	6.91E-10	5.34E+03
9500	0.095	4.99E-10	5.34E+03
10000	0.095	3.67E-10	5.35E+03

PTS File No: 38090
Client: Shaw Environmental



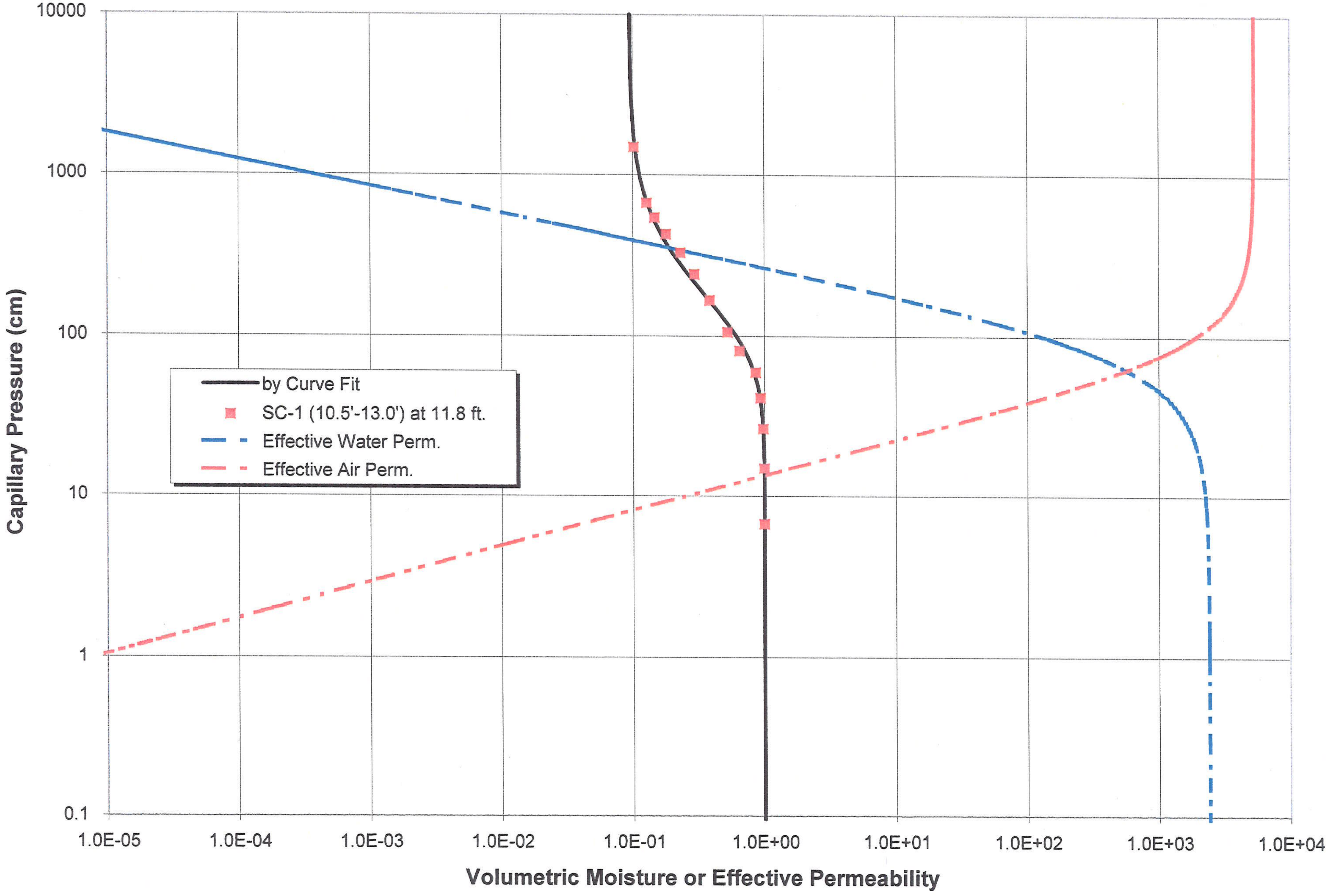
Notes: The residual saturation is estimated by visual inspection of the data. An iterative solver is then used to fit the van Genuchten alpha and n to the data.

Curve fit by AQUI-VER, INC.

PTS File No: 38090
Client: Shaw Environmental

PTS Laboratories

CAPILLARY CURVE FIT: SC-1 (10.5'-13.0') at 11.8 ft.



Curve fit by AQUI-VER, INC.

PTS File No: 38090
Client: Shaw Environmental

PHYSICAL PROPERTIES DATA - AIR/WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000

Capillary Pressure		Height Above Water Table, ft	Sample ID **SC-2 (15.0'-17.5') at 15.95 ft.**	
psi	cm water		Saturation, % pore volume	Moisture, % dry weight
0.000	0.00	0.000	100.0	21.2
0.090	6.35	0.209	100.0	21.2
0.203	14.3	0.470	100.0	21.2
0.361	25.4	0.836	98.4	20.9
0.564	39.7	1.31	95.2	20.2
0.812	57.1	1.88	89.7	19.1
1.11	77.7	2.56	78.6	16.7
1.44	102	3.34	61.9	13.2
2.26	159	5.22	44.4	9.4
3.25	228	7.52	34.1	7.3
4.42	311	10.2	27.0	5.7
5.78	406	13.4	22.2	4.7
7.31	514	16.9	19.0	4.1
9.03	635	20.9	16.7	3.5
20.3	1428	47.0	12.7	2.7

Shaw Environmental
File No.: 38090

CAPILLARY PRESSURE
Centrifugal Method
Air Displacing Water System - ASTM D6836

Project Name: Port of Tacoma
Project No: 111487 01000000

Sample ID: SC-2-15.0'-17.5'
Depth, ft: 15.95

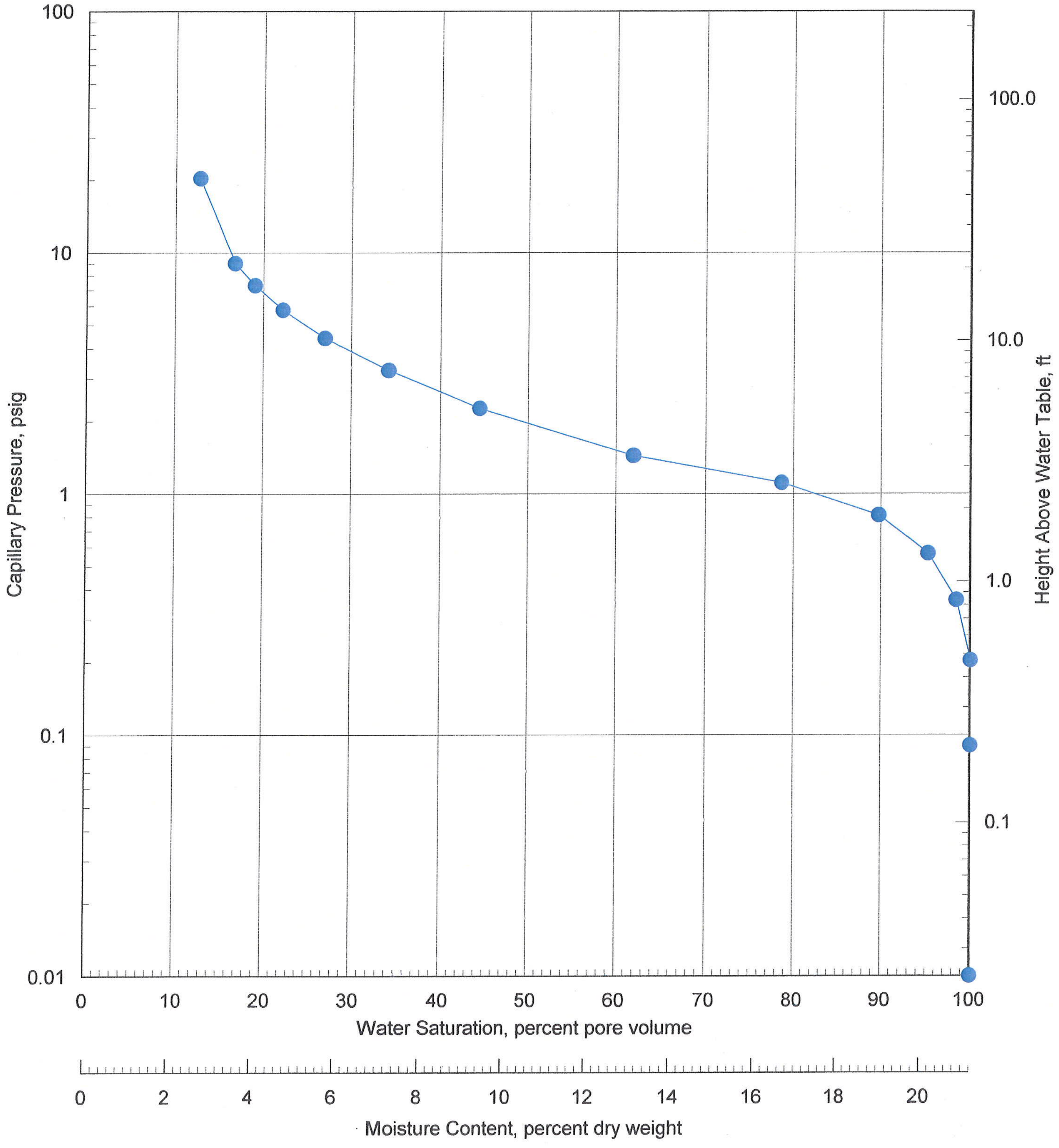


TABLE 1

SOIL MOISTURE RETENTION CURVE FITTING FOR QUANTIFYING THE HYDRAULIC FUNCTIONS OF UNSATURATED SOILS

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000
SAMPLE ID: SC-2 (15.0'-17.5') at 15.95 ft.

van Genuchten Parameters	
alpha (1/cm)	1.046E-02
n	2.516
residual water	0.110
total water	1.000
m	0.603
Water Perm (mD)	2178
Air Perm (mD)	4841
R^2	0.99781

Notes: alpha, n, and residual saturation are capillary parameters defined by the following equation (van Genuchten, 1980), with m = 1-1/n, S = water saturation, and h = capillary head (cm):

$$S_r + [(S_s - S_r)/(1 + (\alpha h)^n)^m]$$

Laboratory Measured Data

Capillary Head (cm)	**SC-2 (15.0'-17.5') at 15.95 ft.** Volumetric Moisture	Predicted Moisture by Curve Fit	RPD (%)
0.00	1.000	1.000	0.00%
6.35	1.000	0.999	-0.06%
14.28	1.000	0.996	-0.45%
25.38	0.984	0.981	-0.27%
39.66	0.952	0.946	-0.66%
57.11	0.897	0.879	-1.96%
77.74	0.786	0.782	-0.49%
101.53	0.619	0.669	8.06%
158.65	0.444	0.466	4.82%
228.45	0.341	0.333	-2.47%
310.95	0.270	0.254	-5.72%
406.13	0.222	0.208	-6.51%
514.01	0.190	0.179	-6.09%
634.58	0.167	0.160	-3.87%
1427.81	0.127	0.125	-1.76%

TABLE 2

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000
SAMPLE ID: SC-2 (15.0'-17.5') at 15.95 ft.

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

Capillary Head (cm)	(van Genuchten, 1980) Volumetric Moisture	(Mualem, 1976) Effective Water Perm.	(Mualem, 1976) Effective Air Perm.
0.001	1.000	2.18E+03	1.62E-18
0.02	1.000	2.18E+03	6.16E-13
0.04	1.000	2.18E+03	1.21E-11
0.05	1.000	2.18E+03	3.14E-11
0.08	1.000	2.18E+03	2.36E-10
0.09	1.000	2.18E+03	3.91E-10
1	1.000	2.17E+03	1.20E-05
1.2	1.000	2.17E+03	2.62E-05
1.3	1.000	2.17E+03	3.69E-05
1.5	1.000	2.17E+03	6.83E-05
2	1.000	2.17E+03	2.35E-04
3	1.000	2.16E+03	1.34E-03
5	1.000	2.13E+03	1.19E-02
7	0.999	2.10E+03	5.05E-02
9	0.999	2.06E+03	1.48E-01
11	0.998	2.01E+03	3.50E-01
15	0.995	1.92E+03	1.31E+00
20	0.990	1.78E+03	4.43E+00
25	0.982	1.64E+03	1.13E+01
30	0.972	1.49E+03	2.39E+01
35	0.960	1.33E+03	4.46E+01
40	0.945	1.19E+03	7.55E+01
45	0.928	1.04E+03	1.18E+02
50	0.909	9.10E+02	1.75E+02
60	0.866	6.77E+02	3.30E+02
70	0.820	4.92E+02	5.39E+02
75	0.795	4.17E+02	6.60E+02
80	0.771	3.52E+02	7.89E+02
85	0.747	2.97E+02	9.26E+02
90	0.722	2.50E+02	1.07E+03
95	0.699	2.10E+02	1.21E+03
100	0.676	1.77E+02	1.35E+03
120	0.591	8.95E+01	1.91E+03
140	0.520	4.66E+01	2.40E+03
160	0.462	2.52E+01	2.81E+03
180	0.415	1.42E+01	3.14E+03
200	0.376	8.34E+00	3.40E+03
220	0.345	5.08E+00	3.61E+03
240	0.318	3.20E+00	3.78E+03
260	0.296	2.08E+00	3.92E+03

TABLE 2

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000
SAMPLE ID: SC-2 (15.0'-17.5') at 15.95 ft.

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

Capillary Head (cm)	(van Genuchten, 1980) Volumetric Moisture	(Mualem, 1976) Effective Water Perm.	(Mualem, 1976) Effective Air Perm.
280	0.278	1.39E+00	4.03E+03
300	0.262	9.48E-01	4.13E+03
320	0.249	6.62E-01	4.21E+03
340	0.237	4.72E-01	4.27E+03
360	0.227	3.42E-01	4.33E+03
380	0.218	2.53E-01	4.37E+03
400	0.210	1.89E-01	4.42E+03
420	0.203	1.43E-01	4.45E+03
440	0.197	1.10E-01	4.48E+03
460	0.191	8.54E-02	4.51E+03
480	0.186	6.70E-02	4.53E+03
500	0.182	5.31E-02	4.56E+03
550	0.172	3.07E-02	4.60E+03
600	0.165	1.87E-02	4.64E+03
650	0.158	1.18E-02	4.66E+03
700	0.153	7.69E-03	4.68E+03
750	0.149	5.17E-03	4.70E+03
800	0.145	3.56E-03	4.72E+03
850	0.142	2.51E-03	4.73E+03
900	0.140	1.81E-03	4.74E+03
950	0.137	1.32E-03	4.75E+03
1000	0.135	9.82E-04	4.76E+03
1050	0.133	7.41E-04	4.76E+03
1100	0.132	5.66E-04	4.77E+03
1150	0.130	4.38E-04	4.77E+03
1200	0.129	3.42E-04	4.78E+03
1250	0.128	2.70E-04	4.78E+03
1300	0.127	2.16E-04	4.79E+03
1350	0.126	1.73E-04	4.79E+03
1400	0.125	1.40E-04	4.79E+03
1450	0.124	1.15E-04	4.80E+03
1500	0.124	9.42E-05	4.80E+03
1550	0.123	7.79E-05	4.80E+03
1600	0.122	6.48E-05	4.80E+03
1650	0.122	5.43E-05	4.80E+03
1700	0.121	4.57E-05	4.81E+03
1750	0.121	3.86E-05	4.81E+03
1800	0.120	3.28E-05	4.81E+03
1850	0.120	2.80E-05	4.81E+03
1900	0.120	2.40E-05	4.81E+03

TABLE 2

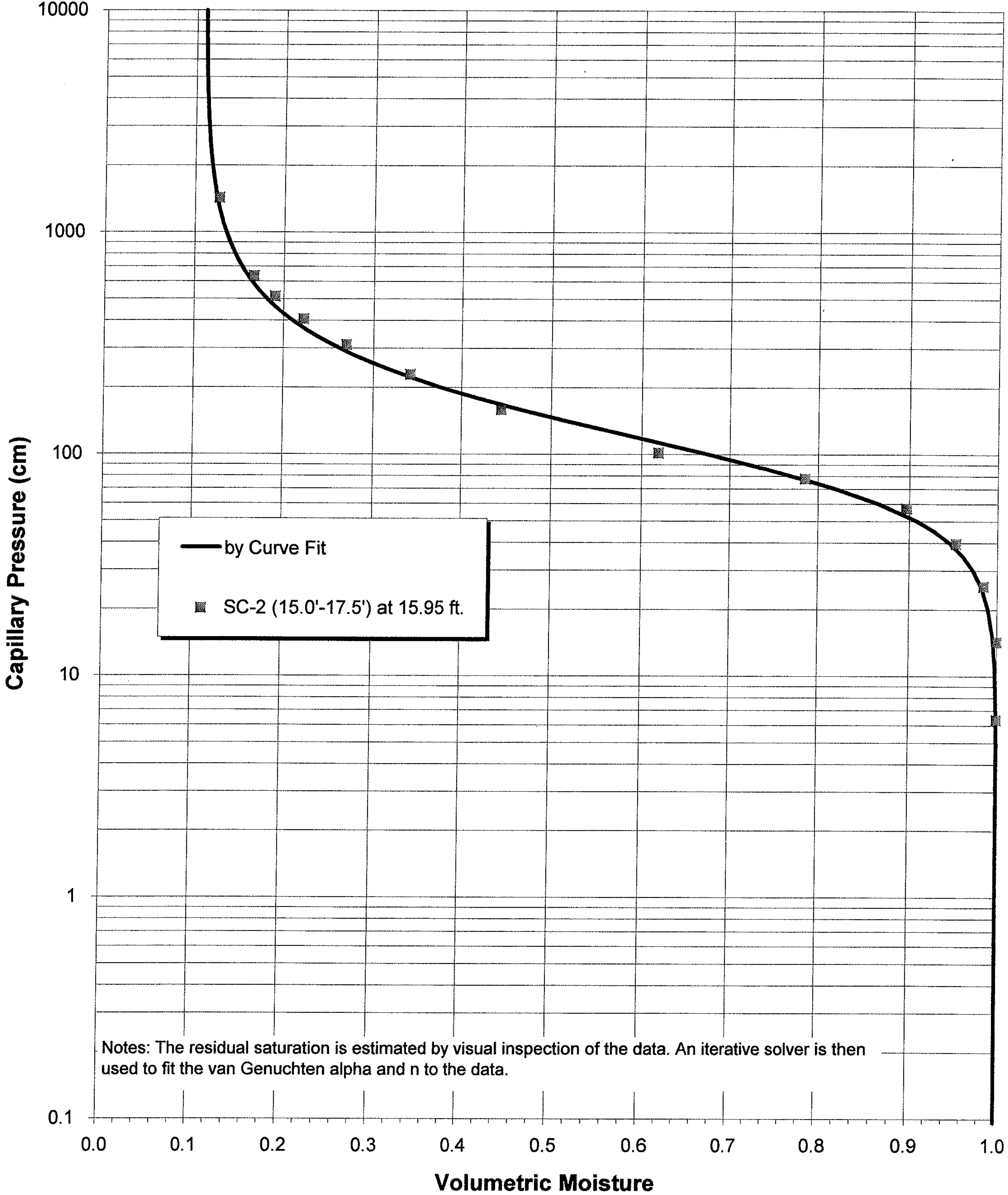
FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

PROJECT NAME:	Port of Tacoma
PROJECT NO:	111487 01000000
SAMPLE ID:	SC-2 (15.0'-17.5') at 15.95 ft.

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

Capillary Head (cm)	(van Genuchten, 1980) Volumetric Moisture	(Mualem, 1976) Effective Water Perm.	(Mualem, 1976) Effective Air Perm.
1950	0.119	2.06E-05	4.81E+03
2000	0.119	1.78E-05	4.81E+03
2200	0.118	1.03E-05	4.82E+03
2400	0.117	6.20E-06	4.82E+03
2600	0.116	3.90E-06	4.82E+03
2800	0.115	2.54E-06	4.83E+03
3000	0.115	1.70E-06	4.83E+03
3200	0.114	1.17E-06	4.83E+03
3400	0.114	8.26E-07	4.83E+03
3600	0.114	5.93E-07	4.83E+03
3800	0.113	4.34E-07	4.83E+03
4000	0.113	3.22E-07	4.83E+03
4200	0.113	2.43E-07	4.83E+03
4400	0.113	1.86E-07	4.83E+03
4600	0.113	1.44E-07	4.83E+03
4800	0.112	1.12E-07	4.83E+03
5000	0.112	8.86E-08	4.84E+03
5200	0.112	7.06E-08	4.84E+03
5400	0.112	5.67E-08	4.84E+03
5600	0.112	4.60E-08	4.84E+03
5800	0.112	3.75E-08	4.84E+03
6000	0.112	3.08E-08	4.84E+03
6500	0.111	1.94E-08	4.84E+03
7000	0.111	1.26E-08	4.84E+03
7500	0.111	8.47E-09	4.84E+03
8000	0.111	5.83E-09	4.84E+03
8500	0.111	4.10E-09	4.84E+03
9000	0.111	2.95E-09	4.84E+03
9500	0.111	2.15E-09	4.84E+03
10000	0.111	1.60E-09	4.84E+03

CAPILLARY CURVE FIT: SC-2 (15.0'-17.5') at 15.95 ft.



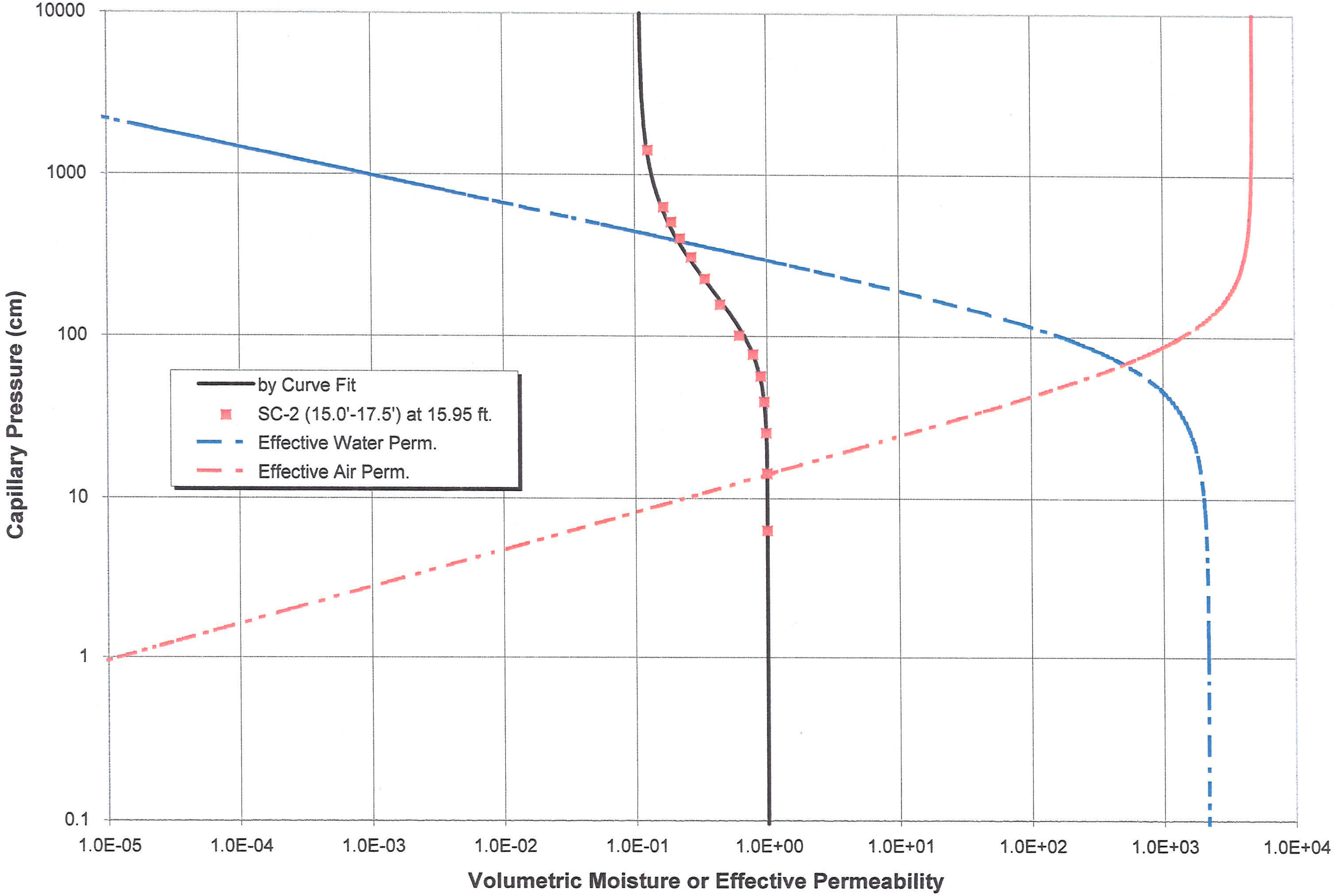
Notes: The residual saturation is estimated by visual inspection of the data. An iterative solver is then used to fit the van Genuchten alpha and n to the data.

