APPENDIX 5F

NAPL Evaluation

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NAPL EVALUATION

1.0 INTRODUCTION

Nonaqueous phase liquid (NAPL) in upland and lake sediment has been thoroughly studied in the Area of Investigation (AOI). This appendix explains the NAPL evaluation in the AOI.

Section 2 describes the types of NAPL found in the AOI as well as the NAPL terminology. The many types of NAPL-related data generated through multiple investigations in the AOI over the years are discussed in Section 3. Section 4 presents the chemistry data that were used to determine the extent of NAPL impacts and relationships between NAPL areas in the AOI. Sections 5 and 6 describe how the Tar-specific Green Optical Screening Tool (TarGOST®) probe works, provide an evaluation of TarGOST results, and describe the process of integrating these results with NAPL field observations in order to map NAPL areas for the remedial investigation (RI) report. The methodology for mapping the extent of NAPL and the results of the NAPL distribution evaluation (Figure 5F-1) in the AOI are presented in Section 7. Section 8 provides an evaluation of NAPL stability in the AOI, while Section 9 discusses the conceptual site model (CSM), including sources of NAPL and NAPL transport and exposure pathways.

This appendix supports the RI report Section 5 (Nature and Extent of Contamination), Section 6 (Contaminant Fate and Transport), and Section 8 (Conceptual Site Model). The following additional RI report appendices are pertinent to this appendix:

- Appendix 2A – 2013 Supplemental Investigation (SI) Data Report
- Appendix 2C – Previous Environmental Investigations
- Appendix 2D – Special Studies
- Appendix 3C – Compilation of Well and Boring Logs
- Appendix 3H – Soft Sediment Probing Figures
- Appendix 3J – Monitoring Well Construction Details and Groundwater and NAPL Elevation Tables
- Appendix 5B – Chemistry Data Tables

This appendix (Appendix 5F) includes the following attachments:

- Attachment 5F-1 – UV Photographs and Petrophysical Results
- Attachment 5F-2 – TarGOST
- Attachment 5F-3 – Geomatrix DNAPL Migration Evaluation for Western Sediment Area (WSA)
- Attachment 5F-4 – Floyd|Snider GWS WSA Data Report Appendix G - Supplemental PAH Analyses

2.0 NAPL TYPES

The terminology associated with the different types of NAPL in the AOI and their state in site media are described in this section and presented in further detail in Table 5F-1.

2.1. Physical Properties

NAPL is typically classified as LNAPL (light NAPL) or DNAPL (dense NAPL). LNAPLs have densities less than water and tend to float whereas DNAPLs have densities greater than water and tend to sink. In addition to NAPL, tar is also referenced in this appendix. Tar, when used to describe conditions in the AOI, refers to a solid or semi-solid and is not considered a NAPL. In this and more recent reports for the AOI, the terms “DNAPL” and “tar” are differentiated, with the latter term referring to semi-solid, pliable solid, or solid material[1].

The physical properties (viscosity, specific gravity, soil saturation) of NAPL measured in the AOI are presented in Table 5F-2. LNAPL viscosity is low compared with DNAPLs in the AOI. The wide range of DNAPL viscosity in the AOI (22 centistokes at MW-09 to 1,128 centistokes at MW-18, measured at 70 degrees) is an indication of the variety of DNAPL products and byproducts present, the various degrees of weathering, or both.

The specific gravity of LNAPL from MW-09 is 0.92 at 70 degrees (water at the same temperature has a specific gravity of 1.0), which is relatively high for an LNAPL and may not be representative of other LNAPL areas in the AOI (Table 5F-2). Specific gravity of the AOI DNAPLs ranges from 1.02 to 1.11 (at 70 degrees) (Table 5F-2).

LNAPL saturation in soil (%Pv), where measured, ranges from 4.8 to 46.6 percent; only one sample was more than 20 percent saturated. This sample was obtained from PT-02, a petrophysical borehole, along the eastern shoreline in NAPL Area 13 (Figure 5F-1), southeast of the Play Barn (Sub-attachment 5F-1.4). DNAPL saturation in soil, where measured, ranges from 2.1 to 14.5 percent. The maximum DNAPL saturation in soil encountered in the AOI was at PT-03 near the Harbor Patrol Helicopter Pad (Sub-attachment 5F-1.4).

2.2. NAPL Chemical Composition

The actual composition of NAPL varies based on the original source, the amount of time since the release, and environmental conditions where it occurs. The types of NAPL in the AOI include the following:

- LNAPL
    - Petroleum-based LNAPL (e.g., fuel oil)
    - Benzol or monoaromatic-rich LNAPL (also referred to as “light oil” in this RI report and other references)
    - Naphthalene-rich LNAPL
- DNAPL
    - Naphthalene-rich DNAPL (also referred to as both a “light oil” and “middle oil’ or “medium oil” by various authors)

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[1] In this RI, tar is considered a semisolid, pliable solid, or solid material. This physical description of tar differs from usage in previous reports and references to specific products and byproducts (e.g., coal tar). Tar is dark in color and dominated by heavier compounds (e.g., polycyclic aromatic hydrocarbon [PAHs]) with very low aqueous solubilities; tar analysis results are included in Table 5F-4. Tar typically occurs as small discrete masses, layers, or deposits within the fill unit and soil or sediment surface in the AOI. Small masses are interspersed sporadically within the fill unit; some larger deposits have also been identified (Figure 5F-2).

- Polycyclic aromatic hydrocarbon (PAH)-rich DNAPL, previously referred to as coal tar, creosote (a coal-tar-based product that may also contain petroleum), or even tar (Attachment 2C-1 of RI Appendix 2C). This DNAPL may be derived from various MGP processes.
- Lower PAH DNAPL with petroleum

PAHs commonly contain two to seven fused benzene rings. When at least one hydrogen atom is substituted with another organic functional group, the new compound becomes an alkylated PAH.

Pyrogenic materials are complex mixtures of hydrocarbons produced from organic matter subjected to *high temperatures* with insufficient oxygen for complete combustion (EPRI 2008). Pyrogenic materials have high two- to six-ring PAH content and greater abundance of parent to alkylated PAH.

Petrogenic materials are formed at relatively *low temperatures* during the maturation of crude oil and coal (EPRI 2008). Petrogenic materials have a lower four- to six-ring PAH content and greater abundance of alkylated PAH to parent.

The PAH-rich DNAPL may be coal tar, carbureted-water gas tar (CWGT), oil-gas tar (OGT), or other product derived from or containing these materials. Coal tar, CWGT and OGT are primarily derived from a manufactured gas plant (MGP) processes; for example, coal tar is a byproduct of coal carbonization. PAH-rich DNAPL was also a raw material, byproduct, or product of the tar refinery and other industrial or commercial operations. Tar refinery DNAPLs could also be coal tar (the feedstock) or various grades of creosote (common names for products). Likewise, other industrial and commercial operations used coal tar and its derivatives (including creosotes) as feedstock and products.

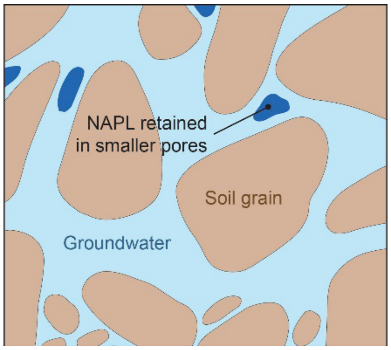
In this report, the term "MGP DNAPL" is used when there is a clear association with MGP operations, and "refinery DNAPL" is used when there is a clear association with the tar refinery. The more generic term "DNAPL" is used where the source is unclear. Of note, in some cases the DNAPL is almost entirely of pyrogenic origin, while in other cases the DNAPL has a petrogenic component. The latter may represent CWGTs, OGTs, creosote, other industrial and commercial materials, or a mixed source (i.e., petroleum mixed with pyrogenic DNAPL such as coal tar).

2.3. Stability Terminology

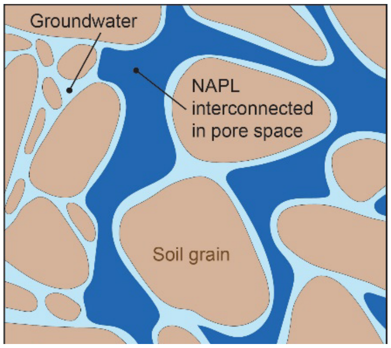
When NAPL is released to the environment, it moves through soil pore spaces, replacing air (in soil) or water (in sediment or saturated soil) within the pore spaces. NAPL is relatively insoluble in water and moves separately from water. NAPL stability (whether NAPL is moving through site soil, sediment, or water now) is described using the following terminology:

- *Residual* – refers to NAPL that is trapped in the pore spaces between soil particles or sediment particles and cannot be easily moved hydraulically (see Inset A). Almost all NAPL in the AOI is in residual form.

Inset A. Residual NAPL



Inset B. Mobile NAPL



- *Mobile* – refers to NAPL that exceeds residual saturation and is hydraulically connected in the pore space (see Inset B). Some mobile NAPL has the potential to expand its footprint, but most mobile NAPL is not spreading vertically or laterally. Mobile NAPL includes migrating NAPL, but not all mobile NAPL is migrating NAPL. Mobile NAPL is measurable in wells because the well creates a void space for mobile NAPL to move into (ITRC 2009). Mobile NAPL areas in the AOI have been identified by measurable NAPL in wells.
- *Migrating* – is where the NAPL area is expanding vertically and/or horizontally or otherwise resulting in an increased volume of NAPL-impacted media. On the pore level, mobile and migrating NAPL appear as shown in Inset B. On the macro level, migrating NAPL is actively moving through soil or sediment. Lateral and downward movement is only likely to occur shortly after a release occurs or if the release is ongoing (ITRC 2009). Except for rare observations of ebullition, no evidence of current migrating NAPL has been observed in the AOI and NAPL appears to be in equilibrium.

This terminology is used extensively in Sections 7 through 10.

3.0 NAPL DATA

A multitude of investigations of the AOI have generated many types of NAPL-related data, including:

- Field screening results and observations of its presence in soil and sediment;
- Monitoring well NAPL occurrence and thickness measurements and LNAPL baildown[2] results for NAPL characterization;
- Results from chemical analysis of NAPL/tar and NAPL-impacted soil and sediment, NAPL/tar physical properties, and results of petrophysical testing;
- Ultraviolet (UV) photographs of soil cores; and
- TarGOST data.

Table 5F-3 lists AOI NAPL/tar-related data sets and associated sampling locations.

3.1. Field Screening

Several types of field screening were conducted over the years in the AOI. Field screening commonly included visual and manual examination, sheen testing, and headspace vapor screening. More aggressive field screening consisting of shake testing and UV/black light screening[3] were performed during some investigations to better quantify the amount of NAPL present. Except for UV/black light screening, field screening methodologies are described in more detail in Section 2.1.2 of RI Appendix 2A. The UV/black light screening was conducted by collecting eight ounces of sediment in a sealed plastic bag and flattening

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[2] LNAPL baildown testing evacuates LNAPL from a well then measures LNAPL recharge to determine the LNAPL transmissivity.

[3] UV/black light screening was performed during the Eastern Study Area (ESA) Phase 3 sediment investigation. The data are presented in Appendix 3C of the RI under "Eastern Study Area (ESA) Phase 3 – Core Logs 2005" and "Eastern Study Area (ESA) Phase 3 – Surface Grabs 2004-2005."

it until evenly distributed. The sample was illuminated with a four-watt broad-spectrum UV light (350 nanometer) in a room with no ambient light. The fluorescence intensity, area fluorescing, and distribution of fluorescence was recorded.

The field screening data described below, along with the various NAPL data types described in this section, were used to evaluate NAPL subsurface conditions and identify and delineate NAPL-impacted areas.

The presence and degree of NAPL impact and the presence of tar at each sample location is color-coded according to the NAPL and tar occurrence categories listed and shown below for use in NAPL/tar mapping in Figures 5F-1 and 5F-8 through 5F-12. In borings where both tar and heavy sheen with NAPL were observed, the symbols are color-coded as tar. In borings where tar was not observed, the symbols are color-coded with the highest degree of impact observed at each location.

NAPL and Tar Occurrence Categories:

▨ No Data/No Description – No physical description of impacts available.

☐ No Impacts – No visual or olfactory evidence of hydrocarbons present.

🟨 Staining and/or Odor – Presence of hydrocarbon or naphthalene-like odor, hydrocarbon staining of the soil or sediment matrix, or both.

🟩 Slight to Moderate Sheen – Observations of hydrocarbon sheen ranging from trace to slight to moderate or medium sheens that may be described as spotty, white, colored, or rainbow sheens.

🟩 Heavy Sheen and/or Trace NAPL – Observations of heavy, oily, or strong hydrocarbon sheens; minor NAPL observations described as trace NAPL; small, scattered, or occasional oil blebs (less than ⅛ inch in size) or NAPL veinlets; or oily water or oil emulsions.

🟩 Heavy Sheen with NAPL – Observations of sheens plus NAPL where NAPL is described as present, abundant, or saturated, including observations of oil/NAPL drops or blebs (greater than ⅛ inch in size), oil, or oil/NAPL on equipment. The NAPL may occur in lenses, layers, fractures, seams, or veins. NAPL implies a lower-viscosity liquid that occurs in and moves through the interstitial pore space or voids in the soil or sediment matrix.

🟫 Tar or Tar-Impacted Interval – A higher-viscosity NAPL, semisolid, or solid hydrocarbon that behaves as a plastic solid or solid substance. Descriptions include globular pieces or chunks of hydrocarbon; ductile or gummy NAPL; pliable or hardened tar; and tarry, pitch, or pliable layers. Tar may occur as a deposit or layer or as a mixture with natural material and debris rather than in the pore space of soil or sediment.

These NAPL and tar occurrence categories are used in Figures 5F-1 and Figure 5F-2 to delineate NAPL and tar areas.

3.2. Monitoring Wells

Since their installation, monitoring wells in the AOI have been repeatedly monitored for the presence and thickness of LNAPL and DNAPL. In addition, LNAPL baildown "recovery" testing has occurred at MW-09.

NAPL thickness data are included in Table 3J-2 of RI Appendix 3J. Baildown testing is described in Attachment 2A-8 of RI Appendix 2A. Groundwater explorations, including current and former wells and grab samples with detected NAPL or tar, are presented in Figure 5F-3. Wells with trace or small amounts of LNAPL or DNAPL detected in only one gauging event and not subsequently confirmed are suspect and excluded (i.e., not identified as a well with NAPL).

3.3. Analytical Testing

NAPL and tar samples collected from the upland and offshore within the AOI, as well as heavily impacted samples of soil and sediment, have been characterized through the following:

- Chemical testing (PAHs, alkylated PAHs, volatile organic compounds [VOCs], total petroleum hydrocarbons [TPH], semivolatile organic compounds [SVOCs]) (Table 5B-3.7 of RI Appendix 5B). Contaminant of concern (COC) results of NAPL, tar and heavily impacted soil and sediment samples within NAPL and tar areas plus isolated tar samples are included in Table 5F-4.
- Physical properties (viscosity, density) (Table 5F-2).
- Special studies (RI Appendix 2D) – A wide variety of special studies were conducted typically to provide detailed information on the nature of NAPL, tar and impacted soil and sediment. Studies included hydrocarbon fingerprinting, carbon isotope ratios, chromatogram evaluation, petrography, scanning electron microscopy, and more.

3.4. Petrophysical Testing

Petrophysical testing (e.g., free-product mobility, saturation) has occurred during various investigations:

- Petrophysical testing has been conducted on 20 samples. Tests have included NAPL saturation, soil free product mobility and porosity. Petrophysical testing was conducted as part of the 2006 shoreline investigation (Attachment 2C-2), 2007 northeast corner investigation (Floyd|Snider 2008a), 2007 eastern shoreline investigation (AECOM 2008), and 2013 SI (RI Appendix 2A).
- Seven free-product mobility tests (two under air, five under water) were conducted as part of the SI (Sub-attachment 5F-1.4). The petrophysical borings were close to TarGOST borings.

Petrophysical testing results are summarized in Table 5F-5 and included in Attachment 5F-1.

3.5. UV Photography

UV photography of upland soil cores was included in the SI (11 cores totaling 25 linear feet from four petrophysical borings), the eastern shoreline investigation (AECOM 2008), and the northeast corner investigation (Floyd|Snider 2008a). UV photographs of soil cores are included in Attachment 5F-1.

3.6. TarGOST

During a TarGOST investigation conducted in 2013 to assess and delineate upland NAPL, 49 locations were probed. TarGOST data, description of data processing, Dakota's investigation report, and background information are provided in Attachment 2A-2 of RI Appendix 2A. Attachment 5F-2 presents supplemental TarGOST information: Dakota Technologies' TarGOST Reference Log and TarGOST response to various products on sand as well as TarGOST response to and classification plot for NAPL samples.

Several types of laser-induced fluorescence (LIF) TarGOST data were generated, including the following:

- Raw data (NAPL LIF responses, TarGOST logs and associated electrical conductivity [EC] data, and TarGOST confirmation samples data[4])
- Data processing products (Dakota Technologies [Dakota] classification plots)
- Data analysis products (the Dakota Gas Works Park report, and non-negative least squares [NNLS] waveform analysis)

General TarGOST data interpretation and integration are discussed in Sections 5 and 6 below.

4.0 NAPL CHEMISTRY

Chemistry data from NAPL areas were used to characterize NAPL, evaluate the extent of NAPL impacts, and identify NAPL areas. In some locations, a cursory review of gas chromatograms (GCs) was also used. Table 5F-4 presents chemistry data for NAPL and tar as well as soil and sediment samples impacted by NAPL or tar (i.e., samples that were described as NAPL or tar impacted); the corresponding NAPL or tar area is listed in the first column. NAPL area chemical composition, including interpreted NAPL type, is summarized in Table 5F-6.

The highest benzene concentration was measured in LNAPL near the eastern shoreline (B-10 in NAPL Area 12) and was approximately 33 percent benzene and 84 percent benzene, toluene ethylbenzene, and xylenes (BTEX). The LNAPL in this area was subsequently remediated through extraction and air sparging/soil vapor extraction. Benzene is also present (1 to 2 percent) in DNAPL in the Harbor Patrol product samples from wells DW-4, DW-5, DW-7 and MLS-4-1 (Table 5F-4).

Station 1 (see Figure 5F-2) contained the highest naphthalene concentration measured in the AOI containing approximately 38 percent naphthalene and 42 percent total PAH (TPAH). Naphthalene is present at a maximum of 12 percent in DNAPL (MLS-4-1 in NAPL Area 12) and a maximum of 1.3 percent in LNAPL (MW-09 in NAPL Area 11) (Table 5F-4).

The NAPL chemistry reflects the effects of weathering, differences in chemistry results between samples of NAPL and samples of NAPL-impacted soil or sediment, and sources.

5.0 TARGOST INTERPRETATION

As discussed in Sub-attachment 2A-2.6 of RI Appendix 2A, the TarGOST probe works by using a green laser to excite the larger PAH molecules (high-molecular-weight PAHs [HPAHs]; those with at least four or five benzene rings) that exist in NAPL form, as opposed to smaller PAH molecules (low-molecular-weight PAHs [LPAHs]; those with two or three rings). Probing with TarGOST generates TarGOST logs (a detailed reference log is presented in Sub-attachment 5F-2.1). The following are key components of a TarGOST log:

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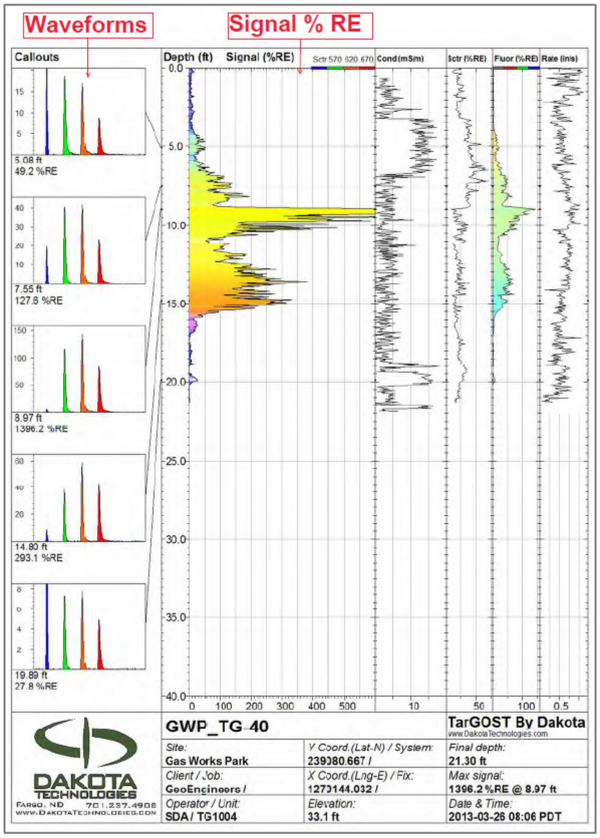
[4] Soil confirmation samples (soil splits) were collected from soil borings conducted adjacent to six of the TarGOST probe locations; the split soil samples were sent to Dakota's laboratory for LIF analysis, and to Analytical Resources, Inc. (ARI) laboratory for chemical analysis.

- Waveforms, which are fluorescence response versus time at specific depths, are shown on the left of the TarGOST logs. Waveforms are like “fingerprints” for various NAPLs. Response (a combination of reflected laser light and emitted fluorescence versus time) is recorded on four channels[5]. The relative height of peaks (magnitude of response recorded along the y-axes) and decay times (length of time a response is measured recorded along the x-axes) at the four channels help distinguish NAPL types (see similar discussion of the fill color in the bullet below). Waveforms at select depths are posted on the log (labeled as “Callouts”).
- The signal % Reference Emitter (signal %RE), or %RE for short, is plotted versus depth. %RE is a measure of the total response and relative measure of the amount and type of NAPL. The total geometric area of the waveform is divided by the total area of the RE[6] waveform, yielding the %RE value. The fill color is a sum of the relative contributions of each channel’s geometric area to the total waveform; the calculation is described in Sub-attachment 5F-2.1, The %RE is used to determine relative NAPL saturation, and the fill color is used to distinguish NAPL types.

The following sections summarize interpretation of TarGOST-related results that affect the NAPL evaluation. The data processing writeup in Attachment 2A-2 of RI Appendix 2A provides additional TarGOST data evaluation. Attachment 5F-2 also includes TarGOST response to various known products (Sub-attachment 5F-2.2) and to AOI NAPL (Sub-attachment 5F-2.3).



5.1. NAPL Sample LIF Responses

Prior to fieldwork, Dakota analyzed five representative samples of NAPL from the AOI upland in their laboratory using TarGOST equipment: LNAPL from MW-09 and DNAPL from DW-4, DW-5, DW-7 and MW-18 (see Figure 5F-3 for well locations). The results are plotted at the beginning of Sub-attachment 5F-2.3. The findings are discussed below and in Section 3.3 of Attachment 2A-2 in RI Appendix 2A. For reference purposes, Dakota provided example TarGOST responses of known products on sand (Attachment 5F-2).

As shown in Sub-attachment 5F-2.3, the response from DNAPL collected from monitoring wells on the western side of the AOI upland (i.e., DW-4, DW-5, DW-7 and MW-18) are similar (similar %RE and orange fill

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[5] The returning fluorescence is divided into four wavelength channels plotted on charts referred to as waveforms (energy versus time). Channel refers to one of the four wavelength bands where energy (a combination of reflected laser light and emitted fluorescence) are recorded versus time. The four peaks in a callout box constitute the waveform measured at a specific depth.

[6] The Reference Emitter (RE) is a standard (i.e., known material) used by Dakota for calibration.

color). The western DNAPL sample responses were similar to typical coal tar. Waveform peaks are slender (short lifetime), and the response appears as orange on the TarGOST log's signal %RE.

The response from LNAPL from MW-09 was 10 times as great as that from the western DNAPL. This difference does not necessarily indicate higher PAH concentrations. Corroborating evidence is provided by chemical analysis: although MW-09 LNAPL contained 80 percent less HPAHs than the Harbor Patrol DNAPL, there was enough HPAH in MW-09 LNAPL (0.5 percent) to generate a TarGOST response[7]. The MW-09 LNAPL could contain "solvents" (e.g., petroleum) that give the LNAPL a stronger response than western DNAPLs. Dakota correlated MW-09 LNAPL to other TarGOST responses encountered in the AOI upland that were longer-lived than MW-09 (St. Germain 2013b). These other responses and, to a lesser extent MW-09 LNAPL, are blue-shifted[8] which is indicative of solvated NAPL and/or petroleum components. Compared to the DNAPL responses, the peaks on the waveform plot for MW-09 LNAPL are broader (long lifetime), and the response appears as yellow in the TarGOST log's signal %RE (Sub-attachment 5F-2.3). Dakota concluded that LNAPL in the vicinity of MW-09 is at least in part petroleum-based.

5.2. TarGOST Logs and EC Data

TarGOST logs and EC data were used both to make NAPL interpretations and to assist with geologic interpretation (made by observing changes in scatter of laser light and EC, and depth of refusal). A sharp drop in scatter with no change in fluorescence suggests transition into a dark-colored soil, such as TG-05 at 11 to 16 feet (see Sub-attachment 5F-2.4) below ground surface (bgs). An increase in electrical conductivity was used to interpret increasing clay content, with surrounding borings used as confirmation. In addition, a chaotic EC signature (variable readings) was diagnostic of the fill unit, whereas a smoother signature was observed in native soil.

TarGOST logs were used to interpret the amount and type of NAPL present. Interpretations of NAPL type were made by observing change in the color of fluorescence with signal %RE as well as change in waveform. As discussed in Dakota Technologies' TarGOST guide (Sub-attachment 2A-2.6 of Attachment 2A-2 in RI Appendix 2A), TarGOST is most sensitive to PAHs occurring as part of a liquid (i.e., NAPL) as they come into direct contact with the sapphire window on the tool. TarGOST does not respond well to PAHs attached in "dry" form (e.g., black carbon) or dissolved-phase PAHs, and, as described in the Dakota TarGOST guide, there is "preferential sensitivity of TarGOST toward less viscous (more mobile) oil-like materials." In other words, TarGOST responds preferentially to potentially mobile NAPL. For a given chemical composition, TarGOST response appeared to be proportional to the viscosity and amount of the NAPL (the lower the viscosity and the greater the saturation, the more likely the NAPL is to be detected). In general, the TarGOST "reporting limit" is typically 100 to 1,000 parts per million of coal tar in soil—TarGOST does not respond to

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[7] The signal %RE is a function of PAH concentration, which corresponds to NAPL content and the state of the PAHs, which is a function of solvent content. TarGOST is designed to respond to PAHs in a liquid state such as NAPL-impacted soils, not PAHs in "dry" form (e.g., sorbed to soil particles) or dissolved-phase PAHs. The response (%RE) is more sensitive (higher for a given amount of NAPL) to lower viscosity ("runny") NAPL than higher viscosity NAPL and tar. Another phenomenon that affects the response is quenching of fluorescence emissions at higher PAH concentrations—the %RE increases with NAPL content to a point but may diminish at higher concentrations.

[8] The term blue-shifted is used to describe waveform plots with blue and green dominant peaks (left side of the waveform/Callout plots). In general, blue-shifted waveform peaks have a broader base (longer lifetime/slower decay) and the blue and green peaks are more dominant in a blue-shifted waveform. Blue-shifting is likely a response to petroleum-based LNAPL. The alternative is a red-shifted response where the orange and red peaks are dominant and indicative of DNAPL.

concentrations below this limit (St. Germain 2013a). The concentrations corresponding to the reporting limit represent low soil saturations indicative of residual (or no) NAPL.

The following observations were made on in-situ TarGOST logs. Locations of TarGOST borings are shown on Figure 5F-4; all TarGOST logs are included in Sub-attachment 2A-2.2 of Attachment 2A-2 in RI Appendix 2A. Select TarGOST logs discussed below are in Attachment 5F-2, Sub-attachment 5F-2.4.

- The difference between LNAPL and DNAPL can be seen in TG-14 and TG-46, where LNAPL and DNAPL were detected in the same boring. LNAPL TarGOST responses are from 13 to 16 feet bgs in TG-14 and 7 to 13 feet bgs in TG-46. DNAPL responses are from 19 to 22 feet bgs in TG-14 and 16 to 24 feet bgs in TG-46.
- Blue-shifted long-lived responses, interpreted as LNAPL, were encountered in the gully between Kite Hill and the Cracking Towers (NAPL Area 6, see Figure 5F-1). The response differs from MW-09 LNAPL (a more detailed comparison to the confirmation boring is discussed in Section 5.3 below). In the gully area (e.g., TG-36, TG-38), the green peak is predominant, which suggests a higher light hydrocarbon content. The waveform is indicative of petroleum-like material, with higher responses in peaks to the left (the blue and green peaks) compared to other NAPLs. The response appears as light green in the TarGOST log signal %RE. This gully LNAPL is best exhibited in TG-36 and TG-38, where it does not appear to be mixed or co-occur with other NAPLs.
- Red-shifted, very short-lived responses, interpreted as DNAPL, were encountered in the Harbor Patrol area. The waveform is indicative of coal tar-like material, with dominant peaks on the right (orange and red peaks). The response appears as deep orange in the TarGOST log signal %RE. TG-21 is a good example of the signature of this DNAPL.
- Overall, many logs show overlapping responses, potentially suggesting the mixing of different products (e.g., TG-39).
- The rapid increase in fluorescence in between zones of “clean” response suggests that lateral migration typical of DNAPL “fingering” occurred and DNAPL exists in thin discontinuous layers (e.g., TG-11).
- TG-31 shows zones of slightly elevated response, which is probably due to non-NAPL fluorescence such as soil (i.e., false positive): the simultaneous rise and fall of the scatter and fluorescence data often indicate a response to soil color/mineral fluorescence, not NAPL (St. Germain 2013b).

5.3. TarGOST Confirmation Samples

Six confirmation borings were completed next to TarGOST explorations. Confirmation soil sample TarGOST responses were compared to in-situ TarGOST responses. The soil confirmation boring samples represent a composite of a 1- to 4-foot zone, whereas response on the in-situ TarGOST logs is more precise (i.e., less than an inch). Sub-attachment 2A-2.3 of RI Appendix 2A presents the 11 TarGOST confirmation soil sample responses; multiple confirmation samples were collected for TG-11 and TG-39 because of their heterogenous response with depth. Figures 2A-2-1 to 2A-2-7 in Attachment 2A-2 of RI Appendix 2A, compare in-situ TarGOST explorations with soil confirmation samples TarGOST screening plus analytical results, field screening and geologic units. Figure 2A-2-5 does not have a confirmation soil sample but is included for comparison of in-situ TarGOST response and analytical results. Below are the main findings and observations. TarGOST logs for the confirmation samples are in Sub-attachment 5F-2.4.

