Cascadia Associates, LLC

August 2, 2017

Andrew Smith, P.E., LHG
UST/Technical Services Unit Supervisor
Ecology's Toxics Cleanup Program
Southwest Regional Office
PO Box 47775
Olympia, WA 98504-7775

Re: Additional Investigation Summary Report and Pilot Study Work Plan
NuStar Vancouver Annex Terminal
Vancouver, Washington

Dear Mr. Smith:

Enclosed, please find the *Additional Investigation Summary Report and Pilot Study Work Plan (*"Report/Work Plan*")*. The Report/Work Plan was prepared on behalf of NuStar Terminals Operations Partnership, L.P. (NuStar) by Apex Companies, LLC and Cascadia Associates, LLC. Per our discussions with you last September 2016 and July 2017, this letter presents the proposed schedule for implementation of the pilot study described in the attached report and work plan. Work at the site is being performed pursuant to Agreed Order No. 08-TC-S DE5250, which requires the performance of Remedial Investigation (RI), Risk Assessment (RA) and a Feasibility Study of remedial action.

The RI and RA were completed and documented in the RI and Risk Assessment Report (RI/RA Report) submitted to Ecology in December 2010. NuStar submitted a draft Feasibility Study on July 12, 2012 which proposed monitored natural attenuation to address residual hydrocarbon impacts in the eastern portion of the tank farm. On October 16, 2013 Ecology provided NuStar with comments on the Draft FS. In the months following receipt, NuStar held several meetings with Ecology to discuss Ecology's comments on the FS, as well as additional comments that were presented to NuStar in a February 4, 2014 meeting. The meetings culminated in a Final Project Coordinator's Decision (the "Decision") issued by Ecology on August 26, 2014 which established a series of steps for collecting additional data to support resubmittal of a revised FS. The additional steps included one year of quarterly monitoring of four wells at the site, MW-1 through MW-4, and additional investigation in the western portion of the terminal near historical borings SB-8 and SB-9. The additional investigation near borings SB-8 and SB-9 indicated the presence of petroleum hydrocarbons in saturated soil and groundwater. NuStar conducted further investigations to delineate the extent of the hydrocarbons and conducted quarterly monitoring of two new wells, MW-5 and MW-6, installed near the historical locations of SB-9 and SB-8. The results of these investigations have been submitted to Ecology electronically and the enclosed Report/Work Plan summarizes the results and presents a work plan for a proposed pilot study to evaluate the efficacy of injecting chemical oxidants to address petroleum hydrocarbons detected in groundwater in the western terminal area.

The proposed pilot study is being conducted to support preparation of the revised Feasibility Study required by the Agreed Order and the Decision. The following presents the anticipated schedule for completing the pilot study and preparing a revised Feasibility Study:

Activity	Schedule
Implement Pilot Study	Within 60 days of Ecology approval of Report/Work Plan
Implement Quarterly Monitoring	Within one week of completion of ISCO injections
Submit Preliminary Pilot Study Results (following 2 quarters of monitoring)	45 days following receipt of analytical data from second quarterly monitoring event
Submit Revised Feasibility Study	30 days following receipt of analytical data from fourth quarterly monitoring event

If you have any questions, please do not hesitate to contact me at 503-906-6577 ext. 107 or Renee Robinson at 210-918-2975 while Stephanie Bosze Salisbury is out on family leave.

Sincerely,

Amanda Spencer
Principal Hydrogeologist

ENCLOSURE
Additional Investigation Summary Report and Pilot Study Work Plan (1 hard copy and 1 electronic copy)

cc: Ms. Renee Robinson, NuStar Energy, L.P. (electronic deliverable)
Mr. Stephan Rosen, NuStar Energy L.P. (electronic deliverable)
Mr. Aaron Flett, NuStar Energy L.P. (electronic deliverable)

Additional Investigation Summary Report and Pilot Study Work Plan NuStar Vancouver Annex Terminal Vancouver, Washington

Prepared for:
NuStar Terminals Operations Partnership, L.P.

August 2, 2017
1569-09

APEX

Additional Investigation Summary Report and Pilot Study Work Plan NuStar Vancouver Annex Terminal Vancouver, Washington

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NuStar Terminals Operations Partnership, L.P.

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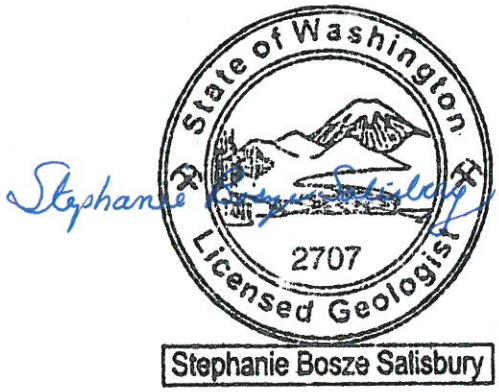

Stephanie Bosze Salisbury, L.G.
Associate Geologist

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1.0 Introduction

This *Additional Investigation Summary Report and Pilot Study Work Plan* summarizes data collected during investigations conducted at the NuStar Terminals Operations Partnership, L.P. (NuStar) Annex Terminal located at 5420 NW Fruit Valley Road, Vancouver, Washington (the Facility) from 2014 through 2016 and presents a work plan to conduct a remedial technology pilot study. A location map for the Facility is provided on Figure 1; a site plan is provided on Figure 2.

On July 12, 2012, NuStar submitted a draft Feasibility Study to the Washington State Department of Ecology (Ecology) in accordance with Agreed Order (AO) No. 09-TC-S DE5250 between the Washington State Department of Ecology (Ecology) and NuStar. The technical basis of the FS was the Remedial Investigation (RI) and Risk Assessment (RA) documented in the *Remedial Investigation and Risk Assessment Report* (RI/RA Report) submitted to Ecology in December 2010 (Ash Creek, 2010). The FS proposed monitored natural attenuation to address residual hydrocarbon impacts in the eastern portion of the tank farm. On October 16, 2013 Ecology provided NuStar with comments on the Draft FS. In the months following receipt, NuStar held several meetings with Ecology to discuss Ecology's comments on the FS, as well as additional comments that were presented to NuStar in a February 4, 2014 meeting. The meetings culminated in a Final Project Coordinator's Decision (the "Decision") issued by Ecology on August 26, 2014, which established a series of steps for collecting additional data to support resubmittal of a revised FS, including one year of sitewide quarterly groundwater monitoring. One of the additional data requests included groundwater investigation near historical borings SB-8 and SB-9 located in the western portion of the terminal. NuStar agreed to the additional investigation, and the results indicated the presence of petroleum hydrocarbons in groundwater at concentrations above Washington Model Toxic Control Act (MTCA) Method A levels. As a result, additional well installation, site investigation and groundwater monitoring has been conducted to evaluate the extent of the petroleum hydrocarbons in the western terminal. This report summarizes the results of the additional groundwater investigations and presents a work plan for a proposed pilot study to evaluate the efficacy of injecting chemical oxidants to address petroleum hydrocarbons detected in groundwater in the western terminal area.

2.0 Background

2.1 Site Location, Description, and History

Location. The Facility address is 5420 NW Fruit Valley Road, Vancouver, Washington 98660 (Latitude: N45º 39.70', Longitude: W122º 41.66'), as shown on Figure 1. The Facility is located on Clark County Tax Lot (TL) No. 147360.

Physical Features. Figure 2 is a Site Plan. The Facility is approximately 31 acres and is roughly rectangular, with dimensions of approximately 800 by 1,800 feet. The Facility is located in a mixed

industrial-agricultural area and currently includes a tank farm containing jet fuel and methanol (seven aboveground storage tanks [ASTs] ranging in size from 30,000 gallons to 3,000,000 gallons); a covered truck refueling rack with two ASTs (approximately a 400-gallon AST and a 7,500-gallon AST containing anti-static additive [ASA] and fuel system icing inhibitor [FSII] additive); and several buildings used for equipment storage and offices. A former underground storage tank (UST) associated with a vapor recovery system was also located on the Facility and was removed in 2001. The vapor recovery system and an associated oil/water separator (OWS) remain on-site. The surface of the Facility is comprised of graveled areas and grass fields, with asphalt-paved roads providing access to the fueling areas, ASTs, and office buildings.

Property History. Support Terminals Operating Partnership, L.P. (STOP) purchased the Facility from Cenex Harvest States Cooperative (Cenex) in 2003. In March 2008, STOP changed its name to NuStar.

The property was developed in 1957 as a truck loading terminal. Records are unclear as to whether the Facility was developed by Cenex. Historically, chemicals and other products stored at the Facility included liquid fertilizers and refined petroleum products such as gasoline, diesel and kerosene, de-natured alcohol, and petroleum product additives. A slop tank is present in the eastern portion of the Facility (Figure 2) and this is typically where waste (such as from tank-bottom cleanouts or the OWS) would be stored prior to off-site disposal or recycling. There is no indication that materials from tank-bottom cleanouts were buried at the Facility.

Prior to or during Cenex's ownership, American Cyanamid conducted agricultural research—including the testing of herbicides and pesticides—in the southeastern portion of the Facility (Figure 2).

2.2 Geology and Hydrogeology

This section presents the understanding of the geology and hydrogeology as discussed in the RI/RA Report (Ash Creek, 2010).

2.2.1 Geology

Regional Geology. The regional geology is summarized below and is based on reports prepared by Pacific Groundwater Group (PGG; 2001) and AMEC (2002a). The vicinity of the Facility is dominated by three primary units: Recent Alluvial deposits; the Pleistocene Alluvial deposits; and the Troutdale Formation.

The Recent Alluvial deposits are the upper unit with deposits approximately 55 feet thick and consist of fine-grained silt and sand within the areas investigated near Vancouver Lake. The Pleistocene Alluvial deposits are approximately 95 to 115 feet thick and consist of coarse-grained sand and gravel. The Pleistocene Alluvial deposits originate from alluvial deposits from the Columbia River and deposits from the catastrophic Missoula Floods. The Troutdale Formation underlies the Pleistocene Alluvial deposits and can

be greater than 1,000 feet thick. It is made up of cemented sandy gravels and semi-consolidated sands, silts, and clays.

Site Geology. During previous Facility investigations performed by others, soil borings have been installed to depths of up to 50 feet below ground surface (bgs) at the Facility. During a 2007 Facility investigation conducted by Ash Creek Associates (Ash Creek, 2007), one boring was completed to a depth of 72 feet bgs. Recent investigations in the western portion of the terminal included installing borings up to depths of 50 feet bgs.

The Recent Alluvial deposits underlying the western portion of the Facility consist of silt and silty clay with some fine sand to depths of approximately 20 to 25 feet bgs. Below 20 to 25 feet bgs, the Recent Alluvial deposits consist of layers of fine- to medium-grained sand to a depth of at least 50 feet bgs. On the eastern portion of the Facility, fine sand or sandy silt with variable layers of sand or silty sand is encountered to a depth of approximately 10 feet bgs. Below 10 feet bgs, the Recent Alluvial deposits in the eastern portion of the Facility consist of layers of fine- to medium-grained sand to a depth of approximately 50 to 60 feet bgs. The Pleistocene Alluvial deposits are encountered below the Recent Alluvial deposits and consist of sand and/or gravel layers of varying thicknesses.

2.2.2 Hydrogeology

Regional Hydrogeology. The regional aquifers, Recent Alluvial Aquifer (RAA); Pleistocene Alluvial Aquifer (PAA); and the aquifers of the Troutdale Formation, follow the regional geology discussed above. The regional hydrogeology summarized below is based on reports prepared in support of Clark Public Utilities (CPU) South Lake Wellfield (PGG, 2001; PGG, 2009), and by Ash Creek (2008a and 2008b).

The RAA is unconfined and receives recharge directly from the land surface and/or surface water features. The PAA directly underlies the RAA and is a productive aquifer with high well yields (several thousand gallons per minute [gpm] without significant drawdown). The groundwater flow system is highly influenced by local surface water bodies. The Columbia River, Vancouver Lake, Vancouver Lake Flushing Channel, and Lake River form natural hydrologic boundaries to the groundwater flow system. Tidal influences and seasonal variations in surface water runoff cause dynamic variation in the stage of the Columbia River, and resulting adjustments in the stages of the other three connected surface water bodies. The groundwater flow system is also influenced by tidal and seasonal variations in the surface water bodies. Regionally, it is anticipated that groundwater within the RAA and PAA near the Facility would have a net gradient towards Vancouver Lake and the Columbia River.

Site Hydrogeology. The depth to first encountered groundwater at the Facility ranges from approximately 15 to 32 feet bgs. This zone corresponds to the silt and fine- to medium-grained sand of the RAA. Deeper groundwater of the PAA is encountered at depths of approximately 50 to 70 feet bgs beneath the Facility (Ash Creek, 2008a).

Shallow groundwater flow at the Facility is, under static conditions, relatively flat with a slight gradient (0.0002 foot per foot [ft/ft]) to the southeast (AMEC, 2002a; SECOR, 2003; and Ash Creek, 2009). Groundwater contour maps prepared for previous investigations are contained in Appendix B of the RI/RA Report (Ash Creek, 2010) and the elevation map from September 2015 is shown on Figure 3 for reference.

3.0 Summary of Site Investigations

The below sections summarize historical and recent investigations conducted at the Facility.

3.1 Summary of Historical Investigations – 2001 thorough 2012

Several investigations have been conducted at the Facility since 2001. The initial investigation assessed the area of a possible fuel release during a UST decommissioning and resulted in further work to define the extent of impacted soil and groundwater (AMEC 2002a, 2002b). In 2003, SECOR conducted a comprehensive Phase II Environmental Site Assessment (ESA) of the Facility as a part of due diligence activities for Cenex during the property transaction to NuStar (SECOR, 2003). From 2007 to 2008, Ash Creek completed several investigations to further characterize the site (Ash Creek, 2007, 2008a, and 2008b). Four monitoring wells were installed in 2004 and were monitored periodically or quarterly during the 2004 to 2012 investigation period. The scope and results of each of these investigations are detailed in the RI/RA Report (Ash Creek, 2010). Table 1 summarizes the depth to groundwater and groundwater elevation data collected during these investigations; Table 2 summarizes the historical groundwater monitoring data; and Table 3 summarizes the historical soil data.