Curve fit by AQUI-VER, INC.

PTS File No: 38090
Client: Shaw Environmental

PTS Laboratories

CAPILLARY CURVE FIT: SC-2 (15.0'-17.5') at 15.95 ft.



Curve fit by AQUI-VER, INC.

PTS File No: 38090
Client: Shaw Environmental

PHYSICAL PROPERTIES DATA - AIR/WATER CAPILLARY PRESSURE

(ASTM D6836; Centrifugal Method: air displacing water)

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000

Capillary Pressure		Height Above Water Table, ft	Sample ID	
			SC-2 (15.0'-17.5') at 16.75 ft.	
psi	cm water		Saturation, % pore volume	Moisture, % dry weight
0.000	0.00	0.000	100.0	24.9
0.093	6.57	0.216	100.0	24.9
0.210	14.8	0.487	100.0	24.9
0.374	26.3	0.865	97.8	24.4
0.584	41.1	1.35	94.2	23.5
0.841	59.1	1.95	87.0	21.7
1.14	80.5	2.65	62.5	15.6
1.50	105	3.46	45.2	11.3
2.34	164	5.41	30.7	7.7
3.36	237	7.79	22.8	5.7
4.58	322	10.6	17.7	4.4
5.98	420	13.8	14.1	3.5
7.57	532	17.5	12.0	3.0
9.34	657	21.6	10.8	2.7
21.0	1478	48.7	9.1	2.3

PTS Laboratories

Shaw Environmental
File No.: 38090

CAPILLARY PRESSURE
Centrifugal Method
Air Displacing Water System - ASTM D6836

Project Name: Port of Tacoma
Project No: 111487 01000000

Sample ID: SC-2-15.0'-17.5'
Depth, ft: 16.75

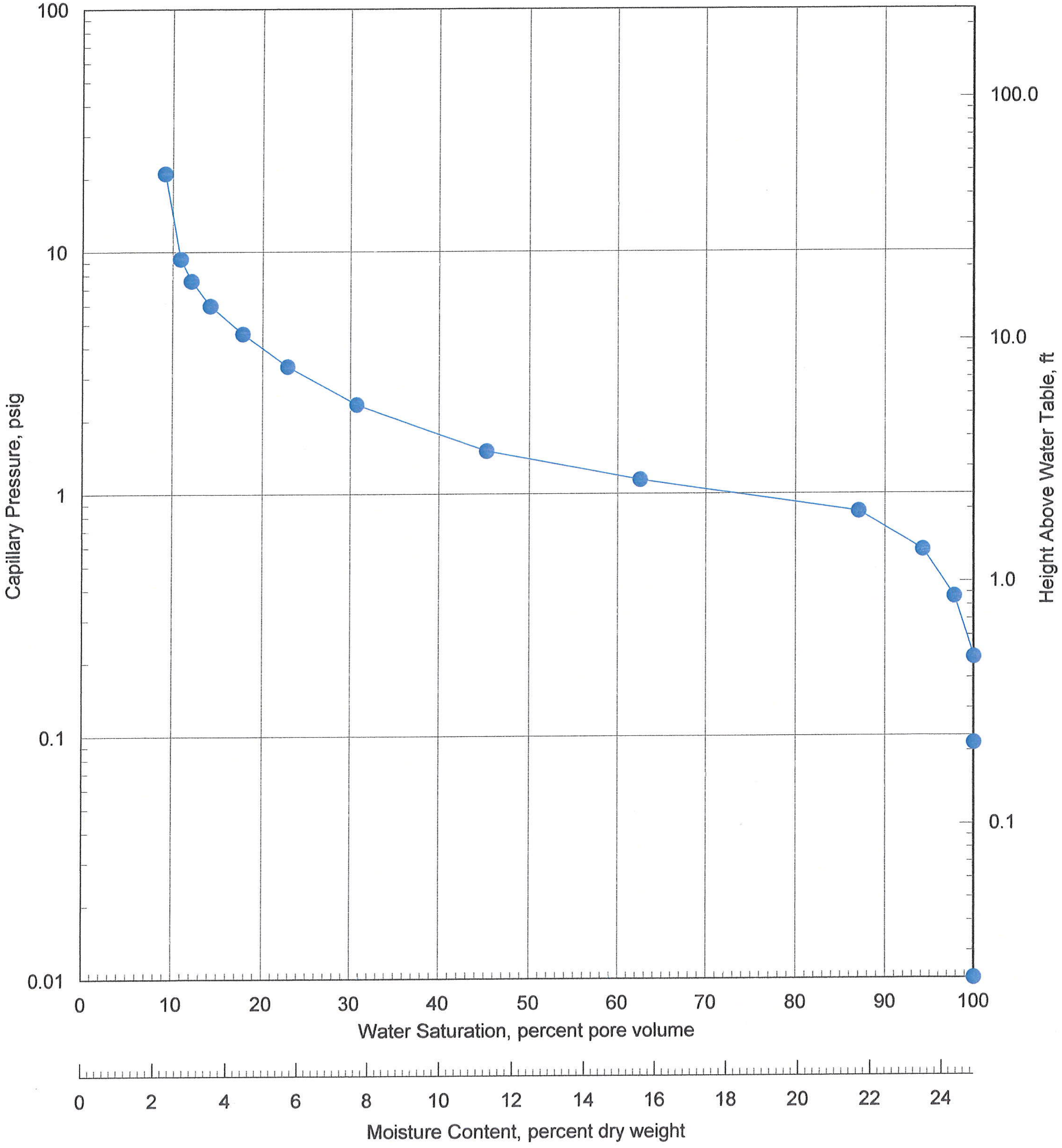


TABLE 1

SOIL MOISTURE RETENTION CURVE FITTING FOR QUANTIFYING THE HYDRAULIC FUNCTIONS OF UNSATURATED SOILS

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000
SAMPLE ID: SC-2 (15.0'-17.5') at 16.75 ft.

van Genuchten Parameters	
alpha (1/cm)	1.266E-02
n	3.172
residual water	0.091
total water	1.000
m	0.685
Water Perm (mD)	3858
Air Perm (mD)	6139
R^2	0.99608

Notes: alpha, n, and residual saturation are capillary parameters defined by the following equation (van Genuchten, 1980), with m = 1-1/n, S = water saturation, and h = capillary head (cm):

$$S_r + [(S_s - S_r)/(1+(\alpha h)^n)^m]$$

Laboratory Measured Data

Capillary Head (cm)	**SC-2 (15.0'-17.5') at 16.75 ft.** Volumetric Moisture	Predicted Moisture by Curve Fit	RPD (%)
0.00	1.000	1.000	0.00%
6.57	1.000	1.000	-0.02%
14.78	1.000	0.997	-0.30%
26.28	0.978	0.982	0.32%
41.06	0.942	0.929	-1.37%
59.13	0.870	0.813	-6.52%
80.48	0.625	0.645	3.26%
105.12	0.452	0.479	5.96%
164.25	0.307	0.265	-13.78%
236.52	0.228	0.173	-23.98%
321.92	0.177	0.134	-24.68%
420.47	0.141	0.115	-18.67%
532.16	0.120	0.105	-11.98%
656.99	0.108	0.100	-7.48%
1478.22	0.091	0.093	1.83%

TABLE 2

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000
SAMPLE ID: SC-2 (15.0'-17.5') at 16.75 ft.

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

Capillary Head (cm)	(van Genuchten, 1980) Volumetric Moisture	(Mualem, 1976) Effective Water Perm.	(Mualem, 1976) Effective Air Perm.
0.001	1.000	3.86E+03	5.84E-26
0.02	1.000	3.86E+03	2.41E-18
0.04	1.000	3.86E+03	1.47E-16
0.05	1.000	3.86E+03	5.51E-16
0.08	1.000	3.86E+03	8.93E-15
0.09	1.000	3.86E+03	1.80E-14
1	1.000	3.86E+03	2.85E-08
1.2	1.000	3.86E+03	8.39E-08
1.3	1.000	3.86E+03	1.35E-07
1.5	1.000	3.86E+03	3.15E-07
2	1.000	3.86E+03	1.74E-06
3	1.000	3.85E+03	1.92E-05
5	1.000	3.84E+03	3.97E-04
7	1.000	3.82E+03	2.92E-03
9	0.999	3.79E+03	1.29E-02
11	0.999	3.75E+03	4.24E-02
15	0.997	3.65E+03	2.65E-01
20	0.992	3.47E+03	1.44E+00
25	0.984	3.23E+03	5.28E+00
30	0.972	2.95E+03	1.50E+01
35	0.956	2.64E+03	3.57E+01
40	0.934	2.31E+03	7.38E+01
45	0.908	1.98E+03	1.37E+02
50	0.878	1.66E+03	2.31E+02
60	0.807	1.10E+03	5.31E+02
70	0.728	6.87E+02	9.75E+02
75	0.688	5.34E+02	1.24E+03
80	0.649	4.13E+02	1.52E+03
85	0.611	3.17E+02	1.80E+03
90	0.575	2.43E+02	2.09E+03
95	0.541	1.86E+02	2.38E+03
100	0.509	1.42E+02	2.65E+03
120	0.403	5.02E+01	3.60E+03
140	0.328	1.90E+01	4.29E+03
160	0.274	7.79E+00	4.77E+03
180	0.236	3.45E+00	5.11E+03
200	0.208	1.64E+00	5.34E+03
220	0.187	8.32E-01	5.51E+03
240	0.171	4.44E-01	5.63E+03
260	0.158	2.48E-01	5.73E+03

PTS File No: 38090
Client: Shaw Environmental

PTS Laboratories

TABLE 2

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000
SAMPLE ID: SC-2 (15.0'-17.5') at 16.75 ft.

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

Capillary Head (cm)	(van Genuchten, 1980) Volumetric Moisture	(Mualem, 1976) Effective Water Perm.	(Mualem, 1976) Effective Air Perm.
280	0.149	1.44E-01	5.80E+03
300	0.141	8.71E-02	5.85E+03
320	0.134	5.42E-02	5.90E+03
340	0.129	3.47E-02	5.93E+03
360	0.125	2.28E-02	5.96E+03
380	0.121	1.53E-02	5.98E+03
400	0.118	1.05E-02	6.00E+03
420	0.115	7.29E-03	6.02E+03
440	0.113	5.17E-03	6.03E+03
460	0.111	3.72E-03	6.04E+03
480	0.109	2.71E-03	6.05E+03
500	0.108	2.01E-03	6.06E+03
550	0.104	9.89E-04	6.08E+03
600	0.102	5.19E-04	6.09E+03
650	0.100	2.87E-04	6.10E+03
700	0.099	1.65E-04	6.10E+03
750	0.098	9.90E-05	6.11E+03
800	0.097	6.13E-05	6.11E+03
850	0.096	3.91E-05	6.12E+03
900	0.096	2.56E-05	6.12E+03
950	0.095	1.71E-05	6.12E+03
1000	0.095	1.17E-05	6.12E+03
1050	0.094	8.14E-06	6.13E+03
1100	0.094	5.76E-06	6.13E+03
1150	0.094	4.14E-06	6.13E+03
1200	0.093	3.02E-06	6.13E+03
1250	0.093	2.23E-06	6.13E+03
1300	0.093	1.67E-06	6.13E+03
1350	0.093	1.26E-06	6.13E+03
1400	0.093	9.61E-07	6.13E+03
1450	0.093	7.40E-07	6.13E+03
1500	0.093	5.76E-07	6.13E+03
1550	0.092	4.51E-07	6.13E+03
1600	0.092	3.56E-07	6.13E+03
1650	0.092	2.84E-07	6.13E+03
1700	0.092	2.27E-07	6.13E+03
1750	0.092	1.83E-07	6.13E+03
1800	0.092	1.49E-07	6.13E+03
1850	0.092	1.21E-07	6.14E+03
1900	0.092	9.94E-08	6.14E+03

TABLE 2

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

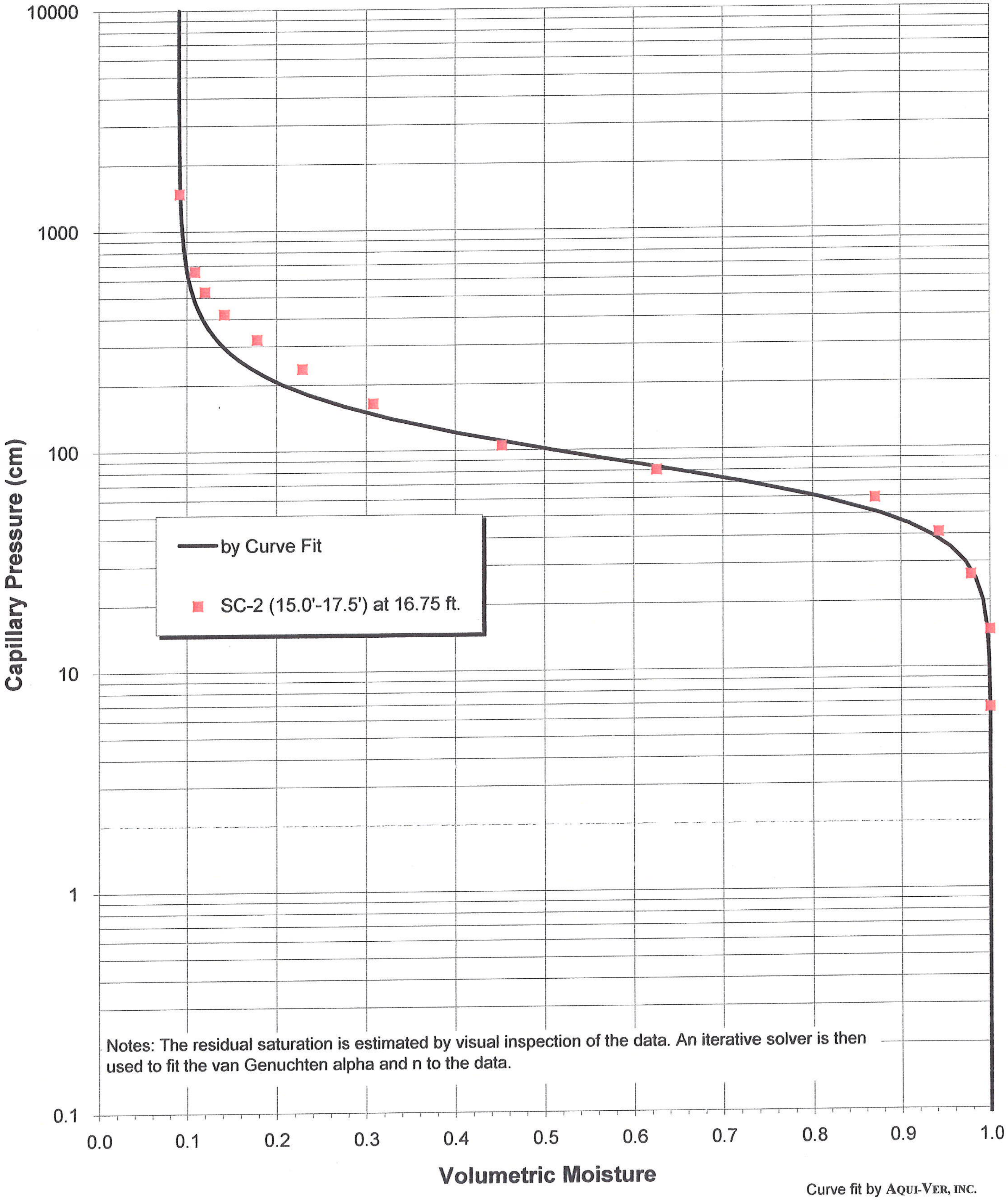
PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000
SAMPLE ID: SC-2 (15.0'-17.5') at 16.75 ft.

FUNCTIONAL RELATIONSHIPS BASED ON DERIVED CAPILLARY PARAMETERS

Capillary Head (cm)	(van Genuchten, 1980) Volumetric Moisture	(Mualem, 1976) Effective Water Perm.	(Mualem, 1976) Effective Air Perm.
1950	0.092	8.20E-08	6.14E+03
2000	0.092	6.79E-08	6.14E+03
2200	0.092	3.35E-08	6.14E+03
2400	0.092	1.75E-08	6.14E+03
2600	0.091	9.67E-09	6.14E+03
2800	0.091	5.58E-09	6.14E+03
3000	0.091	3.34E-09	6.14E+03
3200	0.091	2.07E-09	6.14E+03
3400	0.091	1.32E-09	6.14E+03
3600	0.091	8.62E-10	6.14E+03
3800	0.091	5.77E-10	6.14E+03
4000	0.091	3.94E-10	6.14E+03
4200	0.091	2.74E-10	6.14E+03
4400	0.091	1.94E-10	6.14E+03
4600	0.091	1.40E-10	6.14E+03
4800	0.091	1.02E-10	6.14E+03
5000	0.091	7.51E-11	6.14E+03
5200	0.091	5.61E-11	6.14E+03
5400	0.091	4.24E-11	6.14E+03
5600	0.091	3.24E-11	6.14E+03
5800	0.091	2.49E-11	6.14E+03
6000	0.091	1.94E-11	6.14E+03
6500	0.091	1.07E-11	6.14E+03
7000	0.091	6.17E-12	6.14E+03
7500	0.091	3.69E-12	6.14E+03
8000	0.091	2.29E-12	6.14E+03
8500	0.091	1.46E-12	6.14E+03
9000	0.091	9.54E-13	6.14E+03
9500	0.091	6.38E-13	6.14E+03
10000	0.091	4.36E-13	6.14E+03

PTS File No: 38090
Client: Shaw Environmental

CAPILLARY CURVE FIT: SC-2 (15.0'-17.5') at 16.75 ft.



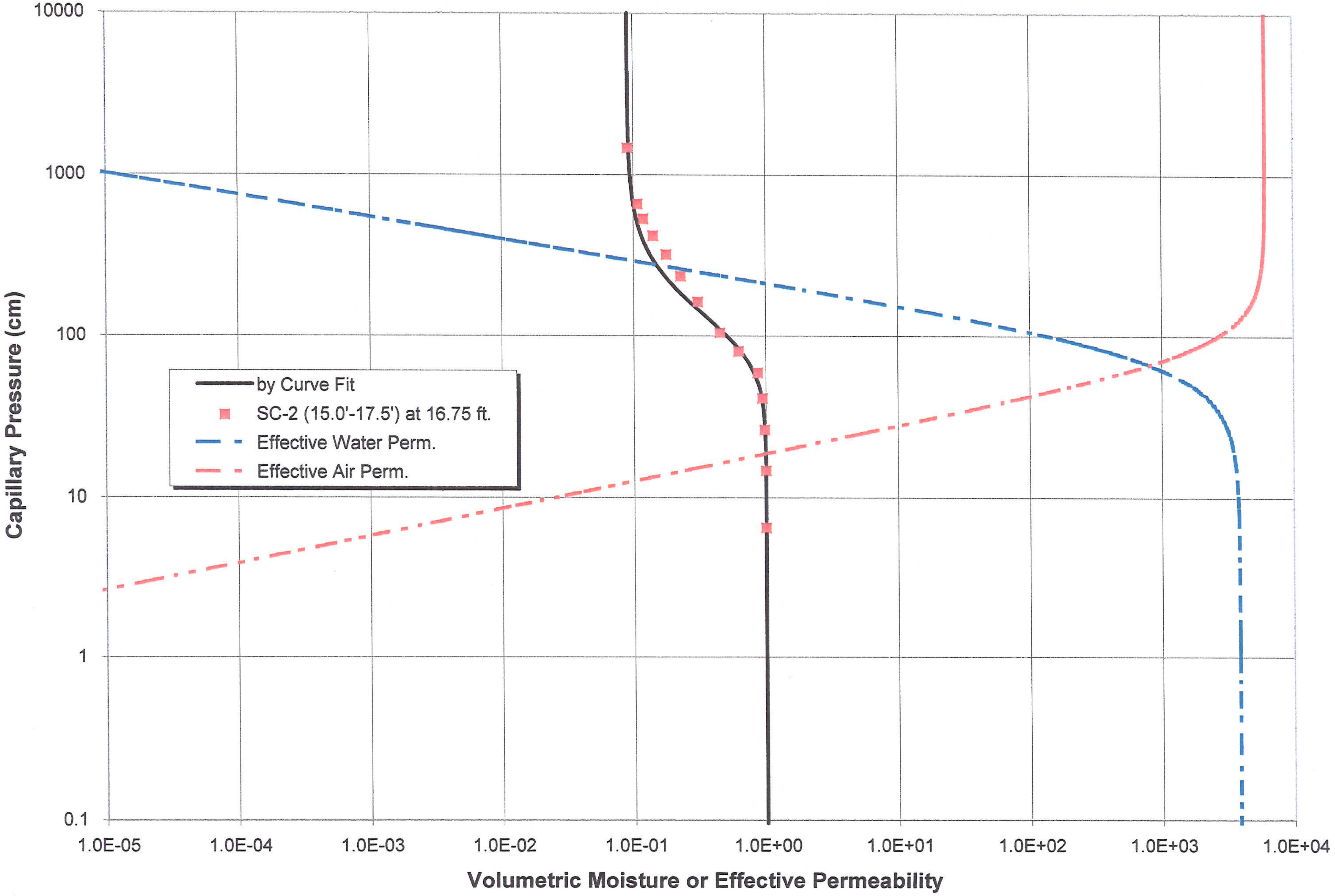
Notes: The residual saturation is estimated by visual inspection of the data. An iterative solver is then used to fit the van Genuchten alpha and n to the data.

Curve fit by AQUI-VER, INC.

PTS File No: 38090
Client: Shaw Environmental

PTS Laboratories

CAPILLARY CURVE FIT: SC-2 (15.0'-17.5') at 16.75 ft.



Curve fit by AQUI-VER, INC.