- In some cases, TarGOST response to confirmation samples was weak compared to in-situ readings, likely reflecting the overall low NAPL saturations and thin NAPL intervals (i.e., NAPL is not pervasive in-situ), which resulted in low saturations when the sample was homogenized.
- An LNAPL response (similar to the LNAPL response encountered in TarGOST borings within NAPL Area 6, (i.e., gully area) was observed in confirmation soil samples GEI-12 (11 to 15 feet bgs) near the Cracking Towers and GEI-13 (8 to 9.5 feet bgs) adjacent to MW-09; Dakota noted a petroleum-like odor from both.
- The TarGOST response at GEI-12 (25 to 26 feet bgs), which shows a pink/purple signal %RE color and red-shifted waveform, suggests a coal-tar-like DNAPL.
- Based on TarGOST responses, confirmation soil samples GEI-12 (15 to 17 feet bgs), GEI-13 (13 to 16 feet bgs) and GEI-13 (23 to 24 feet bgs) also appear impacted with NAPL; however, a distinct type of NAPL was not identified.
- A direct relationship between signal %RE and the sum of PAHs with at least four rings was not observed for the split soil samples[9].

5.4. Classification Plots

Dakota prepared classification plots to help identify fluorescence signatures indicative of different NAPL types. All the AOI upland classification plots are presented in Sub-attachment 2A-2.4 of Attachment 2A-2 in RI Appendix 2A. For each exploration, all waveforms are plotted in a single x-y scatter plot.

- The x-axis is wavelength. The “center of gravity” of the four peaks of the waveform determines the x-axis position. More blue-shifted (shorter wavelength) waveforms will plot on the left.
- The y-axis is lifetime. The average lifetime (tau) of the four peaks determines the y-axis position. Longer-lived waveforms (i.e., broad peak bases) will plot higher.
- The fill color of the dots corresponds to the signal %RE in the TarGOST logs.

In Dakota’s report (Sub-attachment 2A-2.5 of Attachment 2A-2 in RI Appendix 2A), Dakota gives examples of classification plots for three logs with differing characteristics (note: the classification plots discussed below are in Sub-attachment 5F-2.4):

- TG-02 (in the northeast corner) shows a broad spread (dots are loosely grouped) of two waveform types (above the dark blue scatter on the classification chart), which indicates heterogeneity of the fluorescent materials, due either to differing NAPL types or a combination of NAPL and false positives.
- TG-21 (in Harbor Patrol) shows an opposite behavior: a tightly grouped cluster with little spread along the y-axis (lifetime), which indicates a single type of waveform or NAPL (i.e., homogeneous chemistry with depth)—in this case, a red-shifted coal tar-like DNAPL. The dots “stream” away from the dark blue (clean) cluster of dots along the x-axis, indicating variable degrees of contamination.

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[9] It should be noted that signal %RE is a function of both PAH concentration and solvent content of the NAPL. TarGOST may be most sensitive to moderate concentrations because of potential energy transfer, which quenches fluorescence at high PAH concentrations.

- TG-39 (in the gully area) shows a high degree of heterogeneity of fluorescent materials with three distinct clusters: one likely representing LNAPL; one likely representing DNAPL; and one likely representing a mixture of the two or a third type of NAPL.

Classification plots for the TarGOST explorations, combined with locations of potential historical sources and previous investigation results, were used to group NAPL impacts into the following areas (see Figure 5F-1):

- NAPL Areas 4 and 5A in the western region of the upland;
- NAPL Areas 6 and 7 in the gully;
- NAPL Areas 10 and 11 in the MW-09 vicinity;
- NAPL Areas 13 and 15 in the east shore; and
- NAPL Area 16 in the northeast corner.

Signature patterns were compared to %RE on the TarGOST logs and field observations when a confirmation boring or nearby boring was available. Approximate depths were inferred from fill colors and tau data.

Sub-attachment 5F-2.3 presents a classification plot for the LNAPL and DNAPL samples collected from AOI wells. A corresponding log for each NAPL sample is also included. The four DNAPL samples collected from the western region of the site group together, indicating very similar wave forms (short-lived and red-shifted).

5.5. NNLS/Waveform Analysis

NNLS waveform analysis was used on all TarGOST logs to identify closest “matches” to four components identified by GeoEngineers. The four components and corresponding TarGOST exploration and depth of the response are as follows (all NNLS logs are presented in Sub-attachment 2A-2.7 in RI Appendix 2A; the NNLS logs for the ones discussed below are in Sub-attachment 5F-2.4):

- Light 1 – Petroleum-like LNAPL from the gully harvested from TG-39 between 11.37 to 13.32 feet bgs;
- Light 2 – MW-09-like LNAPL harvested from TG-12 between 8.87 to 10.73 feet bgs thought to be representative of MW-09 LNAPL;
- Dense 1 – DNAPL occurring within the MGP footprint harvested from TG-15 northeast of the Cracking Towers between 27.31 to 28.68 feet bgs; and
- Dense 2 – DNAPL from Harbor Patrol and the former tar refinery harvested from TG-21 between 22.15 to 25.58 feet bgs.

Further discussion on this analysis is provided in Section 3.7 of Attachment 2A-2 in RI Appendix 2A.

Information from the waveform analysis was used to identify the closest component match[10] per depth interval within each log. Waveform analysis also aided in distinguishing other substances that generated a false NAPL positive (as identified by Dakota).

The Dakota report indicates that "a relatively wide variety of waveforms were observed at this site, indicating relatively high heterogeneity of fluorescing materials."

6.0 TARGOST INTEGRATION

This section summarizes the steps taken to understand TarGOST findings and relate them to existing AOI NAPL impact designations interpreted from other NAPL characterization data and chemical analytical results; such a process was necessary to map NAPL extent and fine-tune the CSM. The 2013 SI included upland TarGOST explorations (Figure 5F-4). Primary TarGOST explorations were advanced first, followed by step out explorations to delineate the extent of NAPL areas. It also included confirmation soil borings for comparison to the TarGOST explorations. The confirmation borings were field-screened and sampled for laboratory analysis.

A critical step to integrate TarGOST and NAPL impact designations is to establish the signal %RE value that represents the threshold between presence or absence of NAPL based on raw TarGOST data. To establish this cutoff point, three data types were analyzed: the raw in-situ TarGOST data logs, the visual NAPL observations recorded for the co-located confirmation borings, and the ex-situ TarGOST readings performed on split soil samples from the confirmation boring cores. Six co-located confirmation cores were completed adjacent to TarGOST probes, providing a total of 173 total feet of comparable observational data and in-situ subsurface TarGOST readings. The TarGOST tool was used to scan 11 ex-situ soil samples.

6.1. TarGOST Response vs. NAPL Occurrence vs. Analytical Results

Four different approaches were used to determine the TarGOST response signal cutoff appropriate to delineate the presence versus absence of NAPL using confirmation boring/TarGOST pairs. Each technique was intended to provide a line of evidence to select the most representative %RE cutoff value for NAPL presence versus NAPL absence. The following subsections describe techniques used to achieve this goal.

6.2. Visual Comparison of In-situ TarGOST Response to NAPL Occurrence

TarGOST log and confirmation boring pairs were plotted side by side on Figures 2A-2-1 to 2A-2-7 (Attachment 2A-2 in RI Appendix 2A) for comparison of %RE to field-observed NAPL occurrence and geology. Figures 2A-2-1 to 2A-2-7 also include ARI soil analytical results for TPAH, benzo(a)pyrene, naphthalene and the sum of heavier (greater than four ring) PAHs; TarGOST screening results for split soil samples (showing wave forms, %RE, fill colors, etc.); and TarGOST classification plots corresponding to the soil sample depths. The figures show the following:

- TarGOST responses successfully identified the two zones of NAPL (or "tar globules") in the borings (TG-11/GEI-13 from 15 to 24.5 feet bgs and TG-39/GEI-12 from 13 to 19 feet bgs). These results support that TarGOST is useful for identifying NAPL-impacted intervals.

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[10] It should be noted that the waveform analysis is a "best fit" technique. For example, waveform analysis that shows a best fit to "LIGHT1" does not necessarily imply that all of that %RE is attributable to LNAPL.

- In general, where there was a signal of greater than approximately 100 %RE, at least heavy sheen was also observed. Intervals of elevated TarGOST response generally had corresponding NAPL field observations of at least slight sheen and, in most cases, greater NAPL impacts.
- However, areas of field observations of slight to heavy sheens did not always have a TarGOST response. For example, some intervals of heavy sheen did not generate a TarGOST response (e.g., TG-42/GEI-6 from 11 to 21.5 feet bgs). Descriptions of “staining” suggest that sheens represent heavier residual impacts or more tar-like material in some cases. In other cases, such apparent discrepancies may be explained by heterogeneity.
- As expected, because of high viscosity or lack of mobile NAPL, intervals of tar-like material were not detected by the TarGOST probe or produced a minor TarGOST response (e.g., TG-39/GEI-12 from 23.5 to 26 feet bgs).

6.3. TarGOST Response vs. Field Observed NAPL Occurrence

TarGOST response was compared to field screening results by plotting total %RE and field-observed NAPL occurrence versus depth for co-located confirmation soil borings. Similar techniques have been used at other MGP sites (i.e., EPRI 2006). %RE versus field observed NAPL occurrence was plotted for four paired TarGOST explorations and confirmation borings (Figure 5F-5). The evaluation included relatively high %RE pairs (TG-11/GEI-13 and TG-39/GEI-12) and relatively low %RE pairs (TG-27/GEI-8 and TG-42/GEI-6). The following is gathered from the plots:

- The no-impact field observation category correlates well with low TarGOST responses. For depth intervals where “no impacts” were observed (NAPL impact Category 1), %RE was usually below 5 percent (less than 3 %RE, except for one 11 %RE response). This is most evident in pair TG-27/GEI-8 but also in pair TG-11/GEI-13 from 0 to 5 feet bgs and pair TG-39/GEI-12 from 18 to 23 feet bgs.
- The slight to moderate impact categories do not correlate very well with TarGOST responses.
- TarGOST successfully identified all zones of heavy sheen with NAPL (NAPL impact Category 5). Where field observations showed heavy sheen with NAPL, the TarGOST responses in the interval exceeded 50 %RE. As the heavy sheen with NAPL impact category represents NAPL that is most likely to be mobile, the paired boring comparison supports the ability of TarGOST to detect mobile NAPL. It should be noted that in most and perhaps all cases TarGOST might be responding to residual NAPL. Although TarGOST is a good tool for detecting mobile NAPL, it also responds to residual NAPL.
- TarGOST response to semi-solid to solid material (e.g., tar) is attenuated. Observations of stiffer non-mobile tars corresponded with relatively low TarGOST readings. For example, the %RE remained below 10 percent in the tar occurrence at TG-39/GEI-12 from 25 to 26 feet bgs.
- TarGOST appears to provide better resolution of NAPL impact with depth than field NAPL screening (e.g., TG-11/GEI-13 from 16 to 25 feet bgs and TG-39/GEI-12 from 5 to 15 feet bgs).
- There are depth shifts between field screening results and %RE response. For example, at TG-39/GEI-12 there is a decrease in observed impacts at 16 feet bgs versus a rapid decrease in %RE at 17 feet bgs, and at TG-42/GEI-6 an increase in observed impacts from 7 to 27 feet bgs versus an increase in %RE from 4 to 24 feet bgs. Depth shifts likely reflect site heterogeneity as the explorations are approximately 5 feet apart.

6.4. Statistical Evaluation of TarGOST Response and Field Observed NAPL Occurrence

ProUCL, a statistical software, was used to evaluate the range of %RE values corresponding to the various field observed NAPL impact categories. ProUCL box and whisker plots are presented in Figure 5F-6. The box plot for heavy sheen with NAPL has very little overlap with the other NAPL impact categories, suggesting %RE response to heavy sheen with NAPL is distinct (and higher than) %RE response to other, lesser NAPL impacts. Elevated %RE is a good indicator of zones with NAPL and meets the main objective of identifying and delineating areas of mobile and potentially migrating NAPL.

6.5. TarGOST Response versus Analytical Results

To correlate %RE with analytical results, split soil samples from the confirmation borings were delivered to Dakota and ARI for comparison to the co-located TarGOST explorations. Figure 5F-7 presents the %RE for the in-situ and ex-situ sample intervals and TPAH results for the ex-situ samples. In general, TarGOST “sees” heavier-weight PAHs (at least four rings). The following qualitative conclusions can be drawn:

- The in-situ TarGOST results generally match the confirmation soil sample (ex-situ) TarGOST results, with some exceptions, perhaps due to heterogeneities or sample preparation (mixing).
- %RE does not correlate with TPAH. The primary reason for lower than expected %RE (or higher than expected TPAH concentration) is that TarGOST responds to mobile NAPL, whereas much of the TPAH is associated with semi-solid to solid material (e.g., tar, black carbon) that has a relatively high TPAH concentration.

6.6. Inferred NAPL Presence

The methods used to establish the TarGOST %RE value to distinguish between the presence and absence of NAPL have limitations, such as reliance on professional judgment, poor core recovery and sample bias. Based on combined review of the analyses above, a site-specific TarGOST %RE response value of 10 %RE was selected as representing a lower bound, below which NAPL that has the greatest potential to be mobile is absent. The observed impact categories that have the greatest potential to be mobile are the “heavy sheen and/or trace NAPL” and “heavy sheen with NAPL” categories. This value is conservative inasmuch as Dakota (St. Germain 2014) indicates the cutoff for the AOI “should not be less than 10 %RE in light of the variability of the natural soil fluorescence (‘clean soil’) often approaching 10 %RE.” Although typical background values can vary widely from site to site, 50 %RE is often chosen as being indicative of NAPL presence based on multiple lines of site-specific evidence (St. Germain 2013a). For NAPL mapping purposes, responses above 10 %RE were assumed to represent “heavy sheen and/or trace NAPL” or “heavy sheen with NAPL” categories.

As described in Section 4.3 of Attachment 2A-2 in RI Appendix 2A, equivalent field observations (NAPL degrees of contamination) were assigned to TarGOST probe depth intervals. Observed NAPL impacts data were supplemented with the TarGOST data using equivalent field observations. Ultimately, TarGOST information in concert with NAPL field observations were used to map NAPL extent, as discussed in Section 7.1. Some TarGOST explorations near NAPL Areas 6 and 16 showed responses above 10 %RE that were purposely not included in the mapped extent of NAPL. Rationale is described below:

- Three TarGOST explorations south of NAPL Area 6 were not included in NAPL Area 6 (Figure 5F-9).
  - TG-32B (peak response of 15 %RE at an elevation of 15.19 to 14.39 feet United States Army Corps of Engineers [USACE]) and TG-35 (peak responses of 18 %RE and 38 %RE at an elevation of 20.01 to 18.81 feet USACE) were not included in NAPL Area 6 because these responses

were deemed to be representative of isolated impacts related to drier tarry material or “black, dry petroleum residue” identified at similar depths in nearby borings GEI-11 and MW-14. The depths of these responses were vertically incongruent with NAPL Area 6.

  - TG-31 (peak response of 17.5 %RE at an elevation of 19.85 to 19.65 feet USACE) was not included because waveforms do not match the closest TarGOST exploration in NAPL Area 6 and, according to Dakota, exploration TG-31 showed zones of false positives (slightly elevated responses probably due to background non-NAPL fluorescence such as soil color/mineral fluorescence): the simultaneous elevated rise and fall of both the scatter and elevated fluorescence data often indicate a response to soil color/mineral fluorescence, not NAPL.

- TarGOST exploration TG-09 (18 %RE response at about 18.6 feet USACE), just outside the southeast of NAPL Area 16, was not included in NAPL Area 16 because the waveform does not match the closest TarGOST exploration in NAPL Area 16 (Figure 5F-12).

7.0 NAPL AND TAR AREAS

The extensive NAPL data collected in the AOI has been used to identify NAPL areas and evaluate potential NAPL sources, stability, and transport and exposure pathways. The evaluation methodology used to identify and map where NAPL areas are and then evaluate the NAPL areas themselves are discussed in this section, as well as the distribution of NAPL within these areas and regions of the AOI.

7.1. Mapping Methodology

TarGOST readings were integrated with NAPL field observations as described in Section 6 to map NAPL extent in the upland portion of the AOI. In addition to TarGOST and NAPL field observations, NAPL and tar mapping considered geology; NAPL, soil and sediment chemistry (including ratios and special studies work); petrophysical results; and NAPL thickness in wells.

Areas of tar, LNAPL and DNAPL were mapped to support development of the CSM for the AOI. NAPL/tar maps provide a graphic interpretation of the distribution of tar, LNAPL and DNAPL. These maps can be used to infer potential historical sources and identify the relationship of tar and NAPL in the upland to that in the sediment to help identify potential upland-to-sediment migration pathways and, ultimately, identify any potentially active NAPL migration pathway to a receptor (i.e., in surface sediment). Potential exposure pathways to receptors are considered to be areas where NAPL is shallow and where NAPL is shallowing downslope and potentially converging with the mudline.

Figures 5F-1 and 5F-2 depict the inferred extent of NAPL as LNAPL and DNAPL (as identified by field observations of NAPL and/or TarGOST results), including both residual and mobile, and tar (as identified by field observations of tar or tar-impacted intervals of soil). The conceptual extent of NAPL depicted on Figure 5F-1 includes both observed occurrences of heavy sheen and/or trace of NAPL (likely residual) as well as areas of heavy sheen with NAPL (potentially mobile). On Figures 5F-1 and 5F-2, when two or more adjacent sample locations indicate the presence of NAPL or tar at a similar elevation and with similar descriptions, the maps depict an interpolated line around those sample locations. Interpolated lines are not drawn around single occurrences of NAPL or tar without similar occurrences in adjacent boring locations. The rationale and assumptions underlying this protocol are listed below:

- The observed presence of NAPL and tar at individual locations is compared to adjacent locations to determine whether available evidence supports an interpretation of connectivity between the locations.

This connectivity may be interpreted as a continuous area of NAPL or tar (e.g., connected stringers or veins of NAPL), in which case the adjacent locations are mapped as being connected.

- The interpreted continuity of NAPL and tar are designated by color as being tar (purple), DNAPL (dark blue), or LNAPL (light blue). The two types of NAPL may overlap each other (e.g., interpreted LNAPL overlying interpreted DNAPL) in plan view when more than one NAPL occurrence is observed in an area.
- The evidence used to interpret the continuity of NAPL and tar includes type (i.e., LNAPL, DNAPL, or tar) chemical similarities/differences, elevation and physical characteristics; the geologic unit is also considered.
- In most areas, the extent of NAPL or tar is assumed to extend halfway to sample locations in which no NAPL or tar was observed or documented.
- Tar in eastern offshore locations was mapped by diver observation and probing; probing maps are provided in RI Appendix 3H.
- Where sample locations are spatially distant, an interpretation of continuity relies on additional evidence, including physical characteristics of the material, location of the closest occurrence and stability. For example, DNAPL observed in subsurface sediment and inferred to be attributable to migration by gravity along a fine-grained unit is not interpreted to be continuous with DNAPL observed in surface sediment and inferred to be attributable to over-water release.
- Elevations of NAPL and tar were considered. NAPL at adjacent locations may not be interpreted to be connected if elevations are significantly different. Conversely, inferred downslope migration was used to connect DNAPL in areas where elevations differed. Downslope migration or inferred flow paths were used to interpret the lateral extent of NAPL in some areas.

The depth to NAPL (i.e., to the shallowest observed occurrence of NAPL) shown in Figures 5F-8 to 5F-12 is included for the evaluation of potential exposure of receptors. The purpose of tracking depth to NAPL is twofold: (1) to identify where NAPL is shallow and (2) to identify where NAPL is shallowing and potentially converging with the ground surface/mudline, which would only happen in a downslope and/or downgradient direction. The information used for these maps is field observations of NAPL impacts (heavy sheen with NAPL as well as heavy sheen and/or trace NAPL). As a conservative measure, these maps include the trace NAPL category, which reflects residual NAPL.

The elevations of top of NAPL shown in Figures 5F-8 to 5F-12[11] represent the shallowest observed occurrence of NAPL, as identified by field observations. The contours show the relative elevations of NAPL and can be used to better understand the nature and extent of NAPL, including historical and potentially ongoing NAPL movement (i.e., NAPL drains downward through unsaturated soil and DNAPL flows downslope).

Cross section interpretations on Figures 5F-13 through 5F-24 (NAPL cross sections E-E’ to P-P’) consider spatially relevant “out of plane” data as well as the interpreted extents of NAPL and tar depicted on the

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[11] Elevation of top of NAPL figures use ground surface elevations at time of boring, where available, to calculate elevation from depth. In offshore areas, sometimes the mudline elevation measured at time of coring does not match the bathymetry elevation. For this reason, the top of NAPL interpreted by the kriging sometimes is above the ground surface or mudline shown on bathymetry maps. To rectify this discrepancy, control points were inserted appropriately to modify the NAPL elevation to more closely match the bathymetry; however, some minor discrepancies could persist.

NAPL and tar maps. The observation of NAPL or tar at a single location that is interpreted as unconnected to adjacent locations is depicted through color-coding of the sample location symbols, and represents laterally discontinuous tar, DNAPL or LNAPL.

In addition to the physical data described above, the following chemical, UV photography, and TarGOST data were used to distinguish different types of NAPL and identify related and unrelated NAPL to map NAPL areas:

- NAPL chemical characterization – Chemical testing (for PAHs, alkylated PAHs, VOCs, SVOCs, TPH) and gas chromatograms distinguished between different NAPL types (e.g., benzene-rich LNAPL or naphthalene-rich DNAPL).
- Soil UV photography – Different UV fluorescence color schemes were used to identify different types of hydrocarbons, ranging from gasoline-range hydrocarbons to DNAPL.
- Data generated from TarGOST work (NAPL sample readings, in-situ soil probe readings and ex-situ soil sample readings) and ensuing analysis:
    - Response colors and corresponding waveform callouts on logs helped determine NAPL types and degree of mixing by depth.
    - Classification plots helped to differentiate NAPLs and weathering patterns, explain heterogeneity, correlate NAPL in nearby TarGOST explorations, and identify lateral distribution patterns.
    - NNLS waveform and primary component analysis helped to differentiate and identify comparable NAPLs in the AOI.

Specific examples of rationale for NAPL and tar area delineation and separation are provided below:

- NAPL Areas 1, 2, and 3 were interpreted to represent separate releases based on NAPL chemistry and/or the distribution of NAPL (e.g., depth to top of NAPL) using the following lines of evidence:
    - Area 1 versus Area 2 – NAPL impacts at GWS-GC06 (the closest location to Area 1 within Area 2) are relatively deep in sediment, whereas NAPL impacts in Area 1 are shallow (see Figure 5F-8). Furthermore, Area 2 appears to have petrogenic (i.e., petroleum) impacts that were not observed in Area 1.
    - Area 2 versus Area 3 – VOCs were not detected in Area 2, whereas they were detected in Area 3. Samples in Areas 2 and 3 that are closest together (ST-03 and GWS-EC13, respectively) do not appear chemically similar. Review of chemical data indicates low TPAH at GWS-EC15 (Area 2) as compared to GWS-EC13 (Area 3). Whereas Area 2 appears to have mixed DNAPL and petroleum impacts, Area 3 appears to have at least three distinct types of NAPL: a PAH-rich DNAPL; NAPL with petroleum; and a light DNAPL rich in naphthalene. Although chemistry suggests different NAPL types in Areas 2 and 3, the NAPL area outlines between the two areas are dotted (see Figure 5F-8) to indicate uncertainty whether the two areas of NAPL are separated (as mapped) or connected.
- NAPL Areas 8 and 9 were interpreted to be separated but the outlines between the two areas are dotted (see Figure 5F-9) to indicate uncertainty whether the two areas of NAPL are separated (as mapped) or connected. The following lines of evidence support separation of the two areas:
    - Vertical NAPL distribution – NAPL impacts are at different elevations and higher at NLU 418 than NLU 48, which does not support downslope migration from NAPL Area 8.

  - NAPL impacts occur in different geologic units – DNAPL is in shallow recent deposits and Qva at NAPL Area 8 and within deeper recent deposits and Qvr at NAPL Area 9 (Figure 5F-9).
  - There are samples between the two areas without a trace of NAPL – These samples (NLU07-US and NLU72-DC) are presented in Figures 5F-9 and 5F-10.
- The extent of related near-surface tar in sediment in the eastern sediment area at CR-10 and CR-12 (Figure 5F-2) was determined visually during diver probing near the shoreline or shallow subsurface investigation in early 2005.

7.2. NAPL Areas by Region

Three geographic regions have been identified to describe the nature and extent of NAPL in the AOI:

- Western Region (Figure 5F-8) – Upland area west and northwest of Kite Hill (includes Harbor Patrol), the northwestern portion of the AOI, and the offshore area south of Harbor Patrol and Kite Hill.
- Central Region (Figures 5F-9 and 5F-10) – Upland area adjacent to and beneath the Cracking Towers and extending west to Kite Hill, and the offshore area south of the Prow and west of the southeast-trending glacial till ridge.
- Eastern Region (Figures 5F-11 and 5F-12) – Upland east of the Cracking Tower area, extending to the eastern shoreline and north to the northern boundary of the AOI, including adjacent offshore areas.

Each region has unique geologic, hydrogeologic, NAPL and tar attributes, which are depicted on cross sections E-E’ to P-P’ on Figures 5F-13 through 5F-24. Descriptions of the regions, along with a summary of the nature and extent of NAPL and tar, are presented in the following sections. For each of the identified 16 individual NAPL-impacted areas (Table 5F-6 and Figure 5F-1), depth bgs and elevation of the top of the DNAPL and LNAPL are depicted on Figures 5F-8 through 5F-12. Depth is color-coded on these figures to identify the shallowest NAPL (green areas). The shallowest occurrence of NAPL at each location is contoured to provide a means of inferring historical migration and current stability (e.g., DNAPL migrates downslope).

7.2.1. Western Region

The western region of the AOI has five DNAPL areas, most of which are offshore, and one tar area. These areas are presented in Table 5F-6 and shown on Figure 5F-8. The following are the key findings for the western region:

- NAPL Area 4 is the sole upland occurrence of DNAPL in this region; the DNAPL in this area does not appear to extend offshore or impact shallow sediment (see cross section F-F’ in Figure 5F-14). As described below, there is a discontinuity in the elevation of DNAPL in the upland and offshore areas. This is the same DNAPL area investigated as part of the EPRI study (Attachment 2C-1 in RI Appendix 2C). Although the extent of the DNAPL area has been refined by new investigation results, current interpretations of this DNAPL area are consistent with the main conclusions of the EPRI study.
- NAPL Area 5A is the other upland DNAPL area in the western region. NAPL Area 5A is shallower than the underlying NAPL Area 4. NAPL Area 5A is potentially connected to the nearby offshore sediment NAPL Area 5B; this is shown on cross section G-G’ (Figure 5F-15). NAPL Area 5A appears to be related to former nearshore releases now buried by more recent fill. NAPL Area 5A and NAPL Area 4 are separated vertically by unimpacted soil (see cross section G-G’). Cross section O-O’ (Figure 5F-23)

shows the NAPL occurrences for NAPL Areas 4 and 5A along the shoreline; the shallow heavy sheen with NAPL (dark green sections in the fill unit) of PT-03 and GEI-14 correspond to NAPL Area 5A.

- NAPL Area 5B is offshore from Harbor Patrol and Kite Hill. Depth to the top of NAPL for NAPL Area 5B can range from near surface to greater than 9 feet below mudline (bml) (see depth to NAPL shading in Figure 5F-8). It is present within the fill, recent and recessional outwash units, as shown in cross sections F-F' and G-G' (Figures 5F-14 and 5F-15). This DNAPL area consists of a complex, mostly PAH-rich DNAPL with localized differences in chemistry and appears to be contiguous with naphthalene-rich DNAPL farther offshore at depth. With the exception of the narrow lobe (NAPL Area 5A—see cross section G-G' in Figure 5F-15), NAPL Area 5B does not extend into the upland, based on the following:
    - To the east, shoreline explorations south of Kite Hill did not encounter DNAPL (see Figure 5F-16, cross section H-H'), which indicates that the eastern part of this DNAPL area does not appear to represent laterally continuous NAPL extending from upland to offshore.
    - To the west, upland and offshore DNAPL are vertically offset, with the southern edge of upland DNAPL (NAPL Area 4) lower than the northern edge of offshore DNAPL (NAPL Area 5B), as shown in cross section F-F' (Figure 5F-14).
- The three far west offshore NAPL Areas 1, 2 and 3 are present in the fill and recent geologic units (see cross section E-E' in Figure 5F-13). Depth to top of NAPL can range from near surface to greater than 9 feet bml (see depth to NAPL shading in Figure 5F-8). The three areas do not appear to be "contiguous" because they have different chemistry, which is potentially indicative of different sources, including petroleum components, as presented in Attachment 5F-4.
- NAPL Areas 3 and 5B were mapped as separate NAPL areas because of the intervening sediment core 4-4 without NAPL, inferred downslope migration from nearshore sources and chemistry (interpolated distribution of TPAH).
- The contiguous area of tar (Tar Area 1) mapped in the upland north of Kite Hill (Figure 5F-2) was observed to be approximately 3 to 8 feet bgs. This area corresponds to the area where tar was removed in 1997 (Parametrix and Key 1998).

7.2.2. Central Region

The central region has three DNAPL areas and one LNAPL area. Tar occurrence is limited to discrete tar bodies in the fill. These NAPL areas are presented in Table 5F-6 and shown on Figures 5F-9 and 5F-10. Key observations in this vicinity are as follows:

- Upland DNAPL and LNAPL areas (NAPL Areas 6 and 7) are located west of the Cracking Towers and depicted on cross section I-I' (Figure 5F-17). These do not appear to extend to the shoreline, judging from the decreasing TarGOST response and absence of NAPL in eight upland borings near and along the shoreline.
- Offshore NAPL impact areas are smaller and cover a smaller proportion of this region compared to the western and eastern regions. Two DNAPL areas are identified in cross section J-J' (Figure 5F-18). NAPL Area 8 is approximately 100 to 200 feet offshore; depth to top of NAPL can range from near surface to 2 feet bml (see green in Figure 5F-9). NAPL Area 9 is farther offshore and at greater depth below the mudline.