3.2 Summary of Additional Investigation – 2014 to 2016

As previously discussed in Section 1.0, Ecology provided NuStar with comments on the Draft FS on October 16, 2013. In the months following receipt, NuStar held several meetings with Ecology to discuss Ecology's comments on the FS, as well as additional comments that were presented to NuStar in a February 4, 2014 meeting. The additional comments included a request for additional groundwater investigation near historical borings SB-8 and SB-9. NuStar agreed to the additional investigation, and the preliminary investigation indicated that petroleum hydrocarbons were present in groundwater near historical borings SB-8 and SB-9 at concentrations above MTCA Method A levels. As a result, additional well installation, site investigation and groundwater monitoring was conducted to evaluate the magnitude and extent of petroleum hydrocarbons in groundwater in the western portion of the terminal. A summary of each investigation is described in the paragraphs below. Boring and monitoring well installations were conducted using a push probe rig operated by Cascade Drilling of Clackamas, Oregon, under the supervision of an Apex field geologist. Groundwater monitoring events were conducted by Apex field technicians.

During each investigation, soils were logged and field screened using a photoionization detector (PID) and sheen tested. The field logging and screening information for each investigation is summarized on the boring logs/monitoring well construction logs provided in Appendix A. Methods and procedures used during the investigations were conducted in accordance with the Standard Operating Procedures (SOPs) contained in Appendix B. Except for soil samples collected in September 2014 during the initial groundwater investigation near historical borings SB-8 and SB-9, soil samples were not collected for laboratory analysis.

Unless otherwise specified, groundwater samples were collected into laboratory approved containers and submitted to Pace Laboratory of Davis, California for the following analyses:

- TPH-Diesel and Heavy Oil by Method NWTPH-Dx;
    - Select samples were also analyzed for NWTPH-Dx with silica gel cleanup for comparison purposes, at the request of Ecology.
- TPH-Gasoline Range by Method NWTPH-Gx; and
- Benzene, toluene, ethylbenzene and xylenes (BTEX) and methyl tert butyl ether (MTBE) by EPA Method 8260.

3.2.1 Groundwater Investigation – September 20, 2014.

A groundwater investigation was conducted on September 29, 2014 in accordance with a scope of work submitted to Ecology in an email on September 17, 2014 and approved by Ecology in an email on September 24, 2014. Borings SB-8R and SB-9R were installed in the vicinity of historical borings SB-8 and SB-9, respectively. Both borings were advanced to a depth of 25 feet bgs. A temporary 3/4-inch diameter PVC well was installed in each boring; the screened interval in boring SB-8R was from 15 to 20 feet bgs and in SB-9R was from 17 to 22 feet bgs. A groundwater sample was collected from the temporary wells in SB-8R and SB-9R using a peristaltic pump from depths of approximately 19 feet bgs and 17 feet bgs, respectively. At the request of Ecology, soil samples were also collected in the vadose zone above the water table, at depths previously sampled from borings SB-8 and SB-9. Soil samples were collected in both borings at a depth of 12 feet bgs and an additional soil sample was collected in boring SB-9R at a depth of 13.5 feet bgs. The soil and groundwater samples were submitted for laboratory analysis of total petroleum hydrocarbons (gasoline, diesel and heavy oil range) by Method NWTPH-Gx and TWTPH-Dx. The soil results are included on Table 3 and the grab groundwater results are shown on Table 4.

Analytical summary tables from this event were provided to Ecology by email on October 30, 2014. The results of the investigation indicated that groundwater from the borings had TPH gasoline and diesel range concentrations in exceedance of MTCA Method A Cleanup Levels. Based on the results and the provisions of the Decision, Ecology required permanent monitoring wells to be installed at the locations of borings SB-8R and SB-9R, followed by four consecutive quarters of groundwater monitoring.

3.2.2 Monitoring Well Installation – December 2, 2014.

On December 2, 2014, monitoring wells MW-5 and MW-6 were installed at the locations of SB-8R and SB-9R, respectively in accordance with the work scope outlined in a November 25, 2014 email to Ecology and approved by Ecology on December 2, 2014. Both monitoring wells were installed using 2 inch-PVC with a screened interval between 10 and 25 feet bgs, to account for seasonal fluctuations in the water table. It should be noted, that given the proximity to the September 30, 2014 boring locations SB-8R and SB-9R, monitoring wells MW-5 and MW-6 were not logged for lithology or screened using a PID or sheet test during installation. Well construction logs which include lithologic and screening information from the original borings, are provided in Appendix A. Additional information on the installation of wells MW-5 and MW-6 is included in the *Groundwater Monitoring Results – December 2014* letter report submitted to Ecology on February 6, 2015 (Apex, 2015a).

3.2.3 Groundwater Monitoring – December 2014 to September 2015.

One of the provisions of the Decision included conducting one additional year of groundwater monitoring of site wells to evaluate groundwater conditions. As such, groundwater samples were collected from wells MW-1 through MW-6 on a quarterly basis between December 2014 and September 2015. The analytical results from each monitoring event were submitted to Ecology in quarterly letter reports and are summarized on Table 2. Results from the quarterly monitoring indicated the following conclusions:

- BTEX concentrations were below method reporting limits in wells MW-1 through MW-4, located in the western portion of the site.
- The historical MTBE plume located near well MW-2 has attenuated to below cleanup levels, as projected in the 2012 FS; MTBE is non-detect in the remaining wells.
- TPH-g and TPH-d concentrations in groundwater samples from wells MW-5 and MW-6, located in the eastern portion of the site, were above MTCA Method A Cleanup Levels.
- Xylenes concentrations in groundwater samples from well MW-5 were above MTCA Method A Cleanup Levels.
- Benzene, ethylbenzene and xylenes in well MW-6 were above MTCA Method A Cleanup Levels.

Based on these results, Ecology requested a plan for additional groundwater investigation to define the extent of petroleum hydrocarbons and related constituents in the areas of wells MW-5 and MW-6 in an email to NuStar dated March 15, 2015. NuStar provided Ecology the additional investigation work plan in the *March 2015 Groundwater Results Report and Groundwater Investigation Work Plan* (Apex, 2015b). Ecology approved the work plan with comments on June 11, 2015. In its comments, Ecology requested:

- Three depth discrete groundwater samples collected from the borings installed downgradient of wells MW-5 and MW-6; and

- Grab groundwater samples collected at the depths exhibiting the highest TPHd and TPHo PID readings from at least two borings be analyzed both with and without silica gel cleanup on the sample extract.

3.2.4 Additional Groundwater Investigation – October 2015.

From October 22 through 30, 2015, an additional groundwater investigation was conducted in the western tank farm in accordance with the *March 2015 Groundwater Results Report and Groundwater Investigation Work Plan* ("the Work Plan"; Apex, 2015b), and included depth discrete groundwater samples and TPHd/TPHo analysis with and without silica gel, as requested by Ecology. This included the installation of 12 borings (B-1 through B-12) and the collection of two to three depth discrete groundwater samples from each boring using temporary wellpoints. Boring locations are shown on Figure 4.

Boring Locations and Installation. The borings were installed using direct push technology following the Apex SOPs included in Appendix B. Soil was continuously screened for the presence of petroleum hydrocarbons using a photoionization detector (PID) and logged for lithologic conditions. Soil samples were not collected for laboratory analysis. Boring logs prepared for each location are contained in Appendix A. Initially, eight borings were installed, B-1 through B-8: one boring to the north, south, east and west of each well, MW-5 and MW-6. During installation of the initial eight boreholes, PID measurements indicated the presence of petroleum hydrocarbons in saturated soil; therefore, four "step-out" borings, B-9 through B-12, were advanced to further delineate the extent of hydrocarbons in groundwater.

Groundwater Sampling Approach and Methodology. Grab groundwater samples were collected from two to three discrete depths from each boring to assess and define the vertical extent of petroleum hydrocarbons in groundwater. Prior to initiating the investigation, depth-to-groundwater levels were measured in wells MW-5 and MW-6 to determine the water table elevation in the investigation areas at the time of drilling. The shallowest groundwater sample was collected from first encountered groundwater in each boring. A second grab groundwater sample was collected at the depth at which PID measurements fell below 5 parts per million (ppm). When collected, a third groundwater grab sample was collected from approximately 10 feet below the second sample location. PID measurements on saturated soil at the water table did not indicate the presence of petroleum hydrocarbons at borings B-7, B-8, and B-12; therefore, grab groundwater samples were collected at the water table and ten feet below the water table to confirm the absence of hydrocarbons in accordance with the Work Plan.

To collect the grab groundwater samples, the boring was advanced to a depth two feet below the identified sampling depth and a temporary well point with a four foot screen was placed in the hole such that the middle interval of the screen was at the targeted sampling depth. Low flow sampling techniques were then employed to purge the well point and collect the grab groundwater sample, with the sample intake placed at the mid-point of the temporary well point screen. The groundwater samples were submitted for laboratory

analysis of BTEX and MTBE by EPA Method 8260B and TPHg by Method NWTPH-Gx and TPHd by Method NWTPH-Dx (with silica gel cleanup).

PID Measurement Results. As shown on the boring logs contained in Appendix A, PID measurements on soil were below 5 ppm on unsaturated soil above the historical water table at all locations except boring B-6 and at this location, significant readings (e.g., greater than 100 ppm) were not encountered until a depth of 8 feet bgs. Boring B-6 is located adjacent to borings SB-8 and SB-8R. These results are consistent with the 2002 investigation in these areas and support that the residual hydrocarbons identified in groundwater in the eastern terminal area are from historical releases (e.g., at least 15 years old).

Groundwater Sampling Results. Analytical results for the depth discrete grab groundwater samples are summarized on Table 4; results for TPH and BTEX are shown on Figures 4 and 5, respectively. As can be seen on the figures, the results indicate two relatively limited areas of hydrocarbons in groundwater around wells MW-5 and MW-6. With the exception of ethylbenzene in two locations, B-5 and well MW-5, and xylenes in one location, well MW-5, BTEX were not detected in groundwater near well MW-5 and TPH concentrations were predominantly in the gasoline and diesel carbon ranges. Although benzene, ethylbenzene, and xylenes are detected in groundwater near well MW-6, BTEX is more limited in extent than TPH.

Two of the groundwater borings in the well MW-5 area indicated detectable TPH concentrations at depths between 40 and 50 feet bgs; TPH was detected in groundwater down to 40 feet bgs in the well MW-6 area.

3.2.5 Additional Groundwater Investigation and Compliance Well Installation – July 2016

The results from the October 2015 investigation were submitted to Ecology in an email dated November 25, 2015 and subsequently discussed with Ecology at a meeting on December 15, 2015. At the December 15, 2015 meeting, Ecology requested additional delineation to the west of wells MW-5 and MW-6. Due to physical restrictions immediately west of the wells, delineation to the west was conducted outside and to the west of the tank farm berm. Ecology also requested that two compliance wells be installed at the terminal to monitor the potential for impacted groundwater to migrate off-site to the north in response to future anticipated pumping from Clark Public Utilities (CPU) wells installed north of the facility in the PAA. Based on discussion in and subsequent to the December 2015 meeting, a work plan was submitted to Ecology in an email dated March 23, 2016. A revised work plan was submitted on May 12, 2016, which included the addition of one "deeper" well located near one of the northern compliance wells to evaluate for a potentially induced vertical gradient once CPU initiates pumping at their supply wells located north of the site. The work scope was approved by Ecology on June 1, 2016 and was implemented from July 6 through 8, 2016. The scope of the July 2016 investigation included the following:

- Installation of boring B-13 outside of the tank farm berm to the west of MW-5 as shown on Figure 4. Using the same methodology that was approved for and used during the October 2015

investigation, temporary well points were installed in the boring at targeted sampling intervals and groundwater was sampled from 15 to 20 feet bgs and from 25 to 30 feet bgs.

- Installation of boring B-14 outside of the tank farm berm to the west of MW-6 (Figure 4). Temporary wells points were installed in the boring using the approved methodology and groundwater was sampled from 15 to 20 feet bgs and from 25 to 30 feet bgs.
- Installation of four compliance wells and one deep well at the locations shown on Figure 4, including:
    - Well MW-8, directly north of well MW-5. This monitoring point will be used to monitor for off-site migration to the north in the direction of the CPU well field (test wells TW-4 through TW-8). MW-8 was installed with a screened interval from 10 to 25 feet bgs.
    - Well MW-8D, a deeper well installed adjacent to well MW-8, and coupled with well MW-8, will be compliance wells used to monitor groundwater gradients and quality after municipal pumping is initiated by CPU. Monitoring well MW-8D was installed with a screened interval from 35 to 45 feet bgs.
    - Compliance wells MW-7, MW-9 and MW-10 were installed to the west of the tank farm, northeast of MW-5, and south of the tank farm, respectively. Each well was installed to a depth of 25 feet bgs with a screened interval from 10 to 25 feet bgs.

The borings were advanced and the monitoring wells were installed, developed, and sampled in accordance with the May 12, 2016 work plan and following Apex SOPs for these activities; these SOPs are contained in Appendix B for reference. Groundwater samples were submitted to Pace Analytical laboratory under chain-of-custody procedures and samples were analyzed for TPHd and TPHo by Method NWTPH-Dx and TPHg by Method NWTPH-Gx, as well as BTEX and MTBE by EPA Method 8260. Analytical results for the groundwater samples collected from the monitoring wells and from borings B-13 and B-14 are summarized on Tables 2 and 4, respectively.

TPH and BTEX concentrations in the samples from wells B-13, B-14, MW-7 through MW-10 and MW-8D were below method reporting limits. The results were presented to Ecology in a meeting on September 22, 2016. During the meeting, Ecology supported the conclusion that the delineation activities were complete and that the compliance well network was acceptable for monitoring purposes.

4.0 Pilot Test Work Plan

In the September 2016 meeting, Ecology stated that the Feasibility Study would need to evaluate active remediation to address the petroleum hydrocarbons in groundwater near wells MW-5 and MW-6 based on the additional groundwater investigations conducted from 2014 to 2016. As such, NuStar indicated that initial evaluations of potential remedial alternatives identified injections of oxygen releasing compound

(ORC) and/or *in-situ* chemical oxidation (ISCO) as possible options. However, due the presence of the heavier hydrocarbons in the saturated soil and shallow groundwater, it was determined that a pilot test would be needed to better evaluate the viability of this option. This section presents the approach, rationale, and scope of the proposed pilot test to assess the viability of ISCO with an ORC component to address the heavier hydrocarbons in groundwater near wells MW-5 and MW-6. The chemical oxidant will be delivered via injection of a proprietary substrate into borings advanced via direct push technology, as detailed below.