PARTICLE SIZE SUMMARY

(METHODOLOGY: ASTM D422/D4464M)

PROJECT NAME: Port of Tacoma
PROJECT NO: 111487 01000000

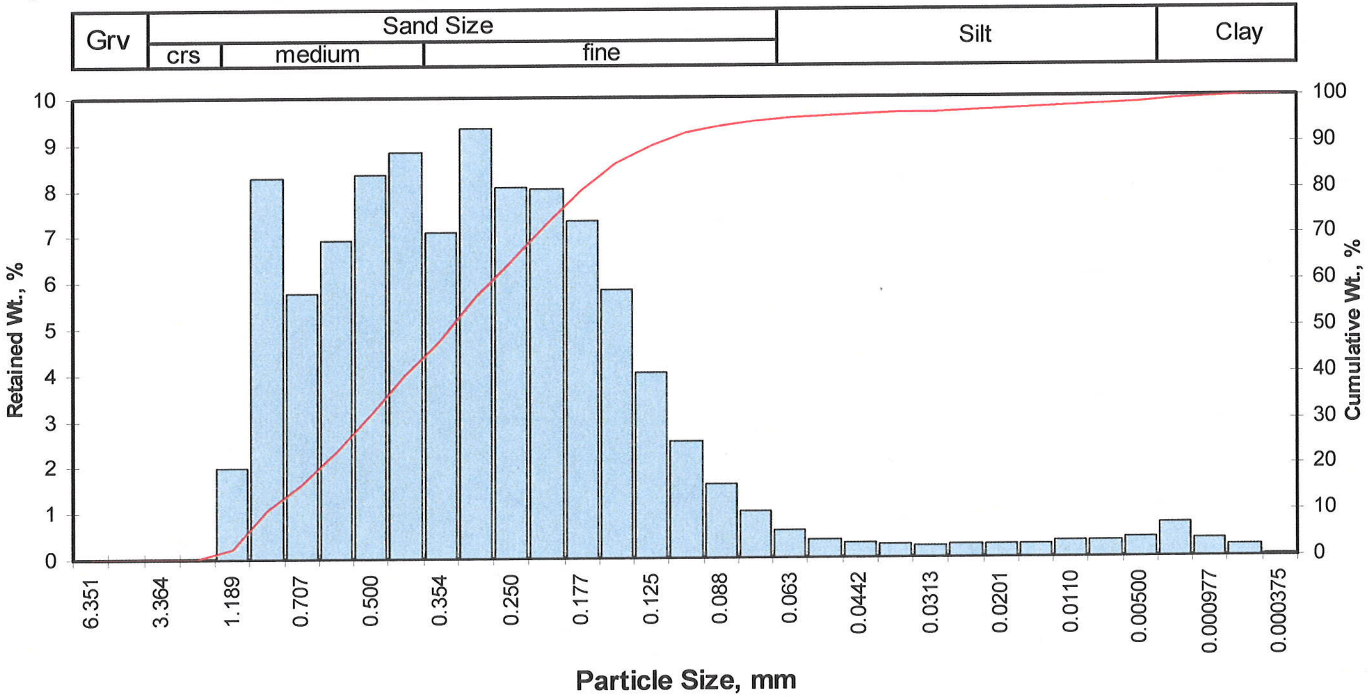
			Median	Particle Size Distribution, wt. percent						Silt
		Mean Grain Size	Grain Size		Sand Size					&
Sample ID	Depth, ft.	Description (1)	mm	Gravel	Coarse	Medium	Fine	Silt	Clay	Clay
SC-1-8'-10.5'	8.9	Fine sand	0.335	0.00	0.00	40.06	54.75	3.80	1.39	5.19
SC-1-10.5'-13.0'	11.65	Fine sand	0.215	0.00	0.00	15.20	75.59	7.24	1.97	9.21
SC-1-10.5'-13.0'	12.2	Fine sand	0.348	0.00	0.00	41.22	53.86	3.67	1.25	4.92
SC-2-7.5-10.0	8.7	Medium sand	1.061	2.43	27.92	40.33	19.71	(2)	(2)	9.61
SC-2-10.0-12.5	10.7	Coarse sand	0.410	33.14	3.00	13.11	39.43	(2)	(2)	11.32
SC-2-15.0'-17.5'	16.1	Medium sand	0.504	0.00	0.00	62.03	34.30	2.85	0.81	3.66
SC-2-15.0'-17.5'	16.6	Fine sand	0.389	0.00	0.00	45.91	49.51	3.43	1.15	4.58

(1) Based on Mean from Trask
(2) Mechanical sieve does not differentiate silt/clay fractions.

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D4464M

Client:	Shaw Environmental	**PTS File No:**	38090
Project:	Port of Tacoma	**Sample ID:**	SC-1-8'-10.5'
Project No:	111487 01000000	**Depth, ft:**	8.9



Opening		Phi of Screen	U.S. No.	Sample Weight, grams	Increment Weight, percent	Cumulative Weight, percent
Inches	Millimeters					
0.2500	6.351	-2.67	1/4	0.00	0.00	0.00
0.1873	4.757	-2.25	4	0.00	0.00	0.00
0.1324	3.364	-1.75	6	0.00	0.00	0.00
0.0787	2.000	-1.00	10	0.00	0.00	0.00
0.0468	1.189	-0.25	16	1.99	1.99	1.99
0.0331	0.841	0.25	20	8.26	8.26	10.25
0.0278	0.707	0.50	25	5.76	5.76	16.01
0.0234	0.595	0.75	30	6.90	6.90	22.91
0.0197	0.500	1.00	35	8.34	8.34	31.25
0.0166	0.420	1.25	40	8.81	8.81	40.06
0.0139	0.354	1.50	45	7.07	7.07	47.14
0.0117	0.297	1.75	50	9.34	9.34	56.48
0.0098	0.250	2.00	60	8.04	8.04	64.52
0.0083	0.210	2.25	70	8.02	8.02	72.54
0.0070	0.177	2.50	80	7.31	7.31	79.85
0.0059	0.149	2.75	100	5.82	5.82	85.67
0.0049	0.125	3.00	120	4.03	4.03	89.70
0.0041	0.105	3.25	140	2.53	2.53	92.23
0.0035	0.088	3.50	170	1.59	1.59	93.82
0.0029	0.074	3.75	200	0.99	0.99	94.81
0.0025	0.063	4.00	230	0.59	0.59	95.40
0.0021	0.053	4.25	270	0.39	0.39	95.79
0.00174	0.0442	4.50	325	0.31	0.31	96.10
0.00146	0.0372	4.75	400	0.28	0.28	96.38
0.00123	0.0313	5.00	450	0.25	0.25	96.63
0.000986	0.0250	5.32	500	0.29	0.29	96.92
0.000790	0.0201	5.64	635	0.28	0.28	97.20
0.000615	0.0156	6.00		0.28	0.28	97.48
0.000435	0.0110	6.50		0.36	0.36	97.84
0.000308	0.00781	7.00		0.35	0.35	98.19
0.000197	0.00500	7.65		0.42	0.42	98.61
0.000077	0.00195	9.00		0.72	0.72	99.33
0.000038	0.000977	10.00		0.38	0.38	99.71
0.000019	0.000488	11.00		0.26	0.26	99.97
0.000015	0.000375	11.38		0.03	0.03	100.00
TOTALS				**100.00**	**100.00**	**100.00**

Cumulative Weight Percent greater than			
Weight percent	Phi Value	Particle Size	
		Inches	Millimeters
5	-0.07	0.0413	1.048
10	0.23	0.0335	0.850
16	0.50	0.0278	0.707
25	0.81	0.0224	0.569
40	1.25	0.0166	0.421
50	1.58	0.0132	0.335
60	1.86	0.0108	0.276
75	2.33	0.0078	0.198
84	2.68	0.0062	0.156
90	3.03	0.0048	0.122
95	3.83	0.0028	0.070

Measure	Trask	Inman	Folk-Ward
Median, phi	1.58	1.58	1.58
Median, in.	0.0132	0.0132	0.0132
Median, mm	0.335	0.335	0.335
Mean, phi	1.38	1.59	1.58
Mean, in.	0.0151	0.0131	0.0131
Mean, mm	0.384	0.332	0.333
Sorting	1.694	1.089	1.135
Skewness	1.002	0.011	0.084
Kurtosis	0.255	0.789	1.050

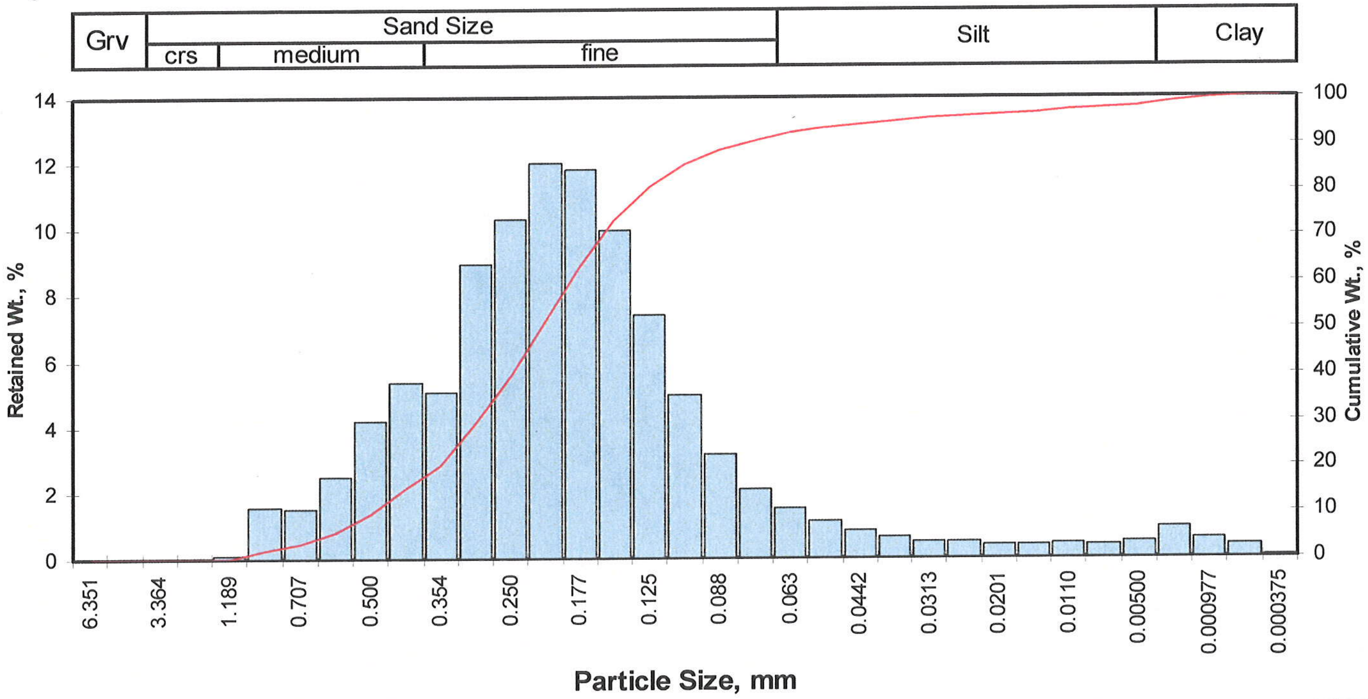
Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.00
Coarse Sand	10	0.00
Medium Sand	40	40.06
Fine Sand	200	54.75
Silt	>0.005 mm	3.80
Clay	<0.005 mm	1.39
	Total	**100**

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D4464M

Client:	Shaw Environmental	**PTS File No:**	38090
Project:	Port of Tacoma	**Sample ID:**	SC-1-10.5'-13.0'
Project No:	111487 01000000	**Depth, ft:**	11.65



Opening		Phi of Screen	U.S. No.	Sample Weight, grams	Increment Weight, percent	Cumulative Weight, percent
Inches	Millimeters					
0.2500	6.351	-2.67	1/4	0.00	0.00	0.00
0.1873	4.757	-2.25	4	0.00	0.00	0.00
0.1324	3.364	-1.75	6	0.00	0.00	0.00
0.0787	2.000	-1.00	10	0.00	0.00	0.00
0.0468	1.189	-0.25	16	0.11	0.11	0.11
0.0331	0.841	0.25	20	1.57	1.57	1.68
0.0278	0.707	0.50	25	1.50	1.50	3.18
0.0234	0.595	0.75	30	2.50	2.50	5.68
0.0197	0.500	1.00	35	4.20	4.20	9.87
0.0166	0.420	1.25	40	5.33	5.33	15.20
0.0139	0.354	1.50	45	5.08	5.08	20.28
0.0117	0.297	1.75	50	8.93	8.93	29.20
0.0098	0.250	2.00	60	10.30	10.29	39.50
0.0083	0.210	2.25	70	12.00	11.99	51.49
0.0070	0.177	2.50	80	11.80	11.79	63.29
0.0059	0.149	2.75	100	9.95	9.94	73.23
0.0049	0.125	3.00	120	7.37	7.37	80.60
0.0041	0.105	3.25	140	4.95	4.95	85.54
0.0035	0.088	3.50	170	3.17	3.17	88.71
0.0029	0.074	3.75	200	2.08	2.08	90.79
0.0025	0.063	4.00	230	1.51	1.51	92.30
0.0021	0.053	4.25	270	1.14	1.14	93.44
0.00174	0.0442	4.50	325	0.83	0.83	94.27
0.00146	0.0372	4.75	400	0.62	0.62	94.89
0.00123	0.0313	5.00	450	0.49	0.49	95.38
0.000986	0.0250	5.32	500	0.51	0.51	95.89
0.000790	0.0201	5.64	635	0.41	0.41	96.30
0.000615	0.0156	6.00		0.38	0.38	96.68
0.000435	0.0110	6.50		0.44	0.44	97.12
0.000308	0.00781	7.00		0.41	0.41	97.53
0.000197	0.00500	7.65		0.50	0.50	98.03
0.000077	0.00195	9.00		0.94	0.94	98.97
0.000038	0.000977	10.00		0.58	0.58	99.55
0.000019	0.000488	11.00		0.41	0.41	99.96
0.000015	0.000375	11.38		0.05	0.04	100.00
TOTALS				100.10	100.00	100.00

Cumulative Weight Percent greater than			
Weight percent	Phi Value	Particle Size	
		Inches	Millimeters
5	0.68	0.0245	0.623
10	1.01	0.0196	0.498
16	1.29	0.0161	0.409
25	1.63	0.0127	0.323
40	2.01	0.0098	0.248
50	2.22	0.0085	0.215
60	2.43	0.0073	0.186
75	2.81	0.0056	0.143
84	3.17	0.0044	0.111
90	3.65	0.0031	0.079
95	4.81	0.0014	0.036

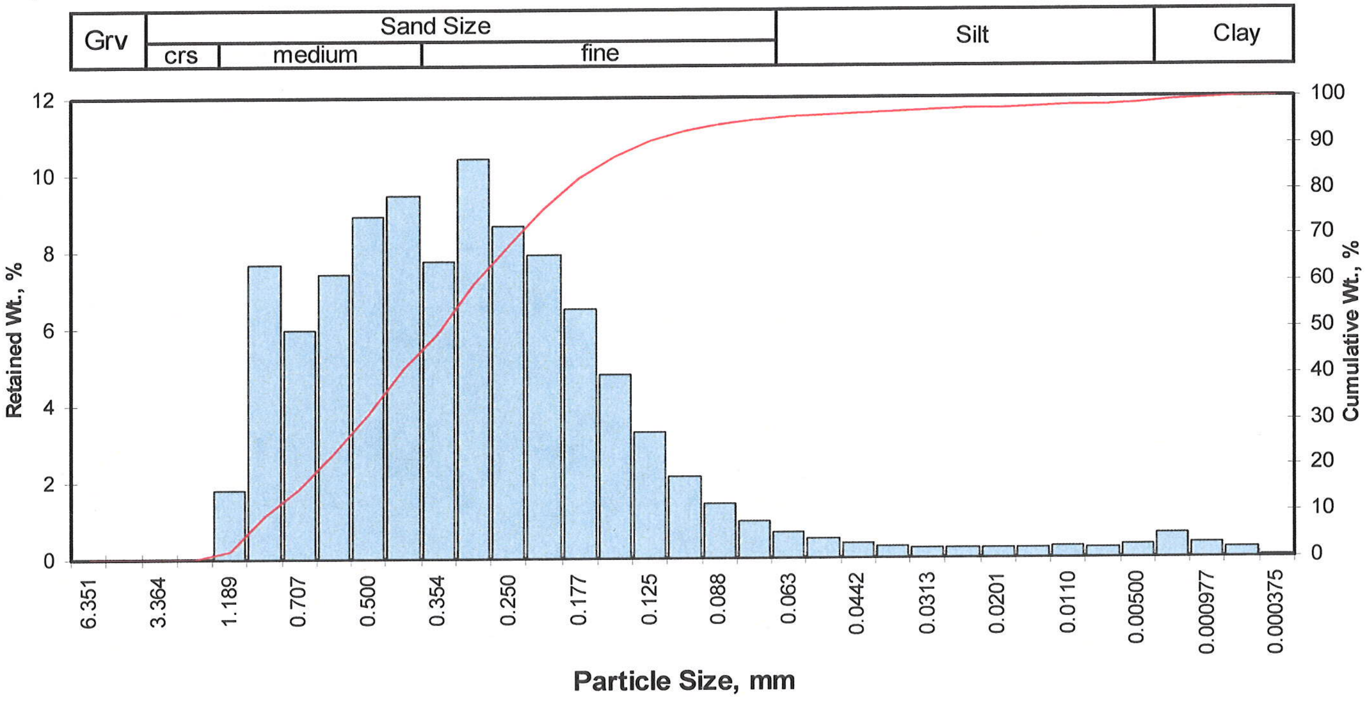
Measure	Trask	Inman	Folk-Ward
Median, phi	2.22	2.22	2.22
Median, in.	0.0085	0.0085	0.0085
Median, mm	0.215	0.215	0.215
Mean, phi	2.10	2.23	2.23
Mean, in.	0.0092	0.0084	0.0084
Mean, mm	0.233	0.213	0.214
Sorting	1.504	0.941	1.096
Skewness	0.998	0.012	0.134
Kurtosis	0.215	1.191	1.435
Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Mean from Trask)		

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.00
Coarse Sand	10	0.00
Medium Sand	40	15.20
Fine Sand	200	75.59
Silt	>0.005 mm	7.24
Clay	<0.005 mm	1.97
	Total	**100**

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D4464M

Client:	Shaw Environmental	**PTS File No:**	38090
Project:	Port of Tacoma	**Sample ID:**	SC-1-10.5'-13.0'
Project No:	111487 01000000	**Depth, ft:**	12.2



Opening		Phi of Screen	U.S. No.	Sample Weight, grams	Increment Weight, percent	Cumulative Weight, percent
Inches	Millimeters					
0.2500	6.351	-2.67	1/4	0.00	0.00	0.00
0.1873	4.757	-2.25	4	0.00	0.00	0.00
0.1324	3.364	-1.75	6	0.00	0.00	0.00
0.0787	2.000	-1.00	10	0.00	0.00	0.00
0.0468	1.189	-0.25	16	1.79	1.79	1.79
0.0331	0.841	0.25	20	7.65	7.65	9.44
0.0278	0.707	0.50	25	5.96	5.96	15.41
0.0234	0.595	0.75	30	7.43	7.43	22.84
0.0197	0.500	1.00	35	8.92	8.92	31.76
0.0166	0.420	1.25	40	9.45	9.45	41.22
0.0139	0.354	1.50	45	7.76	7.76	48.98
0.0117	0.297	1.75	50	10.40	10.40	59.39
0.0098	0.250	2.00	60	8.66	8.66	68.05
0.0083	0.210	2.25	70	7.92	7.92	75.97
0.0070	0.177	2.50	80	6.51	6.51	82.49
0.0059	0.149	2.75	100	4.81	4.81	87.30
0.0049	0.125	3.00	120	3.29	3.29	90.59
0.0041	0.105	3.25	140	2.13	2.13	92.72
0.0035	0.088	3.50	170	1.40	1.40	94.12
0.0029	0.074	3.75	200	0.96	0.96	95.08
0.0025	0.063	4.00	230	0.67	0.67	95.75
0.0021	0.053	4.25	270	0.48	0.48	96.23
0.00174	0.0442	4.50	325	0.37	0.37	96.60
0.00146	0.0372	4.75	400	0.30	0.30	96.90
0.00123	0.0313	5.00	450	0.25	0.25	97.15
0.000986	0.0250	5.32	500	0.27	0.27	97.42
0.000790	0.0201	5.64	635	0.24	0.24	97.66
0.000615	0.0156	6.00		0.23	0.23	97.89
0.000435	0.0110	6.50		0.28	0.28	98.17
0.000308	0.00781	7.00		0.26	0.26	98.43
0.000197	0.00500	7.65		0.32	0.32	98.75
0.000077	0.00195	9.00		0.61	0.61	99.36
0.000038	0.000977	10.00		0.36	0.36	99.72
0.000019	0.000488	11.00		0.25	0.25	99.97
0.000015	0.000375	11.38		0.03	0.03	100.00
TOTALS				**100.00**	**100.00**	**100.00**

Cumulative Weight Percent greater than			
Weight percent	Phi Value	Particle Size	
		Inches	Millimeters
5	-0.04	0.0405	1.028
10	0.27	0.0326	0.827
16	0.52	0.0275	0.697
25	0.81	0.0224	0.570
40	1.22	0.0169	0.430
50	1.52	0.0137	0.348
60	1.77	0.0116	0.294
75	2.22	0.0085	0.215
84	2.58	0.0066	0.167
90	2.96	0.0051	0.129
95	3.73	0.0030	0.075

Measure	Trask	Inman	Folk-Ward
Median, phi	1.52	1.52	1.52
Median, in.	0.0137	0.0137	0.0137
Median, mm	0.348	0.348	0.348
Mean, phi	1.35	1.55	1.54
Mean, in.	0.0155	0.0135	0.0135
Mean, mm	0.392	0.342	0.344
Sorting	1.629	1.029	1.086
Skewness	1.007	0.024	0.097
Kurtosis	0.254	0.831	1.097

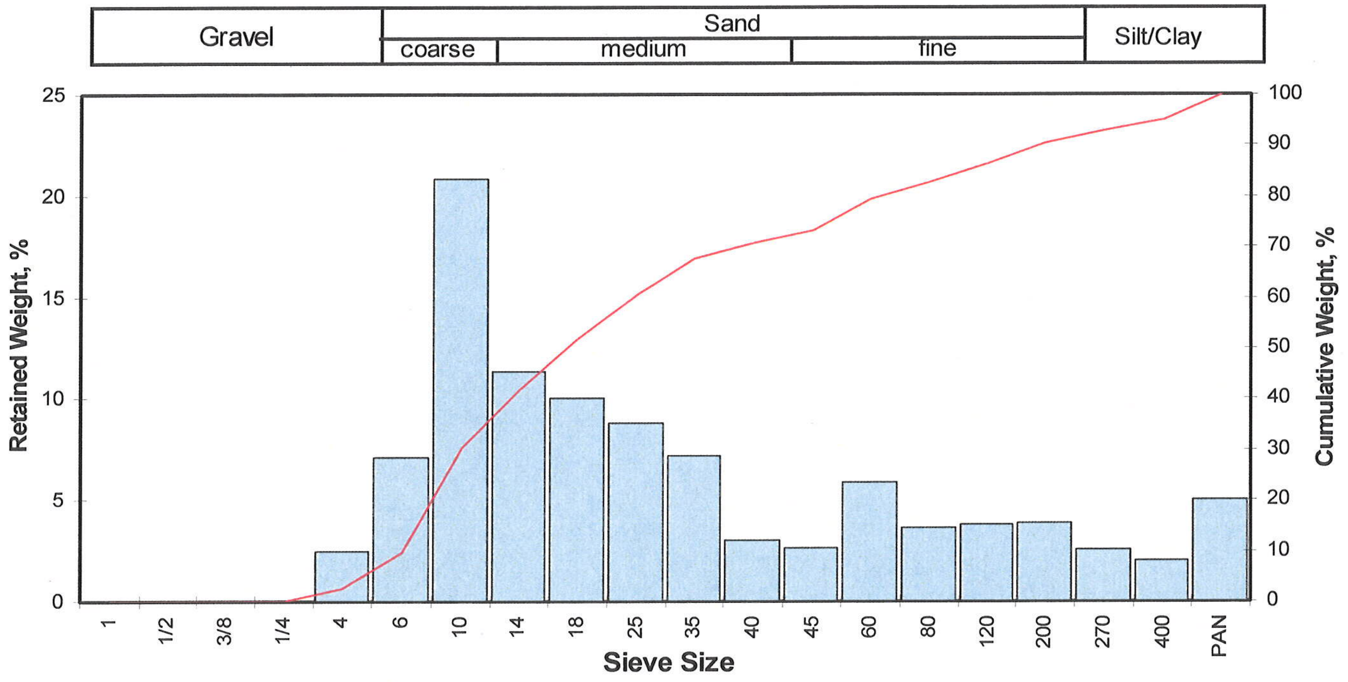
Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.00
Coarse Sand	10	0.00
Medium Sand	40	41.22
Fine Sand	200	53.86
Silt	>0.005 mm	3.67
Clay	<0.005 mm	1.25
	Total	**100**

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	Shaw Environmental	**PTS File No:**	38090
Project:	Port of Tacoma	**Sample ID:**	SC-2-7.5-10.0
Project No:	111487 01000000	**Depth, ft:**	8.7