7.2.3. Eastern Region

The eastern region has four areas each of DNAPL, LNAPL and tar. The northeastern LNAPL and DNAPL areas are comingled and mapped as a single mixed LNAPL/DNAPL area. The majority of NAPL in the upland portion of this area is LNAPL or co-occurring DNAPL and LNAPL (Figure 5F-1). Along the shoreline and offshore, DNAPL and tar are more prevalent. NAPL and tar areas in the eastern region are presented in Table 5F-6 and shown on Figures 5F-11 and 5F-12. The following key observations inform the AOI CSM in this vicinity:

- The only apparent “contiguous” upland-to-sediment NAPL area is NAPL Area 15 along the eastern shoreline, as shown in cross section L-L’ (Figure 5F-20).
- Although multiple monitoring wells are screened in or directly downgradient of the DNAPL and LNAPL areas, DNAPL has been observed in MW-09 only. LNAPL has been observed in MW-09 in NAPL Area 11 and in NAPL Area 13 (MW-44S and MW-45S contain LNAPL).
- DNAPL in NAPL Area 10 and LNAPL in NAPL Area 11 are shown in cross section L-L’ (Figure 5F-20). Based on TarGOST, the elevation of the top of the DNAPL in NAPL Area 10 is about 4 feet below the base of the LNAPL in NAPL Area 11; well gauging generally indicates a 7-foot separation between the base of LNAPL and top of DNAPL. Hence, although both LNAPL and DNAPL have been detected in MW-09, it is unclear whether NAPL Areas 10 and 11 are commingled.
- LNAPL rich in monoaromatic hydrocarbons, namely BTEX, was observed in NAPL Area 12. This monoaromatic-rich LNAPL, believed to represent benzol (referred to as “light oil” in this RI and other references) has been observed in only the southeast corner of the AOI. LNAPL in the shoreline area of NAPL Area 12 has been remediated such that it is no longer a source of groundwater impacts.
- LNAPL in NAPL Areas 11 and 13 and DNAPL in NAPL Areas 10 and 15 do not appear to be connected, as shown on cross sections L-L’ and M-M’ (Figures 5F-20 and 5F-21). Separation of the LNAPL areas is based on chemical differences, geologic controls and intervening borings (see cross section L-L’). DNAPL appears to be separated on the basis of geologic controls.
- Offshore DNAPL in NAPL Areas 14 and 15 slopes downward to the east, as shown in Figure 5F-11 and cross sections K-K’, L-L’ and M-M’ in Figures 5F-19, 5F-20 and 5F-21, respectively.
- In the northeastern portion of the upland, NAPL Area 16 is present primarily in the fill, as shown in cross section N-N’ (Figure 5F-22). The NAPL is a mixture of LNAPL and DNAPL. NAPL Area 16 extends toward the shoreline but does not appear to enter the sediment area.
- Tar is most prevalent in this region. Tar Area 5 (shown in cross section N-N’ on Figure 5F-22), also known as the “tar mound,” is in the northeast corner; this tar mound is locally present at the surface. Two other near-surface tar bodies (Tar Area 3 shown in cross section L-L’ in Figure 5F-20 and Tar Area 4) are present in the fill directly above DNAPL-impacted sediment. Another deeper tar body of limited extent (Tar Area 2) is in the southeastern shoreline; related explorations are shown in shoreline cross section P-P’ in Figure 5F-24). Small tar bodies have been observed along the eastern shoreline (Figure 5F-2); most of these occur along the seasonally submerged bank in eroded fill areas. Several of these solid tar bodies have been removed.

8.0 STABILITY EVALUATION

This section describes evidence determining the stability of NAPL in the AOI.

8.1. LNAPL

Because LNAPL is less dense than water, it tends to accumulate and migrate near the water table. Under unconfined conditions, rising or falling groundwater levels will create a "smear" zone of LNAPL in the soil as NAPL is displaced by water and vice versa. The following lines of evidence show that LNAPL in the AOI is stable:

- Petrophysical testing of LNAPL-impacted soil along the eastern shoreline (e.g., free product mobility, saturation) as shown in Table 5F-5, demonstrates that NAPL saturations do not change significantly before and after being subject to (centrifugal) forces equal to 1,000 times the force of gravity during free-product mobility testing. Analytical saturation data show a maximum LNAPL saturation of 46.6 percent pore volume (%Pv) at PT-02 (NAPL Area 13) along the eastern shoreline. However, this saturation did not change at all before and after testing, which indicates stability. The remaining LNAPL samples had saturations ranging from 4.8 to 20 %Pv. Only one of these four remaining LNAPL samples showed a change in saturation during testing, and the change was slight (0.1 %Pv). Similarly, change in NAPL saturation was low for the mixed LNAPL and DNAPL NAPL Area 16; the highest change for this area was 1.5 %Pv.
- Monitoring well NAPL thicknesses (see Table 3J-2 in RI Appendix 3J):
  - Of the water table monitoring wells screened within LNAPL-impacted areas, only two have measurable thicknesses of NAPL. The lack of LNAPL in other wells indicates that LNAPL surrounding the well is residual.
  - LNAPL presence in three wells (MW-09, MW-44S and MW-45S), indicates the LNAPL is sufficiently mobile in surrounding soil to accumulate in a well. However, data indicate that LNAPL is not migrating (i.e., incapable of moving from one location to another). Preferential flow into the well may occur even though the NAPL is not migrating because, for example, the well may have penetrated a trapped pocket of NAPL.
  - MW-09 – Low-permeability fill (clay) overlying LNAPL in the MW-09 area may act to confine the LNAPL during periods of high groundwater levels. Confined LNAPL observed in the vicinity of MW-09 could explain exaggerated well thickness (see Figure 2A-8-1 in Attachment 2A-8 of RI Appendix 2A). There is no LNAPL in adjacent wells located east and south of MW-09. The baildown test indicate that LNAPL is very slow to recover (i.e., low NAPL transmissivity) and likely not migrating.
  - MW-44S and MW-45S – A small amount of LNAPL has been measured in these wells (maximum measured thickness of 0.34 feet). Downgradient wells (e.g., MW-46S) have not accumulated LNAPL, which indicates mobile LNAPL is localized and not migrating.
- The LNAPL gradient influences LNAPL stability. Where the top of the LNAPL is flat, it has generally stabilized and is no longer migrating laterally. Where the top of the LNAPL slopes downward more steeply, LNAPL is more likely to be migrating because there is a driving gradient. Elevation contours for top of LNAPL as depicted in Figures 5F-10 and 5F-12 show LNAPL gradients. NAPL Areas 6, 11, 12, and 13 are all relatively flat (i.e., low gradients), with some exceptions such as the southern tip of NAPL

Area 12[12]. In general, site LNAPL has "pancaked"— it is only present in the smear zone and is no longer migrating because there is no (or a limited) NAPL gradient, and the hydraulic gradient is unlikely to be sufficiently strong to mobilize LNAPL.

- Combined with gradient information, depth contours for the top of LNAPL as depicted in Figures 5F-10 and 5F-12 can be used to identify areas of potential NAPL exposure. Most LNAPL impacts are at depths of greater than 4 to 5 feet bgs, with two exceptions in the former air sparge area. Although LNAPL migration is unlikely, two areas of potential current or future exposure have been identified by comparing LNAPL gradient, topographic slopes and LNAPL depth:
  - The southeastern tip of NAPL Area 13 (around TMS-7) is an area where LNAPL could potentially be exposed because the depth to LNAPL is less than 2 feet bgs, LNAPL shallows toward the shoreline, and erosion could uncover and expose LNAPL (see Figure 5F-12 and cross section L-L' [Figure 5F-20]).
  - The eastern edge of NAPL Area 12 (around B-2) is the second area where analysis of LNAPL depth (depth to LNAPL is less than 2 feet bgs) and topographic slope suggest erosion could uncover and expose LNAPL. However, this area has been remediated; to the extent LNAPL impacts are still present (they are thought be absent), they are present to a much more limited extent than depicted on the map (see Figure 5F-12).Because this area was remediated and the shoreline has been stabilized, there is no longer a threat of LNAPL becoming exposed.
- Areas of potential LNAPL migration are those areas having the highest observed NAPL impacts (heavy sheen with NAPL) and higher TarGOST responses—specifically, NAPL Area 6 in the gully west of the Cracking Towers. However, TarGOST borings delineate the lateral extent of this LNAPL; the LNAPL does not extend to the shoreline and, because of its flat gradient, does not appear to be migrating.
- Based on comparison of NAPL areas with soil and sediment chemistry, the LNAPL areas with the highest concentrations of TPAH and benzene are NAPL Area 6 in the gully and NAPL Area 13 along the eastern shoreline. Other areas of LNAPL (e.g., Areas 11 and 12) have lower concentrations. Except for NAPL Area 13, concentrations indicate LNAPL saturations are low.
- Petrophysical testing shows that NAPL Area 13 has had several rounds of investigation; four samples were submitted for petrophysical testing, including free-product mobility testing (which includes testing of NAPL saturation). Only one of the tests showed a change in saturation when subjected to 1,000 times the force of gravity—PT-01B at a depth of 11 to 13.2 feet bgs changed from 6.8 to 6.7 percent saturation; this location is approximately 85 feet upgradient from the shoreline. Petrophysical testing at shoreline locations indicate LNAPL is residual. These results are corroborated by downgradient well MW-46S and shoreline well MW-51S—that have not accumulated NAPL.

8.2. DNAPL

DNAPL distribution in the AOI is more complex than LNAPL and involves shallow lateral migration, deep lateral migration and downward migration. The following discussion analyzes DNAPL migration as a liquid. Ebullition (migration in/on gas bubbles) is not considered in this analysis; there have been rare observations of sheen on Lake Union that could be attributed to ebullition. The following lines of evidence suggest that DNAPL is stable and not migrating:

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[12] In the air sparging/soil vapor extraction area and has been remediated.

- Petrophysical testing of DNAPL-impacted soil in several areas of the AOI (free product mobility results) as shown in Table 5F-5, demonstrates that NAPL saturations are generally low or do not change significantly before and after testing. In most cases, starting saturations of DNAPL are low relative to water and therefore the DNAPL is unlikely to migrate. Within DNAPL Areas, there was no change in NAPL saturation where the highest NAPL saturations were measured (PT-03 corresponding to NAPL Areas 4 and 5). The two locations with the highest change in NAPL saturation of 3.2 %Pv are TDW-2 and TSB-2. At TDW-2, within NAPL Area 4, NAPL is located in thin, likely discontinuous lenses in recessional outwash with limited potential for migration to sediment. TSB-2 represents isolated NAPL impacts in deep fill. At both locations, NAPL saturation is low (less than 6 percent) and unlikely to migrate (Attachment 5F-3). The change in NAPL saturation was low for the mixed LNAPL and DNAPL NAPL Area 16; the highest change for this area was 1.5 %Pv. Petrophysical data support stability of NAPL at the shoreline in NAPL Areas 4, 5, 15 and 16.
- Monitoring well NAPL thicknesses (Table 3J-2 in RI Appendix 3J):
    - Most monitoring wells screened within DNAPL-impacted areas do not have measurable thicknesses of NAPL, which indicates that DNAPL surrounding the well is residual.
    - DNAPL is currently present in several wells—mostly in NAPL Area 4 with one well in NAPL Area 10. DNAPL in these wells is slow to accumulate and, based on the depth and location of these wells, DNAPL migration to sediment is considered unlikely.
    - NAPL has not been observed in shoreline wells along the Prow, thus indicating that NAPL Area 6 and 7 did not migrate to the shoreline in this region.
    - There has been no observable DNAPL in wells located east and south of MW-09 along the shoreline. Well pair MW-41S/D directly east and downgradient of MW-09 has not accumulated NAPL, thus indicating that NAPL is not migrating. Shoreline wells in this area have not accumulated NAPL despite being in the core of the shoreline NAPL areas (MW-36S, MW-36D, MW49D, MW-50D and MW-52D) or directly downgradient of NAPL areas (MW 39S, MW 39D and MW-40S) (see shoreline cross section P-P' in Figure 5F-24). Although NAPL impacts were observed in the soil during drilling of wells MW-36S and MW-36D, NAPL has not been observed in any of the five shoreline wells within NAPL Area 15, which indicates that the upland DNAPL is not migrating (although historically may have migrated).
- The viscosity and density test results (Table 5F-2) indicate that AOI DNAPL generally tends to have high viscosity, which limits mobility. Furthermore, as the DNAPL ages and weathers, it becomes more tar-like. At several locations, all that remains at depth and farther from the release is staining or tarry impacts (e.g., cross section I-I'); this indicates reduced mobility with time and distance from the release locations. Insight into DNAPL weathering has been provided by studies showing that DNAPL forms a "tar" skin at the contact with water as it weathers (Luthy et al. 1993).
- Several types of site-specific data are available to help evaluate mobility of NAPL. Despite generally good spatial coverage of mobility data, DNAPL areas with limited mobility data remain (e.g., offshore). Physical properties of soil and sediment and stratigraphic controls are key factors for DNAPL mobility (DNAPL tends to follow preferential pathways downward). For example, DNAPL has been observed to "vein" through the weak, unconsolidated recent lacustrine deposit, indicating downward migration from the initial release). In the western upland area, DNAPL appears to have "stepped down" in outwash deposits, occurring progressively deeper and at a lower elevation away from the source area (see Figure 5F-14 NAPL cross section F-F'). Age of release also has a role in evaluating mobility of NAPL. Conceptually, DNAPL is immobile in the upland because of drainage (DNAPL has had time to migrate), because it has been depleted (i.e., migrating NAPL has become residual), or because it has reached a (capillary) barrier. Where there is downslope migration of DNAPL in sediments, the driving force has dissipated or is dissipating.

- Areas of DNAPL with potential for mobility are those areas having the highest NAPL impact category (heavy sheen with NAPL) and highest TarGOST responses—specifically NAPL Area 10 just west of MW-09. However, borings mostly delineate the lateral extent of this DNAPL; the DNAPL does not extend towards the lake and, because of its flat gradient, does not appear to be migrating. Furthermore, the gradient is towards the interior of the park, as opposed to towards the lake.
- Soil and sediment chemistry suggest relatively low saturations.
- The DNAPL gradient influences potential DNAPL migration: where the top of the DNAPL is flat, there is generally limited potential for lateral migration of DNAPL and for DNAPL to become exposed at the ground or sediment surface; if DNAPL is still migrating, only downward migration is expected. Where the top of the DNAPL slopes downward more steeply, DNAPL has a greater potential to migrate because, if sufficient saturations exist, there is a driving gradient. Elevation contours for the top of DNAPL as depicted in Figures 5F-8, 5F-9, and 5F-11 show the direction of DNAPL gradients. In general, DNAPL impacts appear to show a downslope gradient along the geologic contacts, which dip downwards toward the southwest off the western shoreline, and downwards toward the east off the eastern shoreline.

8.3. Tar

In general, tar occurrences in the AOI are discrete isolated tar bodies or have been delineated and are considered to be stable except for localized areas along the eastern shoreline (Figure 5F-2). Tar Area 5 (i.e., the tar mound) is a potential exception—evidence of movement in the form of new tar “fingers” or small lobes was observed in 2008 (Floyd|Snider 2008a). One mechanism for tar movement at these shoreline locations is upward seepage, where shallow buried tar bodies mobilize during or following a hot weather period in response to soil warming.

Free product mobility test results also indicate that tar has a low potential for mobility. A sample containing tar from the northeast corner (sample SB-12A-S6; see Table 5F-5), described as multiphase matrix (in addition to the tar, there was tar/black carbon), was analyzed for free product mobility. Although pore volume saturation was relatively high (approximately 89 percent), petrophysical testing indicated low mobility (i.e., change in saturation of 0.9 %Pv).

8.4. Conclusions

Given the length of time since original release, it is likely that most of the NAPL and tar exists in a residual state and has stabilized in the AOI. Minor exceptions are ebullition and tar seeps such as at Tar Area 5—the tar mound. The NAPL that is not residual (i.e., mobile NAPL) has likely become trapped or reached a condition where it is no longer capable of further migration (e.g., due to a capillary barrier or accumulation above a layer impervious to NAPL migration). Areas where NAPL and tar have been observed at or near the soil or sediment surface has been limited to uncapped areas and appears to reflect erosion and not ongoing migration.

9.0 NAPL AND TAR CONCEPTUAL SITE MODEL

This section presents the NAPL CSM for the AOI, which includes a NAPL source evaluation, discussion of NAPL fate and transport, and identification of potential NAPL exposure pathways. This section focusses on NAPL because it is the main concern due to potential transport and leaching of contaminants.

9.1. Source Evaluation

The following approaches were used to evaluate potential sources of NAPL and tar in the AOI:

- Tar and NAPL maps and cross sections were used to delineate discrete tar and NAPL occurrences to identify potential source locations.
- NAPL elevations and gradients were used to help identify the general locations of sources. For example, NAPL gradients were used to infer the direction of migration and, hence, where it originated.
- NAPL chemical data were used to identify and separate different types of NAPL.
- The AOI operational history (RI Appendix 1A) and individual MGP structures (RI Appendix 1B) were reviewed to identify facilities and processes that managed or generated raw materials, byproducts, and products indicative of the types of NAPL and tar identified. These facilities/processes are potential historical sources of NAPL.
- The locations of potential historical sources were overlaid with tar and NAPL areas.

Below are the findings of the source evaluation for tar and NAPL.

Most tar occurrences in the upland cannot be traced back to specific sources because it was deposited as part of fill (i.e., not connected to specific point sources) or redistributed as a result of extensive reworking over time. Tar in sediment appears to have been from overwater spills. The primary source for these spills appears to have been the tar loading dock that was located near the largest area of tar in sediment (Tar Area 3, see Figure 5F-2). The historical sources and NAPL/tar areas overlay map (Figure 5F-25) shows the proximity of Tar Area 3 to the former tar loading dock.

NAPL was historically spilled in the upland and over water. NAPL mapping and chemical data described in Section 7 were used to distinguish different types of NAPL and the general locations of sources. Potential sources were identified (see RI Appendix 1B) as shown in the historical sources and NAPL/tar areas overlay map (Figure 5F-25). Most potential historical sources were removed long ago. Possible exceptions are the water-gas-circulator liquor well and tar separator in the northeast corner of the present-day park (see RI Appendix 1B). These structures still exist but have not been in use for over 60 years. Although this overlay approach identified potential historical sources, specific sources of NAPL in the upland generally cannot be traced back to historical sources due to the excavation and off-site disposal of soil from beneath many of the potential sources (see RI Appendix 1B) and subsequent regrading of shallow soil during park redevelopment.

NAPL in sediment appears to have originated from overwater sources and, to a lesser degree, migration from the upland. In most cases, NAPL in the upland does not appear to have reached Lake Union sediment. The exceptions are NAPL Areas 5B and 15, where continuous areas of DNAPL are mapped in the upland and offshore (Figures 5F-8 and 5F-11). However, the vast majority of NAPL in sediment appears to have originated from overwater releases at or near the shoreline.

It is difficult to determine specific sources of NAPL in the sediment because there was a lot of overwater activity in Lake Union during the industrial era in the first half of the twentieth century. NAPL areas likely originated from multiple sources or multiple releases/spills from an individual source. For example, in NAPL Area 15, the presence of several areas where NAPL is found at higher elevation (Figure 5F-11) indicates the possibility that NAPL Area 15 DNAPL originated from multiple spills/releases, potentially both upland

and offshore. Overwater sources likely include docks where products were received or shipped off-site. For example, spills from the historical MGP tar loading dock and the oil dock (RI Figure 1-5) on the eastern shoreline likely contributed to NAPL Areas 14 and 15, respectively. Historical and active docks along the western shoreline, within and west of the AOI, were also potential sources.

9.2. Fate and Transport

This section focuses on historical DNAPL fate and transport. The emphasis is on historical transport because, with minor exceptions, tar and NAPL are stable and no longer migrating. Historical tar and LNAPL fate and transport are also briefly described. DNAPL is discussed in more detail because its widespread, complex distribution is an important part of the AOI CSM, which has implications for development of remedial alternatives in the Feasibility Study (FS).

9.2.1. Tar

Tar has not migrated very far from where it was originally deposited or moved. Tar emergence or seeps have historically been observed in uncapped areas of the AOI upland (Figure 5F-2), typically during or after prolonged hot weather periods. Heat—which decreases viscosity and allows tar to flow more readily—appears to have been the main cause of tar seeps. In addition to heat, burial and erosion may contribute to the emergence of tar. Burial during the original placement of fill or park redevelopment increases the load (i.e., pressure) on subsurface material and could have mobilized subsurface tar. Erosion can expose subsurface tar bodies or create pathways for tar to seep to the surface. Although erosion may explain the occurrence of tar at the ground or seasonally exposed lakeshore surface in some areas, the main controlling factor for tar mobilization and seeps appears to have been surface heating. The most recent observations of tar at the surface has been along the uncapped shoreline (Floyd|Snider 2008b). Many of these observations represent erosion uncovering small tar bodies and not recent seepage to the surface. No new tar seeps have been observed over the past 12 years.

9.2.2. NAPL

NAPL migration is controlled by the rate and volume of the release, NAPL characteristics, and the characteristics of the media it encounters. Soil and sediment characteristics that control NAPL migration include preferential pathways and the presence of fine-grained soil and sediment that impedes migration.

9.2.2.1. LNAPL

LNAPL migration is less complex than DNAPL. Because LNAPL is less dense than water, it tends to accumulate near the water table. LNAPL can penetrate deeper if a release is sufficiently large or the NAPL gradient is high enough to drive it deeper, but this is an exception. LNAPL tends to migrate laterally near the water table and “pancake” (i.e., flatten) after the release has ended. The distance LNAPL migrates is limited by the volume of the release and gradients. LNAPL gradients that drive migration dissipate with time and distance from the point of release. LNAPL changes from migrating to mobile (but not migrating) and residual as it migrates. LNAPL migration can be impeded by geologic (e.g., capillary) barriers as described in Section 9.2.2.2 below for DNAPL.

LNAPL is mostly in the fill unit. Migration was mostly horizontal in the saturated zone—at or slightly below the water table. All LNAPL areas have been delineated, and LNAPL is mostly in a residual state. Lines of evidence that LNAPL is mostly residual and little if any LNAPL is still migrating include the dissipation of the head that drives migration (i.e., historical sources—the driving head for migration—no longer exist), low NAPL saturations relative to water, stability of saturation under pressures equal to 1,000 times the force of gravity, absence of measurable LNAPL in most monitoring wells, and very slow recovery in the baildown test.

9.2.2.2. DNAPL

The distribution of DNAPL in soil and sediment is explained by migration characteristics, which have been observed at numerous sites and the subject of many publications. DNAPL is denser than water. In soil and sediment, water is preferentially attracted to the solids and coats grains (i.e., water is the wetting fluid). In saturated soil and sediment, water occupies the margins of larger pore spaces and fills the smaller pores (Section 2.3, Inset A). DNAPL migrates through the interior of larger pore spaces and initially through a continuous network of interconnected pores containing DNAPL (Section 2.3, Inset B).

DNAPL migration is controlled by capillary forces (Schwille 1988). Fine-grained soil and sediment have smaller pores and higher capillary pressures that resist the entry of the non-wetting fluid (i.e., NAPL) into pores. If capillary pressure is sufficiently high, there is a capillary barrier that stops or diverts migrating DNAPL. Conversely, DNAPL will flow downward via gravity in areas where there are no capillary barriers (e.g., fine-grained soil or sediment layers are absent). Small differences in grain size might provide enough capillary resistance to form a barrier to flow. Upon encountering a barrier, DNAPL might flow laterally along coarser-grained layers (Cohen and Mercer 1993). As DNAPL migrates, a portion of its volume is depleted as it sorbs to organic matter (e.g., black carbon) and is trapped in interstitial spaces by capillary forces.

Consideration of scale helps inform the complexity of DNAPL migration and distribution. On a large scale (tens to hundreds of feet), DNAPL migration will be controlled by soil and sediment layers. Barriers to flow and pathways of preferential flow that might control DNAPL migration can also vary on a smaller scale (inches to feet) due to variations in a soil or sediment layer or the presences of larger material (e.g., shells). On still a smaller scale, DNAPL will migrate laterally and downward through the soil or sediment, depending on the architecture of the pore space (size, distribution, and connectivity of pores). DNAPL occurrence is by nature heterogeneous because the pore architecture that controls migration is heterogeneous.

DNAPL tends to migrate along preferential pathways such as coarse layers (e.g., sand stringers), fractures, seams, and veins). As a result, DNAPL distribution is complex, and DNAPL might occupy a small percentage of the overall volume of NAPL-impacted soil or sediment.

In the AOI, DNAPL migration from the upland in NAPL Areas 5A and 15 was through the fill and outwash units. DNAPL appears to have migrated downslope through the subsurface in these units away from the upland (see Figures 5F-15 and 5F-20). DNAPL released over water would have settled to the bottom of the water body (i.e., mudline) and, if sufficient volume was released, penetrated sediment. DNAPL migration through sediment would have been controlled by the slope of barrier layers and the distribution of preferential flow pathways. Downward and lateral DNAPL migration would have been influenced or controlled by preferential pathways (fractures, seams ,and veins) in the recent lacustrine deposit and coarser layers in outwash deposits. In the AOI, outwash unit layers slope away from the upland beneath Lake Union, so DNAPL migrating above and within the outwash would have migrated downslope beneath the lakeshore and lake slope zones. Downward migration might have continued until a barrier such as the till unit was encountered, thus impeding its migration. DNAPL migration would have continued until the DNAPL volume was depleted (i.e., migrating DNAPL becomes residual DNAPL) or it reached a dead end (i.e., barrier), where it could no longer migrate downward or laterally.

The fate and transport and resulting distribution of DNAPL in sediment were evaluated though NAPL cross sections and by mapping the depth to and elevation of the top of DNAPL (Figures 5F-8, 5F-9 and 5F-11).

NAPL cross sections exhibit various transport mechanisms that contribute to the complex distribution of DNAPL. A general observation is that close to historical source areas in the upland, DNAPL tends to form a larger, more contiguous impact area in soil and its depth is controlled by the geologic layering. Farther from historical sources, DNAPL tends to exist in fingers or lenses and along fractures, seams, and veins. The following observations of historical DNAPL migration are depicted in cross sections:

- DNAPL from overwater and nearshore releases historically migrated downslope and farther offshore at or near the sediment surface (Figures 5F-13, 5F-14, 5F-15, and 5F-16).
- DNAPL spread laterally, or was deposited over a broad area, on the flat lake bottom and subsequently buried over time[13]. Near-horizontal NAPL surfaces in sediment at NAPL Area 1, the north part of NAPL Area 2, and the southwest parts of NAPL Areas 3 and 5B (Figure 5F-8) suggest historical lateral spreading or widespread deposition of oil-particulate aggregates (forming in-situ deposited NAPL sediment) on the flat lake bottom (Figures 5F-13 and 5F-14) from overwater releases close to these areas.
- In other areas (e.g., NAPL Areas 3 and 5B, see Figures 5F-13 and -14), evidence of vertical (downward) migration through the lacustrine sediment unit (Ql) has been observed[14].
- Downslope subsurface migration has also contributed to the distribution of DNAPL, which has resulted in offshore deepening of DNAPL. The distribution of DNAPL suggests downslope migration through recent lacustrine sediment (QL) and the recessional outwash (Qvr) units. Figures 5F-19, 5F-20 and 5F-21 show downslope migration through the lacustrine unit (Ql). Figures 5F-14, 5F-15, 5F-18, and 5F-20 show downslope migration away from the shoreline above and within the relatively permeable glacial recessional outwash unit (Qvr).
- DNAPL also migrated along preferential pathways within the lacustrine sediment unit (Ql), as exhibited by the presence of thin and isolated zones of DNAPL at depth, which suggests some component of lateral migration in the lacustrine unit (e.g., Figure 5F-20).
- In NAPL Areas 3, 8 and 15 (Figures 5F-13, 5F-18, and 5F-20), DNAPL appears to have migrated preferentially near the top of the recessional outwash (Qvr); in these cases, it is assumed that finer-grained beds within the outwash recessional unit form capillary barriers that prevented penetration; this same phenomenon was observed during the EPRI study (EPRI 1999).

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[13] In the western area, "oily" near-surface sediment identified as NAPL by investigators may represent oil-particulate aggregate (OPA) deposition from oil (e.g., petroleum) spills. As oil at the water surface weathers, oil droplets become coated with particles and sink. OPA deposition can form in-situ deposited NAPL sediment that eventually is buried, forming a layer or layers in sediment (Johnson 2018).

[14] Core logs provide examples of where DNAPL is observed along vertical fractures, seams, and veins, suggesting vertical migration.

Depth to DNAPL and DNAPL Elevation Maps (Figures 5F-8, 5F-9 and 5F-11) were also used to evaluate the distribution and fate and transport of DNAPL:

- Depth to DNAPL mapping identified areas where DNAPL is within 2 feet of the mudline. These maps indicate that DNAPL is located within 2 feet of the mudline (indicated by green) close to shore in some areas. DNAPL in offshore areas generally increases in depth with distance from the shore, following the subsurface stratigraphy (i.e., offshore sloping geologic units).
- The western depth to DNAPL and DNAPL elevation mapping (Figure 5F-8) separated upland NAPL Area 4 (where DNAPL appears to have migrated down to the top of the low-permeability till [Qpgt], see Figure 5F-14) from upland NAPL Area 5A and offshore NAPL Area 5B, where DNAPL is shallow and occurs in the fill and recent lacustrine sediment approximately 15 to 25 feet above the top of the till.
- The elevation of DNAPL occurrence provides evidence that mobile DNAPL is gravity-driven in the subsurface and moves downslope (see contours in NAPL Areas 3, 5, 8, 14 and 15 on Figures 5F-8, 5F-9, and 5F-11 and all cross sections showing offshore DNAPL). DNAPL has moved preferentially downgradient (lateral and downward) in coarser material such as the Vashon recessional outwash (Qvr).
- Depth of DNAPL occurrence and comparison of DNAPL elevation to bathymetry, in combination with limited DNAPL in surface samples, suggest that movement of NAPL from subsurface sediments to surface sediments is not occurring (with the exception of rare observations of ebullition).
- Gray areas on Figures 5F-8, 5F-9 and 5F-11 show that DNAPL in downslope areas (i.e., lower lake slope and lake bottom zones) is vertically confined by the overlying recent lacustrine deposit.

Evidence of DNAPL migration was observed in sediment cores. For example, DNAPL was observed along fractures, seams, and veins in samples of the recent lacustrine deposit. These represent small-scale preferential pathways that contribute to dispersing small amounts of NAPL over large areas. Vertical fractures and veins may explain observations of DNAPL deep below the mudline (i.e., greater than 30 feet). Thin horizontal seams of DNAPL beneath clean sediment reflect the complex distribution of DNAPL and the challenges of fully delineating the vertical distribution of DNAPL in sediment.