Nature and Extent of Petroleum Hydrocarbons Near Wells MW-5 and MW-6. Figures 4 and 5 illustrate the aerial extent of groundwater containing TPH and BTEX, respectively, at concentrations above MTCA Cleanup Method A Cleanup Levels. As detailed in Section 3, above, the extent of TPH in shallow groundwater is greater than BTEX, and is identified predominantly in the gasoline and diesel carbon ranges.

The aerial extent of TPH in shallow groundwater near well MW-5 is approximately 120 feet by 75 feet and the highest concentrations are adjacent to well MW-5. Benzene and toluene have not been detected above MTCA Method A levels near well MW-5 and the extent of ethylbenzene and xylenes is limited to two locations, well MW-5 and boring B-5. The aerial extent of TPH in groundwater near well MW-6 is approximately 120 feet by 150 feet, and the extent of benzene, ethylbenzene, and xylenes is approximately half that area. Petroleum hydrocarbons have been detected to depths of 50 feet near well MW-5 and to depths of 40 feet bgs near well MW-6, although, the highest TPH concentrations are observed in first encountered groundwater in the approximate 15 to 25 feet bgs depth interval at both locations.

The presence of petroleum hydrocarbons appears to be limited to groundwater and saturated soil – or soil within the fluctuation range of the water table. PID readings and historical soil sampling do not indicate the presence of TPH above a depth of approximately 15 feet with the exception of one location, boring B-6, where soil vapors above 100 ppm were identified at a depth of 8 feet bgs.

Proposed Pilot Study Area and Vertical Extent. Figure 6 identifies the proposed pilot study area. The area was selected because groundwater in this area contains the highest concentrations of TPH; therefore, injections into this area will be valuable in testing the effectiveness of ISCO and ORC in addressing the heavier TPH observed at the site. Although petroleum hydrocarbons have been detected to depths of 50 feet, the highest TPH concentrations are observed in first encountered groundwater in the approximate 15 to 25 feet bgs depth interval. Therefore, the water table to 25-foot depth interval will be the vertical targeted zone for the pilot study. If ISCO and/or ORC measurably reduce TPH concentrations in this lateral and vertical area that has the highest measured TPH concentrations, this remedial approach could be viable for the remaining groundwater containing TPH above cleanup levels around wells MW-5 and MW-6 and the results of the pilot study will be valuable in assessing the estimated cost to complete the remediation using this technology.

Depth to Groundwater and Saturated Soil Profile. Based on recent groundwater investigations and quarterly monitoring conducted in 2014 and 2015, the depth to groundwater, or water table, in the proposed pilot study area ranges between 16 and 20 feet bgs. The soil in the vertical targeted zone is predominantly a silty clay with some fine sand.

Selected Injection Substrate. RegenOx® (a proprietary ISCO substrate manufactured by Regenesis) and ORCAdvanced (an oxygen releasing formulation also manufactured by Regenesis) have been selected for injection. RegenOx® is an injectable, two-part ISCO reagent that combines a solid sodium percarbonate based alkaline oxidant (Part A), with a liquid mixture of sodium silicates, silica gel, and ferrous sulfate (Part B). RegenOx® produces minimal heat and pressure, and is noncorrosive making it a relatively safe chemical oxidant that is compatible for use in direct contact with underground infrastructure such as utilities, tanks, piping communication lines, etc. As a result, the material can be applied using a wide-range of standard field equipment (e.g. direct push injection rigs). In addition to chemical destruction, RegenOx® ISCO produces a significant short-term oxygen footprint that is optimal for establishing aerobic conditions capable of supporting follow-on, aerobic biodegradation of petroleum hydrocarbons. The ORCAdvanced then continues to release oxygen to the groundwater water to support long-term aerobic biodegradation. ORCAdvanced is a calcium oxy-hydroxide based material which becomes hydrated upon contact with the groundwater, producing a controlled-release of molecular oxygen (17% by weight).

Preparatory Activities. Prior to the injections, a public and private utility locating service will be retained to assess for the presence of buried infrastructure or utilities in the proposed injection area. If buried structures are identified, then the location (and possibly quantity) of borings will need to be adjusted to avoid encountering the buried structures. As an additional safety precaution, each borehole will be cleared to 8 feet bgs using air knife, hand auger, or other minimally invasive excavation technology.

Injection Layout and Boring Installation. Due to the finer-grained nature of the soil in the targeted zone, a finer spaced injection grid is needed to obtain coverage within the pilot study area. To distribute the injection substrate evenly throughout the proposed treatment area, the injections are spaced 15 feet apart. The corresponding layout results in a total of 24 injection points, as shown on Figure 7.

The borings will be installed using direct push technology in accordance with the SOP contained in Appendix B. An injection probe tip will be advanced to 25 feet bgs, withdrawn in 1-foot intervals, and the RegenOx® and ORCAdvanced will be injected through the drill stem via an air diaphragm pump. This process is repeated until the substrate has been injected to the top of the saturated zone (an approximate 10 foot injection interval). Substrate material will not be injected into vadose zone soils.

Abandonment. The injection borings will be abandoned in accordance with Washington Well Construction and Licensing System (WCLS) regulations and procedures. The borehole will be left open for at least 24 hours to allow the substrate material to distribute before backfilling the hole. The abandonment procedure will consist of filling the boring with granular bentonite to approximately 3 feet bgs. Based on our experience from the recent investigations at the Facility, it is anticipated that the boreholes will stay open after removing the injection rod, allowing access for pouring in bentonite. The top few feet of the borehole (potentially enlarged from the utility clearance) will be backfilled with concrete. The surface will be patched with similar material to the adjacent surroundings (e.g., gravel).

Performance Monitoring. RegenOx® works immediately to destroy the petroleum hydrocarbons and the oxidation effects will likely be complete within one month of injection. The ORCAdvanced is a longer-term reaction and will continue to deliver oxygen to the injection area for up to 12 months. Therefore, to assist in monitoring the effectiveness, quarterly monitoring of wells MW-5 and MW-6 will be conducted directly prior to and for one year following the injection event, for a total of five monitoring events. In addition, a deeper monitoring well will be installed adjacent to well MW-5 prior to initiating the injection event to monitor the effect on deeper groundwater, if any, of removing hydrocarbon mass from the shallow groundwater. The deeper well will be screened to evaluate the lower extent of the hydrocarbon impacts near well MW-5, at a depth of approximately 40 feet bgs. The well installation methods are described below. The new well will be identified as MW-5D and will be included in the one year monitoring program.

During each monitoring event, measurements of dissolved oxygen and oxidation-reduction potential will be collected at each well. The wells will then be purged and sampled using low-flow techniques, and DO and ORP measurements will be collected during the purging process to assist in evaluating the pilot study results. Groundwater samples collected during the performance monitoring will be analyzed by a state-certified laboratory for TPHg and TPHd using Pacific Northwest method NW-TPH-Gx and NW-TPH-Dx (with silica gel cleanup), respectively, and BTEX using EPA Method 8260B.

Monitoring Well Installation. Proposed new well MW-5D will be installed using the same techniques as used to install well MW-8D and in accordance with the SOPs contained in Appendix B. The proposed location of the well is shown on Figure 7. The well will be constructed of 2-inch PVC casing, with a screened interval of 0.01-inch slotted PVC extending from 35 to 45 feet bgs. A sand well pack will be installed in the annular space between the casing and the screen, and will extend 2 feet above the screen. One foot of bentonite will be placed above the sand pack and the remainder of the annular space will be filled with a cement-bentonite slurry to within one-foot of the ground surface. The well will be completed with cement and a flush-mount traffic-grade well box to ground surface.

5.0 Schedule and Reporting

The pilot study will be initiated immediately upon approval to proceed. Preparatory activities and coordination with subcontractors are anticipated to require 30 to 60 days to complete. It is anticipated that the field program, including well installation, baseline groundwater monitoring, and the RegenOx®/ORCAdvanced injections can be completed in the 30 days following completion of the preparatory activities. The first post-injection monitoring event will be conducted three months following completion of the field injection program and groundwater monitoring will continue quarterly for one year. Following receipt of the analytical data from the final quarterly performance monitoring event, a pilot study evaluation report will be prepared and the FS for the site will be completed. Barring delays beyond the control of NuStar or its contractors, the pilot study evaluation report will be submitted within 45 days of receipt of the analytical data from the final pilot study performance monitoring event and the FS can be submitted within 30 days following submittal of the pilot study evaluation report.

6.0 References

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Table 1
Groundwater Elevation Data
NuStar Terminals Operations Partnership, L.P. – Annex Terminal
Vancouver, Washington

Well Number	Date of Measurement	Top of Casing Elevation (feet above MSL)[1]	Depth to Water (feet BTOC)	Groundwater Elevation (feet)
MW-1	05/14/02	NS	16.00	NS
	05/25/07	26.66	14.92	11.74
	08/24/07	26.66	18.67	7.99
	11/26/07	26.66	17.91	8.75
	02/27/08	26.66	16.92	9.74
	03/30/10	26.66	17.09	9.57
	09/01/10	26.66	19.19	7.47
	12/16/14	26.66	16.19	10.47
	03/25/15	26.66	15.25	11.41
	06/24/15	26.66	18.43	8.23
	09/15/15	26.66	19.05	7.61
MW-2	05/14/02	NS	27.46	NS
	05/25/07	38.21	26.46	11.75
	08/24/07	38.21	30.17	8.04
	11/26/07	38.21	29.42	8.79
	02/27/08	38.21	28.50	9.71
	03/30/10	38.21	28.66	9.55
	09/01/10	38.21	30.74	7.47
	12/16/14	38.21	27.77	10.44
	03/25/15	38.21	26.79	11.42
	06/24/15	38.21	30.05	8.16
	09/15/15	38.21	30.65	7.56
MW-3	05/14/02	NS	28.15	NS
	05/25/07	39.11	27.17	11.94
	08/24/07	39.11	31.04	8.07
	11/06/07	39.11	30.36	8.75
	02/27/08	39.11	28.71	10.40
	03/30/10	39.11	29.55	9.56
	09/01/10	39.11	31.65	7.46
	12/16/14	39.11	28.54	10.57
	03/25/15	39.11	27.72	11.39
	06/24/15	39.11	30.85	8.26
	09/15/15	39.11	31.52	7.59
MW-4	05/14/02	NS	29.40	NS
	05/25/07	40.17	28.35	11.82
	08/24/07	40.17	32.12	8.05
	11/06/07	40.17	31.40	8.77
	02/27/08	40.17	30.40	9.77
	03/30/10	40.17	30.77	9.40
	09/01/10	40.17	32.62	7.55
	12/16/14	40.17	29.63	10.54
	03/25/15	40.17	28.76	11.41
	06/24/15	40.17	31.92	8.25
	09/15/15	40.17	32.61	7.56
MW-5	12/16/14	NS	16.60	NS
	03/25/15	NS	15.37	NS
	06/24/15	NS	18.89	NS
	09/15/15	NS	19.35	NS
MW-6	12/16/14	NS	16.93	NS
	03/25/15	NS	15.73	NS
	06/24/15	NS	19.34	NS
	09/15/15	NS	19.70	NS

Notes:

1. Survey elevations determined by Statewide Land Surveying, October, 2007.
2. feet above MSL = feet above mean sea level.
3. feet BTOC = feet below top of casing.
4. NS = Not surveyed.

Table 2
Summary of Analytical Results from Monitoring Wells
NuStar Terminals Operations Partnership, L.P. – Annex Terminal
Vancouver, Washington