Opening		Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
Inches	Millimeters					
0.9844	25.002	-4.64	1	0.00	0.00	0.00
0.4922	12.501	-3.64	1/2	0.00	0.00	0.00
0.3740	9.500	-3.25	3/8	0.00	0.00	0.00
0.2500	6.351	-2.67	1/4	0.00	0.00	0.00
0.1873	4.757	-2.25	4	0.40	2.43	2.43
0.1324	3.364	-1.75	6	1.17	7.12	9.55
0.0787	2.000	-1.00	10	3.42	20.80	30.35
0.0557	1.414	-0.50	14	1.86	11.31	41.67
0.0394	1.000	0.00	18	1.65	10.04	51.70
0.0278	0.707	0.50	25	1.44	8.76	60.46
0.0197	0.500	1.00	35	1.18	7.18	67.64
0.0166	0.420	1.25	40	0.50	3.04	70.68
0.0139	0.354	1.50	45	0.43	2.62	73.30
0.0098	0.250	2.00	60	0.97	5.90	79.20
0.0070	0.177	2.50	80	0.59	3.59	82.79
0.0049	0.125	3.00	120	0.62	3.77	86.56
0.0029	0.074	3.75	200	0.63	3.83	90.39
0.0021	0.053	4.25	270	0.42	2.55	92.94
0.0015	0.037	4.75	400	0.33	2.01	94.95
			PAN	0.83	5.05	100.00
TOTALS				16.44	100.00	100.00

Cumulative Weight Percent greater than			
Weight percent	Phi Value	Particle Size	
		Inches	Millimeters
5	-2.07	0.1653	4.198
10	-1.73	0.1309	3.326
16	-1.52	0.1127	2.863
25	-1.19	0.0900	2.286
40	-0.57	0.0586	1.488
50	-0.08	0.0418	1.061
60	0.47	0.0284	0.720
75	1.64	0.0126	0.320
84	2.66	0.0062	0.158
90	3.67	0.0031	0.078
95	4.70	0.0015	0.038

Measure	Trask	Inman	Folk-Ward
Median, phi	-0.08	-0.08	-0.08
Median, in.	0.0418	0.0418	0.0418
Median, mm	1.061	1.061	1.061
Mean, phi	-0.38	0.57	0.35
Mean, in.	0.0513	0.0265	0.0308
Mean, mm	1.303	0.673	0.783
Sorting	2.673	2.089	2.071
Skewness	0.806	0.314	0.364
Kurtosis	0.303	0.621	0.978

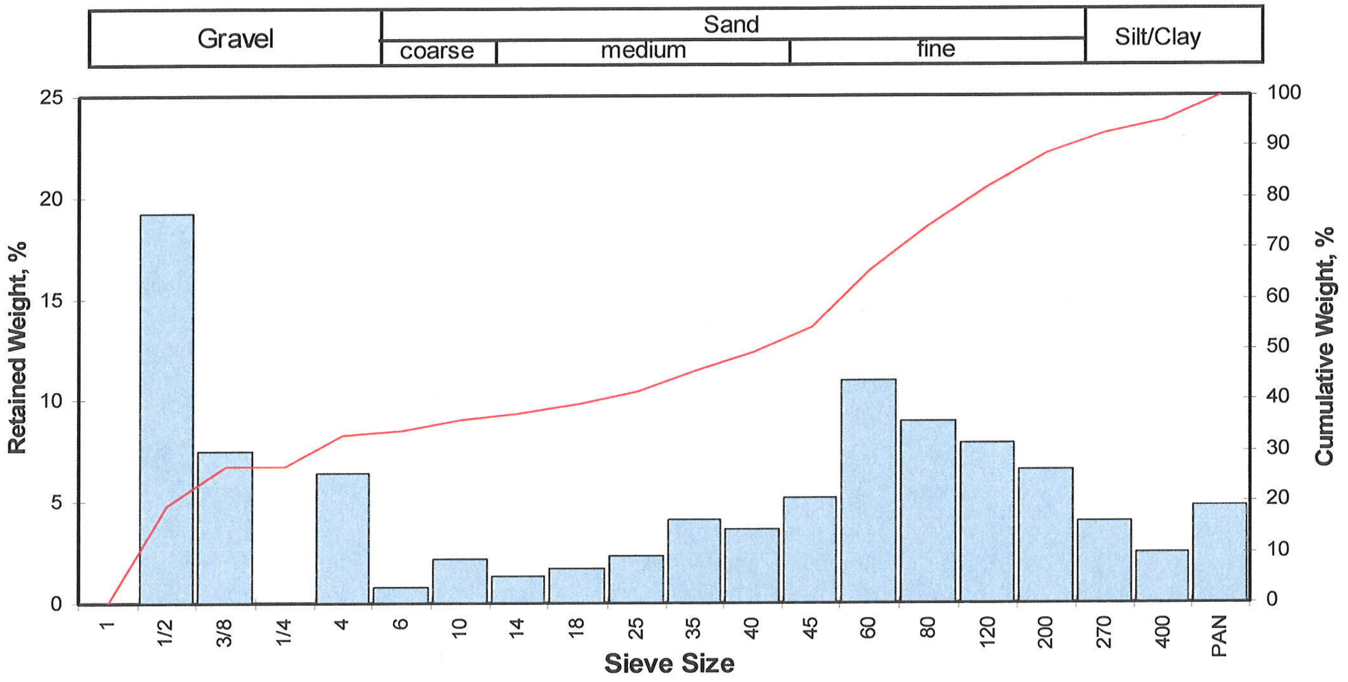
Grain Size Description (ASTM-USCS Scale)	Medium sand (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	2.43
Coarse Sand	10	27.92
Medium Sand	40	40.33
Fine Sand	200	19.71
Silt/Clay	<200	9.61
	Total	100

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	Shaw Environmental	**PTS File No:**	38090
Project:	Port of Tacoma	**Sample ID:**	SC-2-10.0-12.5
Project No:	111487 01000000	**Depth, ft:**	10.7



Opening		Phi of	U.S. Sieve	Sample Weight	Incremental Weight,	Cumulative Weight,
Inches	Millimeters	Screen	No.	grams	percent	percent
0.9844	25.002	-4.64	1	0.00	0.00	0.00
0.4922	12.501	-3.64	1/2	3.33	19.23	19.23
0.3740	9.500	-3.25	3/8	1.30	7.51	26.73
0.2500	6.351	-2.67	1/4	0.00	0.00	26.73
0.1873	4.757	-2.25	4	1.11	6.41	33.14
0.1324	3.364	-1.75	6	0.14	0.81	33.95
0.0787	2.000	-1.00	10	0.38	2.19	36.14
0.0557	1.414	-0.50	14	0.23	1.33	37.47
0.0394	1.000	0.00	18	0.30	1.73	39.20
0.0278	0.707	0.50	25	0.40	2.31	41.51
0.0197	0.500	1.00	35	0.71	4.10	45.61
0.0166	0.420	1.25	40	0.63	3.64	49.25
0.0139	0.354	1.50	45	0.89	5.14	54.39
0.0098	0.250	2.00	60	1.90	10.97	65.36
0.0070	0.177	2.50	80	1.55	8.95	74.31
0.0049	0.125	3.00	120	1.36	7.85	82.16
0.0029	0.074	3.75	200	1.13	6.52	88.68
0.0021	0.053	4.25	270	0.70	4.04	92.73
0.0015	0.037	4.75	400	0.43	2.48	95.21
			PAN	0.83	4.79	100.00
TOTALS				17.32	100.00	100.00

Cumulative Weight Percent greater than			
Weight	Phi	Particle Size	
percent	Value	Inches	Millimeters
5	-4.38	0.8220	20.878
10	-4.12	0.6864	17.435
16	-3.81	0.5529	14.043
25	-2.89	0.2923	7.425
40	0.17	0.0349	0.887
50	1.29	0.0161	0.410
60	1.76	0.0117	0.296
75	2.54	0.0068	0.171
84	3.21	0.0042	0.108
90	3.91	0.0026	0.066
95	4.71	0.0015	0.038

Measure	Trask	Inman	Folk-Ward
Median, phi	1.29	1.29	1.29
Median, in.	0.0161	0.0161	0.0161
Median, mm	0.410	0.410	0.410
Mean, phi	-1.93	-0.30	0.23
Mean, in.	0.1495	0.0485	0.0336
Mean, mm	3.798	1.231	0.853
Sorting	6.581	3.512	3.133
Skewness	2.752	-0.452	-0.350
Kurtosis	0.209	0.295	0.685

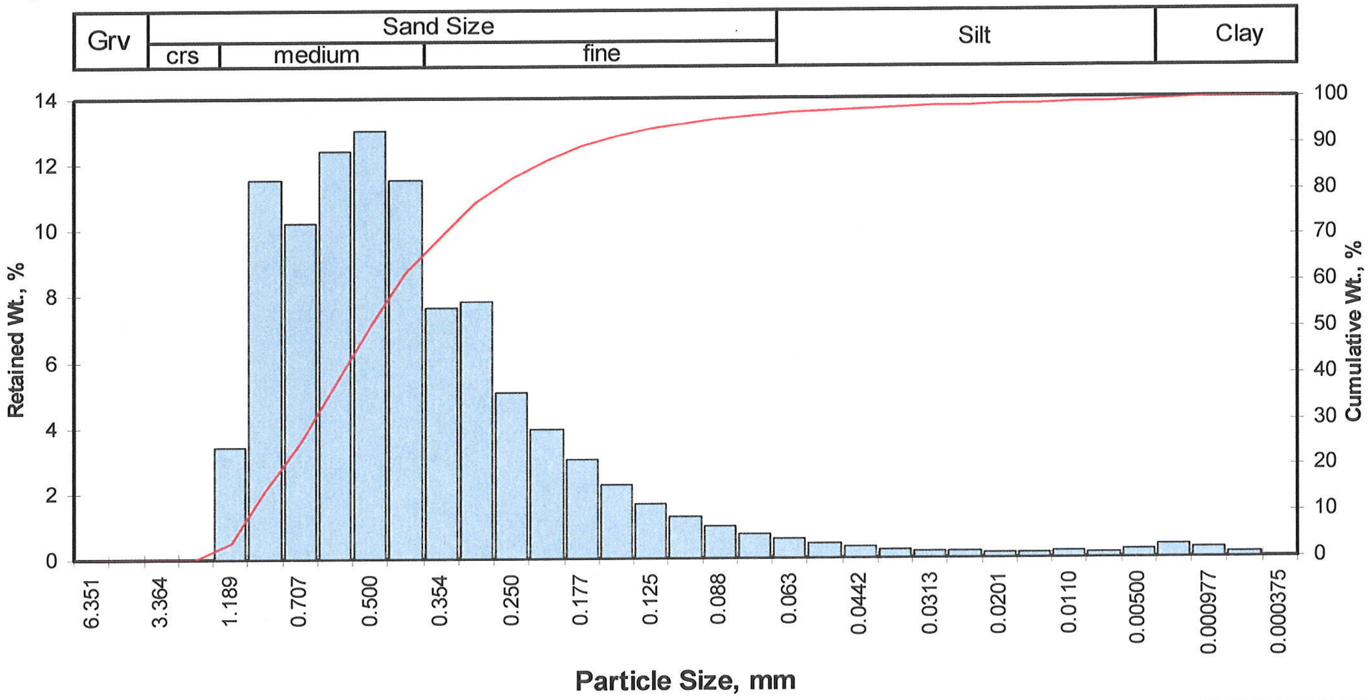
Grain Size Description (ASTM-USCS Scale)	Coarse sand (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	33.14
Coarse Sand	10	3.00
Medium Sand	40	13.11
Fine Sand	200	39.43
Silt/Clay	<200	11.32
	Total	100

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D4464M

Client:	Shaw Environmental	**PTS File No:**	38090
Project:	Port of Tacoma	**Sample ID:**	SC-2-15.0'-17.5'
Project No:	111487 01000000	**Depth, ft:**	16.1



Opening		Phi of Screen	U.S. No.	Sample Weight, grams	Increment Weight, percent	Cumulative Weight, percent
Inches	**Millimeters**					
0.2500	6.351	-2.67	1/4	0.00	0.00	0.00
0.1873	4.757	-2.25	4	0.00	0.00	0.00
0.1324	3.364	-1.75	6	0.00	0.00	0.00
0.0787	2.000	-1.00	10	0.00	0.00	0.00
0.0468	1.189	-0.25	16	3.41	3.41	3.41
0.0331	0.841	0.25	20	11.50	11.50	14.92
0.0278	0.707	0.50	25	10.20	10.20	25.12
0.0234	0.595	0.75	30	12.40	12.40	37.53
0.0197	0.500	1.00	35	13.00	13.01	50.53
0.0166	0.420	1.25	40	11.50	11.50	62.03
0.0139	0.354	1.50	45	7.63	7.63	69.67
0.0117	0.297	1.75	50	7.84	7.84	77.51
0.0098	0.250	2.00	60	5.03	5.03	82.54
0.0083	0.210	2.25	70	3.92	3.92	86.46
0.0070	0.177	2.50	80	2.99	2.99	89.46
0.0059	0.149	2.75	100	2.23	2.23	91.69
0.0049	0.125	3.00	120	1.66	1.66	93.35
0.0041	0.105	3.25	140	1.26	1.26	94.61
0.0035	0.088	3.50	170	0.99	0.99	95.60
0.0029	0.074	3.75	200	0.74	0.74	96.34
0.0025	0.063	4.00	230	0.57	0.57	96.91
0.0021	0.053	4.25	270	0.45	0.45	97.36
0.00174	0.0442	4.50	325	0.32	0.32	97.68
0.00146	0.0372	4.75	400	0.24	0.24	97.92
0.00123	0.0313	5.00	450	0.19	0.19	98.11
0.000986	0.0250	5.32	500	0.20	0.20	98.31
0.000790	0.0201	5.64	635	0.16	0.16	98.47
0.000615	0.0156	6.00		0.15	0.15	98.62
0.000435	0.0110	6.50		0.18	0.18	98.80
0.000308	0.00781	7.00		0.17	0.17	98.97
0.000197	0.00500	7.65		0.22	0.22	99.19
0.000077	0.00195	9.00		0.40	0.40	99.59
0.000038	0.000977	10.00		0.28	0.28	99.87
0.000019	0.000488	11.00		0.13	0.13	100.00
0.000015	0.000375	11.38		0.00	0.00	100.00
TOTALS				**100.00**	**100.00**	**100.00**

Cumulative Weight Percent greater than			
Weight percent	**Phi Value**	**Particle Size**	
		Inches	**Millimeters**
5	-0.18	0.0446	1.134
10	0.04	0.0384	0.975
16	0.28	0.0325	0.826
25	0.50	0.0279	0.709
40	0.80	0.0227	0.575
50	0.99	0.0198	0.504
60	1.21	0.0171	0.434
75	1.67	0.0124	0.314
84	2.09	0.0092	0.234
90	2.56	0.0067	0.169
95	3.35	0.0039	0.098

Measure	Trask	Inman	Folk-Ward
Median, phi	0.99	0.99	0.99
Median, in.	0.0198	0.0198	0.0198
Median, mm	0.504	0.504	0.504
Mean, phi	0.97	1.18	1.12
Mean, in.	0.0201	0.0173	0.0181
Mean, mm	0.511	0.440	0.460
Sorting	1.502	0.908	0.989
Skewness	0.937	0.215	0.276
Kurtosis	0.245	0.943	1.233

Grain Size Description (ASTM-USCS Scale)	Medium sand (based on Mean from Trask)

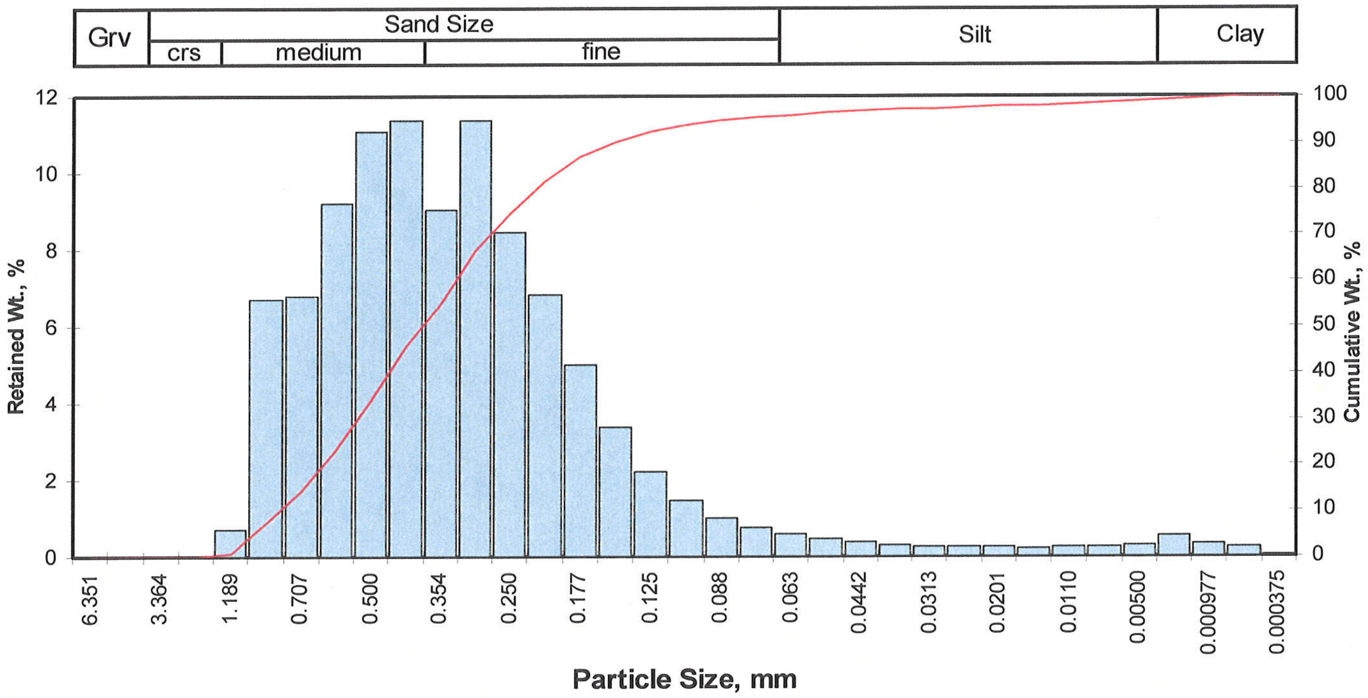
Description	Retained on Sieve #	Weight Percent
Gravel	4	0.00
Coarse Sand	10	0.00
Medium Sand	40	62.03
Fine Sand	200	34.30
Silt	>0.005 mm	2.85
Clay	<0.005 mm	0.81
	Total	**100**

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D4464M

Client: Shaw Environmental
Project: Port of Tacoma
Project No: 111487 01000000

PTS File No: 38090
Sample ID: SC-2-15.0'-17.5'
Depth, ft: 16.6



Opening		Phi of Screen	U.S. No.	Sample Weight, grams	Increment Weight, percent	Cumulative Weight, percent
Inches	Millimeters					
0.2500	6.351	-2.67	1/4	0.00	0.00	0.00
0.1873	4.757	-2.25	4	0.00	0.00	0.00
0.1324	3.364	-1.75	6	0.00	0.00	0.00
0.0787	2.000	-1.00	10	0.00	0.00	0.00
0.0468	1.189	-0.25	16	0.72	0.72	0.72
0.0331	0.841	0.25	20	6.73	6.73	7.45
0.0278	0.707	0.50	25	6.78	6.78	14.22
0.0234	0.595	0.75	30	9.21	9.20	23.42
0.0197	0.500	1.00	35	11.10	11.09	34.52
0.0166	0.420	1.25	40	11.40	11.39	45.91
0.0139	0.354	1.50	45	9.04	9.03	54.94
0.0117	0.297	1.75	50	11.40	11.39	66.34
0.0098	0.250	2.00	60	8.47	8.46	74.80
0.0083	0.210	2.25	70	6.85	6.85	81.65
0.0070	0.177	2.50	80	5.00	5.00	86.64
0.0059	0.149	2.75	100	3.36	3.36	90.00
0.0049	0.125	3.00	120	2.22	2.22	92.22
0.0041	0.105	3.25	140	1.47	1.47	93.69
0.0035	0.088	3.50	170	1.00	1.00	94.69
0.0029	0.074	3.75	200	0.73	0.73	95.42
0.0025	0.063	4.00	230	0.57	0.57	95.99
0.0021	0.053	4.25	270	0.47	0.47	96.46
0.00174	0.0442	4.50	325	0.36	0.36	96.82
0.00146	0.0372	4.75	400	0.29	0.29	97.11
0.00123	0.0313	5.00	450	0.24	0.24	97.35
0.000986	0.0250	5.32	500	0.26	0.26	97.61
0.000790	0.0201	5.64	635	0.23	0.23	97.84
0.000615	0.0156	6.00		0.21	0.21	98.05
0.000435	0.0110	6.50		0.26	0.26	98.31
0.000308	0.00781	7.00		0.24	0.24	98.55
0.000197	0.00500	7.65		0.30	0.30	98.85
0.000077	0.00195	9.00		0.56	0.56	99.41
0.000038	0.000977	10.00		0.34	0.34	99.75
0.000019	0.000488	11.00		0.23	0.23	99.98
0.000015	0.000375	11.38		0.03	0.02	100.00
TOTALS				**100.10**	**100.00**	**100.00**

Cumulative Weight Percent greater than			
Weight percent	Phi Value	Particle Size	
		Inches	Millimeters
5	0.07	0.0376	0.954
10	0.34	0.0310	0.788
16	0.55	0.0269	0.684
25	0.79	0.0228	0.580
40	1.12	0.0181	0.460
50	1.36	0.0153	0.389
60	1.61	0.0129	0.327
75	2.01	0.0098	0.249
84	2.37	0.0076	0.194
90	2.75	0.0059	0.149
95	3.61	0.0032	0.082

Measure	Trask	Inman	Folk-Ward
Median, phi	1.36	1.36	1.36
Median, in.	0.0153	0.0153	0.0153
Median, mm	0.389	0.389	0.389
Mean, phi	1.27	1.46	1.43
Mean, in.	0.0163	0.0143	0.0146
Mean, mm	0.414	0.364	0.372
Sorting	1.527	0.910	0.991
Skewness	0.977	0.104	0.186
Kurtosis	0.259	0.945	1.187

Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.00
Coarse Sand	10	0.00
Medium Sand	40	45.91
Fine Sand	200	49.51
Silt	>0.005 mm	3.43
Clay	<0.005 mm	1.15
	Total	**100**

Appendix E

Soil Core Drilling Photographs


Photo 1. Drilling boring SC-1.


Photo. 2. New Osterberg soil coring device (top) and sampler damaged by subsurface rocks.


Photo 3. Core sampler damaged by subsurface rocks.


Photo 4. Soil filled core sampler prior to capping for shipment to the laboratory.

REV	DATE	DESCRIPTION	DWN BY	DES BY	CHK BY	APP BY

DATE OF ISSUE 5/08
DWN BY JC
DES BY DL
CHK BY
APP BY

Shaw® Shaw Environmental, Inc.

SOIL CORE DRILLING PHOTOGRAPHS

PORT OF TACOMA
FORMER MILWAUKEE RAILYARD SITE
TACOMA, WASHINGTON

PROJECT NO.
111487

File: N:\Cad\Drawings\Port of Tacoma\August 2008\Figure 11x17.dwg Layout: layout User: jascha.coddington Sep 04, 2008 - 11:01am

1" 1/2" 0" 1"

Appendix F

Torkelson Geochemistry, Inc. NAPL and Groundwater Test Data

Torkelson Geochemistry, Inc.
2528 South Columbia Place, Tulsa, Oklahoma 74114-3233
Voice 918-749-8441, Fax 918-749-6005

May 19, 2008

Larry Roberts
TechSolv Consulting Group, Inc.
7518 NE 169th Street
Kenmore, WA 98028

Subject: Analysis and evaluation of five product and two water samples from Port of Tacoma, Former Millwaukee Rail Yard, Tacoma, Washington.

Introduction

Five product/water sample pairs were submitted to Torkelson Geochemistry by TechSolv for hydrocarbon fingerprint (capillary gas chromatography) analysis of the five product samples and one of the water samples, physical property analysis of two of the product/water pairs and evaluation of the results, see chain of custody (Figure 1).

The following are my interpretations of the data. Please keep in mind that these interpretations are made without any specific knowledge of the site, location from which the samples came, or other analyses done on the samples. In addition, the samples have probably been weathered which makes an accurate interpretation of product type somewhat more difficult since some of the key features of the product have been altered or removed by the evaporation, water washing or bacterial processes.