9.3. Potential Exposure Pathways

This section describes the results of the tar and NAPL exposure pathways evaluation in the AOI. Complete exposure pathways are where tar or NAPL is within 1 foot of the ground surface or within top 10 centimeters (cm) of sediment (i.e., surface sediment point of compliance). The exposure pathways are considered “potential” where tar or NAPL are not currently at the ground surface or sediment point of compliance but have the potential to be complete exposure pathways (through erosion, disturbances, or migration). For this evaluation, tar and NAPL within 2 feet of the ground surface or mudline are considered potential exposure pathways.

Most upland tar and NAPL exposure pathways have been eliminated by upland cleanup actions. The lone exception is the tar mound area (Tar Area 5, Figure 5F-2). All other exposed tar in the upland has been removed or capped[15]. There are no remaining exposure pathways to NAPL in the upland. Cleanup actions at NAPL Area 12 (LNAPL was recovered in 1998 to 1999 and remediated by air sparging/soil vapor

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[15] Uncapped fill (which may contain tar) is considered a potential exposure pathway due to wave action (e.g., along the shoreline in the east and southeast).

extraction [AS/SVE] from 2001 to 2006) eliminated potential exposure. There is a potential exposure pathway at NAPL Area 13, where LNAPL is within 2 feet of the ground surface. Although the exposure pathway is currently incomplete (NAPL is greater than a foot beneath the ground surface), it is considered a potential exposure pathway due to erosion. In other areas where NAPL is present, the material occurs at too great a depth for exposure to receptors and is no longer migrating.

There are complete exposure pathways to tar in isolated areas along the eastern shoreline (Figure 5F-2). Except for the lakeshore extension of the tar mound, these are small areas (1 to several square feet) in the lakeshore zone. There are potential exposure pathways to tar in the lake slope zone east of the Play Barn where larger tar bodies (Tar Areas 3 and 4) were detected in the shallow subsurface during coring (cores CR-10 and CR-12) and diver probing (RI Appendix 3H).

In sediment, areas where NAPL is within the upper 10 cm point of compliance are complete exposure pathways. Deeper NAPL does not represent a current complete exposure pathway. The depth of potential exposure pathways was extended to 2 feet to include areas where NAPL could be uncovered and exposed by erosion or disturbance (e.g., anchor drag), and areas where NAPL could migrate to surface sediment. Depth contours of the top of DNAPL, as depicted in Figures 5F-8, 5F-9, and 5F-11, were used to identify areas where DNAPL is within 2 feet of the mudline. Seven areas (NAPL Areas 1, 2, 3, 5, 8, 14 and 15) were identified and are considered potential exposure pathways. These areas are shown as green in Figures 5F-8, 5F-9, and 5F-11.

NAPL depth and gradients were evaluated to identify potential migration pathways to surface sediment in the event NAPL is migrating. Physical evidence indicates that the NAPL is stable and not migrating. In the areas where DNAPL has migrated downslope in sediment, the driving force has dissipated or is dissipating. Analysis of historical fate and transport indicates DNAPL typically moved downward through sediment as it migrated, in most areas to increasing depth with distance from the shoreline. In these areas, DNAPL is confined to subsurface sediment and is not a potentially complete exposure pathway.

Four areas where NAPL migration to surface sediment could conceptually occur were identified. The following areas are where NAPL is at or just below the sediment surface on the lake slope:

- Off the western shoreline where NAPL Area 5A meets NAPL Area 5B (Figures 5F-8 and 5F-15).
- Southeast of the Prow in NAPL Area 8 (Figures 5F-9 and 5F-18).
- The upslope portion of NAPL Area 14 southeast of the Play Barn (Figures 5F-11 and 5F-19).
- The central and northwestern lobe of NAPL Area 15 (Figures 5F-11 and 5F-20).

Although ongoing or renewed NAPL migration is unlikely in these areas, they are considered potential exposure pathways. All of these areas are where NAPL is within 2 feet of the mudline.

9.4. Summary and Conclusions

The first step in developing this CSM was to evaluate potential sources of tar and NAPL. Upland tar and tar in the lakeshore area were likely part of the fill when it was originally deposited. Farther offshore, tar likely originated from overwater spills such as from the tar loading dock. NAPL was historically spilled in the upland and over water. In the upland, potential sources of NAPL have been identified; however, specific NAPL areas generally cannot be traced back to definitive historical sources because of soil excavation and regrading during Gas Works Park development. NAPL in sediment appears to have originated from overwater sources and, to a lesser degree, migration from the upland. The vast majority of NAPL in sediment appears to have originated from overwater releases from multiple sources or multiple releases/spills from an individual source. Overwater sources likely included docks where products were received or shipped off-site.

The historical transport, fate, and current distribution of NAPL was inferred from the NAPL cross sections and maps showing NAPL extent and gradients. NAPL migrated from higher elevations in the interior of the upland towards the shoreline and, in sediment, from nearshore to farther offshore[16]. NAPL distribution also generally follows the dip of geologic units. In most of the heaviest DNAPL impact areas in the upland (NAPL Areas 4, 7 and 10), DNAPL "steps down" away from the release area and is progressively deeper with distance and/or has otherwise migrated downward and "pooled" in depressions in the till. These areas of DNAPL are not capable of reaching a receptor because the pathway-to-surface sediment is incomplete. Historical upland to sediment DNAPL transport occurred in two areas (NAPL Areas 5A and 15)—petrophysical testing in these two areas indicate that DNAPL is stable and not migrating offshore.

Because industrial activities in the AOI upland ceased 60 years ago, DNAPL in sediment has mostly been depleted (migrating NAPL became residual NAPL) and has reached equilibrium with the gravitational forces responsible for its initial flow. NAPL mass has also decreased through partitioning and weathering. Most or all NAPL is stable and no longer migrating through site media and exists in a residual state in the AOI[17]. Mobile NAPL (i.e., NAPL that is not residual) has likely become trapped or reached a condition where it is no longer capable of further migration (e.g., due to a capillary barrier or accumulation above a layer impervious to NAPL migration). Areas where NAPL and tar are present at or near the surface reflect historical migration or ongoing erosion and not active migration.

Based on the extensive data collected and this evaluation, potential NAPL exposure pathways listed below are limited.

- Most upland tar has been remediated (removed or capped). Tar exists at the surface in one area of the upland (i.e., the tar mound) and is a complete exposure pathway.
- Upland NAPL is stable and not migrating. NAPL areas are deep, and there are no complete exposure pathways.
- In sediment, there are complete exposure pathways to tar in isolated tar occurrences along the eastern shoreline--these are small areas in the lakeshore zone. There are potential exposure pathways at two larger tar bodies in the lake slope zone east of the Play Barn.
- Most DNAPL in subsurface sediment occurs at increasing depth with distance from the shore and has limited potential to become exposed. Shallow DNAPL in sediment could be uncovered by erosion or disturbances and is considered a potentially complete exposure pathway.

These areas will be evaluated in the FS.

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[16] An exception is NAPL Area 7, where the DNAPL surface slopes away from the shoreline (Figure 5F-17), thus indicating that DNAPL may have historically migrated into the interior of the upland away from the shoreline.

[17] Possible exceptions would be DNAPL disturbed, for example, by anchor drag and ebullition-driven transport.

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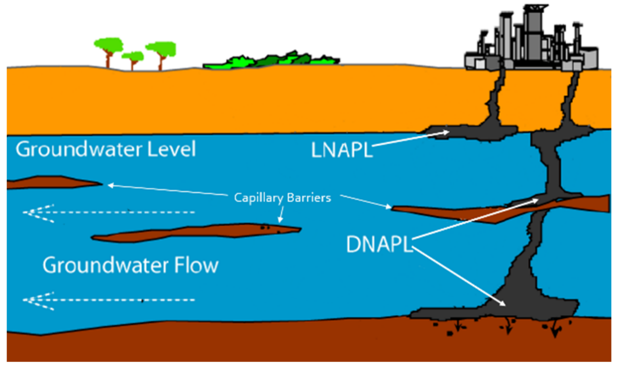
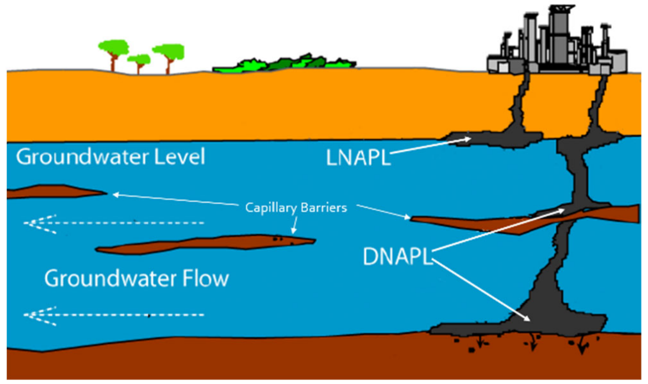
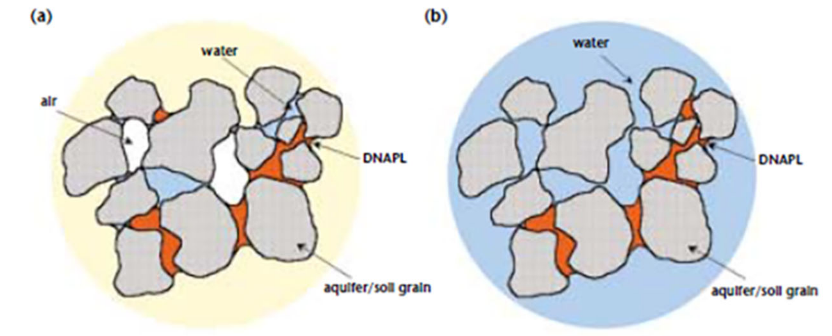
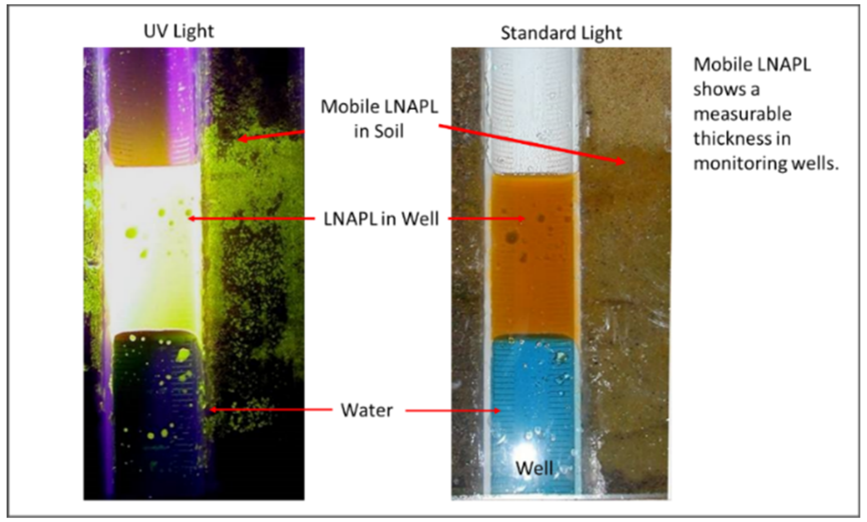
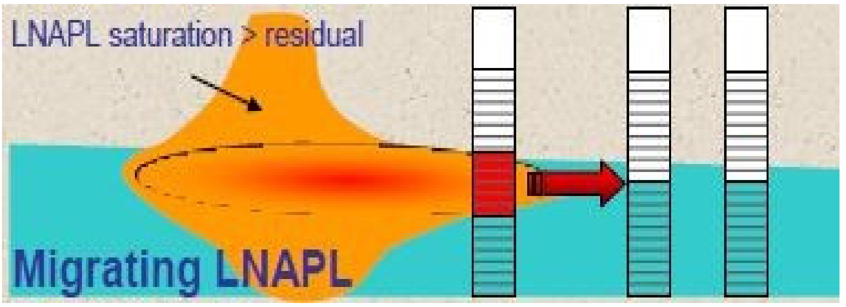
Table 5F-1

NAPL and NAPL-Related Terminology

Gas Works Park Site
Seattle, Washington

Term and Graphic	Definition	Area of Investigation (AOI) Presence and Terminology Used in the Remedial Investigation/Feasibility Study Report
	NAPL And Types Of NAPL	
NAPL Non-Aqueous Phase Liquid  Edublogs.org 2017	NAPLs are organic compounds or mixtures of compounds that are immiscible (resistant to mixing) with water. The term NAPL refers to the undissolved liquid phase of a compound and not to the aqueous phase constituents that may be dissolved in water (modified from EPA 1992).	NAPL is a general term used in the RI/FS to refer to nonaqueous phase liquids. NAPL can refer to light NAPL (LNAPL) and/or dense NAPL (DNAPL), or combinations and mixtures of both.
LNAPL Light Non-Aqueous Phase Liquid  Modified from Eberhard-Karls-University of Tuebingen 2012	Light NAPLs are organic compounds (or mixtures of compounds) such as petroleum oil, gasoline, and diesel fuel that float. LNAPLs have densities less than water (density < 1.0 g/cm^3) and are immiscible (resistant to mixing) with water (modified from ITRC 2009).	In the RI/FS, the term LNAPL refers to three types of LNAPL encountered in the AOI: ■ Fuel oil, petroleum-based LNAPL. ■ Benzol, monoaromatic-rich LNAPL (also referred to as "light oil" in the RI/FS report and other references). ■ Naphthalene-rich LNAPL. Properties of on-site LNAPL: ■ Low viscosity compared with DNAPLs at the Site. ■ Specific gravity: 0.92 at 70 degrees measured in MW-09 (that of water at the same temperature is 1.0). ■ LNAPL saturation in soil (%Pv), where measured, ranges from 4.8 percent to 46.6 percent; only one sample was more than 20 percent LNAPL saturated.
DNAPL Dense Non-Aqueous Phase Liquid  Modified from Eberhard-Karls-University of Tuebingen 2012	Dense NAPLs are organic compounds (or mixtures of compounds) such as coal tar, creosote, and other organic compounds that don't mix well with water (are immiscible) and tend to sink (density > 1.0 g/cm^2). (modified from ITRC 2003).	In the RI/FS, the term DNAPL refers to three types of DNAPL encountered in the AOI: ■ Naphthalene-rich DNAPL previously referred to as "middle oil" and infrequently referred to as "medium oil." ■ PAH-rich DNAPL, previously referred to as coal tar or creosote (a coal-tar-based product that may also contain petroleum) as generic terms. ■ Lower PAH DNAPL with petroleum. Properties of on-site DNAPL: ■ DNAPL viscosity ranges from 22 to 1,128 centistokes (measured at 70 degrees). ■ Specific gravity: ranges from 1.02 to 1.11 at 70 degrees (that of water at the same temperature is 1.0). ■ DNAPL saturation in soil (%Pv), where measured, ranges from 2.1 percent to 14.5 percent.

Term and Graphic	Definition	Area of Investigation (AOI) Presence and Terminology Used in the Remedial Investigation/Feasibility Study Report
	NAPL Stability Terminology for AOI	
Residual NAPL  Figure 3 Residual DNAPL in (a) unsaturated and (b) saturated porous media Environment Agency 2003	The term "residual NAPL" refers to NAPL that is trapped in the pore spaces between soil particles or sediment particles and cannot be easily moved hydraulically (modified from API 2006). Residual NAPL refers to NAPL at the range of saturations greater than zero up to the NAPL saturation, at which NAPL capillary pressure equals pore entry pressure. Includes NAPL that is discontinuous and immobile under the applied gradient (modified from ITRC 2009).	Almost all NAPL in the AOI is in residual form. Residual NAPL is used to refer to LNAPL and DNAPL. Residual NAPL is described in many ways in the RI/FS report to communicate the specific nature and occurrence of residual NAPL: ■ Residual NAPL (LNAPL and DNAPL that is not mobile) ■ Less than residual saturation ■ Stable ■ Immobile ■ Smear (typically associated with LNAPL) ■ Slight to moderate sheen ■ Heavy sheen and/or trace NAPL ■ Blobs, droplets, coating grains Note: The term "Residual NAPL" as used in the RI/FS is not the same as residual saturation defined in MTCA (WAC 173-340-747(10)) "the concentration of hazardous substances in the soil at equilibrium conditions."
Mobile NAPL  ENSR | AECOM 2007	NAPL that exceeds residual NAPL saturation and is hydraulically connected in the pore space. Has the potential to be mobile in the environment. Mobile NAPL is measurable in wells because the well creates a void space for mobile NAPL to move into. Mobile NAPL includes migrating NAPL, but not all mobile NAPL is migrating NAPL. Mobile NAPL can also be referred to as non-residual NAPL (modified from ITRC 2009).	Mobile NAPL refers to NAPL that exceeds residual saturation. Evidence of mobile NAPL is limited to the following areas: ■ East area near the Play Area in monitoring wells MW-09 (NAPL Areas 10 and 11), and MW-44S and MW-45S (LNAPL Area 13). ■ West area near Harbor Patrol (DNAPL Area 4). Other terms used to describe mobile NAPL include: ■ Pooling (DNAPL in till depressions), ■ Non-residual, and ■ Measurable thickness or measurable NAPL (in wells).
Migrating NAPL  ITRC 2009	A non-residual NAPL body that is observed to spread or expand laterally, vertically, or otherwise result in an increased volume of NAPL-impacted media. NAPL migration is typically documented by time-series data (modified from ITRC 2009).	No evidence of migrating NAPL has been documented with time-series data. Industrial activities ended more than 60 years ago and NAPL is expected to be in equilibrium in the AOI. A possible exception are rare observations of ebullition.

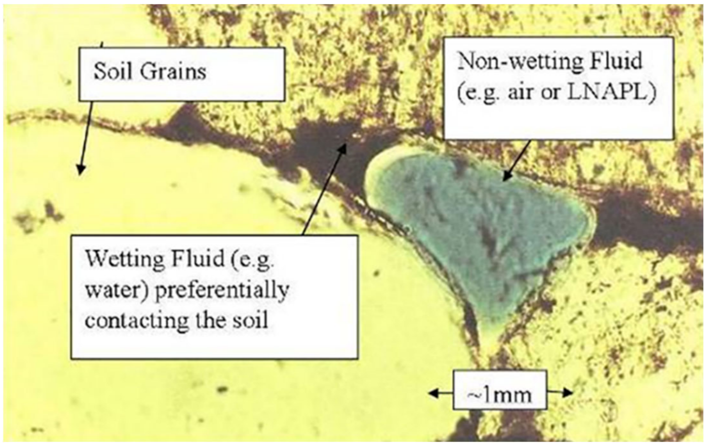
Term and Graphic	Definition	Area of Investigation (AOI) Presence and Terminology Used in the Remedial Investigation/Feasibility Study Report
NAPL Field Screening Terms		
Sheen Testing  Ecology 2016	Sheen testing involves placing a small amount of soil in a pan of water and observing the water surface for signs of sheen. A black plastic gold pan typically is used for sheen testing. ■ NS (no sheen)—No visible sheen on the water surface. ■ SS (slight sheen)—Light, colorless, dull sheen; spread is irregular, not rapid. Natural organic oils or iron bacteria in the soil may produce a slight sheen. ■ MS (moderate sheen)—Pronounced sheen over limited area; probably has some color/iridescence; spread is irregular, may be rapid; sheen does not spread over entire water surface. ■ HS (heavy sheen)—Heavy sheen with pronounced color/iridescence; spread is rapid; the entire surface is covered with sheen. (Modified from Ecology 2016).	Sheens were considered in categorization of NAPL. *Heavy Sheen and/or trace NAPL* and *Heavy sheen with NAPL* categories were used to map NAPL areas. AOI RI/FS NAPL Impacts Categories and Descriptions: ■ No Impacts – No visual or olfactory evidence of hydrocarbons present. ■ Staining and/or Odor – Presence of hydrocarbon or naphthalene-like odor, hydrocarbon staining of the soil or sediment matrix, or both. ■ Slight to Moderate Sheen – Observations of hydrocarbon sheen ranging from trace to slight to moderate or medium sheens that may be described as spotty, white, colored or rainbow sheens. ■ Heavy Sheen and/or Trace NAPL – Observations of heavy, oily or strong hydrocarbon sheens; minor NAPL observations described as trace NAPL; small, scattered or occasional oil blobs (< 1/8 inch in size), or NAPL veinlets; or oily water or oil emulsions. ■ Heavy Sheen with NAPL – Observations of sheens plus NAPL where NAPL is described as present, abundant or saturated, including observations of oil/NAPL drops or blobs (> 1/8 inch in size), oil or oil/NAPL on equipment. The NAPL may occur in lenses, layers, fractures, seams or veins. NAPL implies a lower-viscosity liquid that occurs in and moves through the interstitial pore space or voids in the soil or sediment matrix.
Free Product  Wilson et. al. 1990	General term used to refer to NAPL. Typically used to refer to NAPL observed during drilling (residual or mobile) and NAPL that has accumulated in wells.	Free Product is generally not used to refer to NAPLs in the RI/FS. The term 'free product' is used in the RI/FS to refer to free product mobility testing. NAPLs subjected to free product mobility testing did not show evidence of migration at centrifugal forces representative of 1,000 times gravitational forces (Appendix 2A). Free Product was occasionally used in historical boring logs to refer to NAPL observed during drilling.
Tar		
Tar  Floyd | Snider 2008	Heavy, viscous product obtained when distilling organic materials such as wood, coal, or peat. Although a tar-like product can be obtained from petroleum, the term tar does not properly apply to a product obtained from petroleum (modified from Tver and Barry 1980).	Tar, when used to describe conditions at the AOI, refers to a solid or semi-solid and is not considered a NAPL. The term tar is included here for completeness. In the RI/FS, tar is the term used to refer to semisolid, pliable solid or solid material. Tar in the AOI is dark in color and consists mostly of high molecular weight PAHs with low aqueous solubility. Tar typically occurs as small discrete masses, layers, or deposits within the Fill unit at or near the uncapped soil or sediment surface. Small tar masses are interspersed sporadically within the Fill unit, with some larger deposits identified (Figure 5F-2). The nature and extent of tar has been interpreted separately from LNAPL and DNAPL. Changes in viscosity resulting from higher temperatures during hot summer days have historically resulted in mobilization and surfacing of tar in limited areas. Surfacing of tar has not been observed in areas with a protective soil cap.

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Table 5F-2

NAPL Physical Properties

Gas Works Park Site
Seattle, Washington

Well	Sample ID	Sample Date	NAPL Type	NAPL Area	Analysis						
					Temperature	Specific Gravity	Molecular Weight	Density	Viscosity		Water Content
					°F			g/cc	centistokes	centipoise	Vol percent
DW-4	DW-4-PRODUCT/RE980604-02	6/3/1998	DNAPL	4	72	NM	221	1.08	NM	NM	0.13
					104	NM	NM	NM	18.1	NM	NM
	DW4-DNAPL	5/31/2005	DNAPL		70	NM	NM	1.08	45.8	49.4	NM
					75	NM	NM	1.10	NM	NM	8.0
					100	NM	NM	1.07	20.2	21.6	NM
					130	NM	NM	1.06	11.1	11.8	NM
DW-7	DW07-130415-DNAPL	4/15/2013	DNAPL	4	70	1.08	NM	1.08	46.0	49.6	NM
PZ-3	PZ03-130417-DNAPL	4/17/2013	DNAPL	4	70	1.08	NM	1.08	685	740	NM
MLS-4-1	EL980224-01	2/17/1998	DNAPL	4	72	NM	217	1.08	NM	NM	NM
MW-5	MW-5-PRODUCT/RE980604-01	6/3/1998	DNAPL	4	72	NM	253	1.08	NM	NM	0.20
					104	NM	NM	NM	83.4	NM	NM
MW-9	MW09-130415-DNAPL	4/15/2013	DNAPL	10	70	1.02	NM	1.02	22.2	22.6	NM
	MW09-130415-LNAPL	4/15/2013	LNAPL	11	70	0.92	NM	0.92	14.6	13.4	NM
MW-18	MW18-130422-DNAPL	4/22/2013	DNAPL	4	70	1.11	NM	1.11	1130	1250	NM

Notes:

NM = not measured

g/cc = grams per cubic centimeter

Table 5F-3

NAPL/Tar-Related Data and Sampling Locations

Gas Works Park Site
Seattle, Washington

Method	Data Generated	Year	Study	Number of Explorations	Explorations	Upland/ Sediment
Soil/Sediment Field Screening	NAPL field observations and sheen testing of soil and sediment[1]	pre-2013	Previous Investigations	> 650	Previous explorations (> 650 total locations)	Upland/ Sediment
		2013-2014	Supplemental Investigation	44	GEI-1 to GEI-15, MW-32S, MW-33S(A), MW-33S(B), MW-34S, MW-35S, MW-36S, MW-36D, MW-37S, MW-38S, MW-39S, MW-39D, MW-40S, GEO-1/MW-32D, GEO-2, GEO-3, PAI-1 to PAI-12, PAI-2B, PAI-3B	Upland
NAPL Gauging	Measured NAPL thickness	pre-2013	Previous monitoring events	16	DW-4, DW-5, DW-7, MLS-4, MLS-5, MW-18, PZ-3 and MW-09 are exiting wells and MW-05, MW-07, MW-12, MW-20, R-1, R-2, R-3, R-4 and R-5 are former wells with history of NAPL	Upland
		post-2013	Supplemental Investigation & Addendum	9	DW-4, DW-5, DW-7, MLS-4, MLS-5, MW-18, PZ-3, MW-09 and MW-44S are existing wells that contain NAPL or trace NAPL	
NAPL/Tar Sampling	NAPL/tar chemical analytical results (PAHs, SVOCs, VOCs, TPH)	1984	EPA-84	2	84EPA600, 84EPA700	Upland
		1996	Spectra/ARI	2	GWP Tank (DNAPL and tar)	Upland
		1998	EPRI/META	4	DW-4, MW-5, MLS-4-1, CR-10	Upland/ Sediment
		1998	FFS	1	TP-6	Upland
		1999	RETEC	2	FP-01, FP-03	Sediment
		2002-2003	Battelle/ARI	7	MW-9, DW-5, MW-5, GWP Tank, SS-1, NLU117, NLU117	Upland/ Sediment
		2007	Battelle/Exponent Forensics	11	DW-4, MW-9, Station 1 to 6, Structure 1 to 3	Upland
		2013	Supplemental Investigation	6	DW-5, DW-7, PZ-3, MW-9 (LNAPL and DNAPL), MW-18	Upland
	NAPL viscosity/density testing results	1998	EPRI	3	DW-4, MW-5, MLS-4-1	Upland
		2005	FloydSnider 2005 data report	1	DW-4	Upland
		2013	Supplemental Investigation	4	DW-7, PZ-3, MW-9, MW-18	Upland
NAPL Baildown Testing	LNAPL baildown results	2013	Supplemental Investigation	1	MW-9	Upland
Laser Induced Fluorescence Work (TarGOST®)	TarGOST® NAPL results	2013	Supplemental Investigation	5	DW-4, DW-5, DW-7, MW-9 LNAPL, MW-18	Upland
	TarGOST® drilling: TarGOST® logs			49	TG-01 to TG-45, TG-18B, TG-32B, TG-12R, TG-42R	
	TarGOST® soil split sample results (ARI and Dakota)			6	TG-08, TG-11, TG-27, TG-32/32B, TG-39, TG-42/42R	
	TarGOST® classification plots	2013	Supplemental Investigation	60	TarGOST® TG locations (TG-01 to TG-45, TG-18B, TG-32B, TG-12R, TG-42R); NAPL samples (DW-4, DW-5, DW-7, MW-9 LNAPL, MW-18); soil splits (TG-08, TG-11, TG-27, TG-32/32B, TG-39, TG-42/42R)	
	Waveform analysis (NNLS)	2013	Supplemental Investigation	55	TarGOST® TG locations (TG-01 to TG-45, TG-18B, TG-32B, TG-12R, TG-42R); soil splits (TG-08, TG-11, TG-27, TG-32/32B, TG-39, TG-42/42R)	
Petrophysical Testing	Soil UV photos	2008	FloydSnider NE Corner Report	6	SB-2, SB-2A, SB-3A, SB-5, SB-8, SB-12A	Upland
		2008	AECOM Eastern Shoreline Report	6	GP-02, GP-04, GP-05, GP-09, GP-11, GP-12	
		2013	Supplemental Investigation	4	PT-1, PT-1B, PT-2, PT-3	
	Soil testing results: Free product mobility, Soil shake test, Soil capillary pressure test, Soil pore fluid saturation[2]	2007	FloydSnider Western Shoreline Report	2	TDW2, TSB2	
		2008	FloydSnider NE Corner Report	4	SB-2, SB-2A, SB-3A, SB-12A	
		2008	AECOM Eastern Shoreline Report	6	GP-02, GP-04, GP-05, GP-09, GP-11, GP-12	
		2013	Supplemental Investigation	4	PT-1, PT-1B, PT-2, PT-3	

Notes:

[1] Several types of field screening have been conducted over the years at the Site (i.e., visual and manual, sheen testing, shake testing and UV/black light screening, which are described in more detail in RI Appendix 2A). Observations based on field screening and sheen testing of soil and sediment are compiled and condensed into NAPL impacts designation categories.

[2] Not all these tests performed on all samples.