Well Number	Sample Date	Screened Interval (feet bgs)	Concentrations in mg/L (ppm)																					
			TPHg	TPHd	TPHo	Benzene	Toluene	Ethylbenzene	Xylenes	1,2-Dibromoethane	1,2-Dichloroethane	Ethanol	Tert-Butyl alcohol	Ethyl tert-Butyl Ether (ETBE)	Diisopropyl Ether (DIPE)	Methyl tert-butyl ether (MTBE)	Tert-Amyl Methyl Ether (TAME)	Naphthalene	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	Isopropylbenzene	n-Propylbenzene	n-Butylbenzene	sec-Butylbenzene	Chloroform	Methanol
MW-1	05/14/02	14.5-24.5	<0.080	0.455 [5.]	<0.500	<0.0005	<0.0005	<0.0005	<0.001	<0.0005	<0.0005	--	--	--	--	<0.002	--	<0.002	<0.001	<0.0005	<0.002	<0.0005	--	--	--	--
	05/19/03		--	--	--	<0.001	<0.001	<0.001	<0.002	<0.001	<0.001					<0.001		<0.002	<0.001	<0.001	<0.002	<0.001	<0.05	<0.001	<0.001	--
	05/25/07		<0.080	<0.238	<0.476	<0.0002	<0.0005	<0.0005	<0.001	<0.0005	<0.0005	<0.150	<0.025	<0.001	<0.001	<0.002	<0.001	<0.002	<0.001	<0.0005	<0.002	<0.0005	--	--	--	--
	08/24/07		<0.1	<0.238	<0.476	<0.001	<0.002	<0.002	<0.006	<0.0005	<0.0005	<0.100	<0.020	<0.0005	<0.0005	<0.0005	<0.0005	<5.0	<0.001	<0.001	<0.002	<0.001	--	--	--	--
	11/26/07		<0.080	<0.236	<0.472	<0.001	<0.002	<0.002	<0.006	<0.0005	<0.0005	<0.100	<0.020	<0.0005	<0.0005	<0.0005	<0.0005	<5.0	<0.001	<0.001	<0.002	<0.001	--	--	--	--
	02/27/08		<0.080	<0.294	<0.588	<0.0005	<0.0005	<0.0005	<0.001	<0.0005	<0.0005	<0.100	<0.0010	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	--	--	--	--
	03/31/10		<0.250	<0.250	<0.500	<0.0005	<0.0005	<0.0005	<0.0015	<0.0005	<0.0005	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	--
	09/01/10		<0.250	<0.250	<0.500	<0.0005	<0.0005	<0.0005	<0.0015	<0.0005	<0.0005	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	--
	12/16/14		<0.250	<0.250	<0.500	<0.0005	<0.0005	<0.0005	<0.0005	--	--	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	--	--	--	--	--	--	--	--	<0.050
	03/25/15		<0.250	<0.046	<0.093	<0.0005	<0.0005	<0.0005	<0.001	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--	--
	06/24/15		<0.250	<0.100	<0.250	<0.0005	<0.0005	<0.0005	<0.001	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--	--
	09/15/15		<0.250	<0.130	<0.340	<0.0005	<0.0005	0.0015	0.0022	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--	--
MW-2	05/14/02	20-35	41.4	<0.250	<0.500	4.35	2.68	1.84	8.72	<0.025	<0.025	--	--	--	--	0.7	--	0.106	0.665	0.194	<100	0.071	--	--	--	--
	05/19/03		--	--	--	0.534	0.00975	0.194	0.876	<0.05	<0.05	--	--	--	--	0.0776	--	0.015	0.16	0.0624	0.0099	0.0158	0.0033	<0.05	<0.05	--
	05/25/07		0.439	<0.238	<0.476	0.071	0.00114	0.0361	0.0453	<0.0005	<0.0005	<0.150	<0.025	<0.001	<0.001	0.0182	<0.001	<0.002	0.04	0.0335	0.003	0.00249	--	--	--	--
	08/24/07		0.102	<0.238	<0.476	<0.001	<0.002	<0.002	<0.006	<0.0005	<0.0005	<0.100	<0.020	<0.0005	<0.0005	0.059	<0.0005	<0.05	<0.001	<0.001	0.0032	<0.001	--	--	--	--
	11/26/07		<0.080	<0.236	<0.472	<0.001	<0.002	<0.002	<0.006	<0.0005	<0.0005	<0.100	<0.020	<0.0005	<0.0005	0.083	<0.0005	<0.05	<0.001	<0.001	<0.002	<0.001	--	--	--	--
	02/27/08		0.0817	<0.294	<0.588	0.005	<0.0005	<0.0005	<0.001	<0.0005	<0.0005	<0.100	<0.0010	<0.0005	<0.0005	0.015	<0.0005	<0.0005	<0.0005	<0.0005	0.00034 J	<0.0005	--	--	--	--
	03/31/10		<0.250	<0.250	<0.500	<0.0005	<0.0005	<0.0005	<0.0015	<0.0005	<0.0005	<0.005	<0.005	<0.0005	<0.0005	0.045	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.00051	<0.0005	--
	09/01/10		<0.250	<0.250	<0.500	0.0016	<0.0005	<0.0005	<0.0015	<0.0005	<0.0005	<0.005	<0.005	<0.0005	<0.0005	0.081	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.00051	<0.0005	--
	12/16/14		<0.250	<0.250	<0.500	<0.0005	<0.0005	<0.0005	<0.0005	--	--	<0.005	<0.005	<0.0005	<0.0005	0.008	<0.0005	--	--	--	--	--	--	--	--	<0.050
	03/25/15		<0.250	<0.046	<0.091	<0.0005	<0.0005	<0.0005	<0.001	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--	--
	06/24/15		<0.250	<0.100	<0.250	<0.0005	<0.0005	<0.0005	<0.001	--	--	--	--	--	--	0.0428	--	--	--	--	--	--	--	--	--	--
	09/15/15		<0.250	0.17 D (see note)	0.37	<0.0005	<0.0005	<0.0005	<0.001	--	--	--	--	--	--	0.0061	--	--	--	--	--	--	--	--	--	--
MW-3	05/14/02	24.5-34.5	4.5	<0.250	<0.500	0.0419	0.0096	0.293	0.521	<0.001	<0.001	--	--	--	--	<4.00	--	0.0489	0.296	0.106	0.0213	0.0591	--	--	--	--
	05/19/03		--	--	--	0.0908	0.0097	0.338	0.5382	<0.05	<0.05	--	--	--	--	0.0037	--	0.0308	0.315	0.0895	0.0194	0.0623	--	--	--	--
	05/25/07		0.361	<0.238	<0.476	<0.0005	<0.0005	0.0132	0.0145	<0.0005	<0.0005	<0.150	<0.025	<0.001	<0.001	<0.002	<0.001	<0.002	0.0107	0.00348	0.00532	0.0093	0.0068	<0.05	<0.05	--
	08/24/07		<0.1	<0.238	<0.476	<0.001	<0.002	<0.002	<0.006	<0.0005	<0.0005	<0.100	<0.020	<0.0005	<0.0005	<0.0005	<0.0005	<0.05	<0.001	<0.001	<0.002	<0.001	--	--	--	--
	11/26/07		<0.080	<0.236	<0.472	0.0011	<0.002	0.0066	<0.006	<0.0005	<0.0005	<0.100	<0.020	<0.0005	<0.0005	0.0069	<0.0005	<0.05	<0.001	<0.001	0.0031	0.0012	--	--	--	--
	02/27/08		2.14	0.387 [6.]	<0.500	<0.0005	<0.0005	0.17	0.17	<0.0005	<0.0005	<0.100	<0.0010	<0.0005	<0.0005	<0.0005	<0.0005	0.0064	0.21	0.051	0.022	0.056	--	--	--	--
	03/31/10		2.10	<0.250	<0.500	<0.0005	<0.0005	0.018	0.021	<0.0005	<0.0005	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	0.0018	0.24	<0.0005	0.019	0.050	0.0052	0.012	<0.0005	--
	09/01/10		<0.250	<0.250	<0.500	<0.0005	<0.0005	<0.0005	<0.0015	<0.0005	<0.0005	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	--
	12/16/14		<0.250	<0.250	<0.500	<0.0005	<0.0005	<0.0005	<0.0005	--	--	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	--	--	--	--	--	--	--	--	<0.050
	03/25/15		<0.418	<0.046	<0.092	<0.0005	<0.0005	<0.0005	<0.001	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--	--
	06/24/15		<0.250	0.120	<0.026	<0.0005	<0.0005	<0.0005	<0.001	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--	--
	09/15/15		<0.250	0.140	<0.250	<0.0008	<0.0008	<0.0008	<0.001	--	--	--	--	--	--	<0.00084	--	--	--	--	--	--	--	--	--	--
MW-3 DUP	02/27/08	24.5-34.5	1.85	0.342	<0.485	0.0011	<0.0005	0.19	0.2	<0.0005	<0.0005	<0.100	<0.0010	<0.0005	<0.0005	<0.0005	<0.0005	0.0076	0.23	0.058	0.026	0.066	--	--	--	--
	03/31/10		1.90	<0.250	<0.500	<0.0015	<0.0015	0.018	0.020	<0.0015	<0.0015	<0.015	<0.007	<0.0015	<0.0015	<0.0015	<0.0015	0.0019	0.27	<0.0015	0.018	0.048	0.0050	0.012	<0.0015	--
	09/01/10		<0.250	<0.250	<0.500	<0.0005	<0.0005	<0.0005	<0.0015	<0.0005	<0.0005	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	--
MW-4	05/14/02	20-35	<0.080	0.358 [5.]	<0.500	<0.0005	<0.0005	<0.0005	<0.001	<0.0005	<0.0005	--	--	--	--	<0.002	--	<0.002	<0.001	<0.0005	<0.002	<0.0005	--	--	--	--
	05/19/03		--	--	--	<0.001	<0.001	<0.001	<0.002	<0.001	<0.001	--	--	--	--	<0.001	--	<0.002	<0.001	<0.001	<0.002	<0.001	--	--	--	--
	05/25/07		<0.080	<0.238	<0.476	<0.0002	<0.0005	<0.0005	<0.001	<0.0005	<0.0005	<0.150	<0.025	<0.001	<0.001	<0.002	<0.001	<0.002	<0.001	<0.0005	<0.002	<0.0005	<0.05	<0.001	<0.001	--
	08/24/07		<0.1	<0.238	<0.476	<0.001	<0.002	<0.002	<0.006	<0.0005	<0.0005	<0.100	<0.020	<0.0005	<0.0005	<0.0005	<0.0005	<0.05	<0.001	<0.001	<0.002	<0.001	--	--	--	--
	11/26/07		<0.080	<0.236	<0.472	<0.001	<0.002	<0.002	<0.006	<0.0005	<0.0005	<0.100	<0.020	<0.0005	<0.0005	<0.0005	<0.0005	<0.05	<0.001	<0.001	<0.002	<0.001	--	--	--	--
	02/27/08		<0.080	<0.248	<0.495	<0.0005	<0.0005	<0.0005	<0.001	<0.0005	<0.0005	<0.100	<0.0010	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	--	--	--	--
	03/31/10		<0.250	<0.250	<0.500	<0.0005	<0.0005	<0.0005	<0.0015	<0.0005	<0.0005	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	--
	09/01/10		<0.250	<0.250	<0.500	<0.0005	<0.0005	<0.0005	<0.0015	<0.0005	<0.0005	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	--
	12/16/14		<0.250	<0.250	<0.500	<0.0005	<0.0005	<0.0005	<0.0005	--	--	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	--	--	--	--	--	--	--	--	<0.050
	03/25/15		<0.250	0.074	<0.091	<0.0005	<0.0005	<0.0005	<0.001	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--	--
	06/24/15		<0.250	<0.099	<0.250	<0.0005	<0.0005	<0.0005	<0.001	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--	--
	09/15/15		<0.250	<0.130	<0.340	<0.0005	<0.0005	<0.0005	<0.001	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--	--
MW-5	12/16/14	10-25	15	0.350	<0.500	0.00070	0.00066	0.12	1.2	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--	--
	03/25/15		18.1	<0.045	<0.091	<0.00050	0.00061	0.218	1.45	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--	--
	06/24/15		15	0.33 D (see note)	<0.250	<0.0012	<0.0012	0.228	1.51	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--	--
	09/15/15		17.3	0.82 D (see note)	<0.34	<0.00050	0.00060	0.289	1.92	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--	--
	07/11/16		19.4	0.310	<0.29	<0.00084	0.00100	0.215	1.17	--	--	--	--	--	--	<0.00084	--	--	--	--	--	--	--	--	--	--
Washington DOE MTCA Method A cleanup level [9.]			0.800 [8.]	0.5	0.5	0.005	1	0.7	1	NA	0.005	NA	NA	NA	NA	0.02	NA	0.16	NA	NA	NA	NA	NA	NA	NA	NA

Please refer to notes at end of table.

Table 2
Summary of Analytical Results from Monitoring Wells
NuStar Terminals Operations Partnership, L.P. – Annex Terminal
Vancouver, Washington

Well Number	Sample Date	Screened Interval (feet bgs)	Concentrations in mg/L (ppm)																					
			TPHg	TPHd	TPHho	Benzene	Toluene	Ethylbenzene	Xylenes	1,2-Dibromoethane	1,2-Dichloroethane	Ethanol	Tert-Butyl alcohol	Ethyl tert-Butyl Ether (ETBE)	Diisopropyl Ether (DIPE)	Methyl tert-butyl ether (MTBE)	Tert-Amyl Methyl Ether (TAME)	Naphthalene	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	Isopropyl-benzene	n-Propylbenzene	n-Butyl-benzene	sec-Butyl-benzene	Chloroform	Methanol
MW-5 DUP	12/16/14	10-25	15	<0.250	<0.500	0.00088	0.00081	0.18	1.3	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
	03/25/15		17.2	<0.046	<0.092	0.0005	0.00065	0.236	1.22	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
	06/24/15		16.8	0.560 D (see note)	<0.250	<0.0012	<0.0012	0.232	1.49	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
MW-6	12/16/14	10-25	15	<0.250	<0.500	0.47	0.065	1.3	2.6	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
	03/25/15		13.7	0.047	<0.092	0.516	0.0756	1.40	2.26	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
	06/24/15		17.7	1.2 D (see note)	<0.250	0.423	0.0582	1.58	1.92	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
	09/15/15		15.1	0.54 D (see note)	<0.34	0.306	0.0672	1.23	1.92	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
	9/15/2015 DUP		14	0.44 D (see note)	<0.35	0.328	0.0684	1.32	2.07	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
	07/11/16		15.5	0.23	<0.28	0.358	0.0616	1.63	1.82	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
MW-7	07/11/16	10-25	<0.250	<0.19	<0.29	<0.00050	<0.00050	<0.00050	<0.00015	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
MW-8	07/11/16	10-25	<0.250	<0.19	<0.29	<0.00050	<0.00050	<0.00050	<0.00015	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
	7/11/16 DUP		<0.250	<0.19	<0.29	<0.00050	<0.00050	<0.00050	<0.00015	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
MW-8D	07/06/16	35-45	<0.250	<0.19	<0.29	<0.00050	<0.00050	<0.00050	<0.0015	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
MW-9	07/11/16	10-25	<0.250	<0.19	<0.29	<0.00050	<0.00050	<0.00050	<0.00015	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
MW-10	07/11/16	10-25	<0.250	<0.19	<0.29	<0.00050	<0.00050	<0.00050	<0.00015	--	--	--	--	--	--	<0.0005	--	--	--	--	--	--	--	--	--
Washington DOE MTCA Method A cleanup level[9.]			0.800 [8.]	0.5	0.5	0.005	1	0.7	1	NA	0.005	NA	NA	NA	NA	0.02	NA	0.16	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

1. TPHg = Total petroleum hydrocarbons in gasoline carbon range by NW-TPHgx method.
2. TPHd = Total petroleum hydrocarbons in diesel carbon range by NW-TPHdx method with silica gel cleanup.
3. TPHho = Total petroleum hydrocarbons ion heavy oil carbon range NW-TPHdx method with silica gel cleanup.
4. **Boldface** values represent concentration that exceeds MTCA Method A cleanup level.
5. Analysis completed without silica gel cleanup. Lab detected hydrocarbons with non-petroleum peaks or elution pattern that suggests the presence of biogenic interference.
6. Hydrocarbon pattern most closely resembles a blend of heavy gas-/light diesel-range components.
7. mg/L (ppm) = Milligrams per liter (parts per million).
8. TPHg cleanup level dependent on presence of benzene in groundwater. Cleanup level = 0.800 mg/L if benzene is present and 1.00 mg/L if benzene is not present.
9. Washington DOE MTCA Method A cleanup level = Washington Department of Ecology Model Toxics Control Act Method A cleanup level.
10. < = Not detected at or above the specified laboratory method reporting limit (MRL).
11. bgs = below ground surface
12. The relative percent difference between TPHD concentrations in samples MW-5 and MW-5 DUP exceed the control limit of +/- 30%
13. D = Laboratory report noted discreet peaks that are not indicative of diesel. The laboratory chemist confirmed the peaks were from non-petroleum organic material.