Discussion of Results

Sample CW-4 appears to be a mixture of extremely weathered middle distillate and a heavier material. The chromatogram of CW-4 (Figures 2 and 11) shows a series of peaks starting at about methylcyclohexane (MCHX) and continuing to the end of the chromatogram and one unresolved hump that starts at about nC10, reaches a maximum at about nC17 and continues to about nC24 and a second unresolved hump that starts at about nC24 reaches a maximum at about nC36 and continues to the end of the chromatogram. This includes the ranges typical of middle distillate from about nC8 to nC24 and heavier materials beyond the middle distillate range. The types and proportions of the peaks in the middle distillate range are typical of an extremely weathered diesel fuel or fuel oil. Weathering is primarily biodegradation which has preferentially decreased the size of the normal paraffin peaks (labeled nC8 to nC25) relative to the more biodegradation resistant compounds such as the isoprenoid peaks (labeled IP13 to IP18, Pristane and Phytane). The heavier material beyond the middle distillate range could be a heavy fuel oil, perhaps a lubricating oil or some other heavy material. CW-4 is quite similar to CW-5 and RW-5L3.

Sample CW-5 appears to be a mixture of extremely weathered middle distillate and a heavier material. The chromatogram of CW-5 (Figures 3 and 12) shows a series of peaks starting at about methylcyclohexane (MCHX) and continuing to the end of the chromatogram and one unresolved hump that starts at about nC10, reaches a maximum at about nC17 and continues to about nC24 and a second unresolved hump that starts at about nC24 reaches a maximum at about nC36 and continues to the end of the chromatogram. This includes the ranges typical of middle distillate from about nC8 to nC24 and heavier materials beyond the middle distillate range. The types and proportions of the peaks in the middle distillate range are typical of an extremely weathered diesel fuel or fuel oil. Weathering is primarily biodegradation which has preferentially decreased the size of the normal paraffin peaks (labeled nC8 to nC25) relative to the more biodegradation resistant compounds such as the isoprenoid peaks (labeled IP13 to IP18, Pristane and Phytane). The heavier material beyond the middle distillate range could be a heavy fuel oil, perhaps a lubricating oil or some other heavy material. CW-5 is quite similar to CW-4 and RW-5L3.

Sample RW-2L3 appears to be a mixture of extremely weathered middle distillate and perhaps a very small amount of heavier material. The chromatogram of RW-2L3 (Figures 4 and 13) shows a series of peaks starting at about normal octane (nC8) and continuing to near the end of the chromatogram and one unresolved hump that starts at about nC10, reaches a maximum at about nC15 or nC16 and continues to about nC24 and a small amount of unresolved material that starts at about nC24 and continues to the end of the chromatogram. This includes the ranges typical of middle distillate from about nC8 to nC24 and heavier materials beyond the middle distillate range. The types and proportions of the peaks in the middle distillate range are typical of an extremely weathered diesel fuel or fuel oil. Weathering is primarily biodegradation which has preferentially decreased the size of the normal paraffin peaks (labeled nC8 to nC25) relative to the more biodegradation resistant compounds such as the isoprenoid peaks (labeled IP13 to IP18, Pristane and Phytane). The heavier material beyond the middle distillate range could be a heavy fuel oil, perhaps a lubricating oil or some other heavy material. RW-2L3 is quite similar to RW-2L5 and fairly similar to RW-5L3. The results of the physical property analyses are given in Table 1.

Sample RW-2L5 appears to be a mixture of extremely weathered middle distillate and perhaps a very small amount of heavier material. The chromatogram of RW-2L5 (Figures 5 and 14) shows a series of peaks starting at about normal nonane (nC9) and continuing to near the end of the chromatogram and one unresolved hump that starts at about nC10, reaches a maximum at about nC15 or nC16 and continues to about nC24 and a small amount of unresolved material that starts at about nC24 and continues to the end of the chromatogram. This includes the ranges typical of middle distillate from about nC8 to nC24 and heavier materials beyond the middle distillate range. The types and proportions of the peaks in the middle distillate range are typical of an extremely weathered diesel fuel or fuel oil. Weathering is primarily biodegradation which has preferentially decreased the size of the normal paraffin peaks (labeled nC8 to nC25) relative to the more biodegradation resistant compounds such as the isoprenoid peaks (labeled IP13 to IP18, Pristane and Phytane). The heavier material beyond the middle distillate range could be a heavy fuel oil, perhaps a lubricating oil or some other heavy material. RW-2L5 is quite similar to RW-2L3 and fairly similar to RW-5L3.

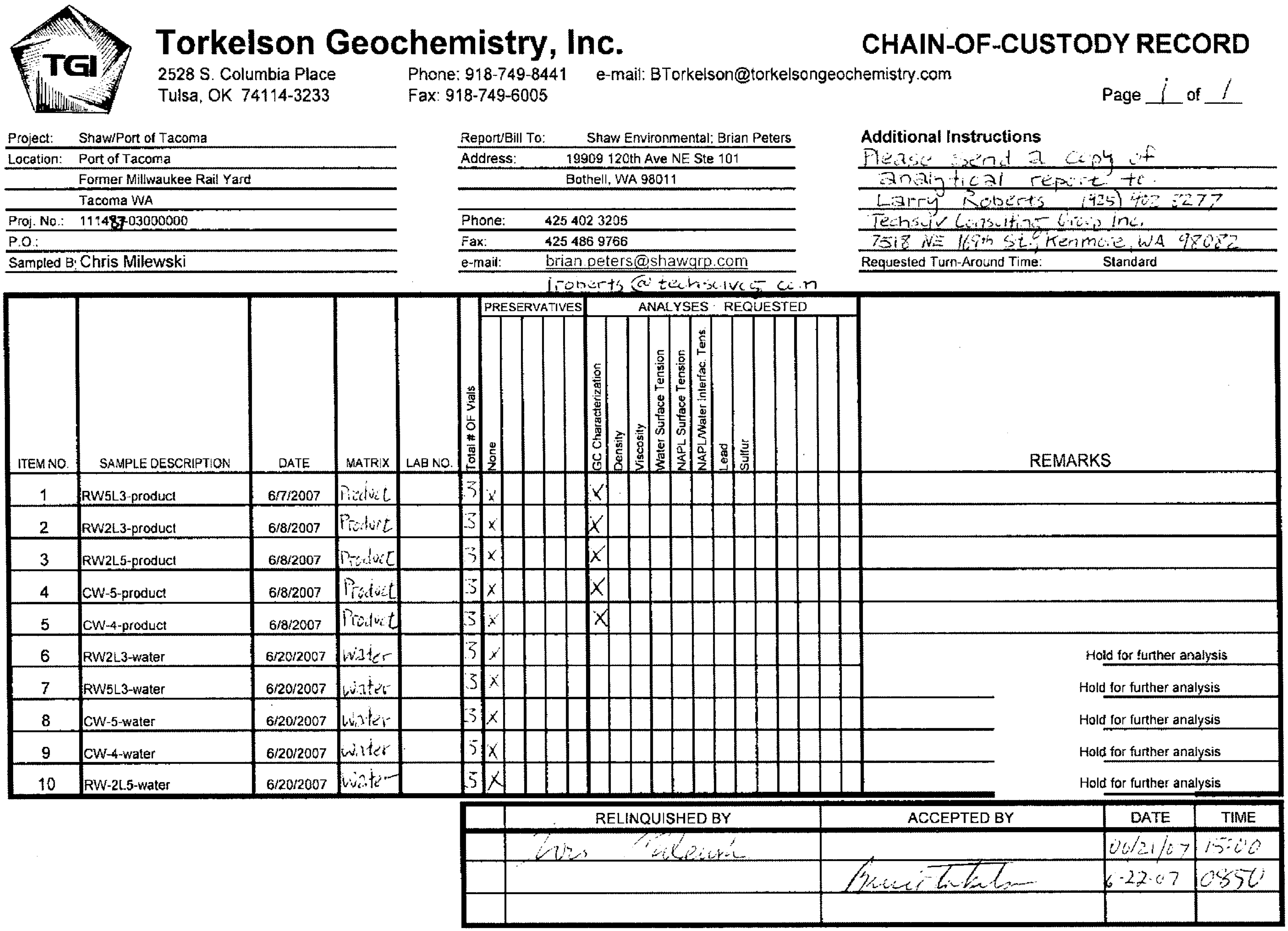
Sample RW-5L3 appears to be a mixture of extremely weathered middle distillate and a heavier material. The chromatogram of RW-5L3 (Figures 6 and 15) shows a series of peaks starting at about methylcyclohexane (MCHX) and continuing to the end of the chromatogram and one unresolved hump that starts at about nC10, reaches a maximum at about nC17 and continues to about nC24 and a second unresolved hump that starts at about nC24 reaches a maximum at about nC36 and continues to the end of the chromatogram. This includes the ranges typical of middle distillate from about nC8 to nC24 and heavier materials beyond the middle distillate range. The types and proportions of the peaks in the middle distillate range are typical of an extremely weathered diesel fuel or fuel oil. Weathering is primarily biodegradation which has preferentially decreased the size of the normal paraffin peaks (labeled nC8 to nC25) relative to the more biodegradation resistant compounds such as the isoprenoid peaks (labeled IP13 to IP18, Pristane and Phytane). The heavier material beyond the middle distillate range could be a heavy fuel oil, perhaps a lubricating oil or some other heavy material. RW-5L3 is quite similar to CW-4 and CW-5. The results of the physical property analyses are given in Table 1.

The material extracted from water sample RW-5L3 appears to be a mixture of extremely weathered middle distillate and perhaps a small amount of heavier material. The chromatogram of RW-5L3 extract (Figures 7 and 16) shows a series of peaks starting at about normal nonane (nC9) and continuing to near the end of the chromatogram and one unresolved hump that starts at about nC10, reaches a maximum at about nC16 and continues to about nC24 and a small amount of unresolved material that starts at about nC24 and continues to the end of the chromatogram. This includes the ranges typical of middle distillate from about nC8 to nC24 and heavier materials beyond the middle distillate range. The types and proportions of the peaks in the middle distillate range are typical of an extremely weathered diesel fuel or fuel oil. Weathering is primarily biodegradation which has preferentially decreased the size of the normal paraffin peaks (labeled nC8 to nC25) relative to the more biodegradation resistant compounds such as the isoprenoid peaks (labeled IP13 to IP18, Pristane and Phytane). The heavier material beyond the middle distillate range could be a heavy fuel oil, perhaps a lubricating oil or some other heavy material. RW-5L3 is fairly similar to RW-2L3 and RW-2L5.

Please let me know if you have any questions regarding this interpretation.

Bruce Torkelson

Bruce Torkelson



Torkelson Geochemistry, Inc.

2528 S. Columbia Place
Tulsa, OK 74114-3233

Phone: 918-749-8441
Fax: 918-749-6005

e-mail: BTorkelson@torkelsongeochemistry.com

CHAIN-OF-CUSTODY RECORD

Page 1 of 1

Project: Shaw/Port of Tacoma
Location: Port of Tacoma
Former Millwaukee Rail Yard
Tacoma WA
Proj. No.: 111487-03000000
P.O.:
Sampled B: Chris Milewski

Report/Bill To: Shaw Environmental: Brian Peters
Address: 19909 120th Ave NE Ste 101
Bothell, WA 98011
Phone: 425 402 3205
Fax: 425 486 9766
e-mail: brian.peters@shawgrp.com
lroberts@techsolvcg.com

Additional Instructions
Please send a copy of
analytical report to
Larry Roberts (425) 402 3277
TechSolv Consulting Group Inc.
7518 NE 169th St, Kenmore, WA 98022
Requested Turn-Around Time: Standard

						PRESERVATIVES					ANALYSES REQUESTED													
ITEM NO.	SAMPLE DESCRIPTION	DATE	MATRIX	LAB NO.	Total # OF Vials	None					GC Characterization	Density	Viscosity	Water Surface Tension	NAPL Surface Tension	NAPL/Water Interfac. Tens.	Lead	Sulfur						REMARKS
1	RW5L3-product	6/7/2007	Product		3	x					X													
2	RW2L3-product	6/8/2007	Product		3	x					X													
3	RW2L5-product	6/8/2007	Product		3	x					X													
4	CW-5-product	6/8/2007	Product		3	x					X													
5	CW-4-product	6/8/2007	Product		3	x					X													
6	RW2L3-water	6/20/2007	water		3	x																		Hold for further analysis
7	RW5L3-water	6/20/2007	water		3	x																		Hold for further analysis
8	CW-5-water	6/20/2007	water		3	x																		Hold for further analysis
9	CW-4-water	6/20/2007	water		3	x																		Hold for further analysis
10	RW-2L5-water	6/20/2007	water		3	x																		Hold for further analysis

	RELINQUISHED BY	ACCEPTED BY	DATE	TIME
			06/21/07	15:00
			6-22-07	0850

Figure 1, Chain of Custody.

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : CW-4-Product
Acquired : Jun 26, 2007 14:04:34

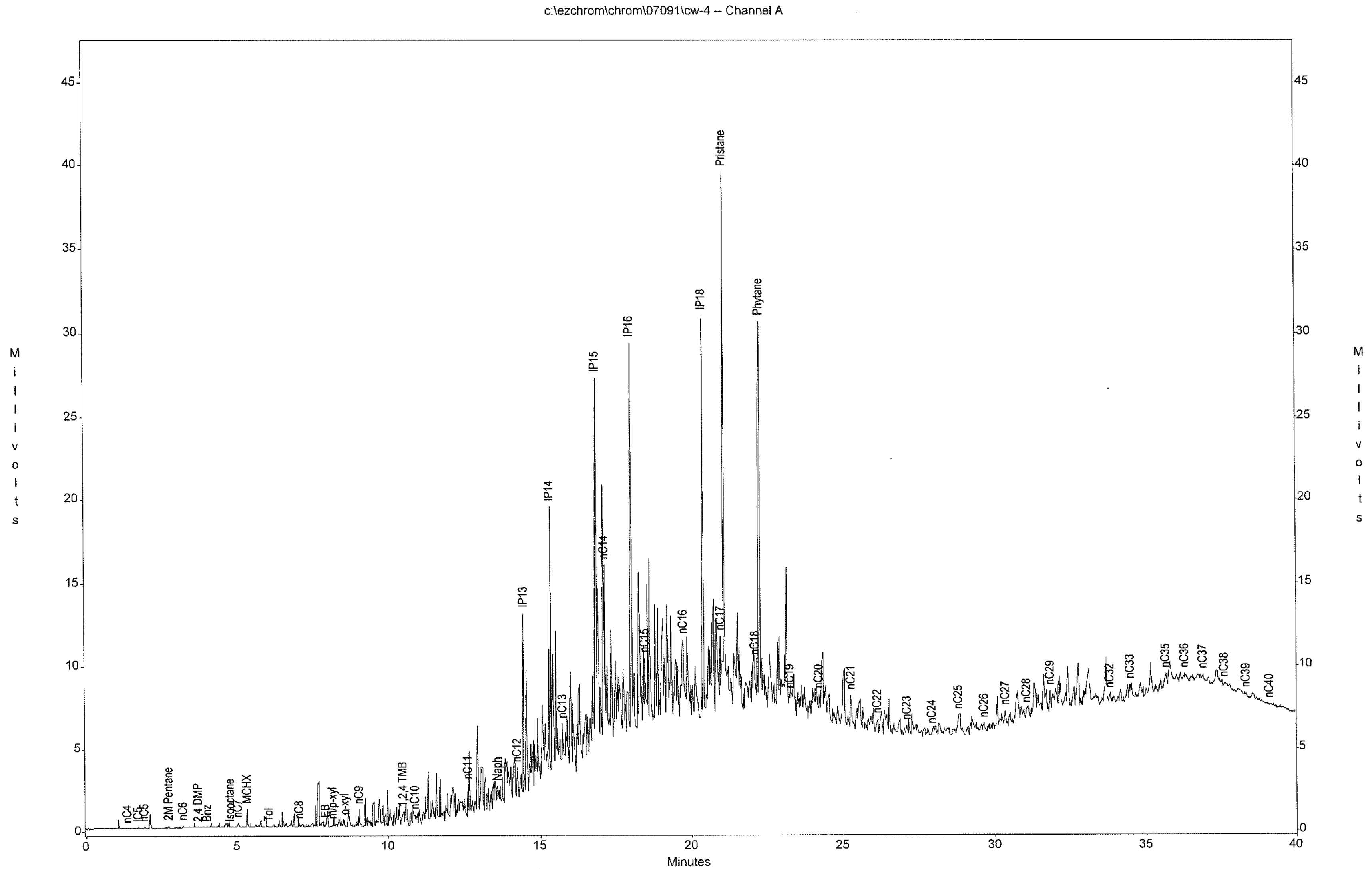


Figure 2, Gas chromatogram of the CW-4 product sample.

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : CW-5-Product
Acquired : Jun 26, 2007 13:08:42

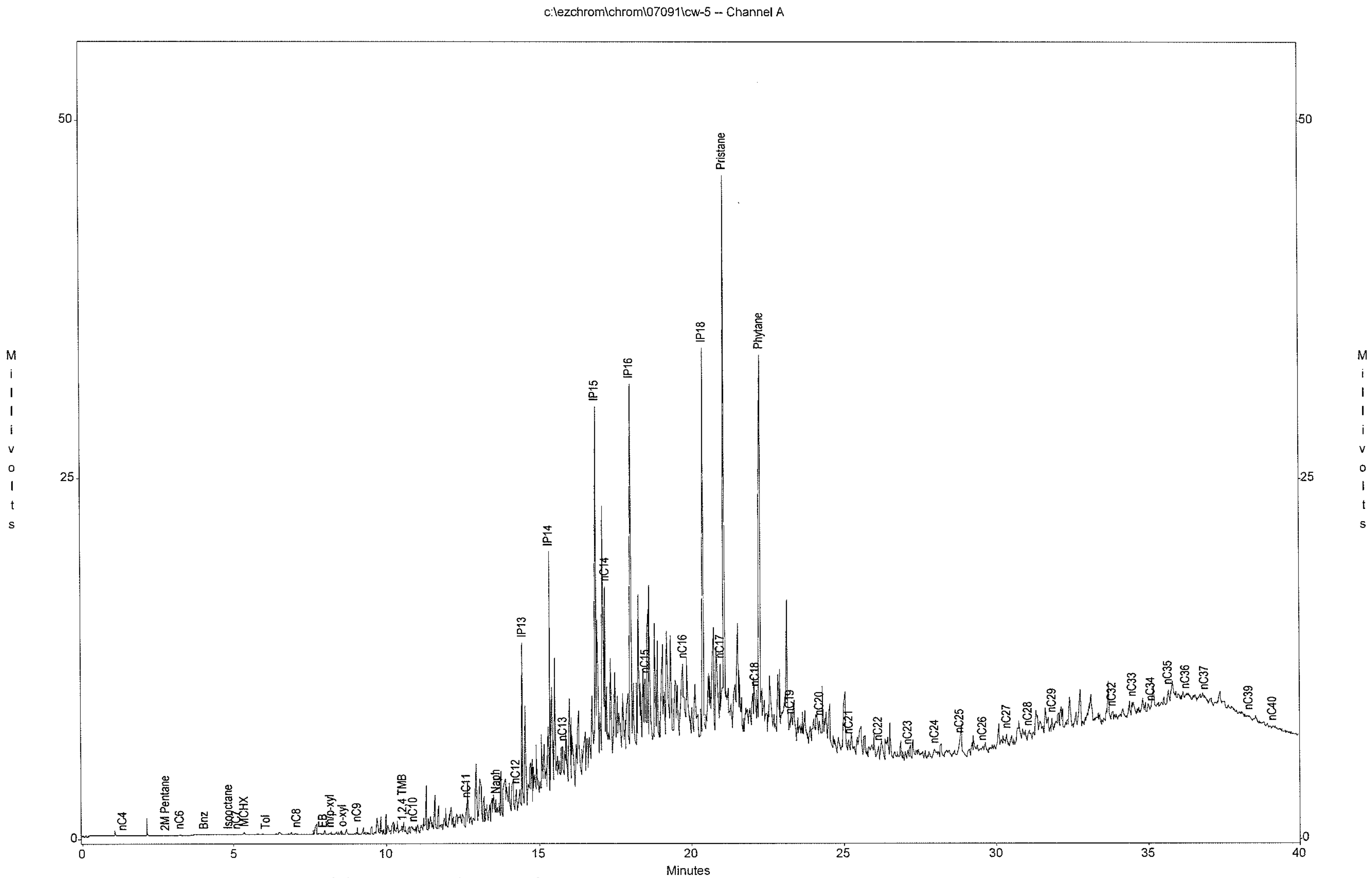


Figure 3, Gas chromatogram of the CW-5 product sample.

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : RW2L3-Product
Acquired : Jun 26, 2007 16:49:41

c:\ezchrom\chrom\07091\rw-2l3 -- Channel A

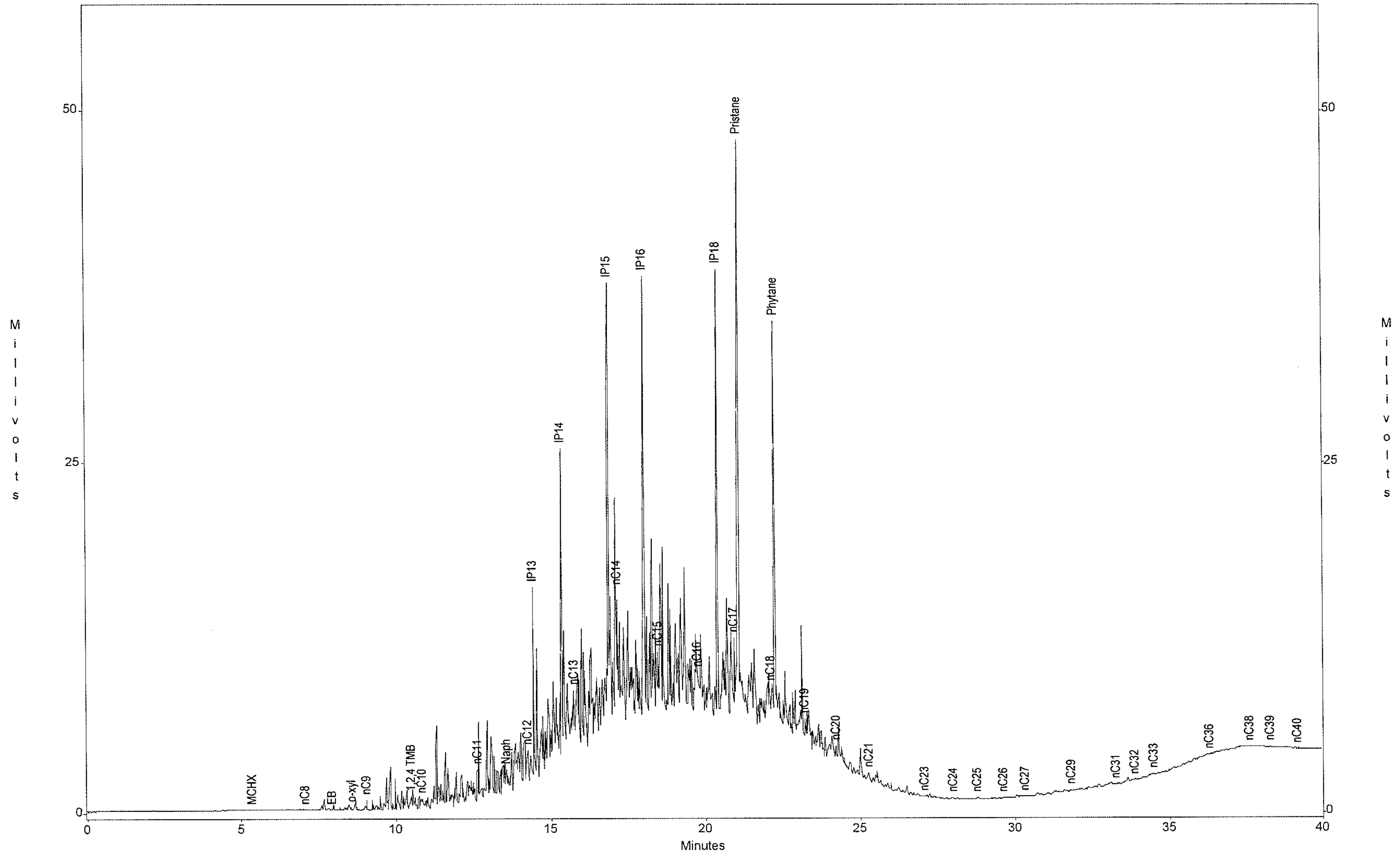


Figure 4, Gas chromatogram of the RW-2L3 product sample.