LNAPL = light nonaqueous phase liquid

NAPL = nonaqueous phase liquid

NNLS = non-negative least squares

TarGOST® =Tar-specific Green Optical Screening Tool

UV = ultraviolet

Table 5F-4

Analytical Results for NAPL and Tar Areas and Isolated Tar Samples

Gas Works Park Site
Seattle, Washington

NAPL and Tar Areas (plus isolated tar impacts)[1]	Location ID[2]	Medium	Start Depth (feet)	End Depth (feet)	Benzene		Ethylbenzene		Toluene		Total Xylenes		Benzo(a) anthracene		Benzo(a)pyrene		Benzo(b) fluoranthene		Benzo(k) fluoranthene		Chrysene		Dibenzo(a,h) anthracene		Fluoranthene		Indeno (1,2,3-cd) pyrene		Naphthalene		Pyrene		Carcinogenic PAH (using 1/2 RL)		High Molecular Weight PAH		Total PAH	
					mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier
1	ST-04-RETEC99	Sediment	0.00	0.33									34		46		29		31		39		4.4		81		20		4.1		120		58.2	T	432	TA	586	TB
2	ST-03-RETEC99	Sediment	0.00	0.33	1.9	U	2.15	J	1.22	J			15		23		14		12		17		1.3		32		6.2		5.4		42		28	T	168	TA	346	TB
3	CR-21-RETEC99	Sediment	0.50	2.70	1.37		2	J	2.52				24		30		27		18		27		2.9		80		14		4.6		94		38.9	T	330	TA	487	TB
3	GWS-EC13	Sediment	0.20	2.20	3.1		10		0.046				22		17		8.7		14		24		2.1	U	64		2.7		700		72		22.1	T	227	TA	1,920	TB
3	GWS-EC14	Sediment	0.72	2.60	0.0052	U	0.0052	U	0.0052	U			0.42		0.55		0.32		0.43		0.49		0.052		0.76		0.2		0.26		0.79		0.697	T	4.19	TA	5.3	TB
3	NLU109D-US-RETEC02	Sediment	2.60	5.50	28	U	28	U	28	U	28	U	180		220		190		140		170		17		530		75		1,900		580		282	T	2,170	TA	6,150	TB
3	NLU109-US-RETEC02	Sediment	0.39	0.46									7.35		9.49		6.38		6.84		8.86		0.979		18.4		7.32		19		22.6		12.5	T	96.9	TA	155	TA
3	NLU109-US-RETEC02	Sediment	0.92	0.98									32		42.5		25.8		30.1		37.5		4.28		92.9		31.8		44.3		134		55.3	T	468	TA	789	TA
3	NLU109-US-RETEC02	Sediment	1.25	1.31									72.4		101		58.3		67.2		83.5		9.84		223		73.2		105		280		130	T	1,050	TA	1750	TA
3	NLU119D-US-RETEC02	Sediment	0.00	0.45	61	U	140		61	U	170		160		150		110		61		200		16		430		52		3,900		600		192	T	1,830	TA	11,200	TB
3	NLU119D-US-RETEC02	Sediment	0.89	1.32	43		110		37	U	140		81		49		42		34		93		3.3		180		10		3,000		240		67	T	741	TA	7490	TB
3	NLU119D-US-RETEC02	Sediment	1.77	2.21	13	U	16		13	U	24		16		10		5.2		7.4		19		3.6	U	41		4		370		54		13.6	T	161	TA	1110	TB
3	NLU119-US-RETEC02	Sediment	0.20	0.26									468		521		273		348		559		48.4		1,350		332		2,210		1700		674	T	5,960	TA	16,600	TA
3	NLU119-US-RETEC02	NAPL[3]	0.52	0.59									399		438		233		292		478		40.2		1,210		271		2,020		1520		566	T	5,180	TA	14,400	TA
3	NLU119-US-RETEC02	Sediment	0.79	0.85									210		268		141		174		244		23.9		638		178		769		784		343	T	2,860	TA	6,230	TA
3	ST-01-RETEC99	Sediment	0.00	0.33	1.19	J	3.38	J	2.43				32		36		24		28		37		0.9	J	74		3.6		5.3		82		45.2	T	320	TA	485	TB
4	B-2-EPRI98	Soil	16.50	17.25									194		146						175				516				6,700		612				1,640	TB	11,800	TC
4	DW-4	NAPL	DNAPL	DNAPL									3,230		3,160		1,550		2,220		3,000		327		7,750		1,560		80,900		8050.52		4,080	T	32,300	TA	163,000	TB
4	DW-4	NAPL	DNAPL	DNAPL									3,280		3,210		1,590		2,220		3,050		337		7,950		1,600		83,200		8352.58		4,150	T	33,100	TA	167,000	TB
4	DW-4	NAPL	DNAPL	DNAPL	2,440		3,130		6,490		8,400	T	4,320		3,480		1,690		2,350		3,890		378		10,400		1,610		131,000		11600		4,550	T	41,300	TA	318,000	TA
4	DW-5	Soil	7.00	7.00									74		65						68				200				968		234				641	TB	2,590	TC
4	DW-5	Soil	27.50	27.50									43		34						37				112				1,310		133				359	TB	2,390	TC
4	DW-5	NAPL	DNAPL	DNAPL	1,800	U	3,400		4,600		3,900	T	3,200		2,200						2,600		380		8,100		940		76,000		7800		2,970	T	29,100	TA	154,000	TB
4	DW-7	Soil	15.00	15.00									13		8						10				33				316		40				104	TB	646	TC
4	DW-7	NAPL	DNAPL	DNAPL	1,800	U	4,800		3,800		6,800	T	3,400		2,400						2,800		390		9,300		1,000		80,000		8600		3,230	T	32,300	TA	163,000	TB
4	MLS-4-1	NAPL	DNAPL	DNAPL	1,760		3,090		5,540		7,160	T	4,250		3,330		1,720		2,270		3,820		384		9,710		1,490		117,000	J	10100		4,380	T	38,600	TA	292,000	TA
4	MW-5	NAPL	DNAPL	DNAPL	563		1,530		2,040		5,140	T	3,090		2,690		1,260		1,720		3,290		293		7,560		1,180		84,400		9840		3,480	T	32,200	TA	233,000	TA
4	MW-18	NAPL	DNAPL	DNAPL	100	U	100	U	100	U	100	UT	3,900		2,800						3,200		300		9,600		1,100		14,000		9500		3,720	T	35,200	TA	99,200	TB
4	PZ-3	NAPL	DNAPL	DNAPL	5.6	U	7.2		5.6	U	10	T	290	U	290	U					290	U	290	U	390		290	U	4,200		440		218	UT	830	TA	7,690	TB
5	CR-01-RETEC99	Sediment	0.50	2.60									44		48		47		18		45		3		150		23		220		130		62	T	529	TA	1,500	TB
5	CR-01-RETEC99	Sediment	2.60	6.90	0.23	U	1.75	J	0.11	J			11		9.7		6		7		10		1.1	J	41		5.1		24		39		12.8	T	135	TA	343	TB
5	CR-01-RETEC99	Sediment	6.90	8.30									6.2		5.8		3.2		4.4		6.4		0.52		23		2.9		8.4		22		7.59	T	77.3	TA	189	TB
5	CR-19-RETEC99	Sediment	0.50	4.70	6.5		37.9	J	14.2				81		74		40		50		84		6.8	J	240		34		170		280		96	T	925	TA	2,590	TB
5	CR-19-RETEC99	Sediment	4.70	10.90									41		37		21		26		43		3.9		110		17		290		140		48.3	T	455	TA	1,700	TB
5	FP-01	Tar	0.00	0.33	0.7	U	1.06	J	1.7		3.38	T	108		64		36		36.7		46.9		4		99.5		43.9		16.7	J	123		87.3	T	621	TA	879	TA
5	GWS-EC06	Sediment	2.30	3.90	1.5		170		2.3				160		160		140		110		170		14	J	530		95	J	1,700		520		214	T	2,000	TA	6,510	TB
5	GWS-EC06	Sediment	4.00	4.90	0.18		29		0.13	U			25		22		17		17		26		2.2	J	80		14	J	200		74		29.8	T	292	TA	922	TB
5	GWS-EC06	Sediment	5.70	6.70	0.051		0.46		0.0045				2.3		2.1		1.4		1.7		2.3		0.2	J	7.8		1.1	J	13		6.4		2.79	T	26.4	TA	70.7	TB
5	GWS-EC07	Sediment	1.30	2.60	0.0014	U	0.0014	U	0.0014	U			1.1		1.3		1		1		1.4		0.17	U	3.6		0.6	J	0.96	J	2.6		1.69	T	13.2	TA	20.2	TB
5	GWS-EC07	Sediment	3.30	4.60	24		66		0.82				120		110		65		77		130		9.2	J	320		59	J	1,600		340		144	T	1,290	TA	5,650	TB
5	GWS-EC07	Sediment	4.60	5.70	0.76		0.58		0.0067				0.41		0.43		0.23		0.35		0.5		0.039	J	1.2		0.16	J	16		1.1		0.554	T	4.55	TA	31.8	TB
5	GWS-EC07	Sediment	5.70	7.00	0.038		0.03		0.0008	U			0.019	U	0.019	U	0.019	U	0.019	U	0.019	U	0.019	U	0.032		0.019	U	0.42	B	0.024		0.0134	UT	0.056	TA	0.845	TB
5	GWS-EC08	Sediment	1.20	2.50	3.1		17		0.11				5.6		3		1.7		2.2		4.7		1.2	U	43		1.2	U	820		40		4.12	T	100	TA	1540	TB
5	GWS-EC08	Sediment	3.60	5.20	4.6		14		0.1				1.2	U	1.2	U	1.2	U	1.2	U	1.2	U	1.2	U	1.6		1.2	U	470		1.2	U	0.846	UT	1.6	TA	760	TB
5	GWS-EC08	Sediment	5.70	7.20	5.1		13		0.26				3.8		3		1.8	U	2		3.6		1.8	U	27		1.8	U	570		21		3.8	T	60.4	TA	1150	TB
5	GWS-EC08	Sediment	7.60	9.20	6.6		14		1.3				14		8.6		5		6.4		12		3.5	U	96		3.5	U	740		78		11.6	T	220	TA	1930	TB
5	GWS-EC08	Sediment	9.80	11.80	4.4		9.3		2.9				1.7	U	1.7	U	1.7	U	1.7	U	1.7	U	1.7	U	3		1.7	U	580		1.7	U	1.2	UT	3	TA	1060	TB
5	GWS-EC08	Sediment	13.60	15.60	3.5		3.4		1.9				0.3	U	0.3	U	0.3	U	0.3	U	0.3	U	0.3	U	0.3	U	0.3	U	210		0.3	U	0.212	UT	0.3	UA	252	TB
5	GWS-SG01	Sediment	0.00	0.33	0.029	U	0.029	U	0.029	U			2.2		4.9		3.5		2		2.8		0.26		7.7		1.8		0.36		5.9		5.9	T	32.8	TA	37.3	TB
5	NLU117D-US-RETEC02	Sediment	0.00	0.33									10		22		13		10		13		2.7		32		14		1.1		36		27.1	T	171	TA	195	TB
5	NLU117-TX-GWSA05	Sediment	0.00	0.33									10		22		13		10		13		2.7		32		14		1.1		36		27.1	T	171	TA	195	TB
5	NLU117-TX-GWSA05	Sediment	0.00	0.33									65		110		76		34		77		17		180		95		7.8		210		139	T	974	TA	1110	TB
5	NLU117-TX-GWSA05	Sediment	0.00	0.35	34	U	34	U	34	U	34	U	730		1000		700		420		900		95		3400		590		220		4600		1260	T	13100	TA	18300	TB
5	NLU117-TX-GWSA05	Sediment	6.17	6.70	12	U	12	U	12	U	12	U	31		27		20		24		30		2.5		94		8.6		48		96		35.9	T	341	TA	865	TB
5	NLU117-TX-GWSA05	NAPL[3]	9.04	9.58	13	U	13	U	13	U	13	U	55		49		41		38		53		4.5		140		15		240		150		64.9	T	559	TA	1650	TB
5	NLU117-US-RETEC02	Sediment	0.26	0.33									364		555		313		341		445		48.4		1160		419		100		1370		708	T	5500	TA	7290	TA

NAPL and Tar Areas (plus isolated tar impacts)[1]	Location ID[2]	Medium	Start Depth (feet)	End Depth (feet)	Benzene		Ethylbenzene		Toluene		Total Xylenes		Benzo(a) anthracene		Benzo(a)pyrene		Benzo(b) fluoranthene		Benzo(k) fluoranthene		Chrysene		Dibenzo(a,h) anthracene		Fluoranthene		Indeno (1,2,3-cd) pyrene		Naphthalene		Pyrene		Carcinogenic PAH (using 1/2 RL)		High Molecular Weight PAH		Total PAH	
					mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier
5	NLU117-US-RETEC02	Sediment	0.92	0.98									108		141		76.4		91		138		9.85		406		92.9		51.2		513		180	T	1700	TA	2420	TA
5	NLU117-US-RETEC02	Sediment	1.57	1.64									18.7		14.5		9.85		12.1		20.6		1.42		70.2		9.04		37.8		61.9		19.8	T	229	TA	446	TA
5	NLU117-US-RETEC02	Sediment	10.30	10.40									238		193		102		154		243		12.7		727		75.7		3210		762		254	T	2590	TA	11100	TA
5	NLU119R2-US-RETEC02	Sediment	1.20	1.50									61.7		36.6		18.9		27.9		73.1		4.33		181		14.6		2860		231		50.1	T	664	TA	6530	TA
5	NLU119R3-US-RETEC02	Sediment	8.30	8.60	61	U	84		68		76		200		180		120		110		210		24	U	550		95		1700		600		236	T	2160	TA	7920	TB
5	NLU119R3-US-RETEC02	Sediment	9.70	10.00	15	U	15	U	15	U	15	U	3.1		2.3		1.1		1.3		3		0.48	U	8.6		1.2		6.4		10		3.02	T	31.8	TA	98.8	TB
6	GEI-12	Soil	11.00	15.00	5.5		4.4		0.52	U	1.1	T	11		14		7.1		3.3		12		1.1		28		6.6		140		41		17.4	T	138	TA	417	TB
7	GEI-12	Soil	5.00	7.00	1.4		18		1.4		21.4	T	69		72		37		18		82		8.8		160		34		1700		230		91.6	T	781	TA	3150	TB
8	CR-14-RETEC99	Sediment	0.50	3.00	3.63		9.58	J	1.59				82	J	110	J	93	J	45	J	81	J	14	J	290	J	79	J	270	J	290	J	142	T	1150	TA	2180	TB
8	CR-14-RETEC99	Sediment	3.00	6.00									2.5	J	2	J	1	J	1.3	J	2.4	J	0.18	J	5.6	J	0.9	J	31	J	6.7	J	2.61	T	23.4	TA	125	TB
8	NLU51-TX-GWSA05	Sediment	0.00	0.33									270		430		300		270		310		24		970		190		24		1000		539	T	3940	TA	4840	TB
8	NLU51-US-RIFSE	Sediment	0.40	2.20	0.64		0.054		0.32	U	0.56	T	110				78		82		120		17		340		62		38				36.1	T	883	TB	1570	TB
8	NLU51-US-RIFSE	Sediment	2.20	3.90	0.0011	U	0.001	U	0.001	U	0.001	UT	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.031		0.02	U	0.0141	UT	0.02	UA	0.074	TB
8	NLU72-US-RIFSE	Sediment	0.00	2.40	0.0053	U	0.0053	U	0.0053	U	0.0057	T	16		26		16		14		19		3.9		51		20		2.5	B	46		33.2	T	241	TA	287	TB
9	NLU418-GE-RIFSE	Sediment	5.00	6.50									18		19		12		8.3		25		1.5	J	41		12		240		64		24.4	T	216	TA	885	TB
9	NLU418-GE-RIFSE	Sediment	11.80	12.50									1.1		0.82		0.31		0.49		1.1		0.078	U	2.3		0.3		8.8		2.8		1.05	T	9.5	TA	43.3	TB
9	NLU48-US-RIFSE	Sediment	1.10	6.60	0.0051	U	0.0051	U	0.0051	U	0.0051	UT	5.4		8.9		6.1		3.2		6.5		0.99		14		5.2		2.1		14		11.1	T	69.9	TA	85.9	TB
9	NLU48-US-RIFSE	Sediment	6.60	8.70	0.0035	U	0.02		0.0011	U	0.0178	T	0.95		0.78		0.32		0.32		0.91		0.088		1.6		0.23		1.1		1.9		0.98	T	7.34	TA	23.2	TB
10	GEI-13	Soil	13.00	16.00	0.49	J	10	J	6.2	J	34	T	5.6		3.7						5		0.41		12		1.3		190		15		4.88	T	48.4	TA	341	TB
10	GEI-13	Soil	23.50	24.50	10	J	33	J	37	J	55	T	14		9.4						12		1		26		2.9		380		38		12.3	T	116	TA	732	TB
10	MW-09	NAPL	DNAPL	DNAPL									1,700		1,100		490		730		1,800		200	U	2,900		360		89,000		4500.0002		1,460	T	13,900	TA	186,000	TB
10	MW-09	NAPL	DNAPL	DNAPL	1,800		8,300		8,100		10,400	T	1,600		920						1,400		130		2,600		260		59,000		3600		1,230	T	11,800	TA	98,100	TB
10	PAI-7	Soil	22.50	23.00	110		310		180		420	T	14		11		4		2.7		14		1.3		28		3.1		390				14	JT	127.8	TA	793.8	JT
11	B-13	Soil	6.50	7.50									0.22		0.27	U	0.4		0.22		0.48		0.27	U	3.42		0.11		6.34		1.74		0.248	T	6.59	TB	12.9	TC
11	GEI-13	Soil	8.00	9.50	0.018		0.0035		0.0027		0.0043	T	1.7		1						1.5		0.14	J	0.79	J	0.46		2.1	J	4.6		1.38	T	12	TA	24.9	TB
11	GEI-13	Soil	8.00	9.50	0.023	J	0.0042	J	0.0035	J			1.3		0.87		0.44		0.25		1.3		0.11		2.7	J	0.34		0.92	J	4.5		1.16	T	12.5	TA	24.6	TB
11	MW-09	NAPL	LNAPL	LNAPL									548		454		188		277		536		47.3		970		171		11,800		1497.93		583	T	4,850	TA	25,100	TB
11	MW-09	NAPL	LNAPL	LNAPL	18	U	56		18	U	26		540		513		226		336		538		56.5		979		229		12,500		1443.38		657	T	5,060	TA	27,200	TB
11	MW-09	NAPL	LNAPL	LNAPL	500	U	680		500	U	500	UT	600		390						540		100	U	1200		110		6,800		1500		514	T	4,910	TA	20,900	TB
11	MW-09	Soil	2.50	2.50									8.6		15						12		2	J	26		13		6		43		19.4	T	155	TA	195	TB
11	MW-09	Soil	5.70	5.70									3.4		2.9						2.5		0.57		4.3		1.8		0.66		5.9		3.91	T	27.4	TA	33.3	TB
12	B-10	NAPL	LNAPL	LNAPL	328,000		6,880		435,000		66,500																											
12	B-16	Soil	9.00	9.00	25	U							1.36		0.683		1.03		0.291		1.47		0.1	U			0.603		144				1.03	T	5.44	TB	149	TC
12	B-30	Soil	7.50	7.50	0.276																																	
13	B-32	Soil	14.00	14.00	0.246																																	
13	B-32	Soil	17.50	17.50	0.063																																	
13	GEI-3	Soil	11.50	12.00	3.8		1.8		23		16.3	T	24		21						28		3.2		78		14		850		79		28.7	T	296	TA	1,410	TB
13	GEI-3	Soil	16.00	17.00	95		24		25		89	T	5.7		4.8						5.8		0.77		17		2.7		250		16		6.37	T	61.8	TA	372	TB
13	GEI-6	Soil	10.00	12.50	12	U	12	U	12	U	69	T	640		630		390		220		580		70		3300		290		110000		4000		819	T	10700	TA	127,000	TB
13	GEI-6	Soil	20.00	21.00	100		170		30		360	T	37		45		27		14		57		6.1		120		26		2200		160		58.1	T	540	TA	3,280	TB
13	GP11	Soil	14.00	14.50	12	U	54		41		400	T	57		73		54		47		57		6.4		170		37		2700		160		93.7	T	700	TA	4,620	TA
13	GP12	Soil	8.00	12.00	1.1		21		2.1		52	T																	440								440	TC
13	GP9	Soil	7.00	8.00	0.67	U	0.67	U	0.67	U	0.67	UT	3.34		9.16		7.4		7.06		3.21		2.72		4.5		81.3		10.2		14.76315		19.4	T	206	TB	310	TB
13	MW-36S	Soil	14.00	15.00	38		170		16		333	T	720		730		400		260		710		88		2200		310		94000		2200		940	T	8,330	TA	108,000	TB
13	MW-37S	Soil	8.00	9.00	3.2		1.2		1.1	U	1.4	T	26		33		22		11		23		4.6		56		17		37		77		41.3	T	303	TA	432	TB
13	PAI-3	Soil	13.00	13.50	15		36		51		38	T	19		12	J	14		7.8		20		3.2		51		7.7		920			J	18.1	JT	189	TA	1,250	JT
13	PAI-11	Soil	18.00	18.50	0.002		0.001	U	0.001	U	0.001	UT	0.3		0.26		0.21		0.11	U	0.39		0.039		1.6		0.17		0.53				0.358	JT	4.94	TA	7.57	JT
14	CR-17-RETEC99	Sediment	0.50	2.70									84		110		78		65		95		10		230		65		380		250		141	T	1,050	TA	1760	TB
14	CR-17-RETEC99	Sediment	2.70	7.50									0.24		0.22		0.14		0.19		0.26		0.028		0.63		0.14		0.68		0.78		0.296	T	2.76	TA	4.4	TB
14	NLU68-SS-RIFSE	Sediment	0.00	0.33	34		5.8		0.43	U	2.26	T	180		290		160		160		200		29		590		170		12		740		362	T	2,700	TA	3,440	TB
14	NLU68-US-RIFSE	Sediment	0.00	1.10	19		3.9		1.2		1.59	T	20				21		17		27		4.2		57		12		64				7.69	T	170	TB	322	TB
14	NLU68-US-RIFSE	Sediment	1.10	4.40	42		4.1		0.044		0.27	T	2.5		2.4		1.9		1.9		2.8		0.24	U	6.8		0.5		60		4.3		3.12	T	23.6	TA	108	TB
14	NLU68-US-RIFSE	Sediment	4.40	7.00	20		0.15	U	0.15	U	0.15	UT	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.06		0.02	U	0.18		0.033		0.0141	UT	0.093	TA	0.344	TB
14	NLU69-US-RIFSE	Sediment	1.20	4.20	0.8	J	22	J	0.63	UJ	19	T	11		11		7.2		5.8		11		1.2		19		3.3		240		23		14	T	96.8	TA	461	TB
14	NLU69-US-RIFSE	Sediment	4.20	5.50	0.13	U	33		0.04	U	19.9	T	12		9.2		4.2		4.2		12		0.72				1.8		890		32		11.6	T	77.6	TB	1,650	TB
15	CR-10-RETEC99	Sediment	3.00	6.00									460		460		380		240		410		52		1,300		260		6,400		970		603	T	4,740	TA	16,000	TB
15	CR-10-RETEC99	Sediment	3.00	6.00									530		510		420		300		460		55		1,400		270		5,100		1100		672	T	5,260	TA	16,100	TB
15	CR-12-RETEC99	Sediment	0.50	3.20									12		15		7.7		4.6		15		0.51		34		6.1		22		44		18.2	T	144	TA	345	TB
15	GEI-3	Soil	22.00	23.00	3.7		1.9		4.7		7.8	T	4.7		4.3						4.3		0.62		16		2.2		100		12		5.66	T	51.9	TA	199	TB
15	GEI-4	Soil	30.00	31.00	0.04		0.07		0.0036		0.004	T	0.027		0.031		0.02		0.011		0.029		0.0044	J	0.06		0.018		0.67		0.07		0.0434	T	0.306	TA	1.13	TB
15	GEI-6	Soil	25.00	26.00	16		23		7		47	T	2.4		2.9		1.4		0.76		2.7		0.28		6.2		1.3		35		8		3.63	T	28.7	TA	87.8	TB
15	GP12	Soil	23.00	24.00	0.084		0.27		0.54		1.39	T	9.59		11.4		7.47		8.77		9.77		1.14		22.3		5.03		401		20.77398		14.3	T	103	TA	711	TA

NAPL and Tar Areas (plus isolated tar impacts)[1]	Location ID[2]	Medium	Start Depth (feet)	End Depth (feet)	Benzene		Ethylbenzene		Toluene		Total Xylenes		Benzo(a) anthracene		Benzo(a)pyrene		Benzo(b) fluoranthene		Benzo(k) fluoranthene		Chrysene		Dibenzo(a,h) anthracene		Fluoranthene		Indeno (1,2,3-cd) pyrene		Naphthalene		Pyrene		Carcinogenic PAH (using 1/2 RL)		High Molecular Weight PAH		Total PAH	
					mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier	mg/kg	Qualifier
15	NLU402-GE-RIFSE	Sediment	6.50	8.00									1.2		1.8		1.4		1.4		1.4		0.15		2.5		0.54		2.3		3.1		2.28	T	14	TA	26.6	TB
15	NLU405-GE-RIFSE	Sediment	5.00	5.50									100		120		78		86		150		14	J	410		94		1,200		450		159	T	1,630	TA	4,390	TB
15	NLU52-US-RIFSE	Sediment	9.20	12.60	140	J	730	J	180	J	480	T	290				180		180		290		24		820		120		5,700		630		82.3	T	2,640	TB	12,400	TB
15	NLU52-US-RIFSE	Sediment	12.60	14.10	26		84		35		71	T	170		170		100		100		150		9.2				47		2,100		360		214	T	1,150	TB	5,220	TB
15	NLU55-TX-GWSA05	Sediment	0.00	0.33									20		27		16		18		22		3.8		49		15		31		46		34.5	T	235	TA	347	TB
15	NLU55-TX-GWSA05	Sediment	0.00	0.33									20		27		16		18		22		3.8		49		15		31		46		34.5	T	235	TA	347	TB
15	NLU55-TX-GWSA05	Sediment	0.00	0.33									60		77		58		47		68		14		140		60		98		150		102	T	731	TA	1,100	TB
15	NLU55-US-RIFSE	Sediment	0.00	2.60	220		30		0.5	U	3.3	T	280		390		180		180		330		44		1,000		250		6200		1000		487	T	3,920	TA	14,200	TB
15	NLU55-US-RIFSE	Sediment	2.60	6.20	3500		120		85		310	T																										
15	NLU57-US-RIFSE	Sediment	5.50	8.10	1.3	J	5.9	J	0.62	U	4.7	T	6.6		6.2		4.3		2.7		6.1		0.45		16		2.1		78		14		7.88	T	61.1	TA	198	TB
15	NLU62-US-RIFSE	Sediment	1.20	4.20	340		41		12		81	T	45		56		34		24		51		7.5	J	120		34		1,300		130	J	71	T	544	TA	2,260	TB
15	NLU73-US-RIFSE	Sediment	0.00	1.80	5.4		1.1		0.0032	U	0.99	T	56		84		41		46		64		12		140		51		480		130		105	T	683	TA	1,780	TB
15	PAI-4	Soil	16.00	16.50	16		2		18		10.7	T	76		30	J	33		17		93		8.1		190		18		940			J	48.1	JT	647.8	TA	2,357.8	JT
16	GEI-1	Soil	16.50	17.00	9.3	J	8.2	J	8.3	J	24	T	46		23		10		6.1		52		2.6		86		5		98		120		31.4	T	364	TA	1,350	TB
16	GEI-14	Soil	8.00	9.00	3.3	U	47		3.3	U	50	T	300		230						330		44		940		100		5,500		900		310	T	3,280	TA	13,800	TB
16	GP1	Soil	12.50	13.00									0.11		0.073		0.06		0.052	U	0.11		0.052	U	0.27		0.052	U	1.2		0.28		0.0963	T	0.903	TA	4.24	TA
16	MW-26	Soil	9.00	9.00									5.1		5.2		4.7		1.7		6.9		0.59		14		2.9		8,200		16		6.77	T	53.7	TB	11,300	TB
16	MW-26	Soil	10.00	10.00									0.37		0.46		0.44		0.14		0.47		0.068		1.2		0.3		52		2		0.597	T	5.18	TB	104	TB
16	SB-10	Soil	15.00	16.50									1.2		1		0.51		0.75		1.1		0.22	U	2.1		0.44		3.3		2.3		1.31	T	9.88	TA	17.4	TA
16	SB-2	Soil	8.00	9.50	1.7		28		0.34	U	3.3	T	24.1		28.5		12.6		17.9		22.8		2.89		59.2		12		281		97.48076		35.7	T	261	TB	976	TB
16	SB-3	Soil	10.00	11.50									1.6		1.5		0.82		0.95		1.8		0.2	U	2.6		0.73		0.63		3.4		1.94	T	14.2	TA	31.5	TA
16	SB-8	Soil	9.00	10.50	1.7		5.6		0.29	U	0.75	T	0.124		0.105		0.0702		0.0763		0.165		0.0113		0.426		0.0724		197		0.63253		0.142	T	1.62	TB	211	TB
1 Tar	TP-10	Tar	0.50	0.50	0.79								1090	J	836	J	639	J	226	J	1,150	J	159	J			468	J	1940	J			1,110	T	4,570	TB	6,510	TC
1 Tar	TP-10	Tar	1.50	1.50	0.25	U							409	J	272	J	295	J	74	J	424	J	48.5	J			138	J	137	J			373	T	1,660	TB	1,800	TC
2 Tar	MW-35S	Soil	5.00	6.00	6.5		1.3		7.7		5.3	T	14		14		8		4.2		15		1.6		38		7		290		50		19.3	T	168	TA	609	TB
3 Tar	CR-10-RETEC99	Tar[3]	0.50	3.00	700		943	J	630				2,100		2,200		2,100		1,400		2,400		220		5,600		1,100		20,000		5700		2,920	T	23,800	TA	68,500	TB
3 Tar	NLU62-US-RIFSE	Sediment	4.20	5.00	0.0012		0.0012	U	0.0012	U	0.0012	UT	0.035		0.054		0.028		0.028		0.039		0.019	U	0.18		0.02		0.9		0.14		0.0664	T	0.543	TA	2.39	TB
5 Tar	SB-6	Soil	1.00	2.00									620		810		480		380		760		80		1,700		490		13,000		100000000		1020	T			32,200	TA
5 Tar	Station 3	Tar	--	--									2,490		3,690		1,810		2,220		2,870		432		7,290		2,600		15,300		10065.014		4,670	T	35,900	TA	74,100	TB
5 Tar	Station 3	Tar	--	--									2,120		3,110		1,530		1,910		2,440		387		6,410		2,290		22,300		8576.5044		3,960	T	31,000	TA	74,600	TB
Isolated Tar	FP-03	Tar	0.00	0.33	8.0		1.2	J	2.1		2.6	T	578		674		555		264		482		12		1,680	J	286		100	J		J	848	T	6,800	TA	10,800	TA
Isolated Tar	84EPA600	Tar	0.00	0.33									3,000		10,000		2,000		2,000		6,000		2,000		8,000		11,000		13,000	T			12,060	T	83,000	TA	114,000	TB
Isolated Tar	84EPA700	Tar	0.00	0.33									3,000		7,000		1,500		1,500		4,000		830		6,000		1,000		2,000	T			7,820	T	46,800	TA	61,400	TB
Isolated Tar	GWP Tank	Tar	--	--									5,520		6,460		3,340		4,060		6,620		850		12,700		4,430		176,000		17100		8,350	T	65,700	TA	315,000	TA
Isolated Tar	SS-1	Tar	--	--									2,780		2,290		776		1,450		3,210		201		3,940		544		59,200		7780		2,900	T	23,700	TA	152,000	TA
Isolated Tar	Station 1	Tar	--	--									779		1,070		613		696		735		120		2,670		762		88,000		2277.0739		1,370	T	10,500	TA	106,000	TB
Isolated Tar	Station 1	Tar	--	--									991		1,290		752		867		919		132		3,690		961		114,000		3063.5451		1,670	T	13,600	TA	138,000	TB
Isolated Tar	Station 1	Tar	--	--									1,330		1,720		950		1,160		1,240		168		4,650		1,240		249,000		3900.5983		2,220	T	17,600	TA	281,000	TB
Isolated Tar	Station 1	Tar	--	--									1,880		2,410		1,300		1,650		1,710		241		6,200		1,730		379,000		4820.6828		3,110	T	23,600	TA	422,000	TB
Isolated Tar	Station 2	Tar	--	--									3,690		4,250		2,610		3,040		3,630		535		11,900		2,790		8,370		11684.717		5,560	T	47,100	TA	81,600	TB
Isolated Tar	Station 2	Tar	--	--									4,140		4,860		2,720		3,010		4,060		606		13,000		3,190		11,300		12912.726		6,270	T	51,900	TA	90,400	TB
Isolated Tar	Station 2	Tar	--	--									3,850		4,640		2,650		3,320		3,660		504		12,400		3,310		12,800		12257.379		6,040	T	49,900	TA	91,000	TB
Isolated Tar	Station 2	Tar	--	--									1,270		1,740		965		1,150		1,190		171		5,060		1,220		145,000		4262.5586		2,230	T	18,300	TA	178,000	TB
Isolated Tar	Station 4	Tar	--	--									229		216		103		146		236		24.9		520		108		223		632.49836		280	T	2,320	TA	4,430	TB
Isolated Tar	Station 5	Tar	--	--									1,640		1,970		1,190		1,440		1,610		301		5,370		1,490		5,000		5122.4208		2,590	T	21,800	TA	39,000	TB
Isolated Tar	Station 5	Tar	--	--									1,350		1,350		1,050		1,250		1,290		224		5,680		992		16,300		5293.3845		1,850	T	19,700	TA	50,600	TB
Isolated Tar	Structure 1	Tar	--	--									2,780		8,190		4,200		3,210		3,840		600		17,800		7,870		12,200		23700.02		10,100	T	83,000	TA	128,000	TB
Isolated Tar	Structure 1	Tar	--	--									2,810		7,610		3,940		3,110		4,320		716		21,400		7,390		21,700		29709.883		9,450	T	92,100	TA	154,000	TB
Isolated Tar	Structure 2	Tar	--	--									1,480		1,450		520		760		1,610		203		1,870		523		31,400		3791.7878		1,810	T	12,800	TA	61,900	TB
Isolated Tar	Structure 3	Tar	--	--									1,610		1,510		568		794		1,750		225		1,860		591		28,100		3955.9927		1900	T	13,700	TA	58,400	TB
Isolated Tar	TP-6	Tar	--	--	191								574	J	616	J	451	J	155	J	572	J	82	J			517	J	12,200	J			800	T	2,970	TB	15,200	TC

Notes:

[1] Isolated tar samples are outside contiguous tar areas.