Table 3
Summary of Soil Analytical Results: TPH and VOCs
NuStar Terminals Operations Partnership, L.P. - Annex Terminal
Vancouver, Washington

				Concentrations in mg/kg (ppm)																
Sample Location	Sample Date	Depth	TPH-HCID	TPHg	TPHd	TPHho	Benzene	Toluene	Ethylbenzene	Xylenes	1,2-Dibromo-ethane	1,2-Dichloro-ethane	Methyl tert-butyl ether (MTBE)	Naphthalene	1,2,4-Trimethyl-benzene	1,3,5-Trimethyl-benzene	Isopropyl-benzene	n-Propyl-benzene	n-Butyl-benzene	Chloroform
Soil Borings																				
GP-2	04/10/02-4/11/02	10-12	--	ND	ND	ND	--	--	--	--	--	--	--	--	--	--	--	--	--	--
GP-3	04/10/02-4/11/02	10-12	--	ND	ND	ND	--	--	--	--	--	--	--	--	--	--	--	--	--	--
GP-5	04/10/02-4/11/02	17-19	--	ND	ND	ND	--	--	--	--	--	--	--	--	--	--	--	--	--	--
GP-7	04/10/02-4/11/02	14-16	--	ND	ND	ND	--	--	--	--	--	--	--	--	--	--	--	--	--	--
GP-8	04/10/02-4/11/02	6-8	--	ND	ND	ND	--	--	--	--	--	--	--	--	--	--	--	--	--	--
GP-9	04/10/02-4/11/02	16-18	--	ND	ND	ND	--	--	--	--	--	--	--	--	--	--	--	--	--	--
GP-12	04/10/02-4/11/02	22-24	--	ND	ND	ND	--	--	--	--	--	--	--	--	--	--	--	--	--	--
GP14	05/09/02	10-12	DET [9.]	3,230	19,700	<1,000	--	--	--	--	--	--	--	--	--	--	--	--	--	--
GP16	05/09/02	10-12	ND [8.]	ND	ND	ND	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW2	05/09/02	25-26.5	ND [8.]	314	<25	<50	--	--	--	--	--	--	--	--	--	--	--	--	--	--
GP26	06/26/02	6-8	--	5,850	--	--	<2.5	9.74	91.3	825	<2.5	<2.5	<10	124	891	293	29.7	125	--	--
GP27	06/26/02	10-12	--	4.96	--	--	<0.0050	<0.0050	<0.0050	<0.1	<0.05	<0.05	<0.2	<0.5	<0.1	<0.05	<0.2	<0.05	--	--
GP31	06/26/02	22-24	--	<2.5	<25	<50	<0.0050	<0.0050	<0.0050	<0.0050	--	--	--	--	--	--	--	--	--	--
GP32	06/26/02	6.5-8	--	910	2,530	<50	<5	<5	<5	16	--	--	--	--	--	--	--	--	--	--
GP33	06/26/02	8-10	--	363	31,500	<2,500	<0.500	<0.500	7.2	33.9	--	--	--	--	--	--	--	--	--	--
GP34	06/26/02	6-8	--	728	13,600	<1,000	<0.500	<0.500	0.717	16.9	--	--	--	--	--	--	--	--	--	--
GP35	06/26/02	8-10	--	10.3	<25	<50	<0.0050	<0.0050	<0.0050	<0.0050	--	--	--	--	--	--	--	--	--	--
SB-2	04/17/03	4	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-2	04/17/03	22	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-4	04/17/03	3	ND [8.]	--	<25	<50	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-4	04/17/03	27	ND [8.]	--	<25	<50	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-5	04/17/03	11	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-6	04/16/03	3	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-6	04/16/03	16	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-7	04/17/03	12	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-8	04/17/03	8	DET [9.]	1,020	7,890	<1,000	<0.500	<0.500	<0.500	7.45	--	--	--	6.14	31	20.4	<1	3.22	3.54	<0.5
SB-8	04/17/03	16	DET [9.]	369	1,440	<50	<0.500	<0.500	<0.500	<1,000	--	--	--	6.47	1.67	<0.5	1.13	0.837	<2.5	0.539
SB-8R	09/30/14	12	--	<5.0	<5.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-9	04/18/03	12	DET [9.]	504	1,890	<50	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-9	04/18/03	15	DET [9.]	168	1,210	<50	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-9R	09/30/14	12	--	1,000	4,000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-9R	09/30/14	13.5	--	--	3,400	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-11	04/16/03	2.5	ND [8.]	--	<25	<50	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-11	04/16/03	14	ND [8.]	--	<25	<50	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-12	04/22/03	3	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-12	04/18/03	12	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-13	04/22/03	2	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SB-13	04/22/03	5	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hand Augers																				
HA-1	04/17/03	3	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
HA-1	04/17/03	6	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
HA-2	04/18/03	2	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
HA-2	04/18/03	5	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
HA-3	04/17/03	2	--	--	--	--	<0.1	<0.1	<0.1	<300	--	--	--	<0.2	<0.1	<0.1	<0.2	<0.1	<0.5	<0.1
HA-3	04/17/03	5.5	--	--	--	--	<0.1	<0.1	<0.1	<300	--	--	--	<0.2	<0.1	<0.1	<0.2	<0.1	<0.5	<0.1
HA-4	04/18/03	2	ND [8.]	--	--	--	<0.1	--	--	--	--	--	--	--	--	--	--	--		
HA-4	04/18/03	5	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--		
HA-5	04/18/03	3	DET [9.]	3,320	4,780	<50	<5.0	10.5	48.5	500	--	--	--	76.4	341	109	<10	39.1	<25	6.6
HA-5	04/18/03	5	DET [9.]	2,290	10,700	<250	6.7	216	177	1,204	--	--	--	141	576	176	20.8	83.3	34	<5
Washington DOE MTCA Method A cleanup level				100/30 [11.]	2,000	2,000	0.03	7	6	9	NA	NA	NA	5	NA	NA	NA	NA	NA	NA

Please refer to notes at end of table.

Table 3
Summary of Soil Analytical Results: TPH and VOCs
NuStar Terminals Operations Partnership, L.P. - Annex Terminal
Vancouver, Washington

				Concentrations in mg/kg (ppm)																
Sample Location	Sample Date	Depth	TPH-HCID	TPHg	TPHd	TPHho	Benzene	Toluene	Ethylbenzene	Xylenes	1,2-Dibromo-ethane	1,2-Dichloro-ethane	Methyl tert-butyl ether (MTBE)	Naphthalene	1,2,4-Trimethyl-benzene	1,3,5-Trimethyl-benzene	Isopropyl-benzene	n-Propyl-benzene	n-Butyl-benzene	Chloroform
Hand Augers																				
HA-6	04/18/03	2	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
HA-6	04/18/03	5	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
HA-7	04/14/03	6	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
HA-8	04/14/03	6	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Soil Sample from Advancement of Temporary Monitoring Wells																				
PMW-5	04/16/03	8	ND [8.]		31	<50	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PMW-5	04/16/03	10	DET [9.]	--	146	<50	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PMW-6	04/16/03	3	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PMW-6	04/16/03	12	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PMW-7	04/16/03	3	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PMW-7	04/16/03	16	ND [8.]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Soil Samples from Excavation Confirmation																				
N. Wall	5/20/2002	10	--	--	--	--	<0.100	<0.100	<0.100	<0.2	--	--	<0.1	<0.2	<0.1	<0.1	<0.2	<0.1	<0.5	<0.1
N. Wall	5/20/2002	3	--	--	--	--	<0.100	<0.100	<0.100	<0.2	--	--	<0.1	<0.2	<0.1	<0.1	<0.2	<0.1	<0.5	<0.1
E. Wall	5/21/2002	10	--	--	--	--	<0.100	<0.100	<0.100	<0.2	--	--	<0.1	<0.2	<0.1	<0.1	<0.2	<0.1	<0.5	<0.1
E. Wall	5/21/2002	3	--	--	--	--	<0.100	<0.100	<0.100	<0.2	--	--	<0.1	<0.2	<0.1	<0.1	<0.2	<0.1	<0.5	<0.1
Washington DOE MTCA Method A cleanup level [12.]				100/30 [11.]	2,000	2,000	0.03	7	6	9	NA	NA	NA	5	NA	NA	NA	NA	NA	NA

Notes:

1. TPH-HCID = Total petroleum hydrocarbons hydrocarbon identification by NW-TPH-HCID
2. TPHg = Total petroleum hydrocarbons in the gasoline carbon range by NW-TPH-Gx method.
3. TPHd = Total petroleum hydrocarbons in the diesel carbon range by NW-TPH-Dx method with silica gel cleanup.
4. TPHho = Total petroleum hydrocarbons in the heavy oil carbon range by NW-TPH-Dx method with silica gel cleanup.
5. mg/kg (ppm) = Milligrams per kilogram (parts per million).
6. -- = Not analyzed or not available.
7. < = Not detected at or above the specified laboratory method reporting limit (MRL).
8. ND= Not detected; MRL not available.
9. DET = Gasoline-, diesel-, and/or heavy oil-range hydrocarbons was detected using NWTPH-HCID. Follow-up analysis was completed.
10. **Boldface** values represent concentration that exceeds MTCA Method A cleanup level.
11. TPHg cleanup level dependent on presence of benzene in soil. Cleanup level = 30 mg/kg if benzene is present and 100 mg/kg if benzene is not present.
12. Washington DOE MTCA = Washington Department of Ecology Model Toxics Control Act.
13. NA = Cleanup level not available.
14. Yellow highlight identifies the 2014 borings installed a the historica (2003) locations of SB-8 and SB-9.

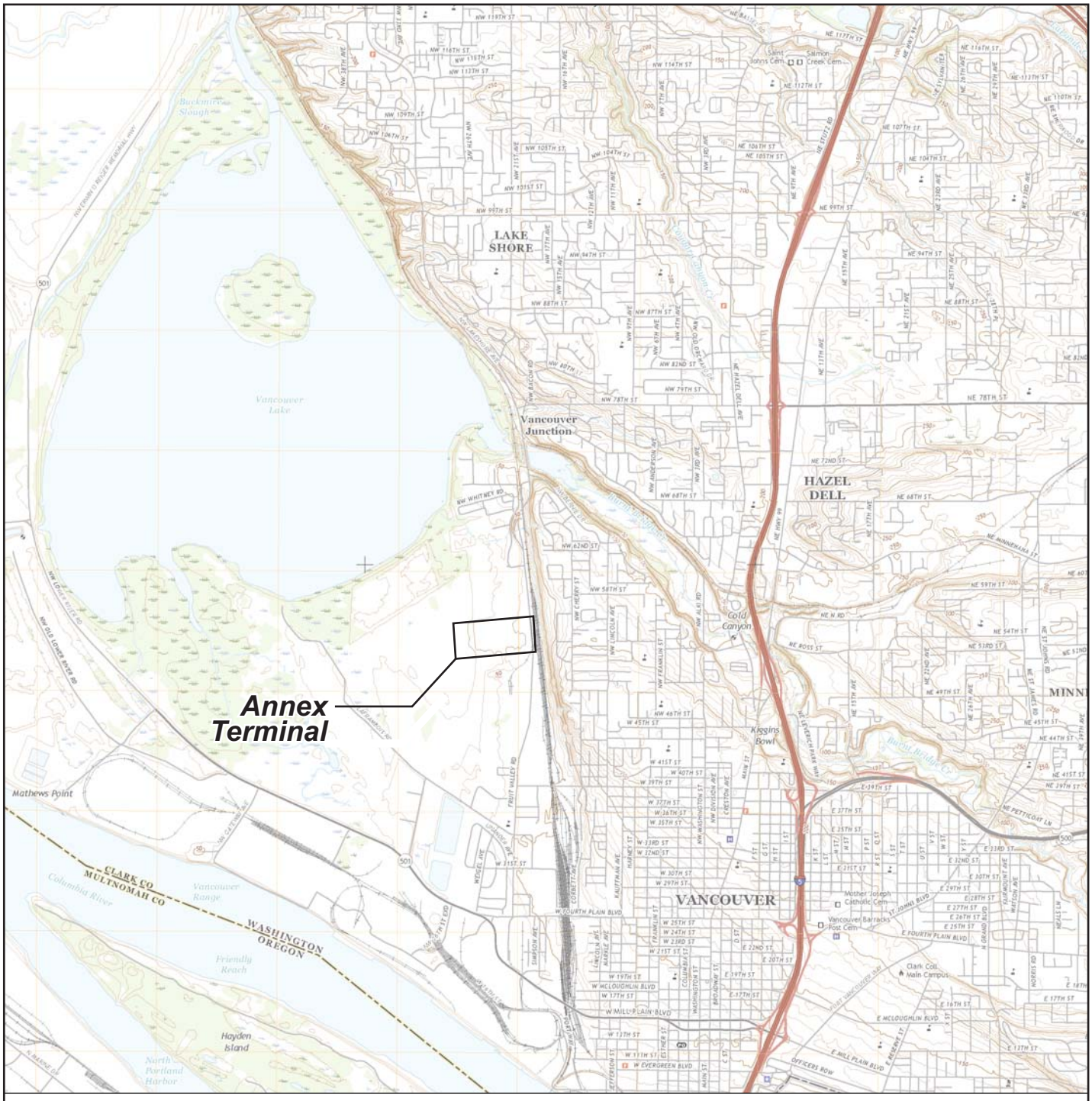
Table 4
Grab Groundwater Sample Analytical Results: TPH, BTEX, MTBE
NuStar Terminals Operations Partnership, L.P. - Annex Terminal
Vancouver, Washington