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : RW2L5-Product
Acquired : Jun 26, 2007 15:57:58

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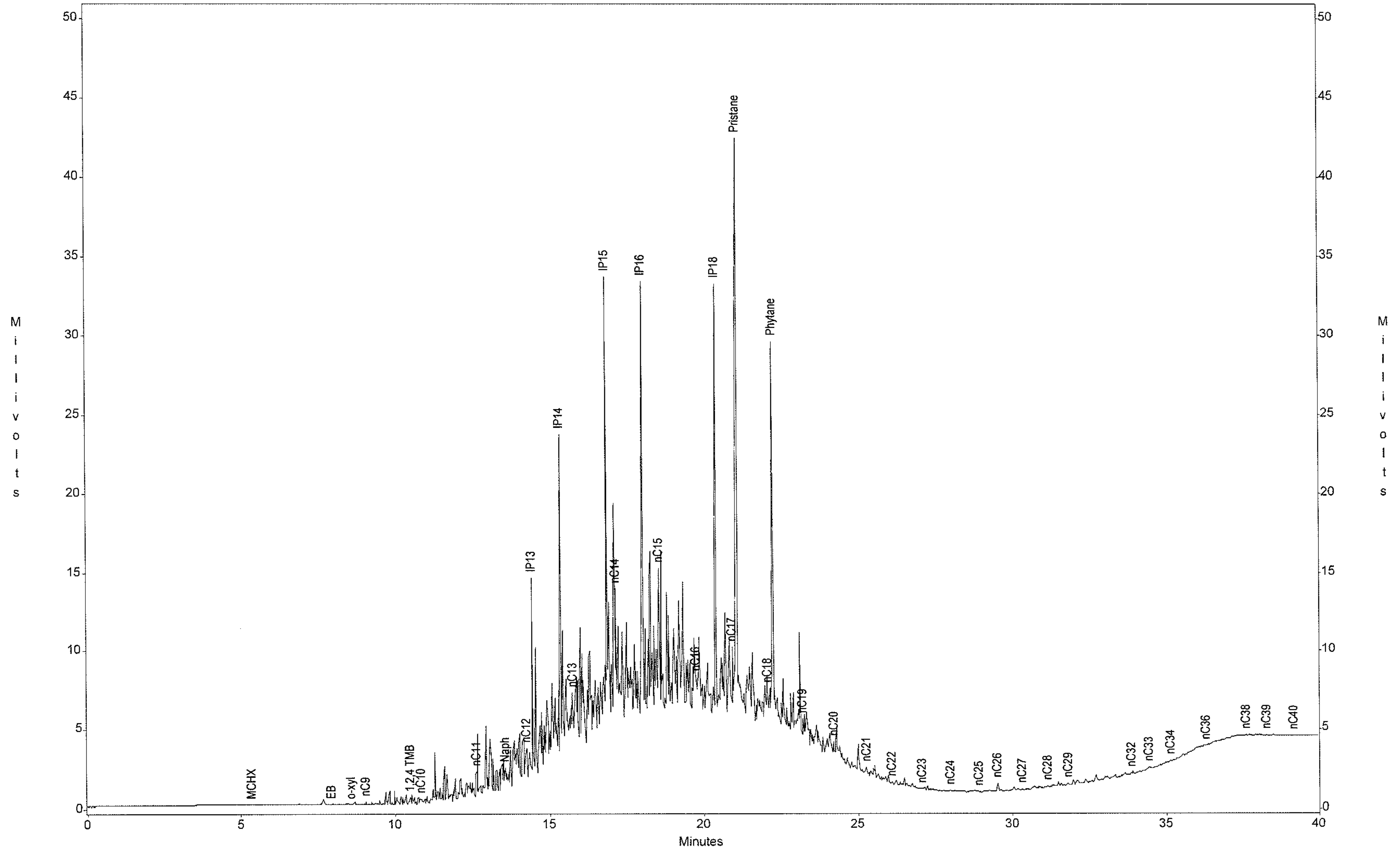


Figure 5, Gas chromatogram of the RW-2L5 product sample.

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : RW5L3-Product
Acquired : Jun 26, 2007 12:15:29

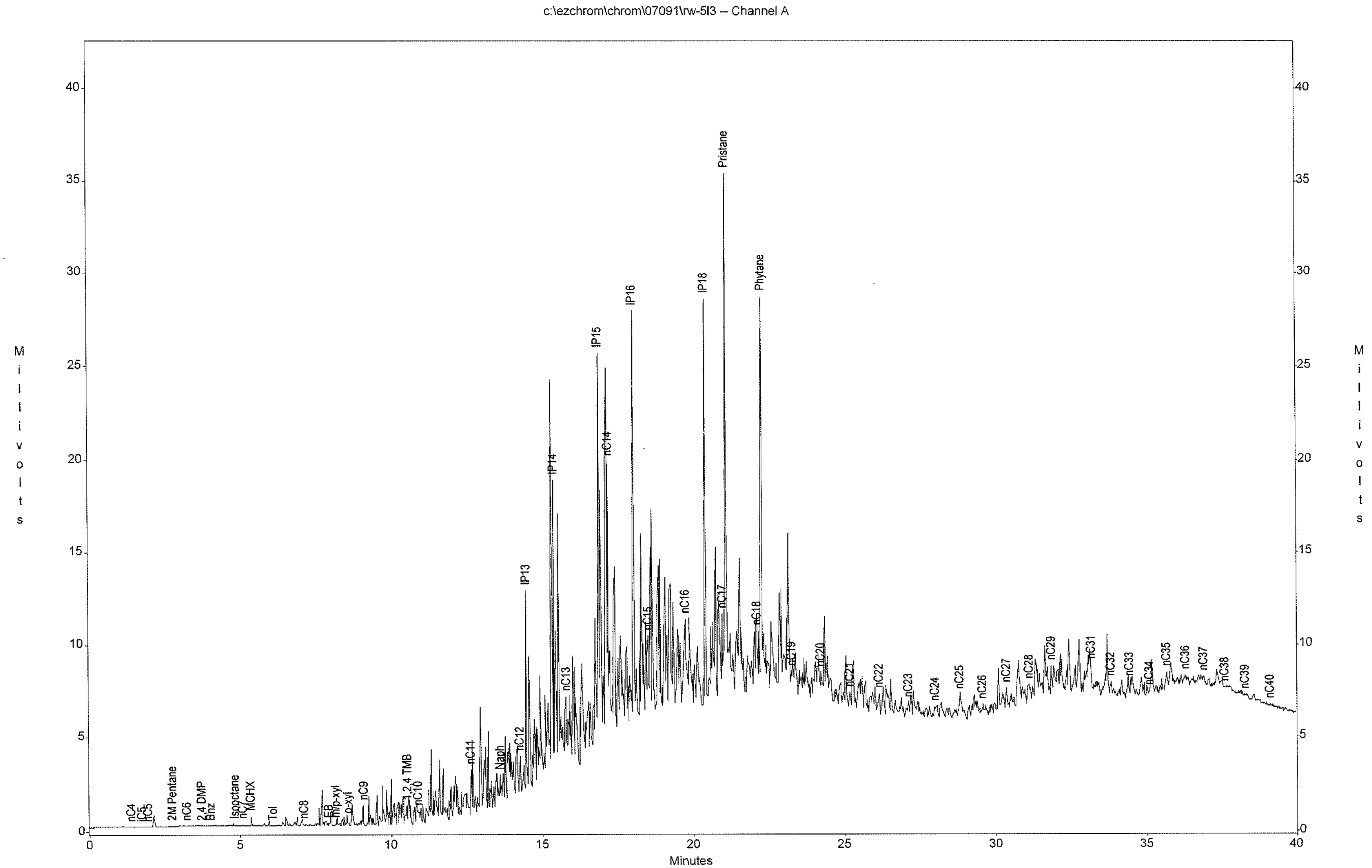


Figure 6, Gas chromatogram of the RW-5L3 product sample.

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : RW5L3 Water Extract
Acquired : Jul 11, 2007 13:43:29

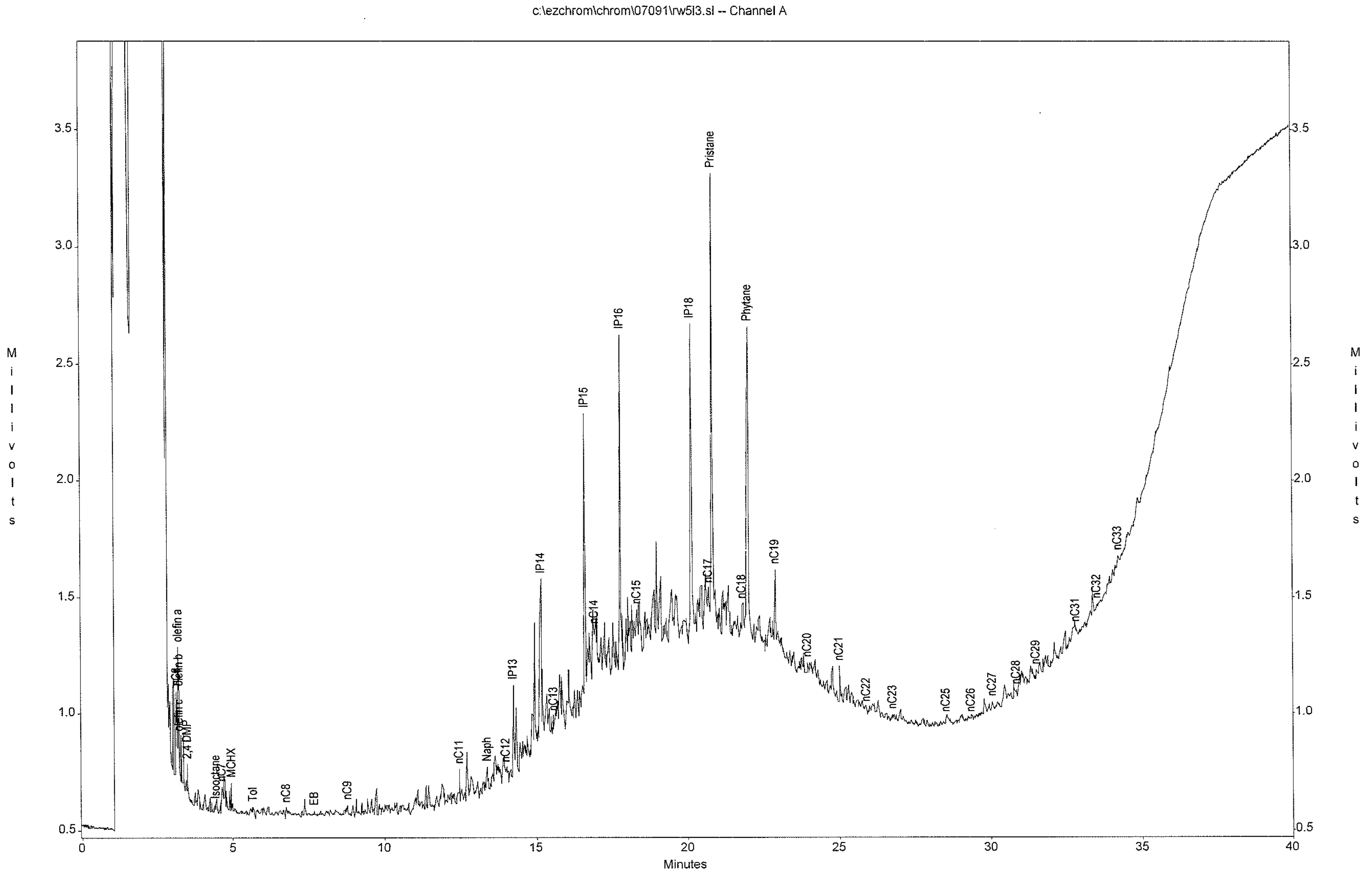


Figure 7, Gas chromatogram of the extract from the RW-5L3 water sample.

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : Gas/Dies/Wax std
Acquired : Jun 26, 2007 09:44:39

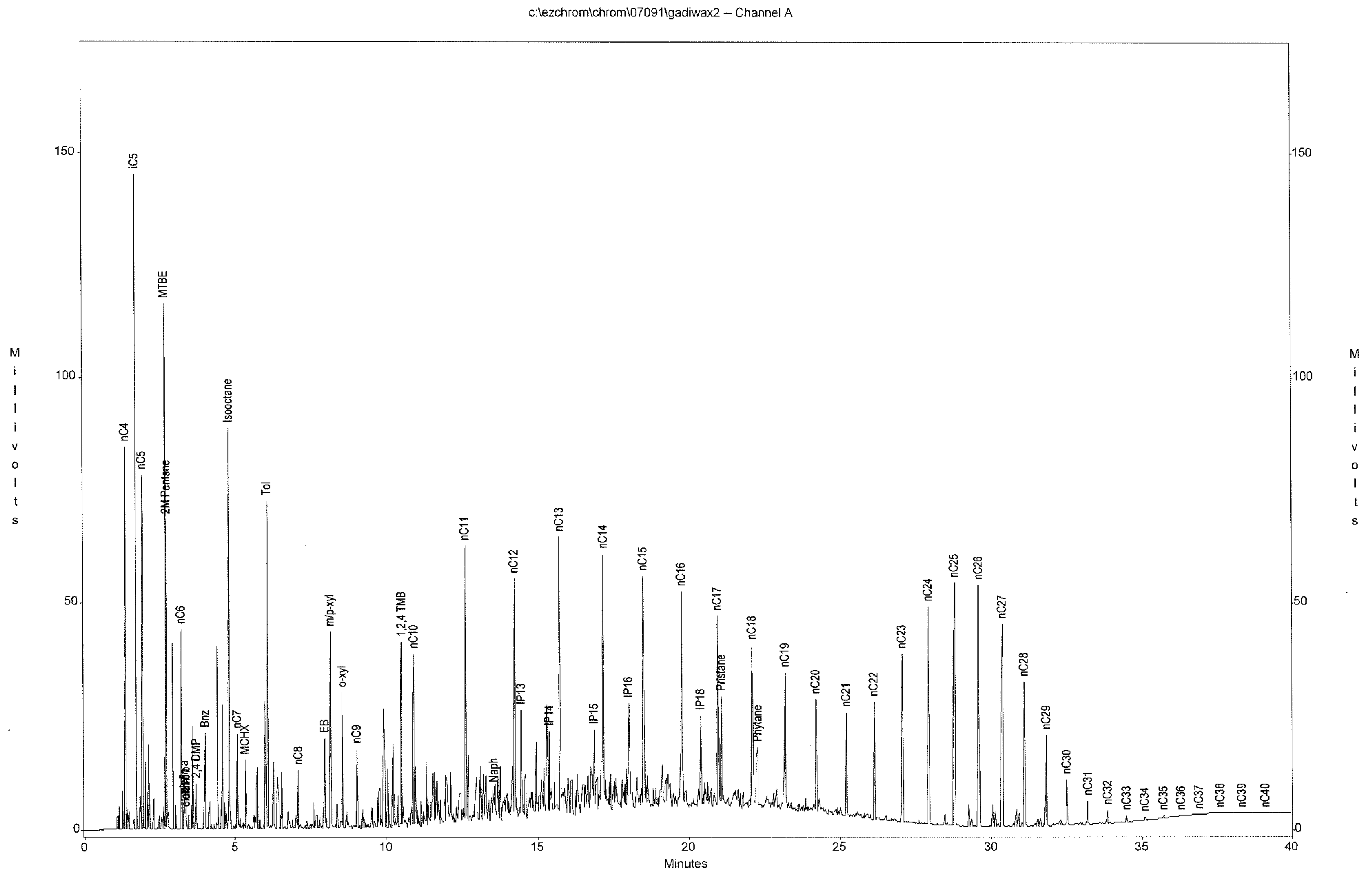


Figure 8, Gas chromatogram of the laboratory standard (gasoline/diesel/wax mixture).

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : Gas/Dies/Wax std
Acquired : Jul 11, 2007 15:23:07

c:\ezchrom\chrom\07091\gadiwax.sl -- Channel A

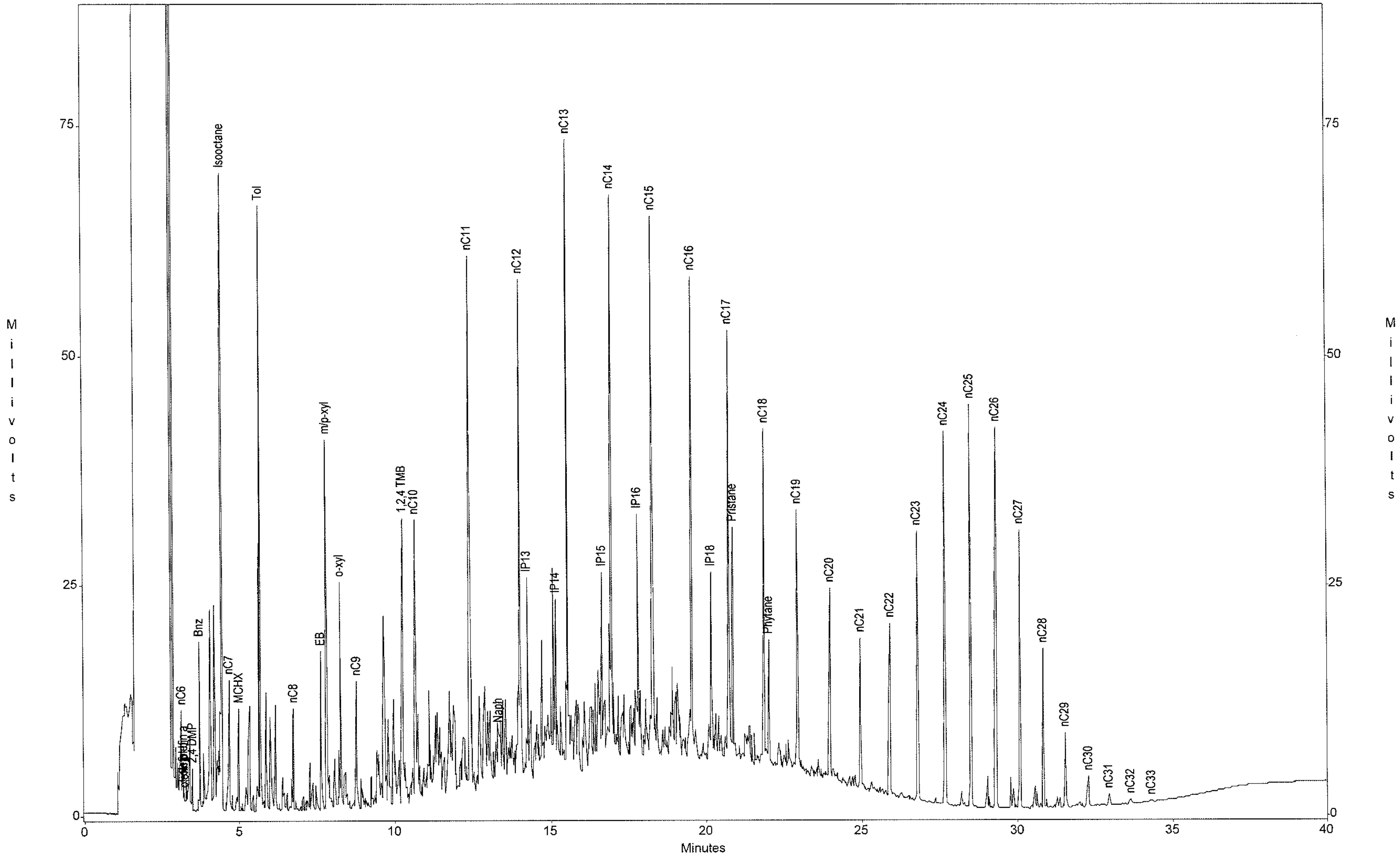


Figure 9, Gas chromatogram of diluted laboratory standard (gasoline/diesel/wax mixture).

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : Blank
Acquired : Jul 11, 2007 14:33:47

c:\ezchrom\chrom\07091\blank.sl -- Channel A

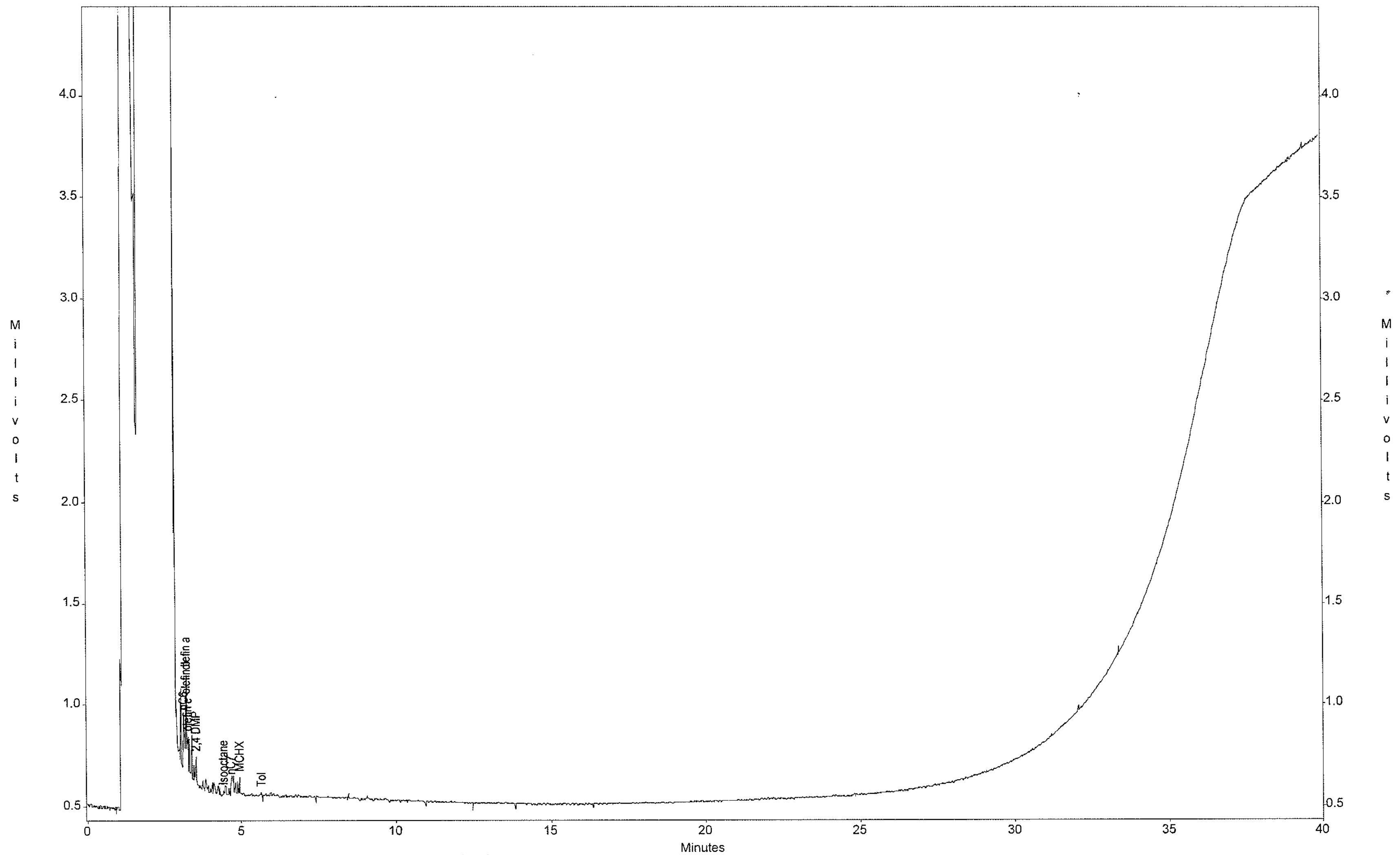


Figure 10, Gas chromatogram of laboratory blank.