[2] Explorations without chemical data (i.e., UV photography, semi-quantitative forensics data) are not included.

[3] Samples (CR-10, NLU117 and NLU119) contained significant amount of tar or NAPL; however, the RI treats samples as sediment on mapping figures and statistics tables.

Analyte qualifiers defined in RI Appendix 5B - Chemistry Data.

Table 5F-5

Petrophysical Testing - Free Product Mobility Results

Gas Works Park Site

Seattle, Washington

NAPL Area	NAPL Type	Geologic Unit	Exploration ID	Sample ID	Sample Depth (ft bgs)	Soil Free Product Mobility		Change in NAPL Saturation (% Pv)[1]
						Initial NAPL Saturation (% Pv)	Final NAPL Saturation (% Pv)	
4	DNAPL	Qva	PT-03	PT03-28-30B	29.7	13.8	13.8	0
4	DNAPL	Qvr	TDW-2	TDW2-15.5-16.0	15.9	5.2	4.1	**1.1**
4	DNAPL	Qvr	TDW-2	TDW2-16.8-17.3	17.1	2.1	0.1	**2.0**
4	DNAPL	Qvr	TDW-2	TDW2-18.3-18.8	18.5	4.4	1.2	**3.2**
5	DNAPL	Fill	PT-03	PT03-10-13B	10.9	14.5	14.5	0
5	DNAPL	Fill	PT-03	PT03-8-10A	8.6	8.4	8.4	0
16	LNAPL/DNAPL	Fill	GP-02	GP-02-12.5-13.0	12.6	4.0	4.0	0
16	LNAPL/DNAPL	Fill	SB-2	SB-2-S4	6.5-6.7	6.7	6.7	0
16	LNAPL/DNAPL	Fill	SB-2A	SB-2A-S1	8.3-8.4	7.0	7.0	0
16	LNAPL/DNAPL	Fill	SB-3A	SB-3A	9.0-9.2	17.6	16.1	**1.5**
13	LNAPL	Fill	GP-09	GP-09R1-11.0-11.5	11.3	4.8	4.8	0
13	LNAPL	Fill	GP-11	GP-11R3-12.0-12.5	12.3	6.7	6.7	0
13	LNAPL	Fill	PT-01B	PT01B-11-13.2A	12.9	6.8	6.7	**0.1**
13	LNAPL	Fill	PT-02	PT02-10-13B	11.8	46.6	46.6	0
13	LNAPL	Fill	PT-02	PT02-20-23	21.5	19.6	19.6	0
15	DNAPL	Fill	GP-11	GP-11-22.5-23.0	22.7	7.9	7.7	**0.2**
15	DNAPL	Qvrl	GP-12	GP-12R1-25.0-25.25	25.2	5.0	4.6	**0.4**
15	DNAPL	Qvrl	PT-01	PT01-21.1-22B	21.2	10.3	10.3	0
--	Tar	Fill	SB-12A	SB-12A-S6	10.4-10.5	88.7	87.8	**0.9**
--	--[2]	Fill	TSB-2	TSB2-21.3-21.8	21.5	5.6	2.4	**3.2**

Notes

[1] Change in NAPL saturation is used to determine NAPL stability, see Appendix 5F Section 8.

[2] TSB-2 represents isolated NAPL impacts. Log indicates oily sheen and staining.

-- Not applicable

Bold text = NAPL produced during centrifuging

NAPL = nonaqueous phase liquid; DNAPL = dense NAPL; LNAPL = light NAPL

ft bgs = feet below ground surface

Qvrl = Vashon Recessional Glaciolacustrine Deposits; Qvr = Vashon Recessional Outwash; Qva = Vashon Advance Outwash

See text for full acronym list.

Table 5F-6

NAPL and Tar Areas[1]

Gas Works Park Site
Seattle, Washington

Number	Upland/ Sediment	NAPL Type	Explorations Within	Approximate Depth Range^2 (feet bml or bgs)	Approximate Elevation Range (feet USACE)	Cross Sections^3	Geologic Units of Occurrence
NAPL 1	Western Region Sediment	DNAPL	NLU115, NS-17, ST-04	0 to 1.1	-18.10 to -20.07	Closest to E-E'	Recent
NAPL 2	Western Region Sediment	DNAPL. Petroleum component DNAPL	GWS-EC15, GWS-SG16, GWS-GC06, NS18, ST-03	0 to 25	-19.10 to -44.70	E-E'	Recent
NAPL 3	Western Region Sediment	DNAPL. Shallow: PAH-rich DNAPL and other material (i.e., containing petroleum). Deep: PAH-rich DNAPL and naphthalene-rich DNAPL	4-1A, 4-2, 4-3, 5-1, 5-2, 5-4, CR-20, CR-21, GWS-EC12, GWS-EC13, GWS-EC14, GWS-GC01, NLU119, NLU119D-US, NLU119R5, NS19, ST-01	0 to 20.8	-3.70 to -40.90	E-E'	Fill and Recent
NAPL 4	Western Region Sediment	Refinery DNAPL and Pitch	B-2(EPRI), DW-4, DW-5, DW-6, DW-7, GEI-14, MLS-4, MW-5, MW-18, PT-03, PZ-2, PZ-3, PZ-4, PZ-6, PZ-7, PZ-8, PZ-10, TDW-2, TG-17, TG-21, TG-24, TMS-14, TSB-3	4.4 to 41.58	32.03 to -16.46	F-F'; G-G'	Fill, Recessional Outwash and Advance Outwash
NAPL 5A	Western Region Sediment	Refinery DNAPL	GEI-14, PT-03, PZ-5 (on perimeter), PZ-6, TG-20	4 to 13	23.00 to 14.00	G-G'; O-O'	Fill
NAPL 5B	Western Region Sediment	DNAPL. Moderate to heavier PAH-rich (heavier cut of coal tar/pitch) product; Tar distillate; Mixed petroleum-related product; Middle weight petroleum distillate; Naphthalene rich product	1-2, 2-1, 2-2A, 3-1, 3-2, 3-3, 3-4, 3-5, CR-01, CR-13, CR-19, FP-01, GWS-EC05, GWS-EC05R4, GWS-EC06, GWS-EC07, GWS-EC08, GWS-EC09, GWS-EC09DUP, GWS-EC24, GWS-GC03, GWS-SG01, GWS-SG05, NLU11-US, NLU84-TX, NLU117R1, NLU117R2-US, NLU117D, NLU117-TX, NLU119R1, NLU119R2, NLU119R3, NLU119R4	0 to 8.6	-8.45 to -35.40	F-F'; G-G'; H-H'	Fill, Recent and Recessional Outwash
NAPL 6	Central Region Upland	Petroleum-Based LNAPL (Fuel Oil)	GEI-12, TG-36, TG-37, TG-38, TG-39, TG-40	3.5 to 18.5	29.63 to 16.18	I-I'	Fill and Recessional Outwash
NAPL 7	Central Region Upland	MGP DNAPL	GEI-12, TG-37, TG-39, TG-40	2.5 to 16.8	32.91 to 16.33	I-I'	Fill and Recessional Outwash
NAPL 8	Central Region Sediment	MGP DNAPL (oil gas related)	CR-14, NLU51-US, NLU51-TX, NLU72-US	0 to 6	4.70 to -13.70	J-J'	Recent and Recessional Outwash
NAPL 9	Central Region Sediment	MGP DNAPL	NLU48-US, NLU418-GE	3 to 13	-24.80 to -34.80	J-J'	Recent and Recessional Outwash
NAPL 10	Eastern Region Upland	MGP DNAPL	B-13, GEI-13, MW-09, PAI-7, TG-11, TG-12, TG-12R/46, TG-14, TG-15, TG-16, TMS-4	10.06 to 29.38	24.35 to 6.43	K-K'; L-L'; M-M'	Fill, Recessional Outwash, and Advance Outwash
NAPL 11	Eastern Region Upland	Petroleum-Based LNAPL	B-13, GEI-13, MW-09, TG-11, TG-12, TG-12R/46, TG-44, TG-45, TMS-4	6 to 12.9	28.41 to 24.35	K-K'; L-L'; M-M'	Fill
NAPL 12	Eastern Region Upland	Benzol Light Oil LNAPL	A-1, B-1, B-2, B-5, B-6, B-7, B-10, B-16, B-23, B-25, B-27, B-29, B-30, F-2,MW-12,OBS-1, OBS-2, OBS-3, TMS-2, TP-6	0.95 to 17.6	24.60 to 7.57	K-K'; P-P'	Fill
NAPL 13	Eastern Region Upland	Petroleum LNAPL; Naphthalene LNAPL	B-32, GEI-3, GEI-6, GP-9, GP11, GP12, GP-13, GP10, HA1, HA2, HA3, HA-4, MW-36S, MW-36D, MW-37S, PAI-1, PAI-3, PAI-4, PAI-8, PAI-10, PAI-11, PAI-12, PT-01, PT-01B, PT-02, TG-43, TG-42, TG-42R, TMS-5, TMS-6, TMS-7	1.76 to 23	23.13 to 6.89	L-L'; M-M'; P-P'	Primarily within Fill. Also extends to Recessional Outwash.
NAPL 14	Eastern Region Sediment	MGP DNAPL	CR-17, NLU68-US, NLU68-SS, NLU69-US	0 to 5.5	1.40 to -21.00	K-K'	Fill and Recent
NAPL 15	Eastern Region Upland and Sediment	MGP DNAPL	CR-10, CR-12, GEI-3, GEI-4, GEI-6, GP11, GP-12, HA2, MW-36S, MW-36D, NLU18-GE, NLU52-US, NLU52-SS, NLU55-DC, NLU55-SS, NLU55-US, NLU55-TX, NLU57-US, NLU62-SS, NLU62-US, NLU63-US, NLU63-DC, NLU63-SS, NLU73-US, NLU73-SS, NLU73-TX, NLU73-DC, NLU109D-US, NLU109-US, NLU402-GE, NLU405-GE, PAI-2, PAI-4, PT-01, PT-01B, PT-02, ST-28, TG-42, TG-42R, TMS-10	0 to 30	14.30 to -34.20	L-L'; M-M'; P-P'	Primarily within Fill and Recent. Also extends to Recessional Outwash and Advance Outwash
NAPL 16	Eastern Region Upland	LNAPL/DNAPL mix. Petroleum-Based LNAPL (Heavy Oil and Gasoline and Diesel-Range); MGP DNAPL	GEI-1, GEI-7, GP-1, GP-2, GP-3, GP-4, GP-5, GP-7, GP-14, MW-26, SB-1, SB-2, SB-2A, SB-3, SB-3A, SB-5, SB-6, SB-7, SB-8, SB-10, SB-11, TG-02, TG-04, TG-05, TG-06, TG-08	1.58 to 24.35	30.42 to 7.49	N-N'; P-P'	Primarily within Fill. Also extends to Advance Outwash
Tar 1	Western Region Upland	Pitch/Semi Solid Tar	MW-5, TP-10	2.67 to 7.95	34.48 to 30.48	Closest to F-F'	Fill
Tar 2	Eastern Region Upland	Pitch/Semi Solid Tar	MW-16, MW-35S	1.44 to 13.94	22.88 to 10.38	P-P'	Mostly in Fill
Tar 3	Eastern Region Sediment	Pitch/Semi Solid Tar with minor motor oil/urban source	CR-10, NLU-62-US	0 to 4.4	-8.80 to -14.00	L-L'	Fill and Recessional Outwash
Tar 4	Eastern Region Sediment	Pitch/Semi Solid Tar	CR-12	3.1 to 5.3	-12.90 to -15.10	--	Recessional Outwash
Tar 5	Eastern Region Upland and Sediment	Pitch/Semi Solid Tar	GEI-15, GP-4, GP-5, HA-5, HA-6, HA-8, SB-6, SS-5	0 to 2.6	27.51 to 21.10	N-N'; P-P'	Fill

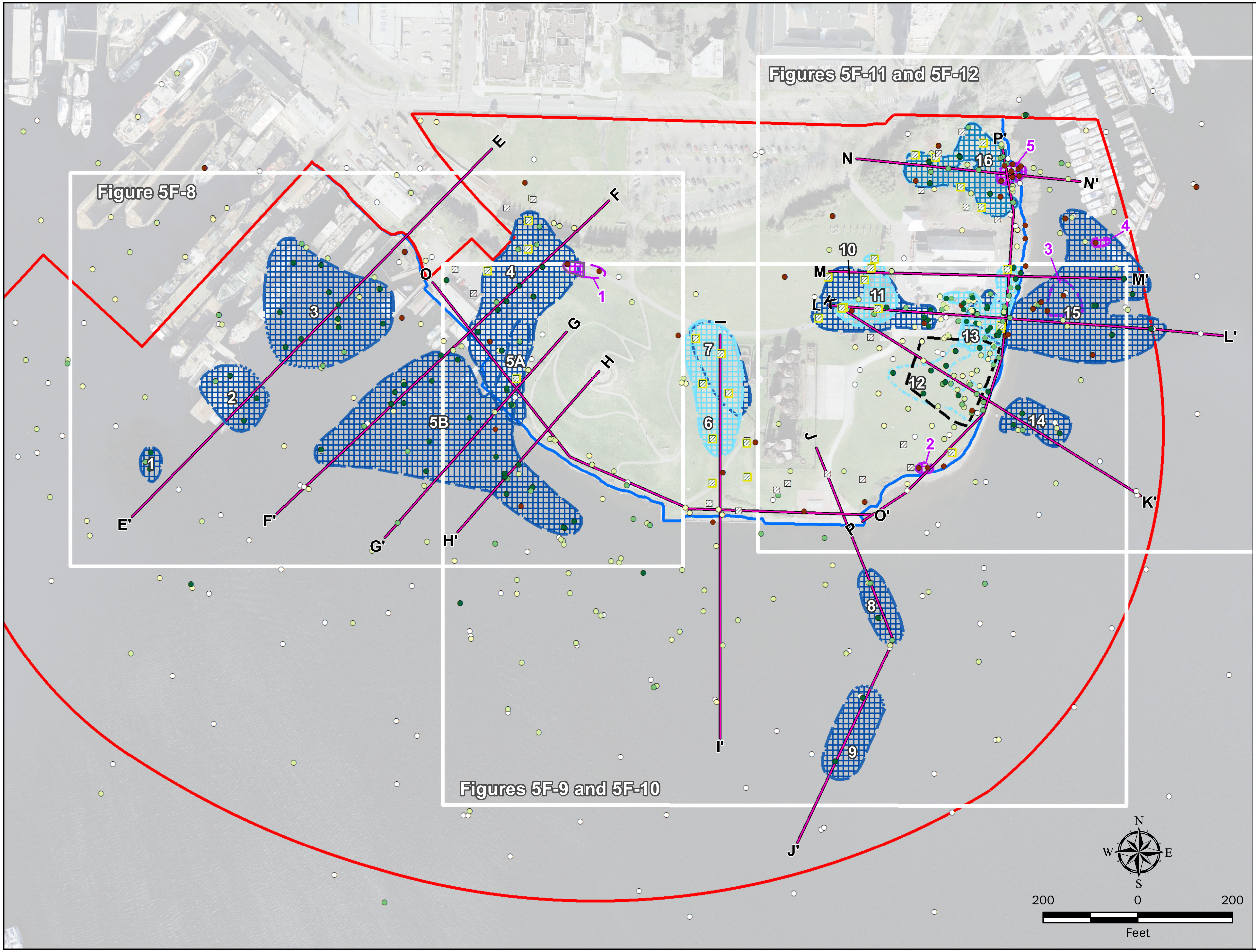
Notes:

[1] This table is intended to show areas where tar or NAPL has been interpreted to exist at multiple adjacent sample locations; it is not inclusive of sporadic occurrences. Refer to Figures 5F-1 and -2 for locations of NAPL and tar areas.

[2] Refer to Figures 5F-8 to 5F-12 for vertical extent of NAPL.

[3] Refer to Figures 5F-13 to 5F-24 (NAPL cross sections E-E' to P-P').

See text for full acronym list.



Legend

▬ Area of Investigation

▬ Shoreline (OHWM)

A A' Cross Section

⌜⌟ 2001-2006: Air Sparging Area

NAPL and Tar Occurrence Categories

● Tar or Impacted Interval

● Heavy Sheen with NAPL

● Heavy Sheen and/or Trace NAPL

● Slight to Moderate Sheen

● Staining and/or Odor

○ No Impacts

Interpreted TarGOST NAPL Occurrence

▨ NAPL Impacts

▨ No Impacts

NAPL/Tar Areas - All Depths

1 Tar Area

1 NAPL Area

▦ Tar

▦ DNAPL

▦ LNAPL

▦ Mixed LNAPL/DNAPL

⌜⌟ Former Tar*

⌜⌟ Former LNAPL

▪▪▪ Estimated Extent of NAPL—Greater Uncertainty

Notes:

1. *Tar Area 1 partially removed in 1997.
2. Mapping Rationale: Where both tar and heavy sheen with NAPL were observed in an exploration, the exploration is shown as tar-impacted.
3. NAPL area 12 is pre-cleanup action. Air sparging/soil vapor extraction system has reduced or eliminated NAPL in this area.
4. Cross sections A, B, C & D are presented in the RI report, used for geology discussion.
5. Basemap 2005 USGS aerial photograph. Does not show current conditions.
6. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

NAPL and Tar Occurrences and Areas

Gas Works Park Site
Seattle, Washington

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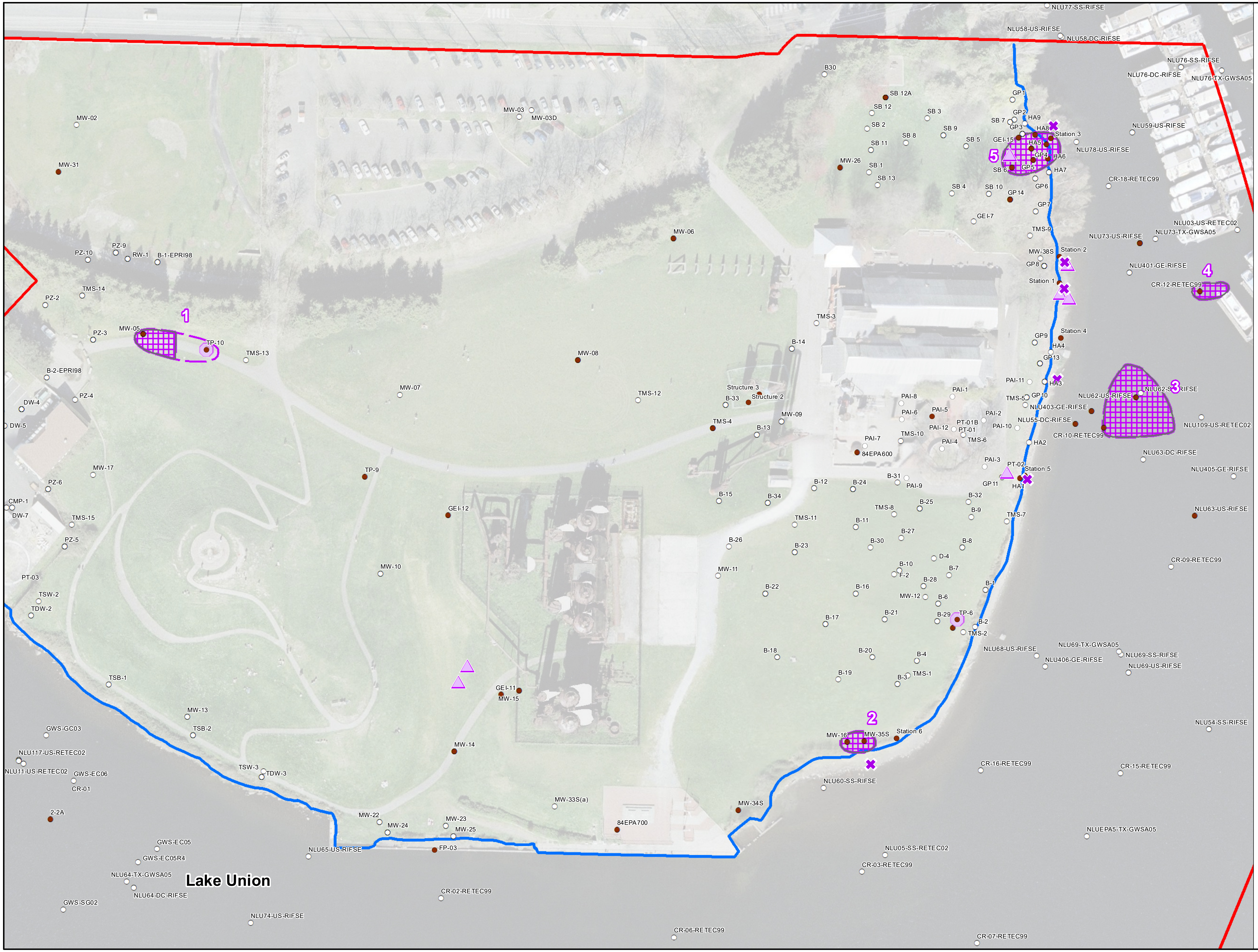
Figure 5F-1

Path: P:\0\0186846\GIS\MXD\Phase01\T1635\0186846_01_F5F-1_ConceptualExtentNAPL.mxd Map Revised: 02 December 2021 maugust



Legend

🟥 Area of Investigation

🟦 Shoreline (OHWM)

Tar Occurrence Categories

● Tar

○ No Tar Impacts

Tar Areas and Isolated Exposed Tar

1 Tar Areas

▦ Tar

✖ Location of surficial tar exposure. Occurrences are isolated, and typically range in size from 1 to several square feet.

Tar Removal

⌜⌟ Former Tar*

⬡ 1997: Approximate location of tar removal

△ 2006-2011: Approximate location of minor tar removal

Notes:

1. *Tar Area 1 partially removed in 1997.
2. Mapping intends to show areas where tar has been interpreted to exist at multiple adjacent sample locations.
3. Observations of contiguous near-surface tar in the offshore delineated by diver probe.
4. Basemap USGS 2005 aerial photograph. Does not show current conditions.
5. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Tar Areas - All Depths

Gas Works Park Site
Seattle, Washington

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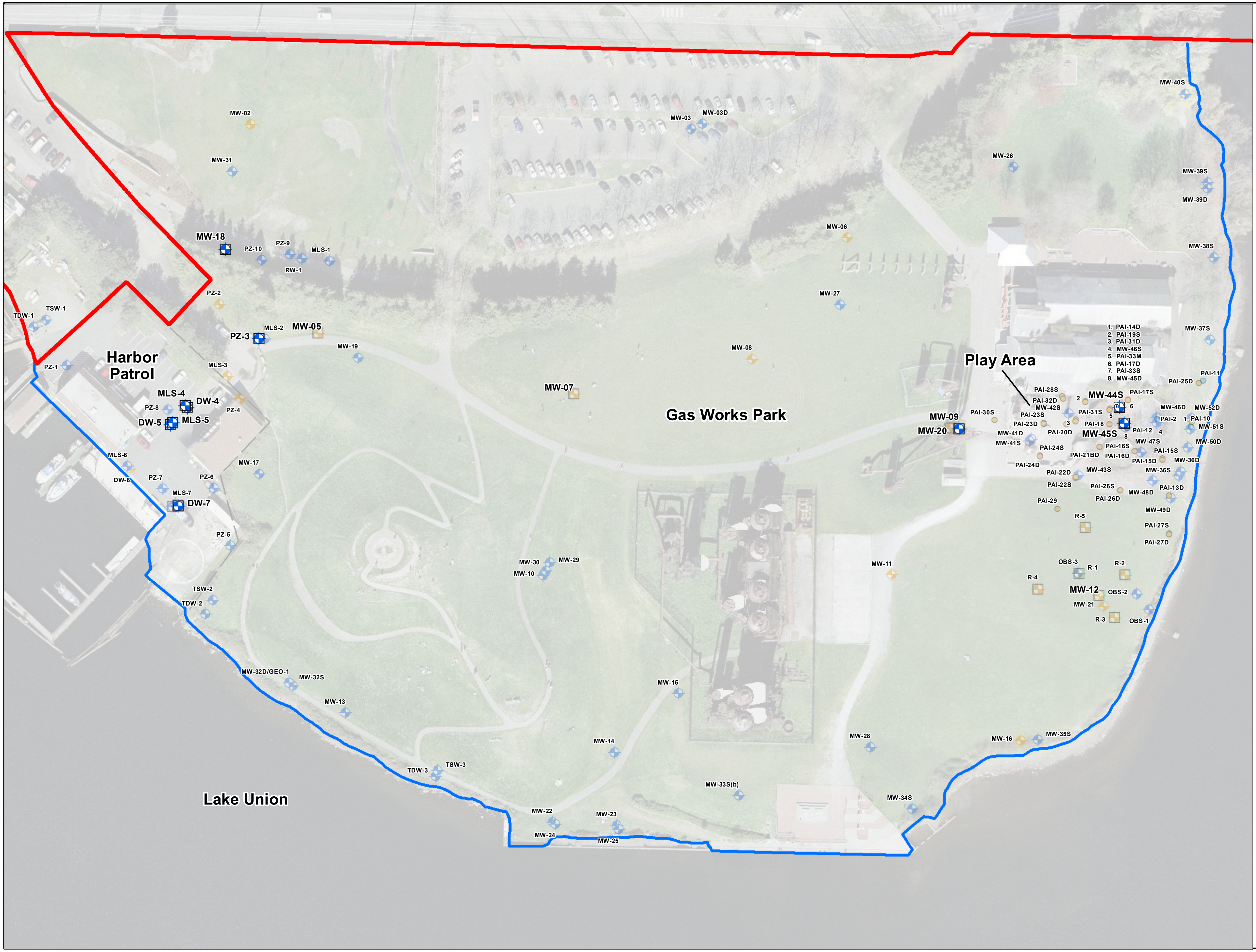
Figure 5F-2

Path: P:\01\0186846\GIS\MXD\Phase01\T1635\018684601_F5F-2_ConceptualExtentTar.mxd Map Revised: 02 December 2021 maugust



Legend

🟥 Area of Investigation

🟦 Shoreline (OHWM)

Groundwater Explorations

● Grab Groundwater Exploration

⊕ Current Groundwater Well - No NAPL

⊕ Former Groundwater Well - No NAPL

⊞ Former Groundwater Well - History of NAPL

⊞ Current Well - NAPL

Notes:

1. As of the last well gauging event (December 2020), measurable NAPL (i.e. >0.01 foot) was detected only in the following wells: MW-09, DW-4, DW-5, DW-7, MLS-4, MLS-5, MW-18, PZ-3, MW-44S, and MW-45.
2. Basemap 2005 USGS aerial photograph. Does not show current conditions.
3. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

DISCLAIMER: This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. The locations of all features are approximate. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

N
W E
S

100 0 100

Feet

Groundwater Explorations with Detected NAPL

Gas Works Park Site
Seattle, Washington

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Figure 5F-3

Path: P:\0\0186846\GIS\MXD\Phase01\T1635\018684601_F5F-3_GWExplorations.mxd Map Revised: 15 December 2021 maugust

Legend

🟥 Area of Investigation

🟦 Shoreline (OHWM)

✚ TarGOST Explorations

● Confimation Soil Borings

Notes:
1. Basemap 2005 USGS aerial photograph. Does not show current conditions.
2. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