Sample Location	Sample Date	Depth (feet bgs)	TPHg	TPHd*	TPHo*	Benzene	Toluene	Ethyl-benzene	Xylenes	Methyl tert-butyl ether (MTBE)
Groundwater Samples from Soil Borings; Concentrations in mg/L										
SB-8R	9/30/2014	15-20	45	9.8	--	--	--	--	--	--
SB-9R	9/30/2014	17-22	26	3.6	--	--	--	--	--	--
B-1(1)	10/22/2015	21-25	0.483	0.51 B	<0.28	<0.00050	<0.00050	<0.00050	<0.0010	<0.00050
B-1(2)	10/22/2015	26-30	<0.250	0.24 B, DG	0.38	<0.00050	<0.00050	<0.00050	<0.0010	<0.00050
B-1(3)	10/22/2015	36-40	0.687	0.35 B	<0.24	<0.00050	<0.00050	0.00053	<0.0010	<0.00050
B-2(1)	10/23/2015	16-20	4.02	0.77 B	<0.30	0.0104	0.0155	1.31	3.18	<0.00050
B-2(2)	10/23/2015	26-30	<0.250	0.2 B,DF	<0.23	<0.00050	<0.00050	0.0057	0.0108	<0.00050
B-2(3)	10/23/2015	36-40	2.37	3.5	<0.28	0.0022	0.0019	0.122	0.184	<0.00050
B-3(1)	10/23/2015	16-20	22.3 E	15.9/3.2*	0.69 DH/<0.003*	3.94	0.112	1.24	3.9	<0.010
B-3(2)	10/23/2015	26-30	25.6 E	37.4	0.46 B	3.91	0.104	1.23	3.52	<0.010
B-4(1)	10/23/2015	16-20	10.3 E	6.2	<0.300	<0.0012	<0.0012	0.26	0.321	<0.0012
B-4(2)	10/23/2015	26-30	9.88 E	2.1 B	<0.260	0.0012	0.001	0.255	0.214	<0.00050
B-5(1)	10/27/2015	16-20	34.7	68.4	3.8 B	<0.025	<0.025	2.77	5.24	<0.025
B-5(2)	10/27/2015	36-40	20.6	0.89 B,DG	<0.30	<0.0031	0.0097	0.955	1.26	<0.0031
B-6(1)	10/27/2015	19-23	48.6	117/67.7*	0.77 DH/0.62*	<0.0025	0.005	0.0743	0.0245	<0.0025
B-6(2)	10/27/2015	51-55	<0.250	0.35 B, DH	0.31 B	<0.00050	<0.00050	<0.00050	<0.0010	<0.00050
B-6(3)	10/27/2015	61-65	<0.250	0.35 B, DH	<0.30	<0.00050	<0.00050	<0.00050	<0.0010	0.0025
B-7(1)	10/28/2015	21-25	<0.250	<0.170	<0.260	<0.00050	<0.00050	<0.00050	<0.0010	<0.00050
B-7(2)	10/28/2015	26-30	<0.250	<0.190	<0.280	<0.00050	<0.00050	<0.00050	<0.0010	<0.00050
B-8(1)	10/28/2015	16-20	<0.250	<0.190	<0.290	<0.00050	<0.00050	<0.00050	<0.0010	<0.00050
B-8(2)	10/28/2015	21-25	<0.250	<0.190	<0.290	<0.00050	<0.00050	<0.00050	<0.0010	<0.00050
B-9(1)	10/29/2015	16-20	1.63	0.24	0.28	<0.00050	<0.00050	<0.00050	<0.0010	<0.00050
B-9(2)	10/29/2015	36-40	3.03	0.38DG	0.62 DF	<0.00050	<0.00050	<0.00050	<0.0010	0.0039
B-9(3)	10/29/2015	46-50	1.55	0.56 DG	<0.300	<0.00050	<0.00050	<0.00050	<0.0010	0.0048
B-10(1)	10/29/2015	16-20	32.7	284	0.58 DH	<0.0012	<0.0012	0.377	0.495	<0.0012
B-10(2)	10/29/2015	36-40	0.421	2.2	0.37	<0.00050	<0.00050	0.0022	0.003	<0.00050
B-11(1)	10/30/2015	21-25	19.2	46.7	0.92 DH	<0.0025	<0.0025	0.455	0.701	<0.0025
B-11(2)	10/30/2015	36-40	1.58	6.9	0.62 DH	<0.00050	<0.00050	0.0112	0.0187	<0.00050
B-11(3)	10/30/2015	41-45	<0.250	0.28	0.3	<0.00050	<0.00050	0.00052	<0.0010	<0.00050
B-12(1)	10/30/2015	16-20	0.265	<0.200	0.36 DF	<0.00050	<0.00050	<0.00050	<0.0010	<0.00050
B-12(2)	10/30/2015	36-40	<0.250	0.29 DG	<0.260	<0.00050	<0.00050	<0.00050	<0.0010	<0.00050
B-12(3)	10/30/2015	41-45	<0.250	<0.200	<0.300	<0.00050	<0.00050	<0.00050	<0.0010	0.001
B-13 (1)	7/7/2016	15-20	<0.250	<0.18	<0.27	<0.00050	<0.00050	<0.00050	<0.0015	<0.00050
B-13 (2)	7/7/2016	25-30	<0.250	<0.18	<0.27	<0.00050	<0.00050	<0.00050	<0.0015	<0.00050
B-14 (1)	7/7/2016	15-20	<0.250	<0.18	<0.27	<0.00050	<0.00050	<0.00050	<0.0015	<0.00050
B-14 (2)	7/7/2016	25-30	<0.250	<0.17	<0.26	<0.00050	<0.00050	<0.00050	<0.0015	<0.00050
Washington DOE MTCA Method A cleanup level			0.800[7]	0.5	0.5	0.005	1	0.7	1	0.02

Notes:

1. TPHg = Total petroleum hydrocarbons in the gasoline carbon range by NW-TPH-Gx method.
2. TPHd = Total petroleum hydrocarbons in the diesel carbon range by NW-TPH-Dx method (with silica gel cleanup)
3. TPHho = Total petroleum hydrocarbons in the heavy oil carbon range by NW-TPH-Dx method.
4. Benzene, toulene, ethylbenzene, and total xylenes (BTEX) and MTBE analysis per EPA Method 8260B.

5. < = Not detected at or above the specified laboratory method reporting limit (MRL).
6. mg/L (ppm) = Milligrams per liter (parts per million).
7. TPHg cleanup level dependent on presence of benzene in groundwater. Cleanup level = 0.800 mg/L if benzene is present and 1.00 mg/L if benzene is not present.
8. Washington DOE MTCA = Washington Department of Ecology Model Toxics Control Act.
9. **Boldface** values represent concentration that exceeds MTCA Method A cleanup level.
10. The screened intervals for the October 2015 samples are shown. Sample intake was generally from the centerpoint of each interval - see boring logs for more detail.
11. * = For TPHd and TPHo, the first value is the concentration without silica gel cleanup and the second is with silica cleanup (i.e. 15.9/3.2). At the request of Ecology, select samples were analyzed with and without silica gel cleanup for comp
12. DF = Discreet peak is present, but atypical of motor oil.
13. DG = Peaks present, atypical for Diesel Fuel.
14. DH = Peaks present, atypical for Motor Oil.
15. B = Analyte was detected in the associated methd blank.
16. E = Analyte exceeds calibration range, result is estimated.
17. -- not analyzed.



Note: Base map prepared from USGS 7.5-minute quadrangle of Vancouver, WA, dated 2017 as provided by USGS.gov.

0 4,000 8,000

Approximate Scale in Feet

Site Location Map

Additional Groundwater Investigation Report
NuStar Terminals Operations Partnership, L.P. - Annex Terminal
Vancouver, Washington

Apex Companies, LLC
3015 SW First Avenue
Portland, Oregon 97201

Project Number	1569-09	Figure
July 2017		1

Legend:

- **B-1** Soil Boring Location (October 2015)
- **SB-8R** Soil Boring Location (September 2014)
- **MW-1** Groundwater Monitoring Well Location (MW-8D is a Deep Monitoring Well Location)
- DP-1 Grab Groundwater Sample Location
- GP-1 Deeper Direct-Push Geoprobe Location
- GP-1 Historical Direct-Push Boring Location (Approximate)
- PMW-5 Historical Temporary Well Location (Approximate)
- HA-1 Historical Hand Auger Location (Approximate)
- Excavation Location

NOTE: Base map completed from a number of sources including but not limited to; Figure VAN1-21-002 provided by NuStar (1/8/2007) and a Monitoring Well Survey by Statewide Land Surveying, Inc (10/30/2007). Locations of roads and containments are approximate. Aerial photograph from Google Earth Pro (4/2015).

Site Plan

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Vancouver, Washington

Apex Companies, LLC
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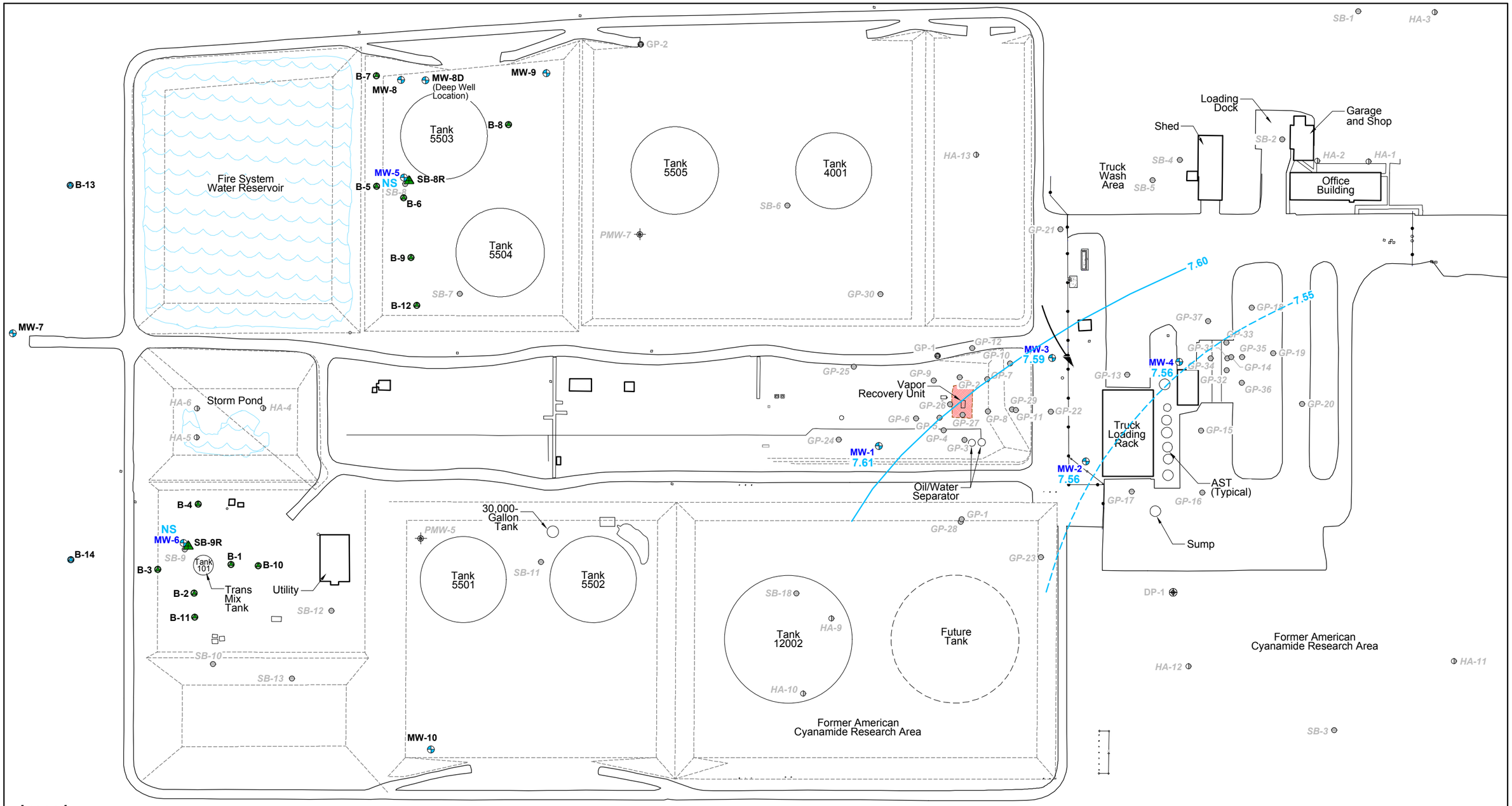
Portland, Oregon 97201

Project Number	1569-09	Figure
July 2017		2



Legend:

- MW-1 / 7.61 — Groundwater Monitoring Well Location and Groundwater Elevation in Feet Above Mean Sea Limit (MSL)
- 7.55 — Groundwater Elevation Contour (Dashed Where Inferred)
- NS — Not Surveyed
- Inferred Groundwater Flow Direction
- Direct-Push Geoprobe Location
- GP-1 — Soil Boring Location (September 2014)
- DP-1 — Grab Groundwater Sample Location
- GP-1 — Historical Direct-Push Boring Location (Approximate)
- PMW-5 — Historical Temporary Well Location (Approximate)
- HA-1 — Historical Hand Auger Location (Approximate).
- Excavation

N

0 100 200

Scale in Feet

NOTE: Base map completed from a number of sources including but not limited to; Figure VAN1-21-002 provided by NuStar (1/8/2007) and a Monitoring Well Survey by Statewide Land Surveying, Inc (10/30/2007). Locations of roads and containments are approximate.