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : CW-4-Product
Acquired : Jun 26, 2007 14:04:34

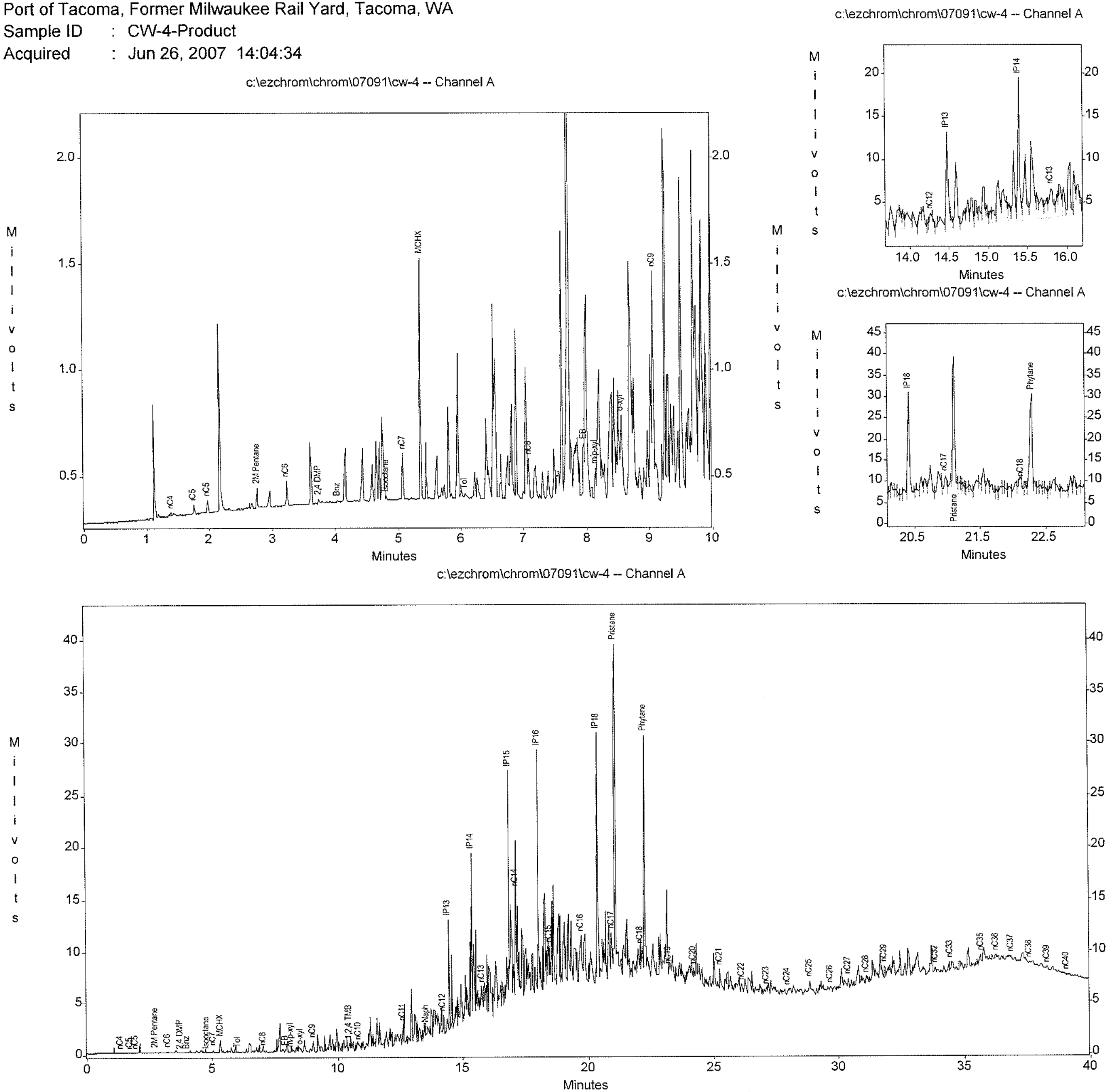


Figure 11, Multipanel display of gas chromatogram of the CW-4 product sample.

Channel A Results

Peak	Area	Height
nC4	13	16
iC5	36	46
nC5	47	58
MTBE	0	0
2M Pentane	88	92
nC6	120	118
olefin a	0	0
olefin b	0	0
olefin c	0	0
2.4 DMP	29	25
Bnz	10	8
Isooctane	28	22
nC7	264	220
MCHX	1379	1144
Tol	54	28
nC8	241	188
EB	379	267
m/p-xyl	266	154
o-xyl	910	398
nC9	1704	1090
1.2.4 TMB	410	309
nC10	1601	617
nC11	4107	1939
Naph	3422	1328
nC12	3222	1865
IP13	16985	11018
IP14	26035	16647
nC13	11999	3388
IP15	37281	22592
nC14	22403	10742
IP16	45379	23347
nC15	13718	4224
nC16	15130	4853
IP18	50114	23750
nC17	11226	4514
Pristane	76921	32351
nC18	4964	3189
Phytane	55713	23560
nC19	3154	1328
nC20	4860	1403
nC21	6044	2065
nC22	3928	909
nC23	2444	627
nC24	2161	445
nC25	7049	1159
nC26	2480	568
nC27	2826	953
nC28	1641	502
nC29	2518	1170
nC30	0	0
nC31	0	0
nC32	2154	542
nC33	1129	645
nC34	0	0
nC35	2565	773
nC36	295	197
nC37	247	184
nC38	116	135
nC39	123	137
nC40	172	102

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : CW-5-Product
Acquired : Jun 26, 2007 13:08:42

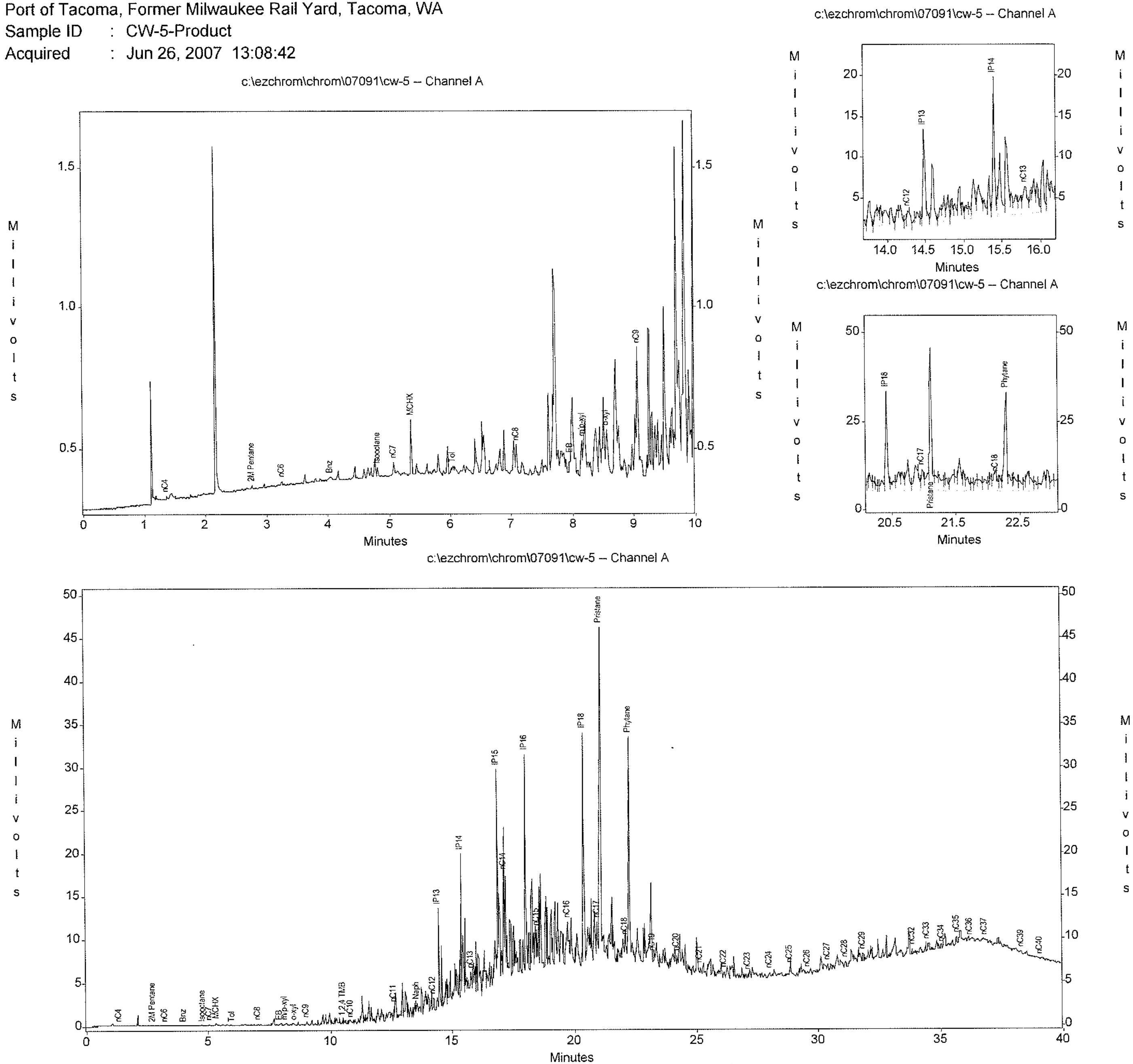


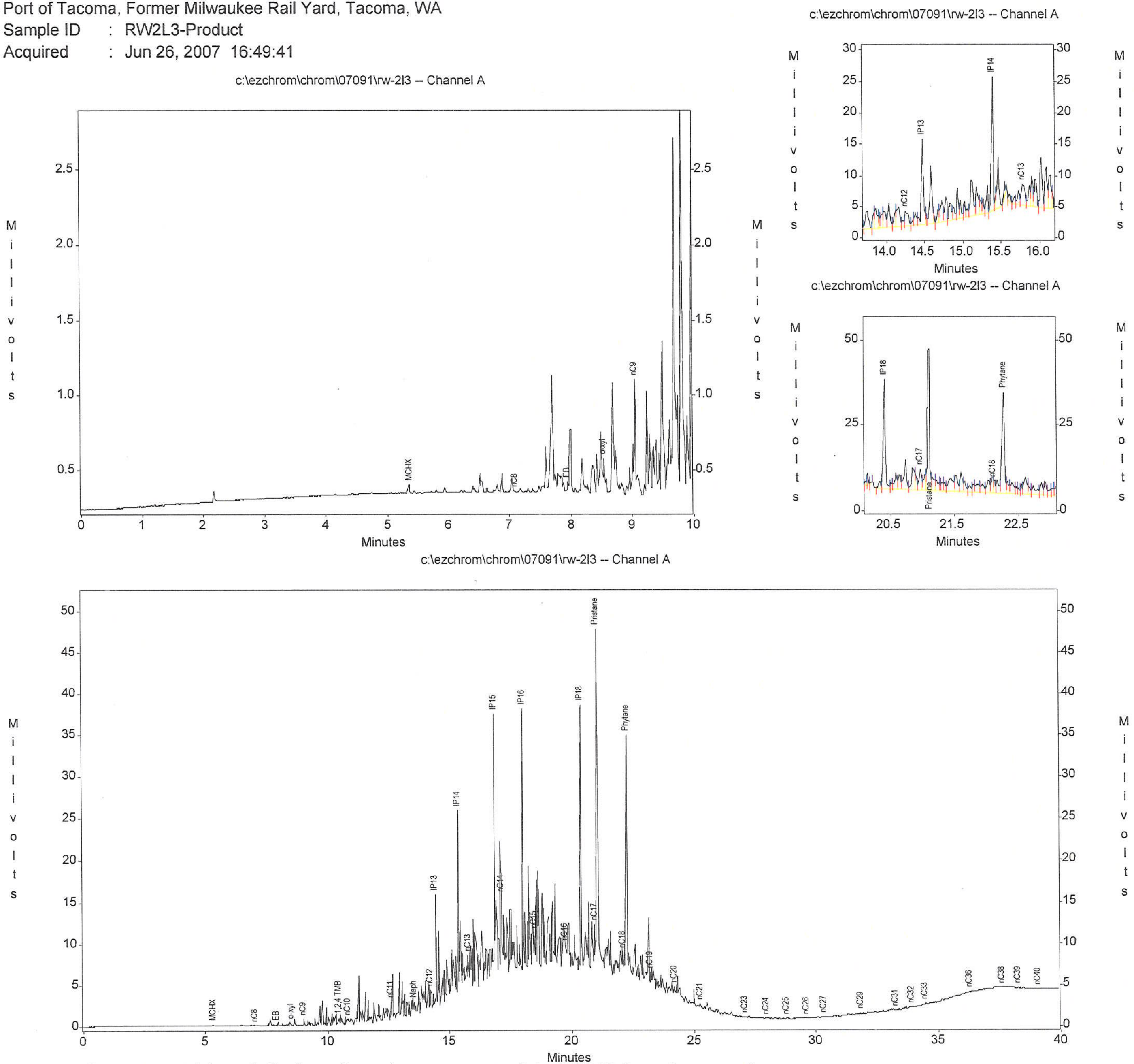
Figure 12, Multipanel display of gas chromatogram of the CW-5 product sample.

Channel A Results

Peak	Area	Height
nC4	18	15
iC5	0	0
nC5	0	0
MTBE	0	0
2M Pentane	19	13
nC6	18	15
olefin a	0	0
olefin b	0	0
olefin c	0	0
2,4 DMP	0	0
Bnz	14	8
Isooctane	40	32
nC7	91	51
MCHX	240	198
Tol	46	30
nC8	152	108
EB	104	70
m/p-xyl	222	128
o-xyl	427	166
nC9	976	462
1,2,4 TMB	689	502
nC10	901	377
nC11	3209	1653
Naph	3482	1433
nC12	707	622
IP13	18253	11500
IP14	26807	17098
nC13	12339	3195
IP15	40255	25147
nC14	24827	12178
IP16	50108	25392
nC15	16002	4932
nC16	17909	6067
IP18	64379	28115
nC17	17144	6152
Pristane	97006	40280
nC18	7376	4313
Phytane	71492	27863
nC19	6627	2493
nC20	7316	2529
nC21	4992	1291
nC22	3887	929
nC23	1962	665
nC24	3355	679
nC25	3237	1271
nC26	2462	519
nC27	3724	847
nC28	1453	445
nC29	2054	888
nC30	0	0
nC31	0	0
nC32	2061	507
nC33	966	570
nC34	145	160
nC35	1188	565
nC36	158	185
nC37	73	119
nC38	0	0
nC39	239	78
nC40	198	156

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : RW2L3-Product
Acquired : Jun 26, 2007 16:49:41



Page 1 of 1 (1)

Channel A Results

Peak	Area	Height
nC4	0	0
iC5	0	0
nC5	0	0
MTBE	0	0
2M Pentane	0	0
nC6	0	0
olefin a	0	0
olefin b	0	0
olefin c	0	0
2.4 DMP	0	0
Bnz	0	0
Isooctane	0	0
nC7	0	0
MCHX	76	58
Tol	0	0
nC8	16	11
EB	119	76
m/p-xyl	0	0
o-xyl	424	224
nC9	1186	768
1.2.4 TMB	1346	934
nC10	1481	694
nC11	4613	2301
Naph	3993	1668
nC12	6778	2370
IP13	23787	13549
IP14	33290	21426
nC13	10921	3313
IP15	54760	32422
nC14	25076	10326
IP16	64052	32208
nC15	23150	5156
nC16	4610	2843
IP18	69498	31897
nC17	15246	6041
Pristane	98420	41580
nC18	7305	3542
Phytane	73074	29674
nC19	4232	2069
nC20	3413	1137
nC21	2328	620
nC22	0	0
nC23	181	83
nC24	703	118
nC25	784	135
nC26	335	66
nC27	237	92
nC28	0	0
nC29	177	96
nC30	0	0
nC31	103	26
nC32	158	27
nC33	261	82
nC34	0	0
nC35	0	0
nC36	180	33
nC37	0	0
nC38	175	42
nC39	138	36
nC40	12	10

Figure 13, Multipanel display of gas chromatogram of the RW-2L3 product sample.

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : RW2L5-Product
Acquired : Jun 26, 2007 15:57:58

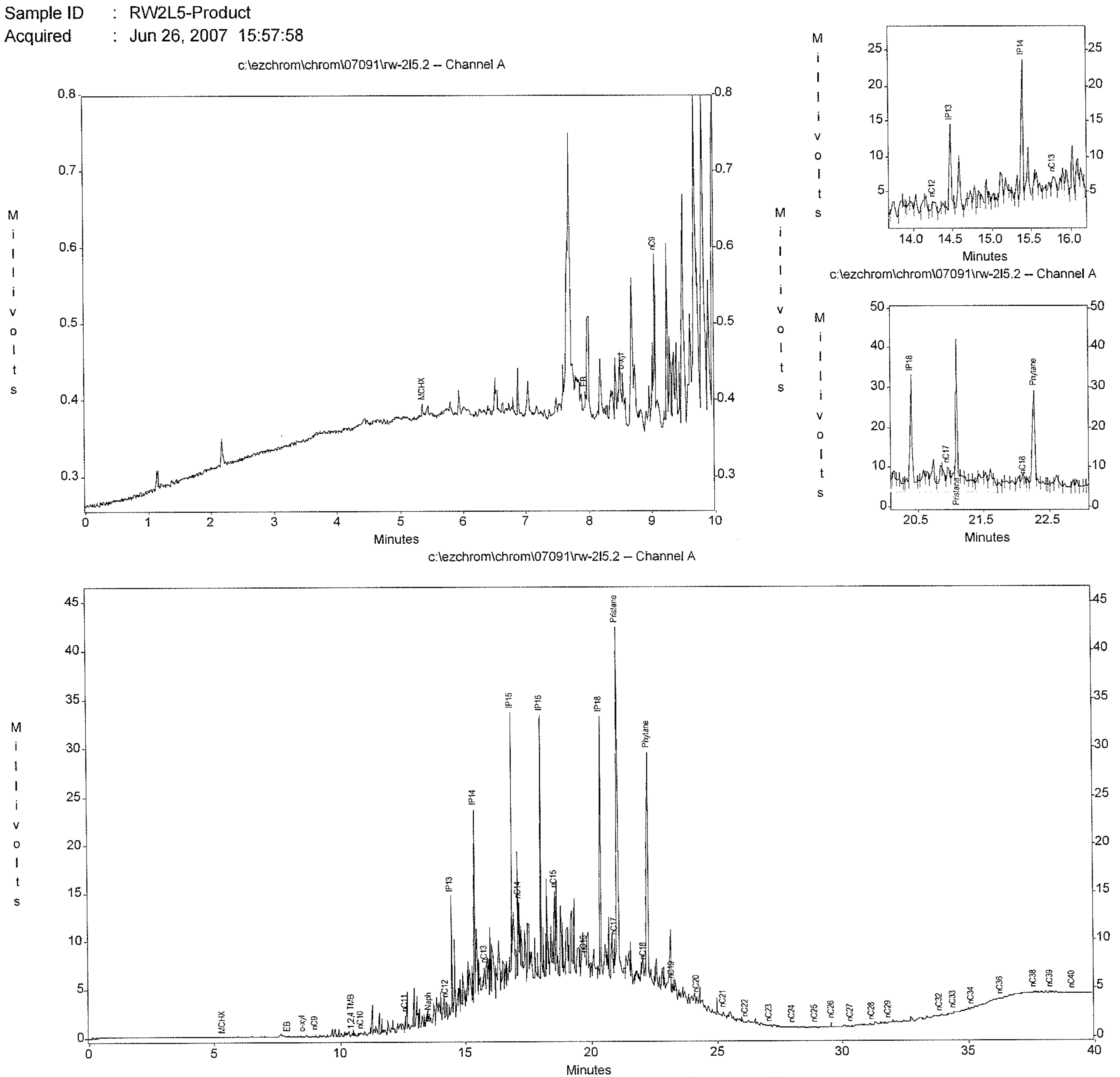


Figure 14, Multipanel display of gas chromatogram of the RW-2L5 product sample.

Channel A Results

Peak	Area	Height
nC4	0	0
iC5	0	0
nC5	0	0
MTBE	0	0
2M Pentane	0	0
nC6	0	0
olefin a	0	0
olefin b	0	0
olefin c	0	0
2.4 DMP	0	0
Bnz	0	0
Isooctane	0	0
nC7	0	0
MCHX	17	13
Tol	0	0
nC8	0	0
EB	72	43
m/p-xyl	0	0
o-xyl	175	73
nC9	463	230
1.2.4 TMB	592	406
nC10	705	324
nC11	3195	1585
Naph	3266	1294
nC12	5489	1907
IP13	21527	12628
IP14	29920	19866
nC13	8734	2609
IP15	49597	29645
nC14	24310	9933
IP16	61825	29385
nC15	26824	11216
nC16	10712	4334
IP18	72528	29297
nC17	18672	6248
Pristane	92448	38449
nC18	7061	3646
Phytane	64144	25651
nC19	3609	1712
nC20	2481	882
nC21	2004	471
nC22	501	133
nC23	195	60
nC24	714	99
nC25	187	38
nC26	1062	531
nC27	232	91
nC28	368	125
nC29	261	104
nC30	0	0
nC31	0	0
nC32	231	111
nC33	181	81
nC34	239	77
nC35	0	0
nC36	235	26
nC37	0	0
nC38	50	26
nC39	65	24
nC40	107	14

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : RW5L3-Product
Acquired : Jun 26, 2007 12:15:29

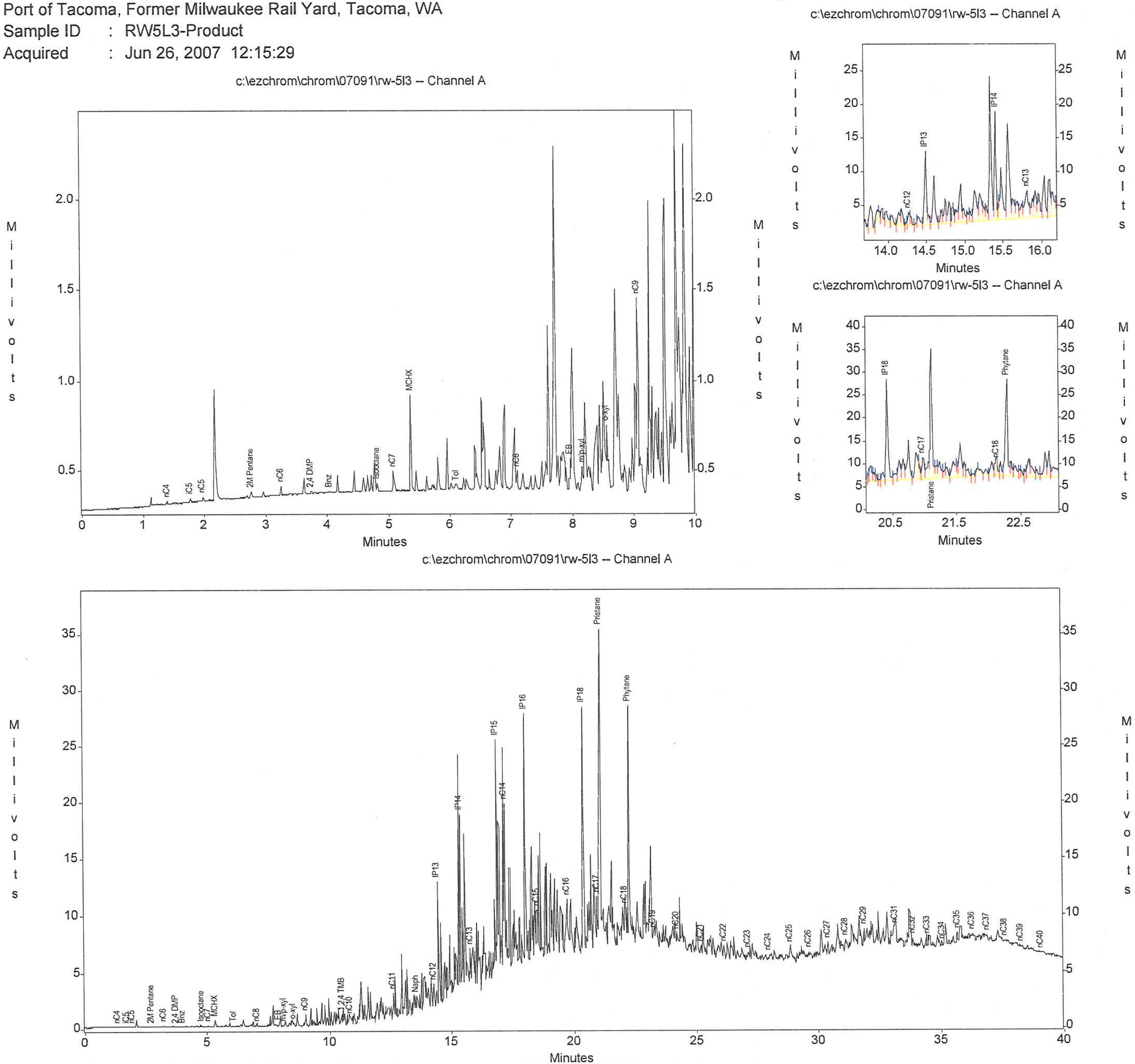


Figure 15, Multipanel display of gas chromatogram of the RW-5L3 product sample.