N
W E
S

100 0 100
Feet

TarGOST Explorations and Confirmation Borings

Gas Works Park Site
Seattle, Washington

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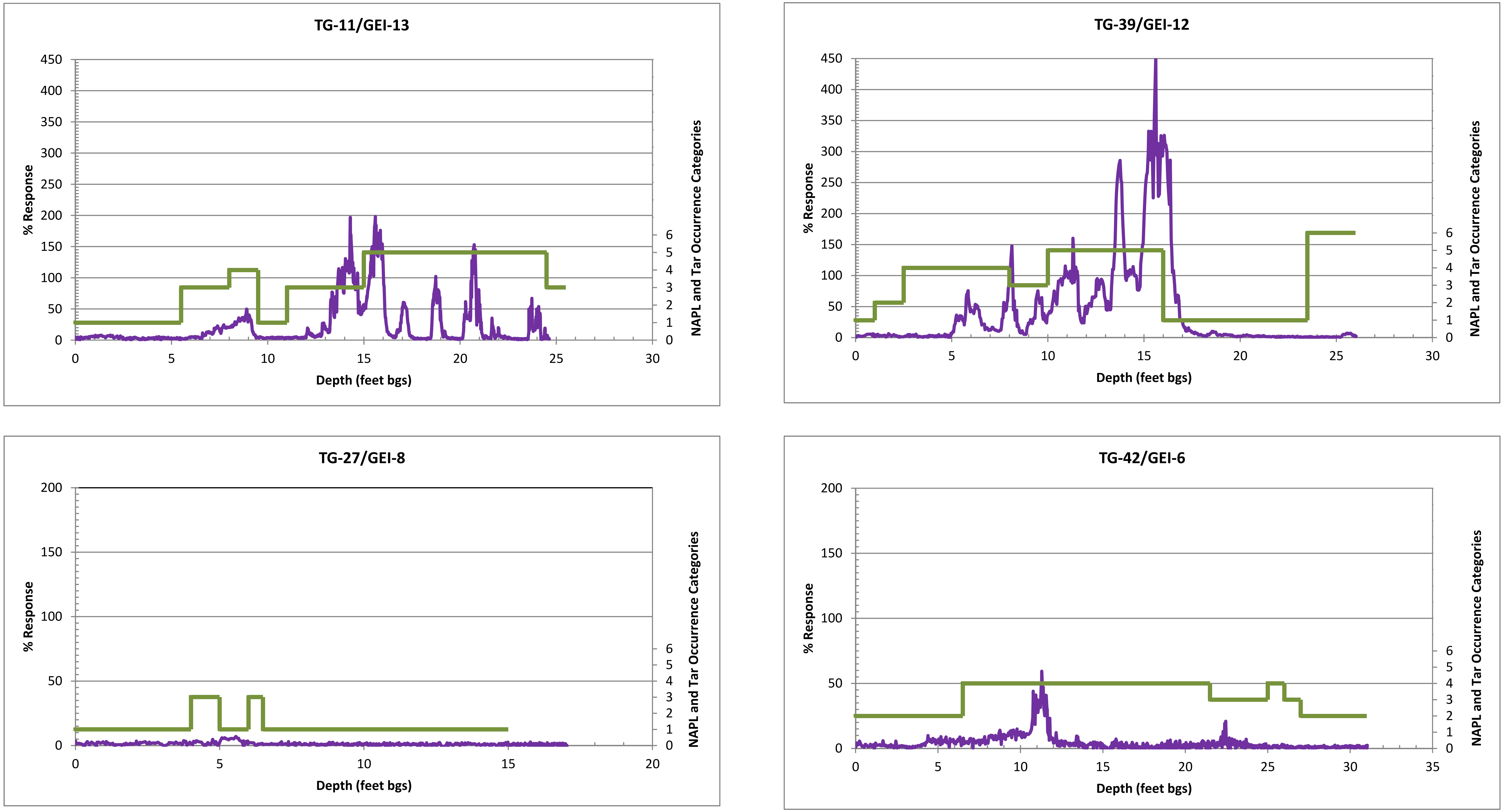
Figure 5F-4

Path: P:\0\0186846\GIS\MXD\Phase01\T1635\018684601_F5F-4_TarGOSTExplorationsConfBorings.mxd Map Revised: 02 December 2021 maugust



Notes:

1. NAPL and Tar Occurrence Categories
   6 = Tar
   5 = Heavy sheen with NAPL
   4 = Heavy sheen and/or trace NAPL 3 = Slight to moderate sheen
   2 = Staining and/or odor
   1 = No impacts

Legend

🟪 TarGOST Total % Response

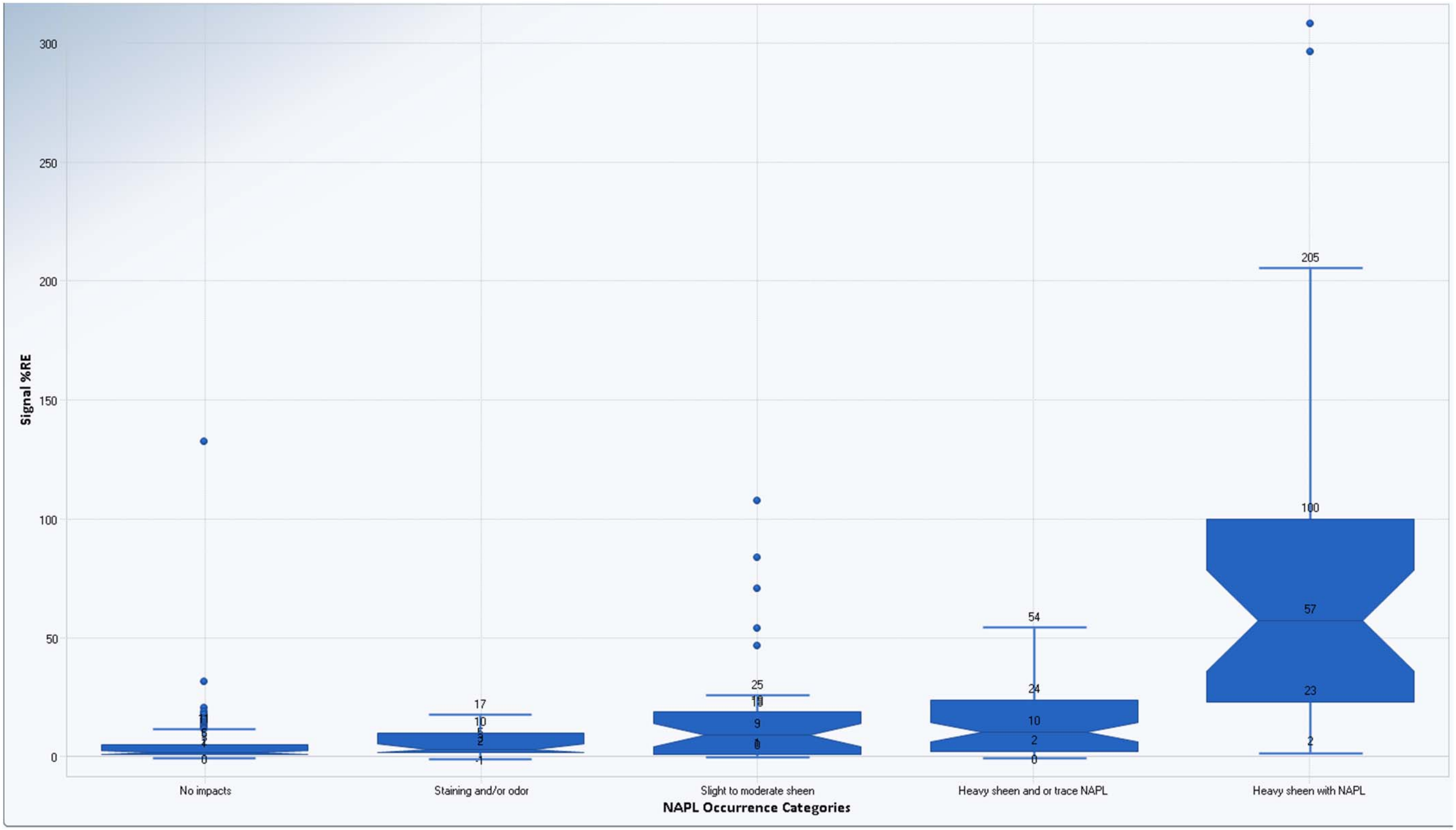
🟩 Confirmation Soil Boring NAPL and Tar Occurrence Categories

TarGOST Response vs. Field Observed NAPL Occurence

Gas Works Park Site
Seattle, Washington

GeoEngineers

Figure 5F-5



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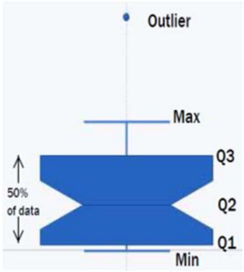

Notes:

1. Signal % RE is the TarGOST total percent response.
2. Box and whisker plots generated by the statistical software ProUCL.
3. Numbers plotted on box plots are minimum, lower or 25% quartile (Q1), median (Q2), upper or 75% quartile (Q3) and maximum. Outliers are not labeled; ProUCL classifies data points as outliers when their values are 1.5 times the quartile range from the closest end of the box.

Statistical Evaluation of TarGOST Response & NAPL Occurrence

Gas Works Park Site
Seattle, Washington

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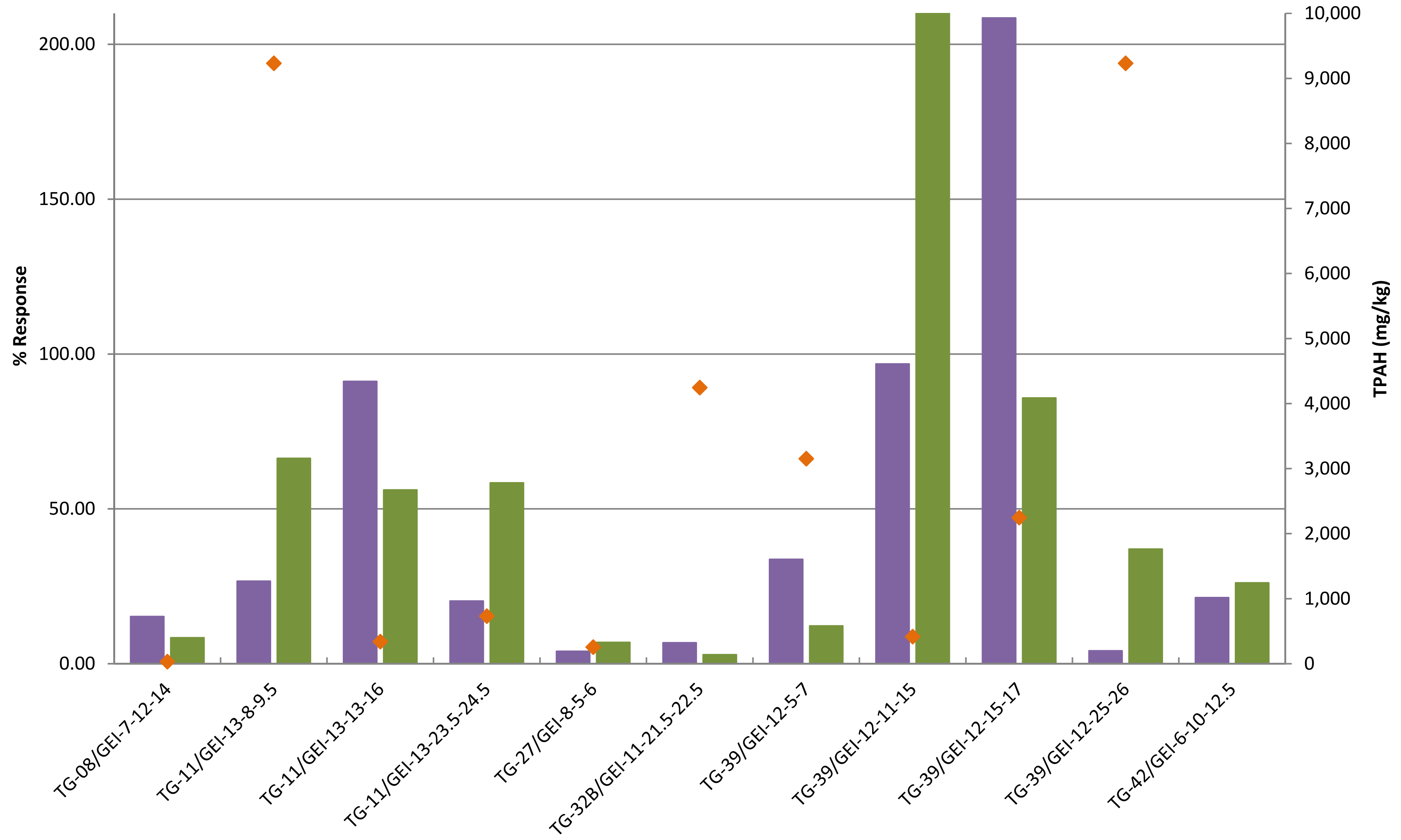
Figure 5F-6



Notes:

1. In-situ corresponds to TarGOST boring and ex-situ to soil confirmation sample. Chart presents in-situ average % response over the corresponding ex-situ sample interval.
2. TPAH result for GEI-6-10-12.5 is 126,970 mg/kg, was not plotted because its an outlier compared to the other results.

Legend

🟪 In-Situ % Response (TarGOST Exploration)

🟩 Ex-Situ % Response (Confirmation Soil Boring)

◆ Ex-Situ TPAH Result (Confirmation Soil Boring)

In-Situ & Ex-Situ TarGOST Response vs. TPAH

Gas Works Park Site
Seattle, Washington

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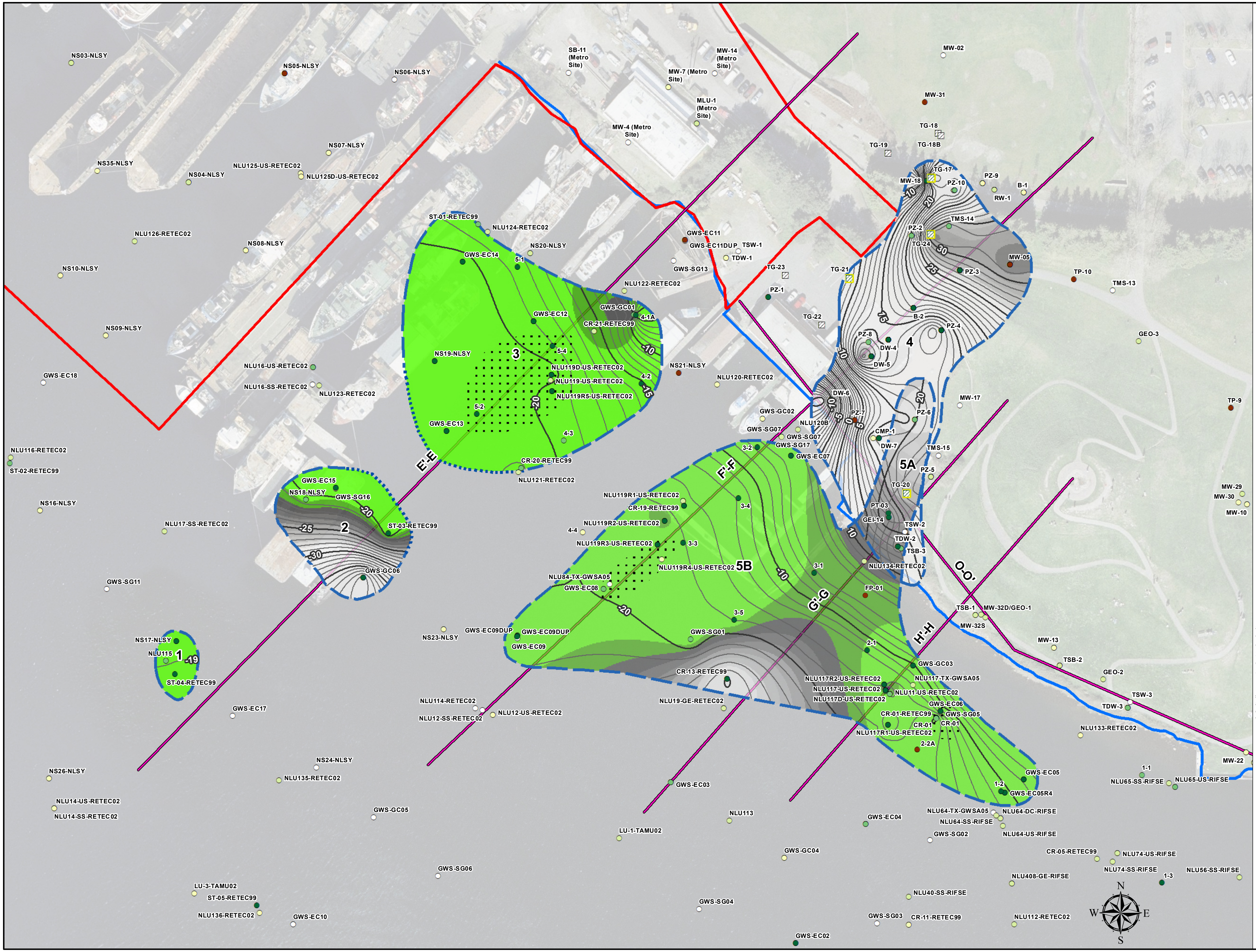
Figure 5F-7



Legend

━	Area of Investigation
━	Shoreline (OHWM)
A ━ A'	Cross Section

NAPL Elevation Contour (feet, USACE)

━	5-feet
─	1-foot

NAPL and Tar Occurrence Categories

●	Tar or Impacted Interval
●	Heavy Sheen with NAPL
●	Heavy Sheen and/or Trace NAPL
●	Slight to Moderate Sheen
●	Staining and/or Odor
○	No Impacts

Interpreted TarGOST NAPL Occurrence

☐	NAPL Impacts
☐	No Impacts

NAPL Areas

┅	DNAPL
⋯	Area of Deep Vertical DNAPL Penetration
┅	Estimated Extent of NAPL - Greater Uncertainty

Depth to Top of NAPL (feet, bgs or bml)

🟩	0 - 1	■	3 - 4	■	6 - 7	☐	>9
🟩	1 - 2	■	4 - 5	■	7 - 8		
■	2 - 3	■	5 - 6	■	8 - 9		

Notes:

1. Site-specific TarGOST %RE response value of 10 %RE was used as a cut-off, responses above 10 %RE were assumed to represent NAPL occurrence ranging from "heavy sheen and/or trace NAPL" or "heavy sheen with NAPL" categories.
2. Basemap 2005 USGS aerial photograph. Does not show current conditions.
3. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

100 0 100

Feet

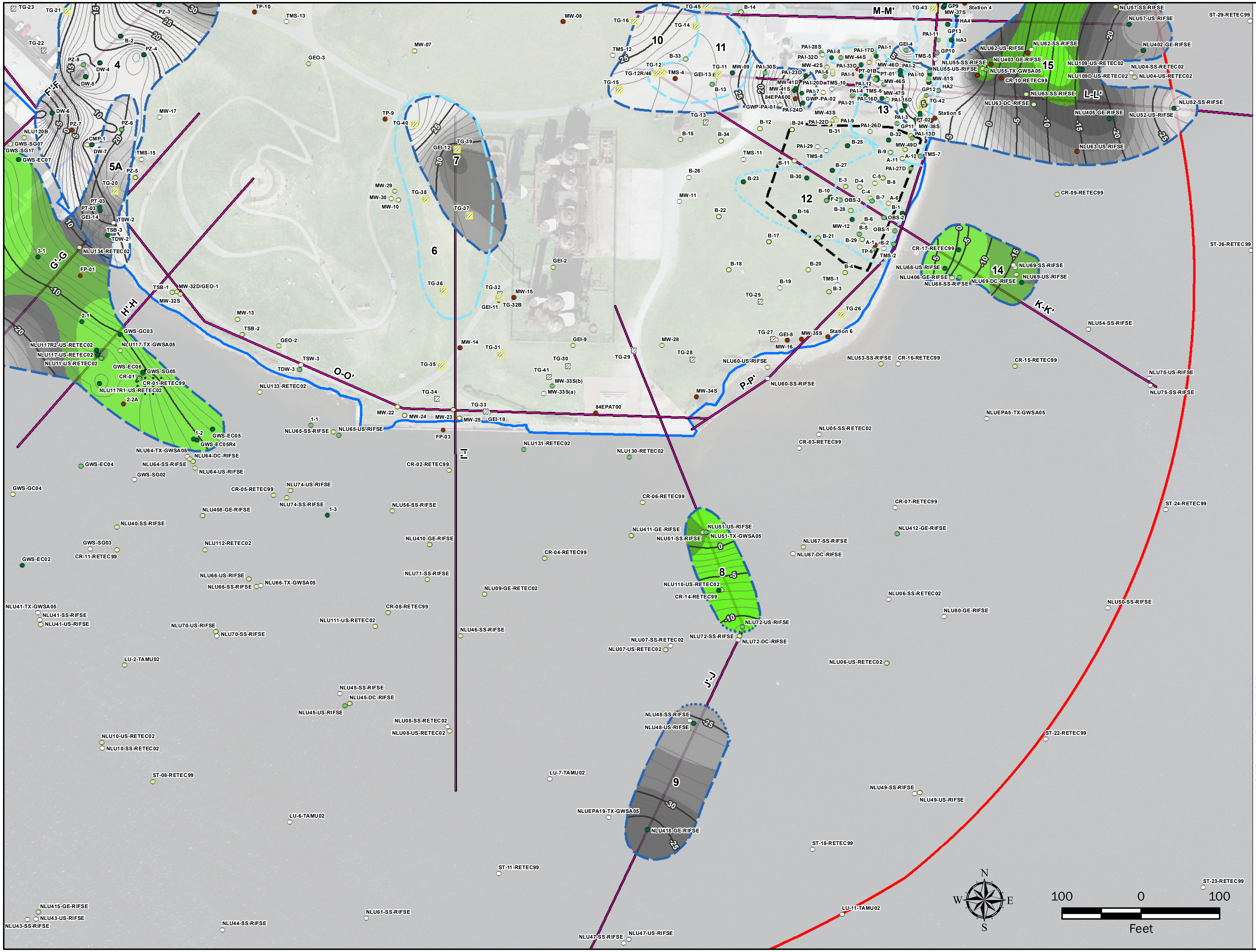
Depth and Elevation to Top of DNAPL - Western Region

Gas Works Park Site
Seattle, Washington

GeoEngineers

Figure 5F-8

Path: P:\0\0186846\GIS\MXD\Phase01\T1635\018684601_F5F-8_TopDNAPL_Western_question.mxd Map Revised: 02 December 2021 maugust



Legend

- Area of Investigation
- Shoreline (OHWM)
- A A' Cross Section
- 2001-2006: Air Sparging Area

NAPL Elevation Contour (feet, USACE)

- 5-feet
- 1-foot

NAPL and Tar Occurrence Categories

- ● Tar or Impacted Interval
- ● Heavy Sheen with NAPL
- ● Heavy Sheen and/or Trace NAPL
- ● Slight to Moderate Sheen
- ● Staining and/or Odor
- ○ No Impacts

Interpreted TarGOST NAPL Occurrence

- ☐ NAPL Impacts
- ☐ No Impacts

NAPL Areas

- DNAPL
- LNAPL
- Former LNAPL/DNAPL
- Area of Deep Vertical DNAPL Penetration
- Estimated Extent of NAPL—Greater Uncertainty

Depth to Top of NAPL (feet, bgs or bml)

🟩	0 - 1	■	3 - 4	■	6 - 7	☐	>9
🟩	1 - 2	■	4 - 5	■	7 - 8		
■	2 - 3	■	5 - 6	■	8 - 9		

Notes:

1. Site-specific TarGOST %RE response value of 10 %RE was used as a cut-off, responses above 10 %RE were assumed to represent NAPL occurrence ranging from "heavy sheen and/or trace NAPL" or "heavy sheen with NAPL" categories.
2. NAPL area 12 is pre-cleanup action. Air sparging/soil vapor extraction system has reduced or eliminated NAPL in this area.
3. Basemap 2005 USGS aerial photograph. Does not show current conditions.
4. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

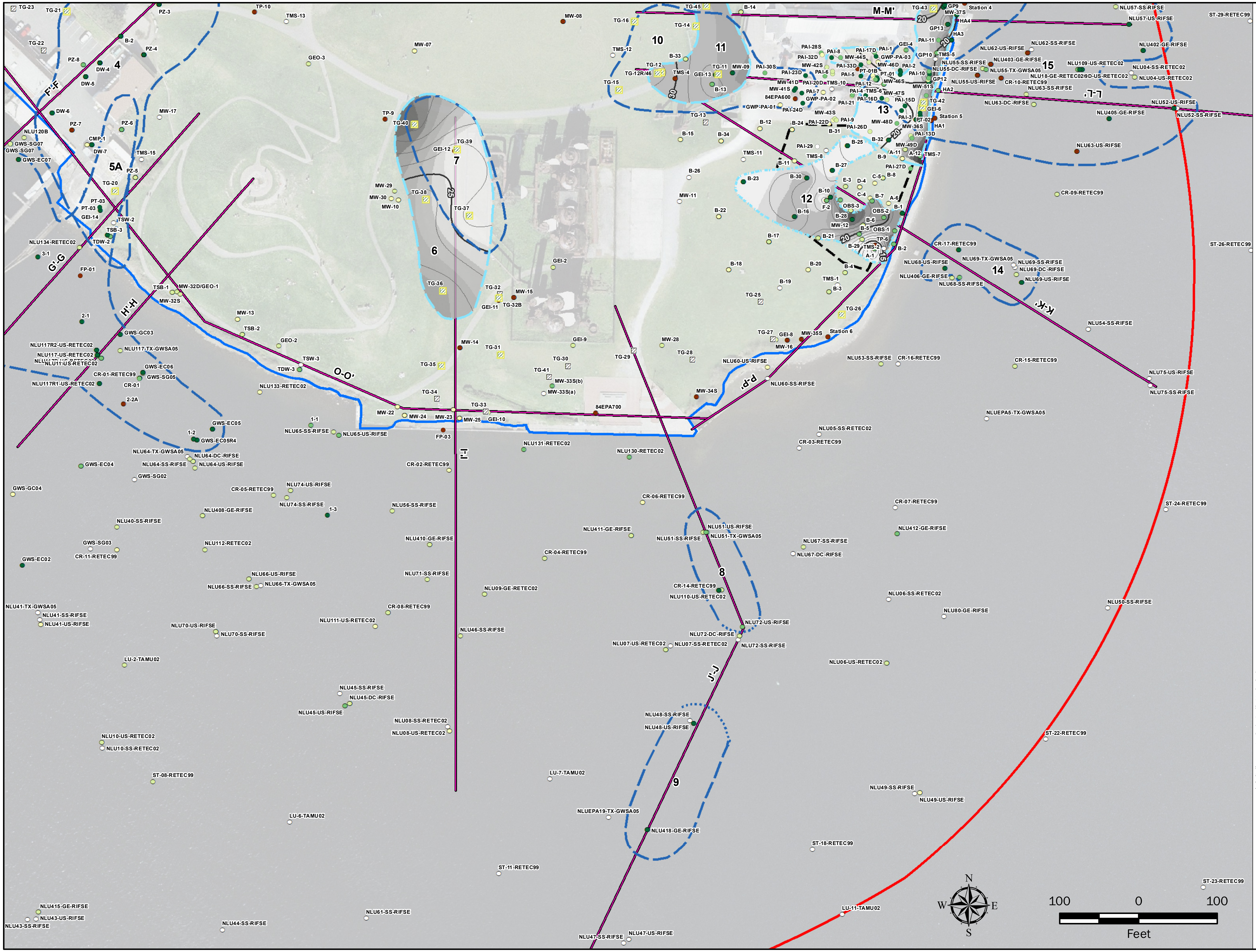
Depth and Elevation to Top of DNAPL - Central Region

Gas Works Park Site
Seattle, Washington

GeoEngineers

Figure 5F-9

Path: P:\0\0186846\GIS\MXD\Phase01\T1635\018684601_F5F-9_TopDNAPL_Central.mxd Map Revised: 02 December 2021 maugust



Legend

- Area of Investigation
- Shoreline (OHWM)
- A A' Cross Section
- 2001-2006: Air Sparging Area

NAPL Elevation Contour (feet, USACE)

- 5-feet
- 1-foot

NAPL and Tar Occurrence Categories

- ● Tar or Impacted Interval
- ● Heavy Sheen with NAPL
- ● Heavy Sheen and/or Trace NAPL
- ● Slight to Moderate Sheen
- ● Staining and/or Odor
- ○ No Impacts

Interpreted TarGOST NAPL Occurrence

- ☐ NAPL Impacts
- ☐ No Impacts

NAPL Areas

- DNAPL
- LNAPL
- Former LNAPL
- Estimated Extent of NAPL—Greater Uncertainty

Depth to Top of NAPL (feet, bgs or bml)

🟩	0 - 1	■	3 - 4	■	6 - 7	□	>9
🟩	1 - 2	■	4 - 5	■	7 - 8		
■	2 - 3	■	5 - 6	□	8 - 9		

Notes:

1. Site-specific TarGOST %RE response value of 10 %RE was used as a cut-off, responses above 10 %RE were assumed to represent NAPL occurrence ranging from "heavy sheen and/or trace NAPL" or "heavy sheen with NAPL" categories.
2. NAPL area 12 is pre-cleanup action. Air sparging/soil vapor extraction system has reduced or eliminated NAPL in this area.
3. AS/SVE = air sparge/soil vapor extraction
4. Basemap 2005 USGS aerial photograph. Does not show current conditions.
5. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

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Depth and Elevation to Top of LNAPL - Central Region

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Figure 5F-10

Path: P:\0\0186846\GIS\MXD\Phase01\T1635\018684601_F5F-10_TopLNAPL_Central.mxd Map Revised: 02 December 2021 maugust

Legend

- Area of Investigation
- Shoreline (OHWM)
- A A' Cross-section
- 2001-2006: Air Sparging Area

NAPL Elevation Contour (feet, USACE)

- 5-feet
- 1-foot

NAPL and Tar Occurrence Categories

- ● Tar or Impacted Interval
- ● Heavy Sheen with NAPL
- ● Heavy Sheen and/or Trace NAPL
- ● Slight to Moderate Sheen
- ● Staining and/or Odor
- ○ No Impacts

Interpreted TarGOST NAPL Occurrence

- ☐ NAPL Impacts
- ☐ No Impacts

NAPL Areas

- DNAPL
- LNAPL
- Mixed LNAPL/DNAPL
- Former LNAPL

Depth to Top of NAPL (feet, bgs or bml)

🟩	0 - 1	■	3 - 4	■	6 - 7
🟩	1 - 2	■	4 - 5	■	7 - 8
■	2 - 3	■	5 - 6	■	8 - 9
				☐	>9

Notes:

1. Site-specific TarGOST %RE response value of 10 %RE was used as a cut-off, responses above 10 %RE were assumed to represent NAPL occurrence ranging from "heavy sheen and/or trace NAPL" or "heavy sheen with NAPL" categories.
2. NAPL area 12 is pre-cleanup action. Air sparging/soil vapor extraction system has reduced or eliminated NAPL in this area.
3. Basemap 2005 USGS aerial photograph. Does not show current conditions.
4. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