Groundwater Elevations - September 2015

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Vancouver, Washington

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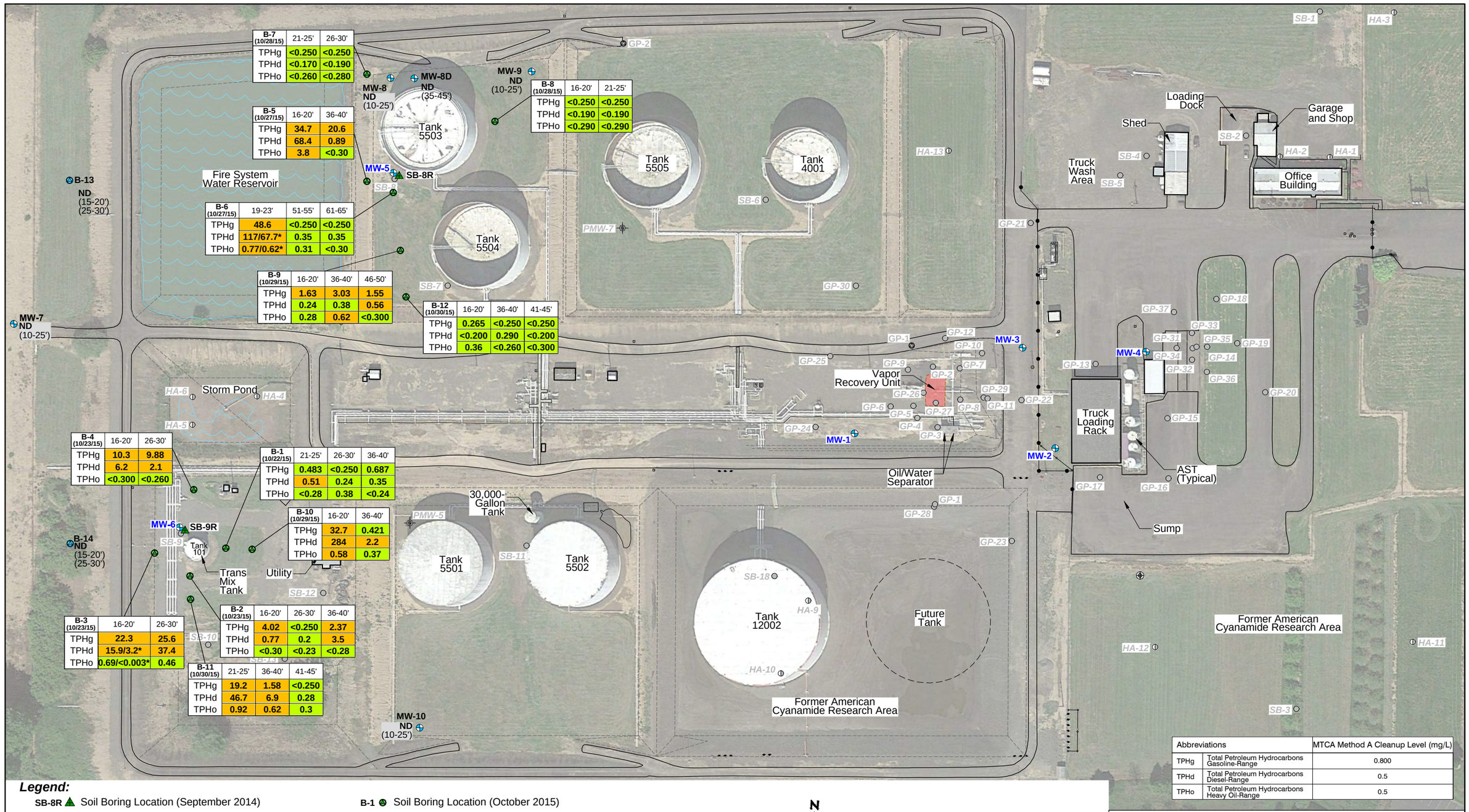
Portland, Oregon 97201

Project Number	1569-09	Figure
July 2017		3



Abbreviations		MTCA Method A Cleanup Level (mg/L)
TPHg	Total Petroleum Hydrocarbons Gasoline-Range	0.800
TPHd	Total Petroleum Hydrocarbons Diesel-Range	0.5
TPHo	Total Petroleum Hydrocarbons Heavy Oil-Range	0.5

Legend:

- **SB-8R** Soil Boring Location (September 2014)
- **MW-1** Groundwater Monitoring Well Location (MW-8D is a Deep Monitoring Well Location)
- DP-1 Grab Groundwater Sample Location
- GP-1 Deeper Direct-Push Geoprobe Location
- GP-1 Historical Direct-Push Boring Location (Approximate)
- PMW-5 Historical Temporary Well Location (Approximate)
- HA-1 Historical Hand Auger Location (Approximate)

B-1 Soil Boring Location (October 2015)

B-1 (10/22/15)	21-25'
TPHg	0.483
TPHd	0.51
TPHo	<0.28

Sample Identification (Date Sampled)
Depth of Sample
Concentration in mg/L
Analyte Sampled

Concentration is Below MTCA Method A Cleanup Level

Concentration is Above MTCA Method A Cleanup Level

* For TPHd and TPHo, the first value is the concentration with silica gel cleanup and the second without (i.e. 15.9/3.2). At the request of Ecology, select samples were analyzed with and without silica gel cleanup for comparison.

N

0 100 200
Scale in Feet

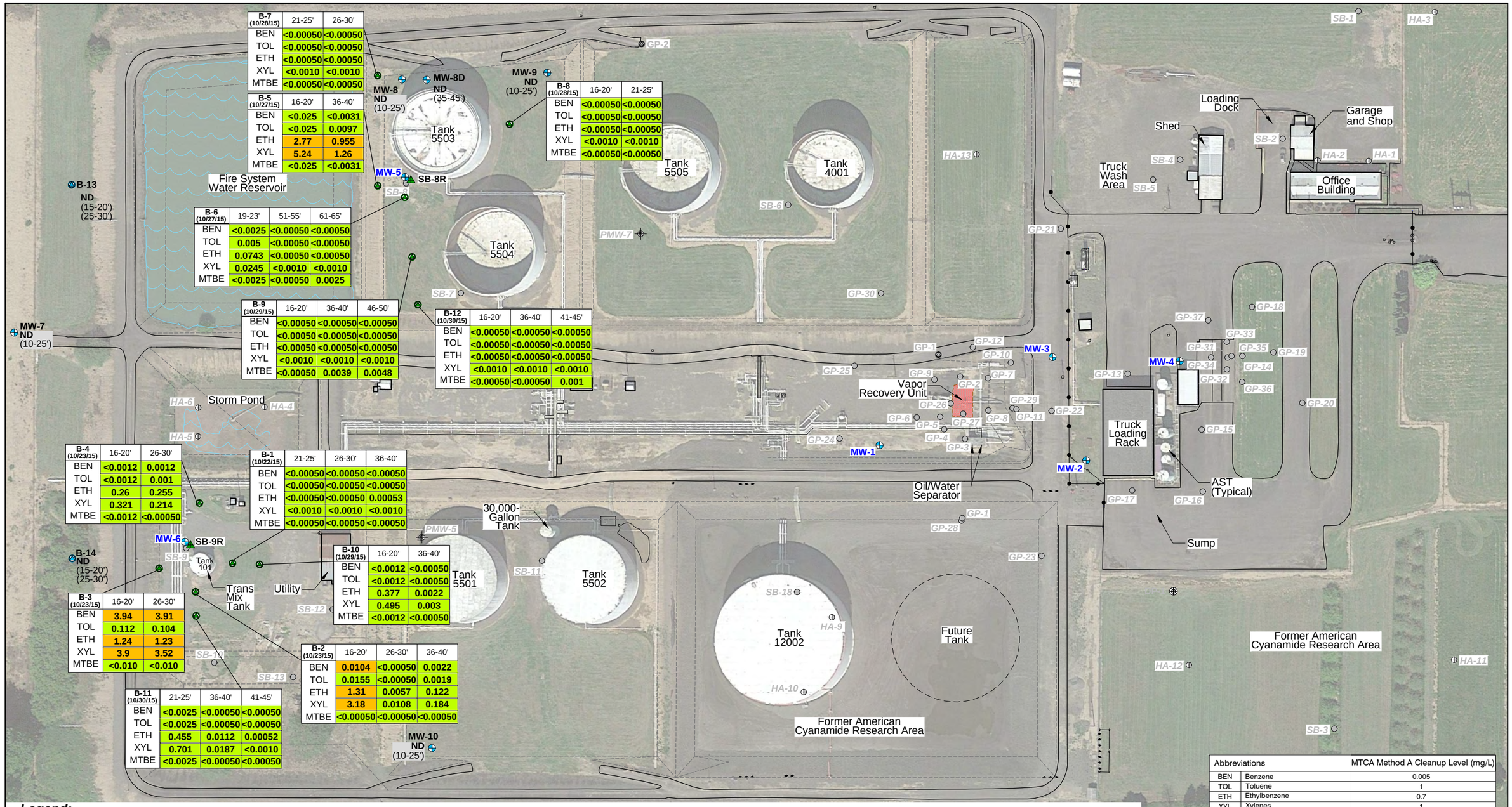
NOTE: Base map completed from a number of sources including but not limited to; Figure VAN1-21-002 provided by NuStar (1/8/2007) and a Monitoring Well Survey by Statewide Land Surveying, Inc (10/30/2007). Locations of roads and containments are approximate. Aerial photograph from Google Earth Pro (4/2015).

TPH Concentrations in Groundwater - October 2015

Additional Groundwater Investigation Report
NuStar Terminals Operations Partnership, L.P. - Annex Terminal
Vancouver, Washington

Apex Companies, LLC
3015 SW First Avenue
Portland, Oregon 97201

Project Number 1569-09
July 2017
Figure 4



Abbreviations		MTCA Method A Cleanup Level (mg/L)
BEN	Benzene	0.005
TOL	Toluene	1
ETH	Ethylbenzene	0.7
XYL	Xylenes	1
MTBE	Methyl Tert-Butyl Ether	0.02

Legend:

- **SB-8R** Soil Boring Location (September 2014)
- **MW-1** Groundwater Monitoring Well Location (MW-8D is a Deep Monitoring Well Location)
- DP-1 Grab Groundwater Sample Location
- GP-1 Deeper Direct-Push Geoprobe Location
- *GP-1* Historical Direct-Push Boring Location (Approximate)
- *PMW-5* Historical Temporary Well Location (Approximate)
- *HA-1* Historical Hand Auger Location (Approximate)
- **B-1** Soil Boring Location (October 2015)

B-1 (10/22/15)	21-25'
BEN	<0.00050
TOL	<0.00050
ETH	<0.00050
XYL	<0.0010
MTBE	<0.00050

Sample Identification (Date Sampled)
Depth of Sample
Concentration in mg/L
Analyte Sampled

Concentration is Below MTCA Method A Cleanup Level

Concentration is Above TCA Method A Cleanup Level

N

0 100 200

Scale in Feet

NOTE: Base map completed from a number of sources including but not limited to; Figure VAN1-21-002 provided by NuStar (1/8/2007) and a Monitoring Well Survey by Statewide Land Surveying, Inc (10/30/2007). Locations of roads and containments are approximate. Aerial photograph from Google Earth Pro (4/2015).

BTEX and MTBE Concentrations in Groundwater - October 2015

Additional Groundwater Investigation Report
NuStar Terminals Operations Partnership, L.P. - Annex Terminal
Vancouver, Washington

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Portland, Oregon 97201

Project Number	1569-09	Figure
July 2017		5

Legend:

- **SB-8R** ▲ Soil Boring Location (September 2014)
- **MW-1** ⊕ Groundwater Monitoring Well Location (MW-8D is a Deep Monitoring Well Location)
- DP-1 ⊕ Grab Groundwater Sample Location
- GP-1 ⊕ Deeper Direct-Push Geoprobe Location
- *GP-1* ○ Historical Direct-Push Boring Location (Approximate)
- *PMW-5* ⊕ Historical Temporary Well Location (Approximate)
- *HA-1* ◐ Historical Hand Auger Location (Approximate)
- **B-1** ⊕ Soil Boring Location (October 2015)
- Pilot Study Area

N

0 100 200

Scale in Feet

NOTE: Base map completed from a number of sources including but not limited to; Figure VAN1-21-002 provided by NuStar (1/8/2007) and a Monitoring Well Survey by Statewide Land Surveying, Inc (10/30/2007). Locations of roads and containments are approximate.

Pilot Study Area

Additional Groundwater Investigation Report
NuStar Terminals Operations Partnership, L.P. - Annex Terminal
Vancouver, Washington

Apex Companies, LLC
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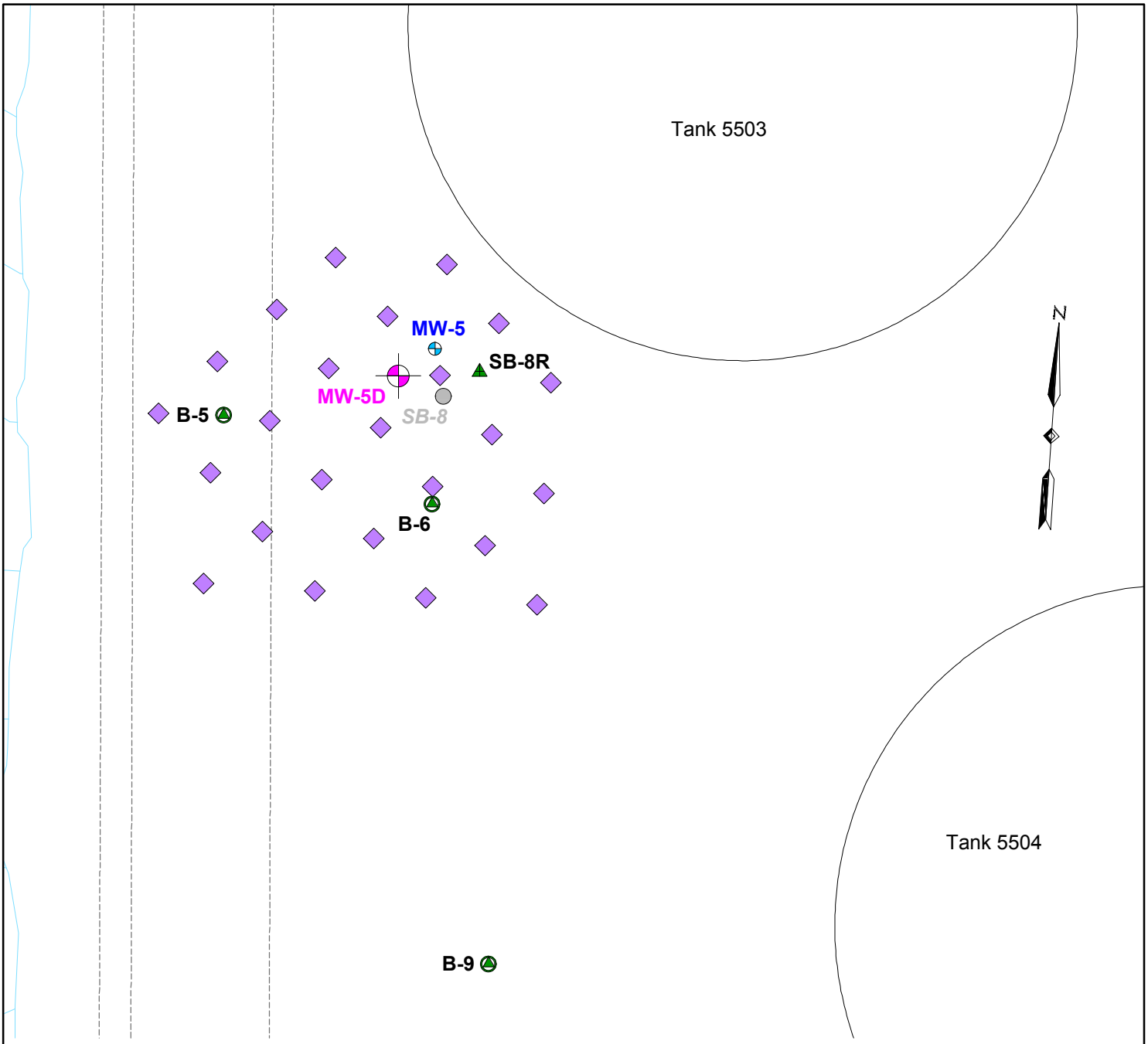
Project Number	1569-09	Figure
July 2017		6



Legend:

SB-8R ▲	Soil Boring Location (September 2014)
MW-5 ⊕	Groundwater Monitoring Well Location
SB-8 ●	Historical Direct-Push Boring Location (Approximate)
B-6 ◎	Soil Boring Location (October 2015)
◆	Injection Boring Location
MW-5D ⊕	Proposed Deep Groundwater Monitoring Well Location

NOTE: Base map completed from a number of sources including but not limited to; Figure VAN1-21-002 provided by NuStar (1/8/2007) and a Monitoring Well Survey by Statewide Land Surveying, Inc (10/30/2007). Locations of roads and containments are approximate.