Channel A Results

Peak	Area	Height
nC4	22	16
iC5	30	26
nC5	23	22
MTBE	0	0
2M Pentane	40	35
nC6	58	51
olefin a	0	0
olefin b	0	0
olefin c	0	0
2.4 DMP	13	12
Bnz	13	10
Isooctane	58	46
nC7	137	112
MCHX	644	532
Tol	103	37
nC8	164	110
EB	270	187
m/p-xyl	245	137
o-xyl	832	371
nC9	1666	1079
1.2.4 TMB	1319	956
nC10	1701	674
nC11	4940	2374
Naph	3503	1502
nC12	3622	1979
IP13	17374	10801
IP14	24973	16066
nC13	13124	3999
IP15	33785	20807
nC14	28521	14736
IP16	41005	21612
nC15	13265	4219
nC16	16685	4857
IP18	47995	21841
nC17	11346	4679
Pristane	64722	28321
nC18	4358	2925
Phytane	46802	20976
nC19	2409	1235
nC20	3744	1079
nC21	2525	791
nC22	4994	1096
nC23	3150	789
nC24	2312	602
nC25	4005	1188
nC26	2437	653
nC27	2983	1156
nC28	3549	925
nC29	2932	1401
nC30	0	0
nC31	366	363
nC32	2178	632
nC33	850	412
nC34	70	121
nC35	2468	782
nC36	343	240
nC37	120	128
nC38	63	118
nC39	112	86
nC40	72	84

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : RW5L3 Water Extract
Acquired : Jul 11, 2007 13:43:29

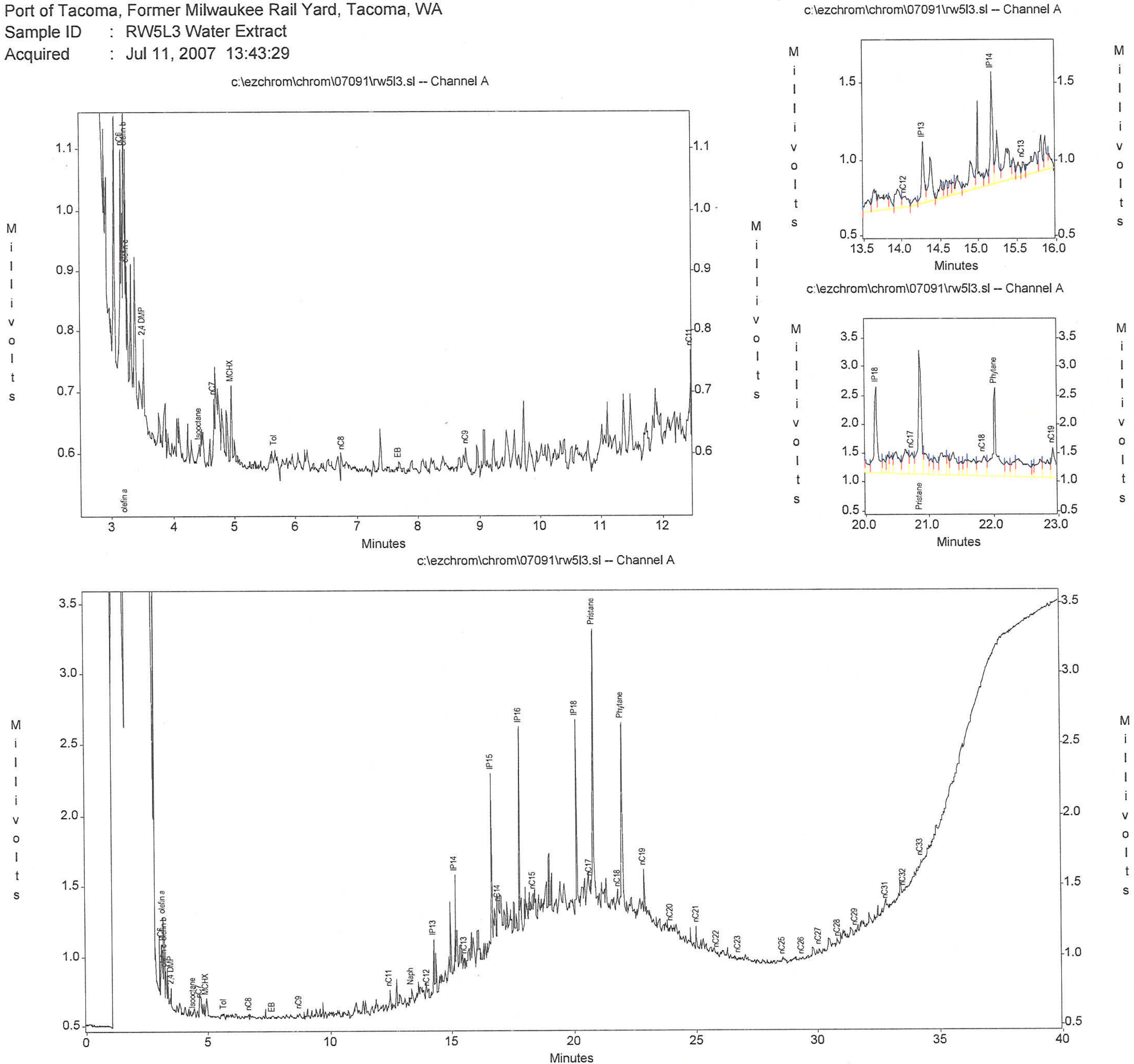


Figure 16, Multipanel display of gas chromatogram the extract from the RW-5L3 water sample.

Channel A Results

Peak	Area	Height
nC6	566	376
olefin a	539	578
olefin b	375	393
olefin c	198	208
2.4 DMP	220	141
Bnz	0	0
Isooctane	76	34
nC7	161	112
MCHX	213	138
Tol	180	50
nC8	64	44
EB	190	27
m/p-xyl	0	0
o-xyl	0	0
nC9	394	47
1.2.4 TMB	0	0
nC10	0	0
nC11	422	151
Naph	608	121
nC12	333	67
IP13	862	401
IP14	1319	730
nC13	172	86
IP15	2749	1273
nC14	1365	305
IP16	3097	1453
nC15	585	190
nC16	0	0
IP18	4780	1475
nC17	1287	364
Pristane	6606	2146
nC18	2801	332
Phytane	6868	1526
nC19	2034	522
nC20	1076	161
nC21	685	182
nC22	181	36
nC23	170	32
nC24	0	0
nC25	474	37
nC26	70	13
nC27	103	38
nC28	72	33
nC29	102	39
nC30	0	0
nC31	130	46
nC32	41	17
nC33	84	36
nC34	0	0
nC35	0	0
nC36	0	0
nC37	0	0
nC38	0	0
nC39	0	0
nC40	0	0

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : Gas/Dies/Wax std
Acquired : Jun 26, 2007 09:44:39

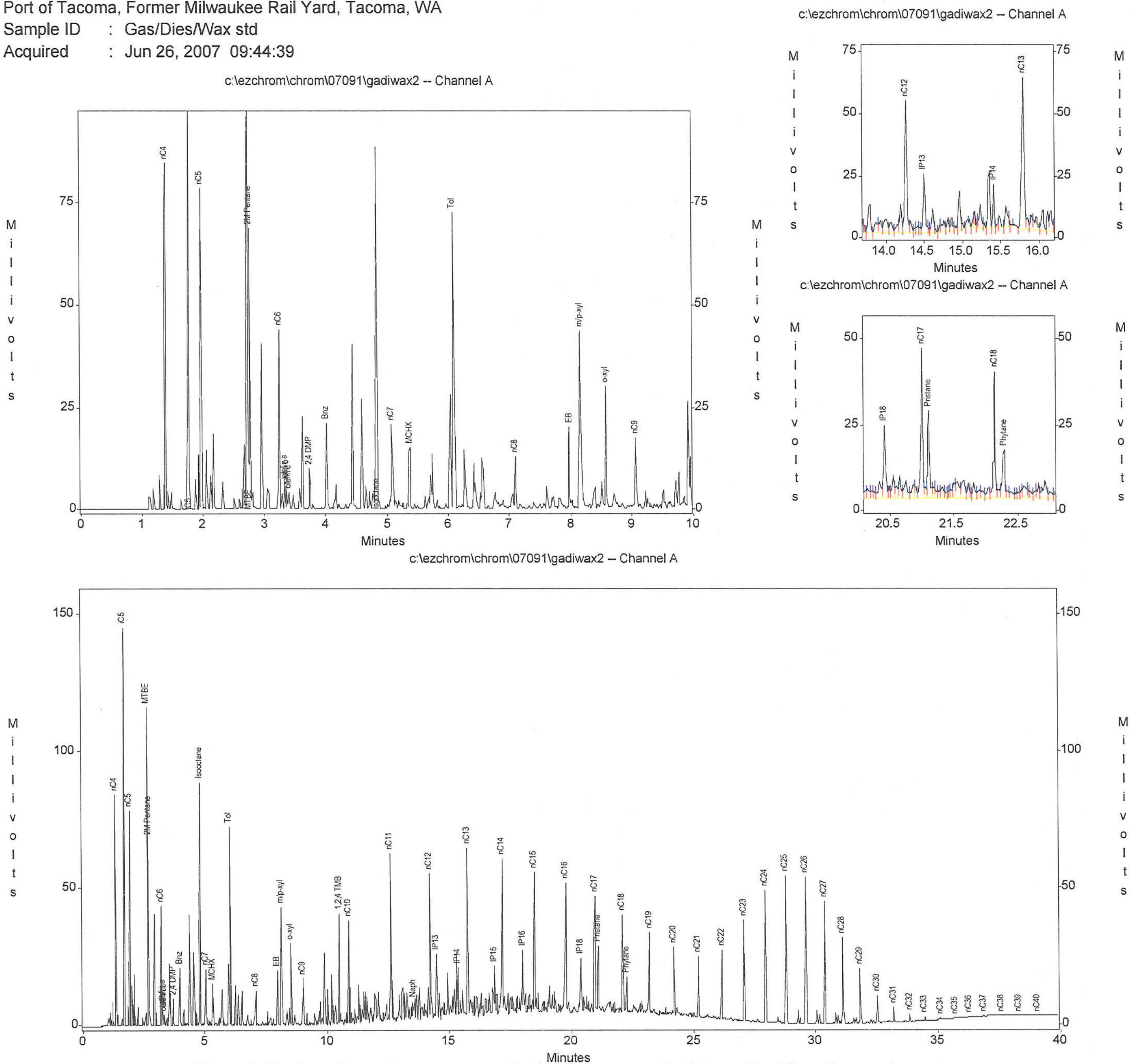


Figure 17, Multipanel display of gas chromatogram the laboratory standard (gasoline/diesel/wax mixture).

Channel A Results

Peak	Area	Height
nC4	50157	84851
iC5	100320	145240
nC5	57064	78680
MTBE	103127	116398
2M Pentane	61646	68571
nC6	42583	43890
olefin a	7565	6865
olefin b	5369	5364
olefin c	4629	4014
2.4 DMP	10623	10173
Bnz	26714	21239
Isooctane	124403	88822
nC7	25571	20773
MCHX	18801	15309
Tol	107221	72723
nC8	15533	13002
EB	27081	20023
m/p-xyl	98780	43413
o-xyl	43001	29891
nC9	25737	17467
1.2.4 TMB	67364	40597
nC10	55647	37873
nC11	102162	61182
Naph	24456	7338
nC12	95126	53225
IP13	39549	23735
IP14	24122	17269
nC13	121205	60935
IP15	30378	18694
nC14	118656	57917
IP16	56696	24555
nC15	111197	52650
nC16	106858	49012
IP18	50953	21415
nC17	93428	43548
Pristane	58415	25555
nC18	75990	36867
Phytane	33634	14221
nC19	74214	30415
nC20	43653	24869
nC21	37912	22543
nC22	46873	25713
nC23	74267	36912
nC24	111100	47938
nC25	131555	53894
nC26	134348	53357
nC27	102848	44594
nC28	65447	31568
nC29	36031	19910
nC30	19259	10044
nC31	9225	5263
nC32	4832	2766
nC33	2646	1514
nC34	1456	801
nC35	833	464
nC36	1014	248
nC37	945	141
nC38	1233	92
nC39	141	50
nC40	102	34

Page 1 of 1 (2)

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Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : Gas/Dies/Wax std
Acquired : Jul 11, 2007 15:23:07

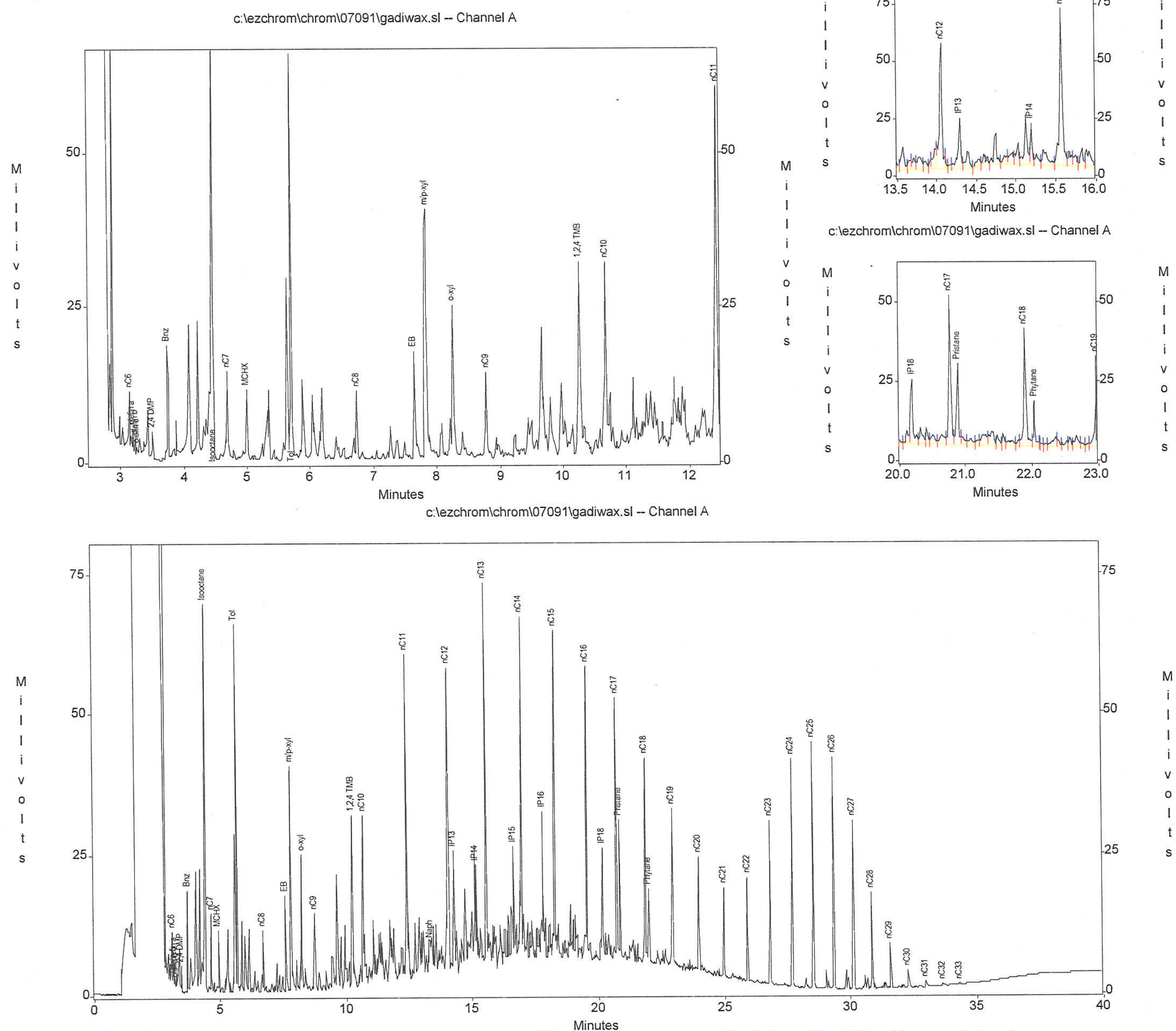


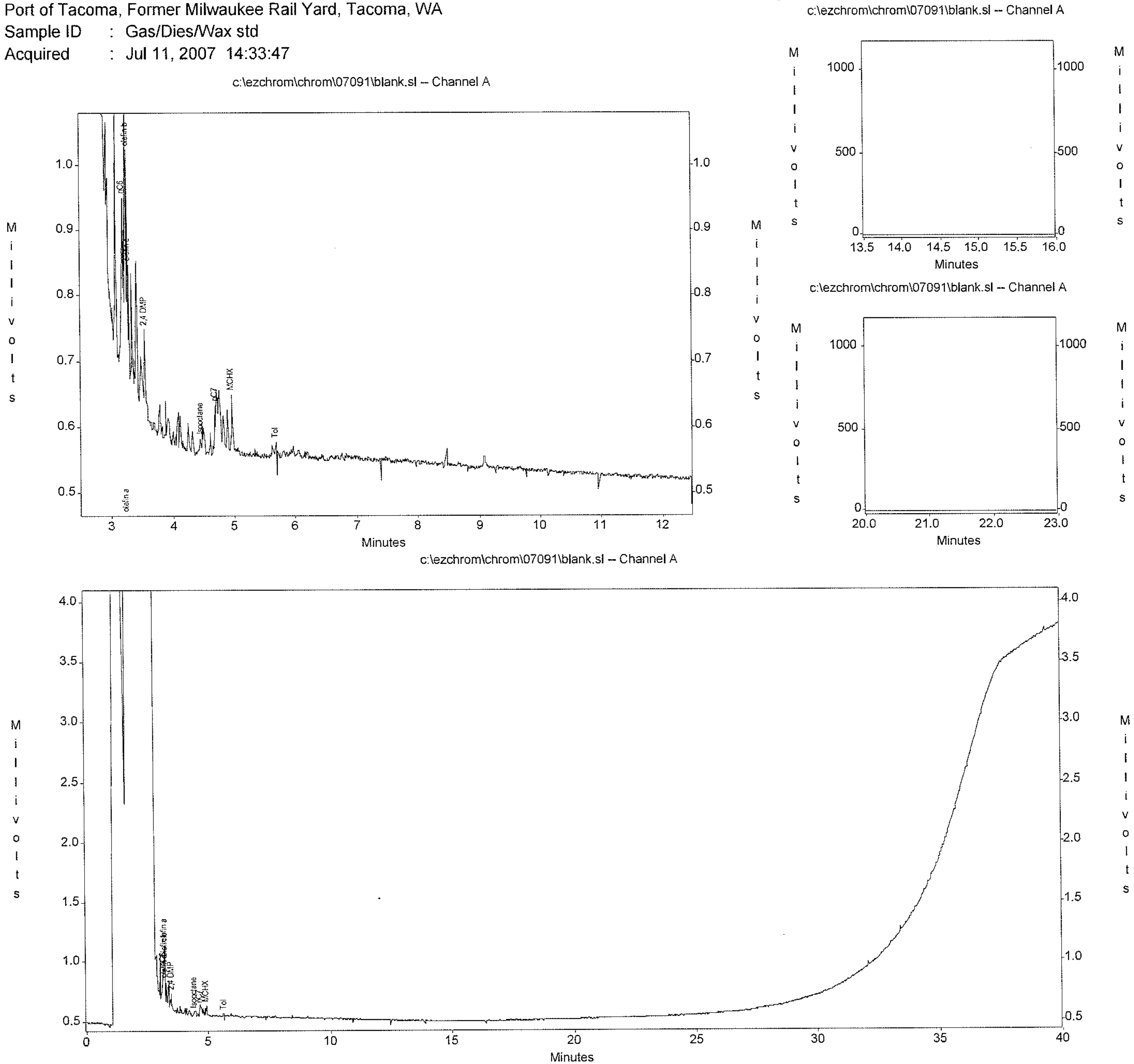
Figure 18, Multipanel display of gas chromatogram diluted laboratory standard (gasoline/diesel/wax mixture).

Channel A Results

Peak	Area	Height
nC6	11044	9356
olefin a	2909	3702
olefin b	1607	2190
olefin c	1147	1014
2.4 DMP	5473	4476
Bnz	20823	18414
Isooctane	100603	69231
nC7	19181	14284
MCHX	16404	11248
Tol	101027	65648
nC8	15368	11146
EB	25389	17260
m/p-xyl	90456	40151
o-xyl	42928	24260
nC9	25776	13689
1.2.4 TMB	66305	30295
nC10	62331	30242
nC11	118730	57305
Naph	23313	6178
nC12	117805	54554
IP13	51751	22038
IP14	29579	17956
nC13	155302	68310
IP15	48951	20944
nC14	127210	61388
IP16	52469	25707
nC15	130804	58446
nC16	111250	52246
IP18	52881	20541
nC17	97131	47119
Pristane	55329	25718
nC18	79214	36969
Phytane	30919	14007
nC19	65181	28705
nC20	40406	21084
nC21	30549	16411
nC22	35335	18856
nC23	56090	29460
nC24	80522	40799
nC25	89453	43917
nC26	84864	41513
nC27	60104	30333
nC28	35411	17339
nC29	18974	8152
nC30	9337	3277
nC31	4626	1222
nC32	2262	515
nC33	1071	186
nC34	0	0
nC35	0	0
nC36	0	0
nC37	0	0
nC38	0	0
nC39	0	0
nC40	0	0

Torkelson Geochemistry, Inc.

Port of Tacoma, Former Milwaukee Rail Yard, Tacoma, WA
Sample ID : Gas/Dies/Wax std
Acquired : Jul 11, 2007 14:33:47



Channel A Results

Peak	Area	Height
nC6	438	264
olefin a	412	471
olefin b	332	353
olefin c	170	179
2.4 DMP	176	130
Bnz	0	0
Isooctane	51	27
nC7	110	77
MCHX	141	93
Tol	92	47
nC8	0	0
EB	0	0
m/p-xyl	0	0
o-xyl	0	0
nC9	0	0
1.2.4 TMB	0	0
nC10	0	0
nC11	0	0
Naph	0	0
nC12	0	0
IP13	0	0
IP14	0	0
nC13	0	0
IP15	0	0
nC14	0	0
IP16	0	0
nC15	0	0
nC16	0	0
IP18	0	0
nC17	0	0
Pristane	0	0
nC18	0	0
Phytane	0	0
nC19	0	0
nC20	0	0
nC21	0	0
nC22	0	0
nC23	0	0
nC24	0	0
nC25	0	0
nC26	0	0
nC27	0	0
nC28	0	0
nC29	0	0
nC30	0	0
nC31	0	0
nC32	0	0
nC33	0	0
nC34	0	0
nC35	0	0
nC36	0	0
nC37	0	0
nC38	0	0
nC39	0	0
nC40	0	0

Figure 19, Multipanel display of gas chromatogram laboratory blank.

Table 1, Physical Properties

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Physical Properties Measurements

Sample	TGI Job	Density (gm/ml)	Viscosity (centipoise)	Surface Tension Air/Water (dynes/cm)	Interfacial Tension NAPL/Water (dynes/cm)	Surface Tension Air/NAPL (dynes/cm)	Temperature of Measurements (Fahrenheit)
RW2L3	07091	0.8803	8.34	58.4	7.1	24.6	60
RW5L3	07091	0.9498	633	56.5	13.7	29.6	60