0 100 200

Scale in Feet

Pilot Study Injection Layout

Additional Groundwater Investigation Report
NuStar Terminals Operations Partnership, L.P. - Annex Terminal
Vancouver, Washington

Apex Companies, LLC
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Portland, Oregon 97201

Project Number	1569-09	Figure
July 2017		7

Appendix A

Soil Boring Lithologic Logs and Monitoring Well Construction Logs

Sample Descriptions

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, and grain size, and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
MAJOR CONSTITUENT with additional remarks; color, moisture, minor constituents, density/consistency.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance. Soil density/consistency in test pits and push probe explorations is estimated based on visual observation and is presented parenthetically on test pit and push probe exploration logs.

SAND and GRAVEL Density	Standard Penetration Resistance in Blows/Foot
Very loose	0 - 4
Loose	4 - 10
Medium dense	10 - 30
Dense	30 - 50
Very dense	>50

SILT or CLAY Density	Standard Penetration Resistance in Blows/Foot	Approximate Shear Strength in TSF
Very soft	0 - 2	<0.125
Soft	2 - 4	0.125 - 0.25
Medium stiff	4 - 8	0.25 - 0.5
Stiff	8 - 15	0.5 - 1.0
Very Stiff	15 - 30	1.0 - 2.0
Hard	>30	>2.0

Moisture

Dry	Little perceptible moisture.
Sl. Moist	Some perceptible moisture, probably below optimum.
Moist	Probably near optimum moisture content.
Wet	Much perceptible moisture, probably above optimum.

Minor Constituents

	Estimated Percentage
Not identified in description	0 - 5
Slightly (clayey, silty, etc.)	5 - 12
Clayey, silty, sandy, gravelly	12 - 30
Very (clayey, silty, etc.)	30 - 50

Sampling Symbols

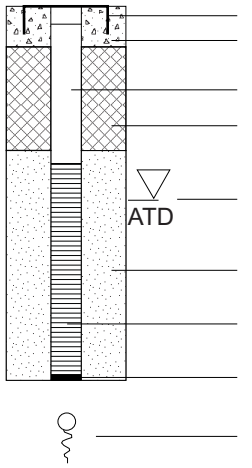
BORING AND PUSH-PROBE SYMBOLS

- Recovery
- No Recovery
- Temporarily Screened Interval
- PID — Photoionization Detector Reading
- W — Water Sample
- Sample Submitted for Chemical Analysis
- NS — No Sheen
- SS — Slight Sheen
- MS — Moderate Sheen
- HS — Heavy Sheen
- BF — Biogenic Film

TEST PIT SOIL SAMPLES

- Grab (Jar)
- Bag
- Shelby Tube

Groundwater Observations and Monitoring Well Construction



- Flush Mounted Monument
- Concrete Surface Seal
- Well Casing
- Bentonite Seal
- Groundwater Level on Date or (ATD) At Time of Drilling
- Sand Pack
- Well Screen
- End Cap
- Groundwater Seepage (Test Pits)

Key to Exploration Logs

NuStar Terminals Operations Partnership, L.P. - Annex Terminal
Vancouver, Washington

APEX
Apex Companies, LLC
3015 SW First Avenue
Portland, Oregon 97201

Project Number	1569-04	Figure
October 2014		Key

Apex Companies, LLC
3015 SW First Avenue
Portland, Oregon 97201

NuStar Terminals Operations Partnership, L.P. - Annex Terminal
Vancouver, Washington

Boring Number: **SB-8R**

Project Number: **1569-04**
Logged By: M. Whitson
Date: September 30, 2014
Site Conditions: Partly Cloudy, 60s (°F)
Drilling Contractor: Cascade Drilling
Drilling Equipment: Geoprobe 7720DT
Sampler Type: Macro Core
Depth to Water (ATD): 12.5'
Surface Elevation: Not Surveyed

Depth, feet	Core Interval/Recovery	Laboratory Sample ID	PID	Sheen	Lithologic Description
0	Hand Auger	SB-8R(5.0)	<5	NS	Clayey SILT to SILT with clay (ML); yellowish brown (10YR 5/4), slightly moist, trace sand, medium stiff.
10		SB-8R(9.0)	<5	NS	SILT (ML); light olive brown (2.5Y 5/3) with rust orange mottling, moist, medium stiff.
		SB-8R(12.0)	<5	NS	
			102	MS	Becomes wet, soft.
15					Becomes very dark greenish gray (GLEY 1 3/10Y).
			132	MS	
20			124	MS	
25					Bottom of Boring at 25.0' BGS.
					Note: Groundwater sample collected from 3/4" PVC temporary well using a peristaltic pump.
30					
35					

Boring Details and Notes:

ATD ▽ At Time of Drilling

SB-8R (Water Sample)

ATS ▽ At Time of Sampling

Apex Companies, LLC
3015 SW First Avenue
Portland, Oregon 97201

NuStar Terminals Operations Partnership, L.P. - Annex Terminal
Vancouver, Washington

Boring Number: **SB-9R**

Project Number: **1569-04**
Logged By: M. Whitson
Date: September 30, 2014
Site Conditions: Partly Cloudy, 60s (°F)
Drilling Contractor: Cascade Drilling
Drilling Equipment: Geoprobe 7720DT
Sampler Type: Macro Core
Depth to Water (ATD): 13.0'
Surface Elevation: Not Surveyed

Boring Details and Notes:

Depth, feet	Core Interval/Recovery	Laboratory Sample ID	PID	Sheen	Lithologic Description
	Hand Auger		<5	NS	Loose coarse gravel surface over SILT with clay (ML); dark yellowish brown (10YR 4/4), moist, medium stiff.
5			<5	NS	
					With very fine sand.
			<5	NS	Becomes very dark gray (2.5Y 3/1), soft.
10		SB-9R(12.0)	102	HS	SAND (SP); very dark greenish gray (GLEY 1 3/5GY), moist, very fine-grained sand, no fines, medium dense.
		SB-9R(13.5)	399	HS	SAND with silt (SP); very dark greenish gray (GLEY 1 3/5GY), wet, very fine-grained sand, silt fines, loose to medium dense.
15					SILT (ML); very dark greenish gray (GLEY 1 3/5GY), wet, trace very fine sand, soft.
			349	HS	
20					
			323	MS	
25					Bottom of Boring at 25.0' BGS.
					Note: Groundwater sample collected from 3/4" PVC temporary well using a peristaltic pump.
30					
35					

ATD ▽ At Time of Drilling

ATS ▽ SB-9R (Water Sample) At Time of Sampling

Appendix B

Apex Standard Operating Procedures (SOPs)

1. PURPOSE AND SCOPE

This Standard Operating Procedure (SOP) describes the methods for observing and sampling from push-probes (i.e., GeoProbe™). Subsurface soil cores may be obtained using this system for purposes of determining subsurface soil conditions and for obtaining soil samples for physical and/or chemical evaluation. Grab groundwater samples may be collected using temporary well screens. Soil vapor samples may be obtained using temporary well points. Shallow (less than 50 feet), small-diameter (2-inch max) pre-packed wells may also be installed using push-probe equipment. This procedure is applicable during all Apex Companies, LLC (Apex) push-probe activities.

2. EQUIPMENT AND MATERIALS

The following materials are necessary for this procedure:

- Traffic cones, measuring tape, spatula, and buckets/drums
- Sampling equipment (water level probe, pumps, tubing) and laboratory-supplied sample containers
- Field documentation materials
- Decontamination materials
- Personal protective equipment (as required by project Health and Safety Plan)

3. METHODOLOGY

Coring Procedure (Conducted by Drilling Subcontractor):

The sampling procedure includes driving a 2-inch outside-diameter, 5-foot-long, push-probe soil sampler to the desired depth using a combination of hydraulic pressure and mechanical hammer blows. When the sampling depth is reached, the pin attaching the sampler's tip is released (if a tip is used), which allows the tip to slide inside the sampler (Macro-Core Sampler with removable plastic liner). The sampler is driven the length of the sampler to collect a soil core, which is then withdrawn from the exploration. When the sampler is retrieved from the borehole the drive head/cutting shoe is detached and the liner is removed. Soil cores are collected continuously to the full depth of the exploration unless otherwise specified in a project-specific sampling and analysis plan (SAP). Verify that the subcontractor decontaminates the sampling device (per SOP 1.2) prior to its initial use and following collection of each soil sample.

Logging and Soil Sample Collection:

Remove the soil core from the sampler for field screening, description, and placement into sample jars. Soil samples will be collected for field screening and possible chemical analysis on two foot intervals unless otherwise specified in a project-specific SAP. The sampling interval will be determined in the field based on recovery, soil variability, and evidence of contamination. Complete field screening as specified in SOP-2.1. Soil samples should be collected using different procedures for volatile on non-volatile analyses, as follows.

- **Volatile Analyses.** Sampling for volatile organics analysis (VOA) is different than other routine physical or chemical testing because of the potential loss of volatiles during sampling. To limit volatile loss, the soil sample must be obtained as quickly and as directly as possible. If a VOA sample is to collected as part of a multiple analyte sample, the VOA sample portion will be obtained first. The VOA sample should be obtained from a discrete portion of the entire collected sample and should not be composited or homogenized. Sample bottles should be filled to capacity, with no headspace. Specific procedures for collecting VOA samples using the EPA Method 5035 are discussed in SOP 2.7.
- **Other Analyses.** Soil samples for non-volatile analyses will be thoroughly homogenized in a stainless steel bowl prior to bottling. Sample homogenizing is accomplished by manually mixing the entire soil

sample in the stainless steel bowl with a clean sampling tool until a uniform mixture is achieved. The sample jar should be filled completely.

Any extra soil generated during probing activities will be placed in Department of Transportation (DOT) approved drums.

Grab Groundwater Sample Collection:

Collect grab groundwater samples using a sampling attachment with a 4 to 5-foot-long temporary screen (specify to drillers whether to use decontaminated stainless steel or disposable PVC. Also, specify whether a filter pack is necessary based on field observations). Obtain samples using a peristaltic pump unless otherwise specified in the SAP with new tubing for each boring. Record field parameters (e.g., temperature, conductivity, and pH) prior to sampling.

Backfilling the Excavation (Conducted by Drilling Subcontractor):

After sampling activities are completed, abandon each exploration in accordance with Oregon Water Resources Department (OWRD) regulations and procedures. The abandonment procedure typically consists of filling the exploration with granular bentonite and hydrating the bentonite with water. Match the surface completion to the surrounding materials.

MONITORING WELL INSTALLATION PROCEDURES

1. PURPOSE AND SCOPE

This Standard Operating Procedure (SOP) describes the methods for installing monitoring wells (using conventional PVC or pre-packed well screens). A pre-packed well screen generally consists of 5-foot sections of an inner PVC well screen and an outer stainless steel wire mesh. The sand filter pack is housed between the inner screen and outer wire mesh. Well installations are typically completed using push probe drilling to save time and cost but may include many other techniques for drilling a borehole to install the well. This procedure is applicable during all Ash Creek Associates (ACA) drilling activities for installation of monitoring wells.

2. EQUIPMENT AND MATERIALS

The following materials are necessary for this procedure:

- Field documentation materials
- Personal protective equipment (as required by project Health and Safety Plan)

3. METHODOLOGY

The soil boring for the monitoring well will be completed in accordance with SOP-2.4.

Installation/Construction of Monitoring Well:

Filter Pack. Wells will be constructed of flush-threaded Schedule 40 PVC casing connected to a conventional PVC well screen or pre-packed well screen, placed at the bottom of the boring. A clean silica sand pack will be placed between the boring wall and the PVC screen/riser (i.e., the annulus) from the bottom of the well to approximately one to two feet above the screened interval. Prior to installation of the seal, the well will be surged using a surge block or similar technique. The depth to sand will be measured prior to setting the bentonite seal.

Seal. A bentonite seal, 1 to 2 feet thick, will be placed above the sand. The bentonite will be hydrated and allowed to sit for a minimum of 30 minutes for proper hydration and sealing. The depth to the top of the seal will be measured prior to placing grout. In Washington State and some California counties, the bentonite seal may be placed to within 1 foot of the ground surface in place of grout (per local/state regulations).

Grout. A cement-bentonite slurry will be placed above the bentonite seal following proper hydration. The cement-bentonite slurry will be placed to within 1 foot of the ground surface.

Surface Seal. A concrete surface seal will secure a flush-mounted, traffic-rated monument, or a bollard protected stove-pipe stickup. A locking cap and lock will secure the wellhead, and tamper-resistant bolts (either pentagonal or Allen wrench) will secure a monument cover if a flush-mounted monument is used for surface completion. Flush-mounted surface completions will be completed slightly above grade to prevent the ponding of water in, and around, the monument. All monuments will be permanently marked with well identification numbers. The identification number should be marked on the well (e.g., punched into monument ring, written on the well casing and/or cap with permanent marker, etc.). A survey point should also be added to the well casing (e.g., v-notch cut in PVC).

Documentation:

The field geologist will document the well construction activities. Details to be noted include the following:

- Length of well components;
- Measurements of bentonite, sand, and concrete depths;
- Types, brands, and amounts of materials used;
- Documentation of decontamination; and
- Any deviation from standard procedures or problems during the installation activities.

The drilling contractor will be responsible for conforming to all applicable regulations pertaining to well construction.