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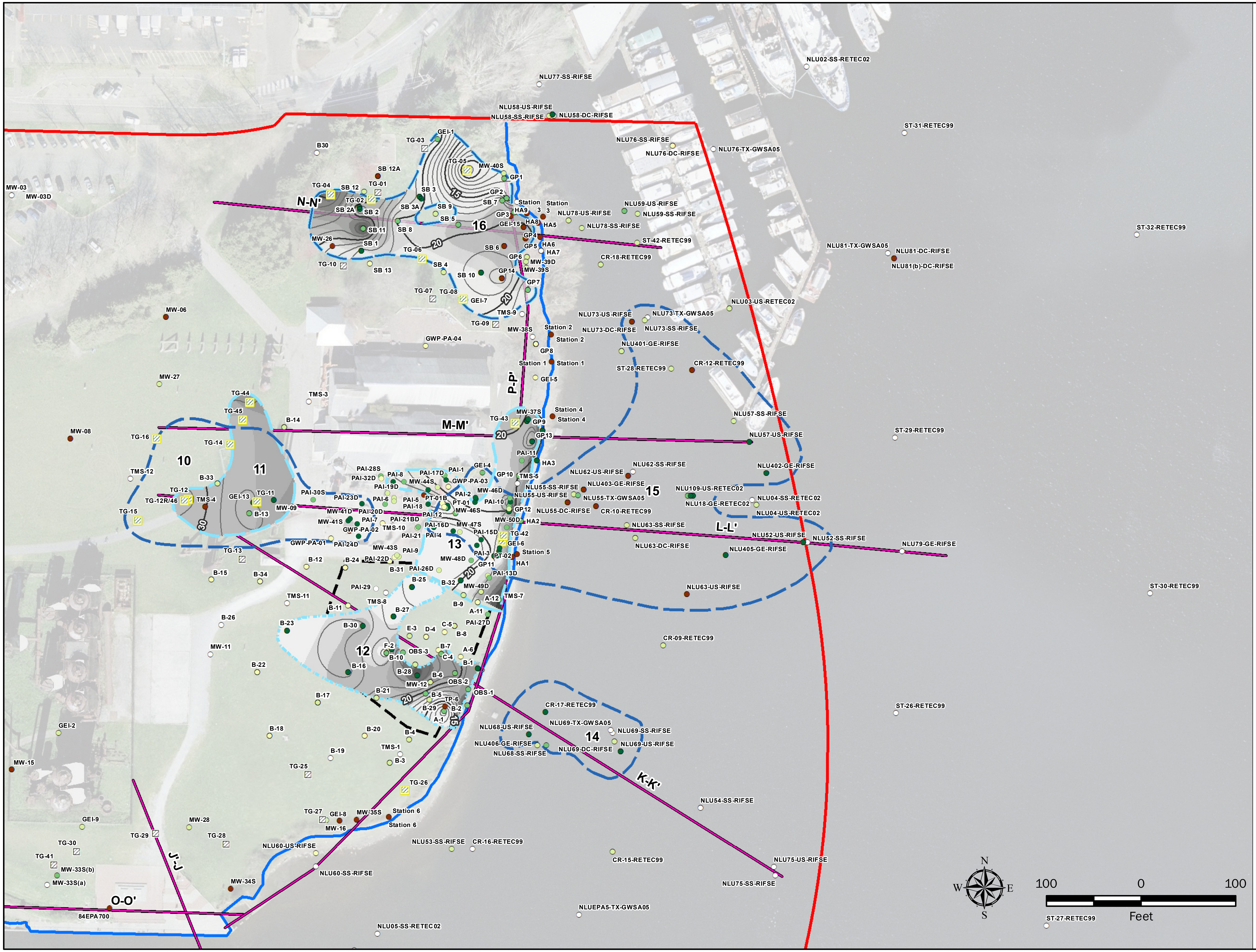
Depth and Elevation to Top of DNAPL - Eastern Region

Gas Works Park Site
Seattle, Washington

GeoEngineers

Figure 5F-11

Path: P:\0\0186846\GIS\MXD\Phase01\T1635\018684601_F5F-11_TopDNAPL_East.mxd Map Revised: 03 December 2021 maugust



Legend

- Area of Investigation
- Shoreline (OHWM)
- A A' Cross Section
- 2001-2006: Air Sparging Area

NAPL Elevation Contour (feet, USACE)

- 5-feet
- 1-foot

NAPL and Tar Occurrence Categories

- ● Tar or Impacted Interval
- ● Heavy Sheen with NAPL
- ● Heavy Sheen and/or Trace NAPL
- ● Slight to Moderate Sheen
- ● Staining and/or Odor
- ○ No Impacts

Interpreted TarGOST NAPL Occurrence

- ☐ NAPL Impacts
- ☐ No Impacts

NAPL Areas

- DNAPL
- LNAPL
- Mixed LNAPL/DNAPL
- Former LNAPL

Depth to Top of NAPL (feet, bgs or bml)

🟩	0 - 1	■	3 - 4	■	6 - 7	☐	>9
🟩	1 - 2	■	4 - 5	■	7 - 8		
■	2 - 3	■	5 - 6	☐	8 - 9		

Notes:

1. Site-specific TarGOST %RE response value of 10 %RE was used as a cut-off, responses above 10 %RE were assumed to represent NAPL occurrence ranging from "heavy sheen and/or trace NAPL" or "heavy sheen with NAPL" categories. TG-9 excluded from NAPL Area 16—see Section 6.6 for explanation.
2. NAPL area 12 is pre-cleanup action. Air sparging/soil vapor extraction system has reduced or eliminated NAPL in this area.
3. Basemap 2005 USGS aerial photograph. Does not show current conditions.
4. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

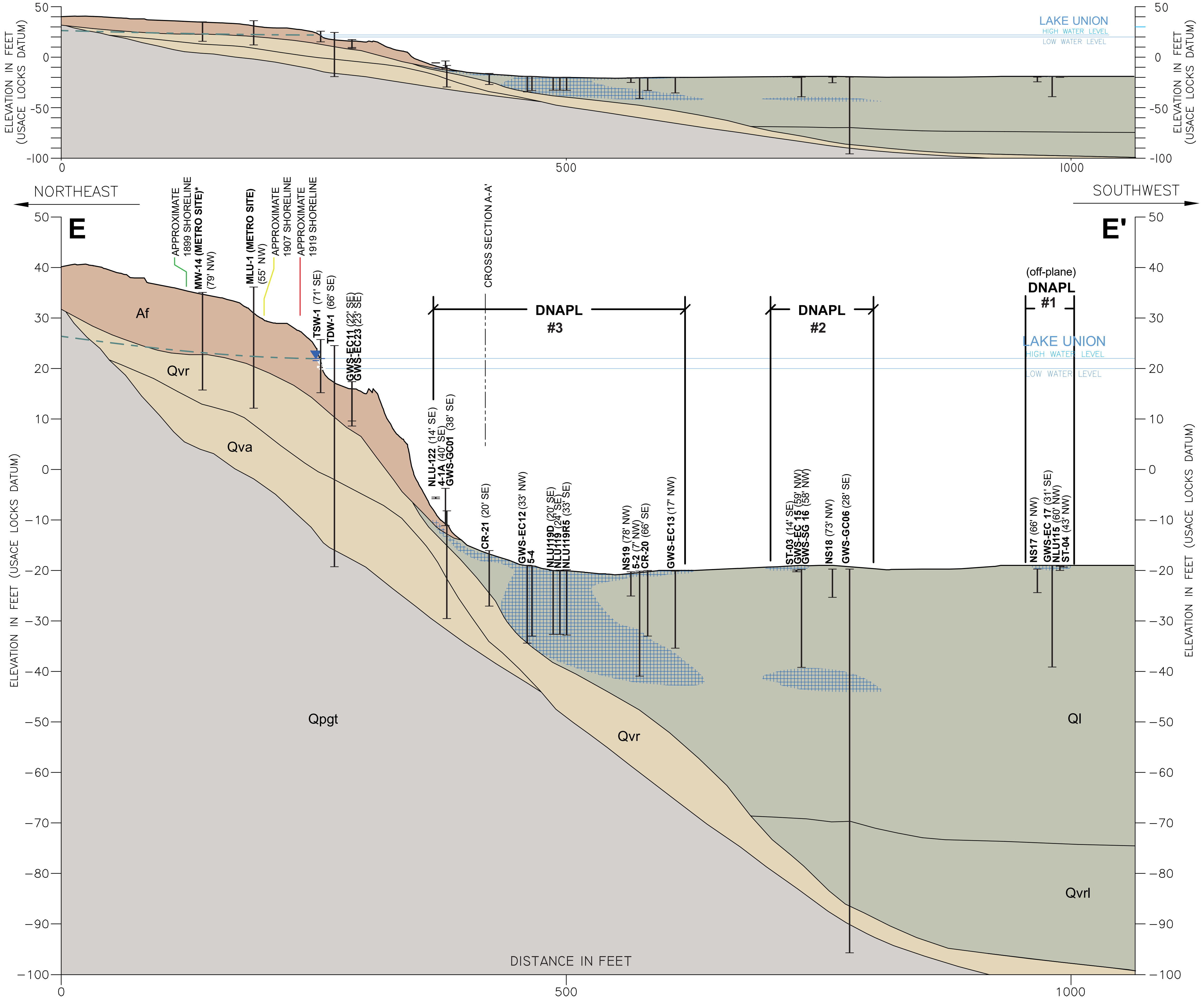
Depth and Elevation to Top of LNAPL - Eastern Region

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Figure 5F-12

Path: P:\0\0186846\GIS\MXD\Phase01\T1635\018684601_F5F-12_TopLNAPL_East.mxd Map Revised: 02 December 2021 maugust



SCALE: 1"=100'

100 0 100

FEET

Legend

MW-26 (2' N)

Location Offset

Location ID

Water Table April 22, 2013

Well Static Groundwater Level April 22, 2013

DNAPL

Notes:

1. * MW-14 (Metro) was not used to interpret lithology.
2. The location and configuration of NAPL brackets depicted in this cross section are approximate, and interpretation is based on multiple data sources/types and field observations. In some cases, borings are projected onto the cross section and the presence of NAPL at a specific location is projected based on data from surrounding explorations.

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HORIZONTAL SCALE: 1"=100'

100 0 100

FEET

VERTICAL SCALE: 1"=20'
VERTICAL EXAGGERATION: 5X

20 0 20

FEET

NAPL Cross Section E-E'

Gas Works Park Site
Seattle, Washington

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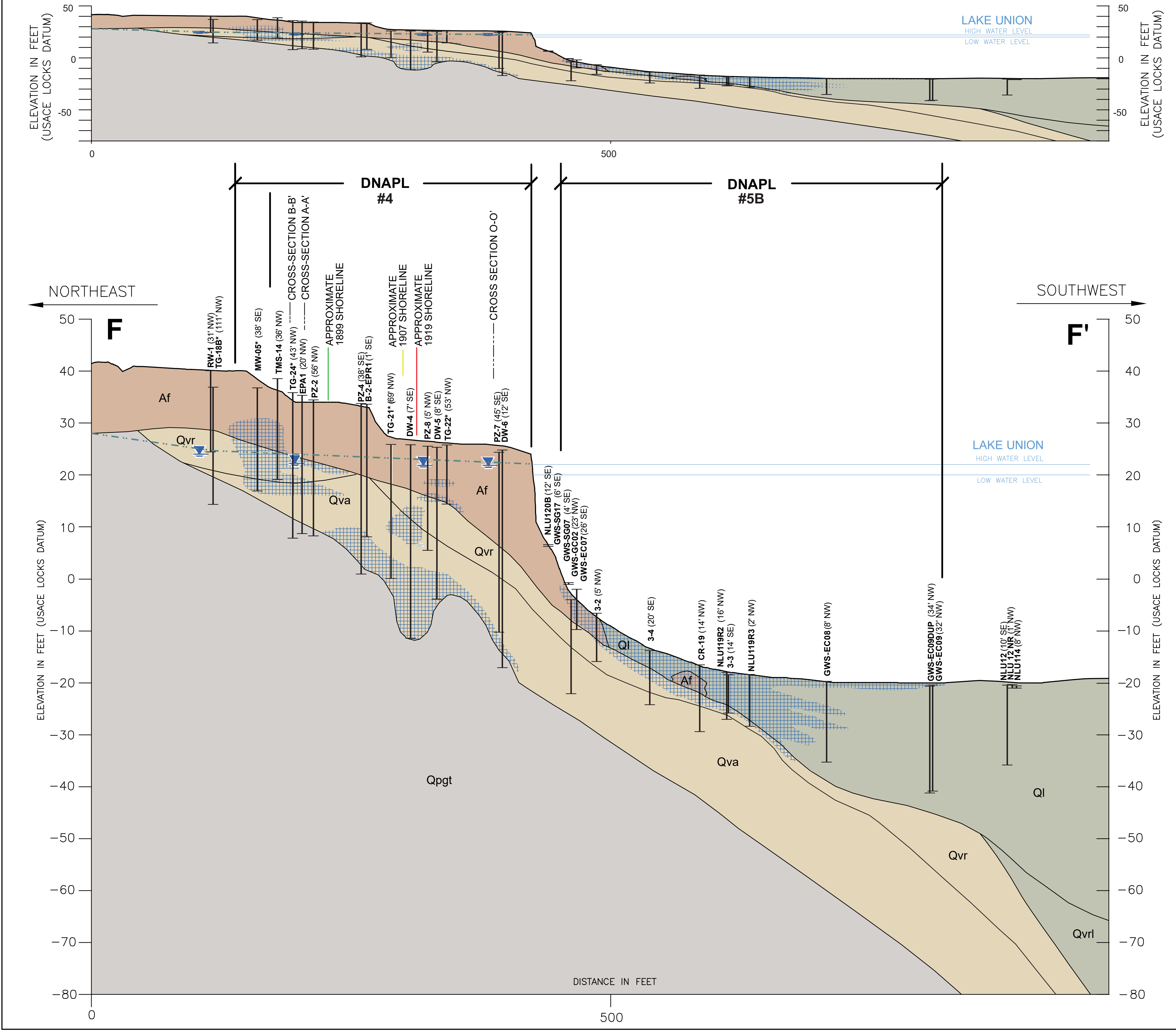
Figure 5F-13

P:\0\0186846\Graphics_Misc\Figure 5F-13 - NAPL E-E.ai   Exported 12/6/21   by spride

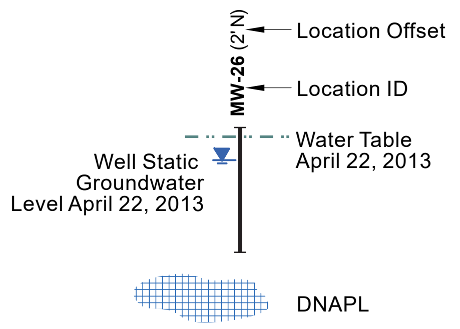


SCALE: 1"=100'

100 0 100

FEET

Legend



Notes:

1. * TG-18B, MW-5, TG-24, TG-21, and TG-22 were not used to interpret lithology.
2. The location and configuration of NAPL brackets depicted in this cross section are approximate, and interpretation is based on multiple data sources/types and field observations. In some cases, borings are projected onto the cross section and the presence of NAPL at a specific location is projected based on data from surrounding explorations.

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HORIZONTAL SCALE: 1"=100'

100 0 100

FEET

VERTICAL SCALE: 1"=20'

VERTICAL EXAGGERATION: 5X

20 0 20

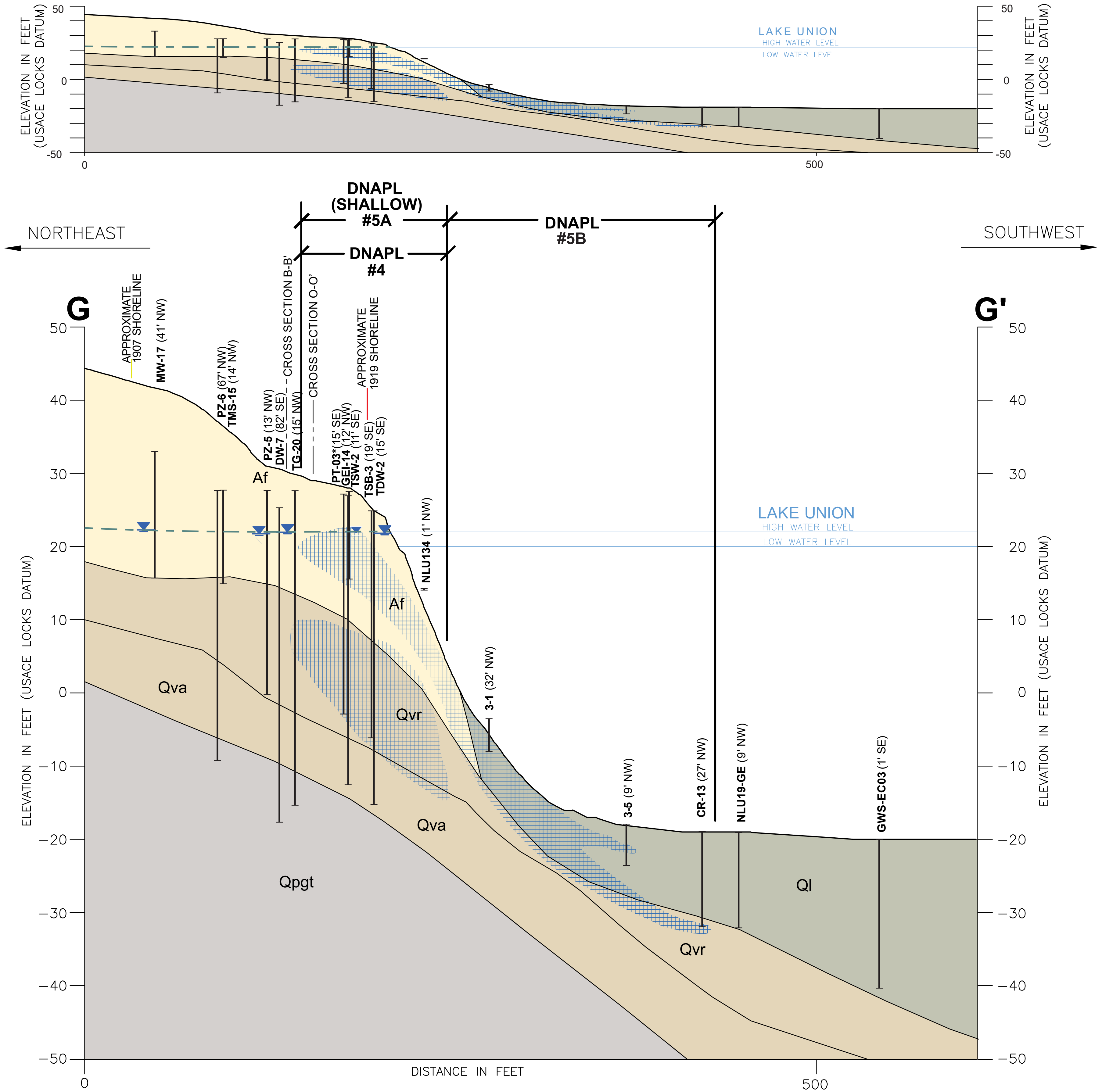
FEET

NAPL Cross Section F-F'

Gas Works Park Site
Seattle, Washington

GeoEngineers

Figure 5F-14



SCALE: 1"=80'

80 0 80
FEET

Legend

MW-26 (2' N)

Location Offset

Location ID

Water Table April 22, 2013

Well Static Groundwater Level April 22, 2013

▦ DNAPL

Notes:

1. * PT-03 was not used to interpret lithology.
2. The location and configuration of NAPL brackets depicted in this cross section are approximate, and interpretation is based on multiple data sources/types and field observations. In some cases, borings are projected onto the cross section and the presence of NAPL at a specific location is projected based on data from surrounding explorations.

HORIZONTAL SCALE: 1"=80'

80 0 80
FEET

VERTICAL SCALE: 1"=16'

VERTICAL EXAGGERATION: 5X

16 0 16
FEET

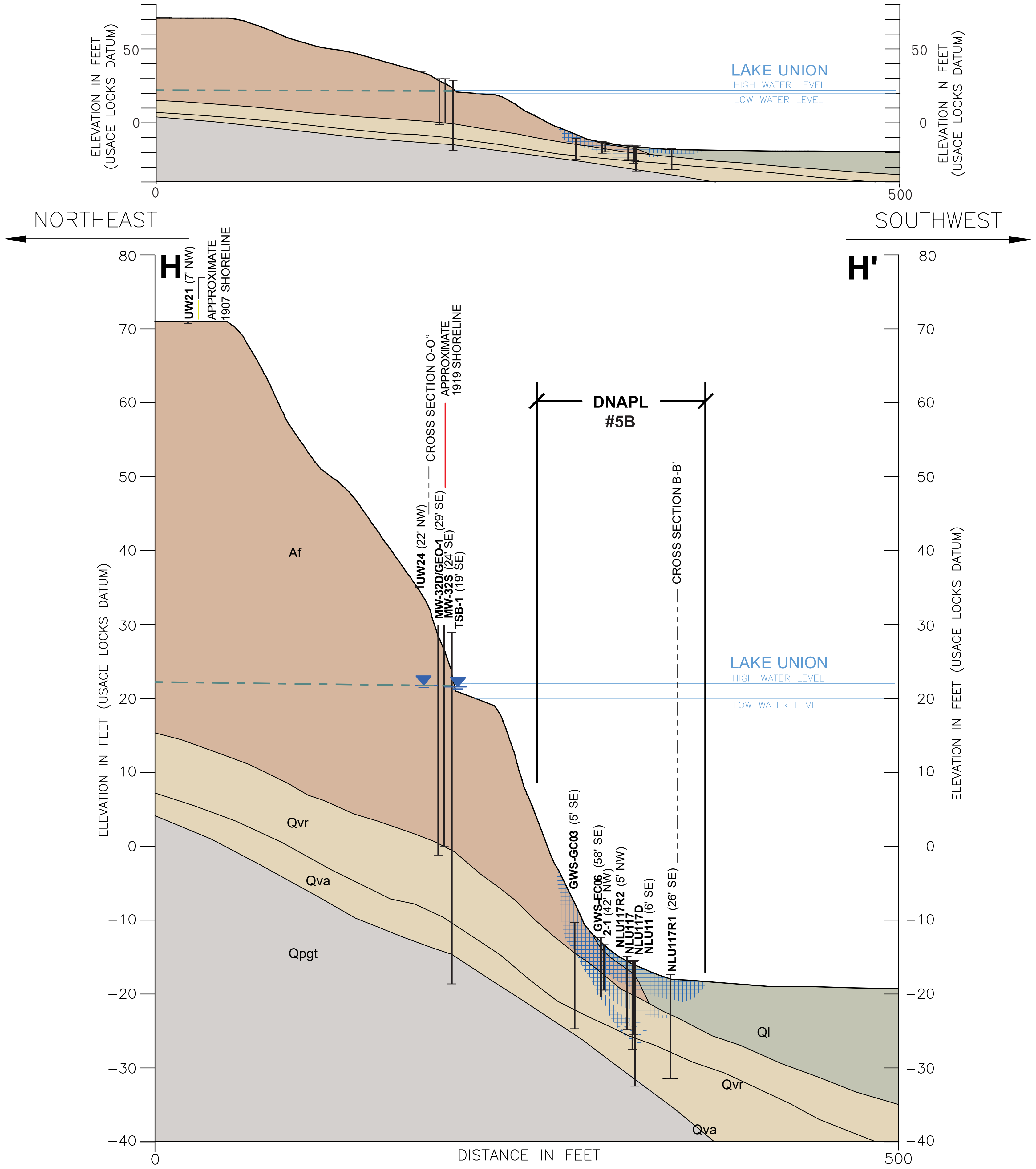
NAPL Cross Section G-G'

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Figure 5F-15

P:\0\0186846\Graphics_Misc\Figure 5F-15 - NAPL G-G.ai Exported 12/6/21 by spride

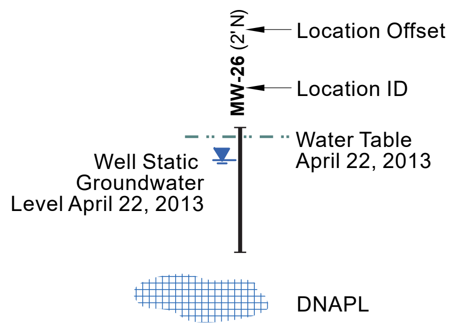


SCALE: 1"=80'

80 0 80

FEET

Legend



Notes:

1. The location and configuration of NAPL brackets depicted in this cross section are approximate, and interpretation is based on multiple data sources/types and field observations. In some cases, borings are projected onto the cross section and the presence of NAPL at a specific location is projected based on data from surrounding explorations.

HORIZONTAL SCALE: 1"=80'

80 0 80

FEET

VERTICAL SCALE: 1"=16'
VERTICAL EXAGGERATION: 5X

16 0 16

FEET

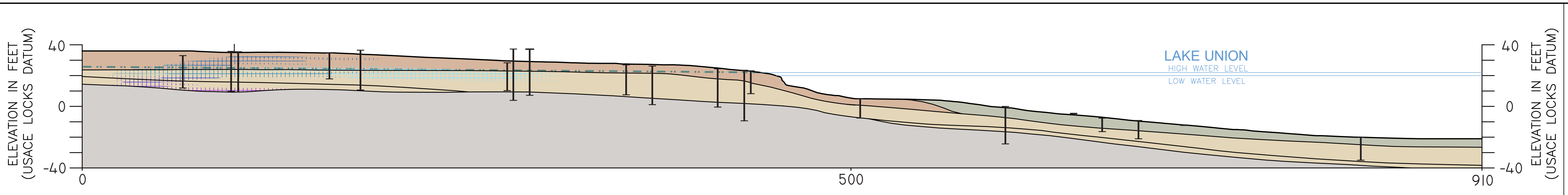
NAPL Cross Section H-H'

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Figure 5F-16

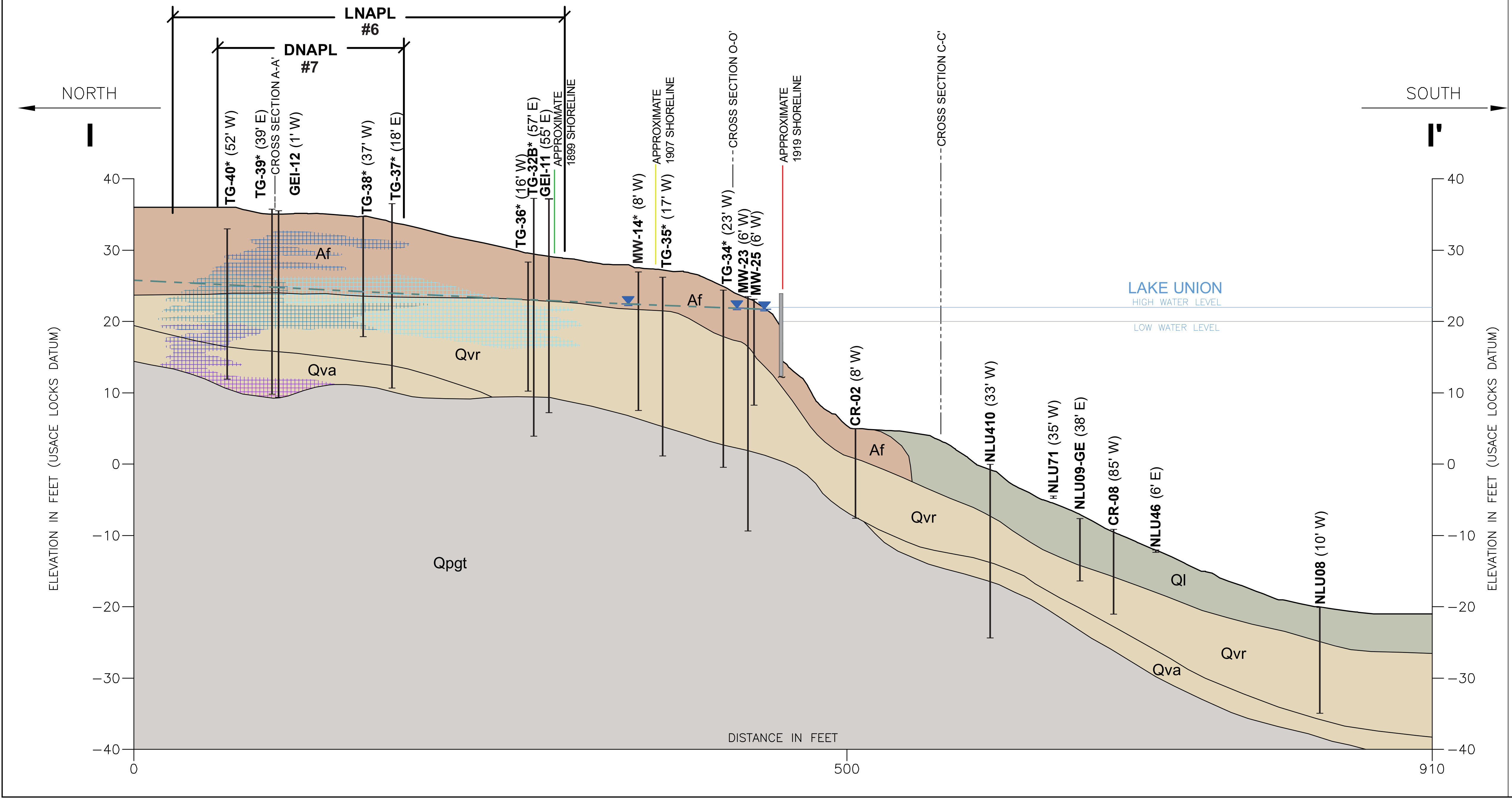
P:\0\0186846\Graphics_Misc\Figure 5F-16 - NAPL H-H.ai Exported 12/6/21 by spride



SCALE: 1"=80'

80 0 80

FEET



Legend

MW-26 (2' N)

Location Offset

Location ID

Water Table April 22, 2013

Well Static Groundwater Level April 22, 2013

▦ LNAPL

▦ DNAPL

▦ Primarily LNAPL with DNAPL

▦ DNAPL—TAR Transitional

▦ Tar

Notes:

1. *TG-40, TG-39, TG-38, TG-37, TG-36, TG-32B, MW-14, TG-35 and TG-34 were not used to interpret lithology.
2. The location and configuration of NAPL brackets depicted in this cross section are approximate, and interpretation is based on multiple data sources/types and field observations. In some cases, borings are projected onto the cross section and the presence of NAPL at a specific location is projected based on data from surrounding explorations.

HORIZONTAL SCALE: 1"=80'

80 0 80

FEET

VERTICAL SCALE: 1"=16'

VERTICAL EXAGGERATION: 5X

16 0 16

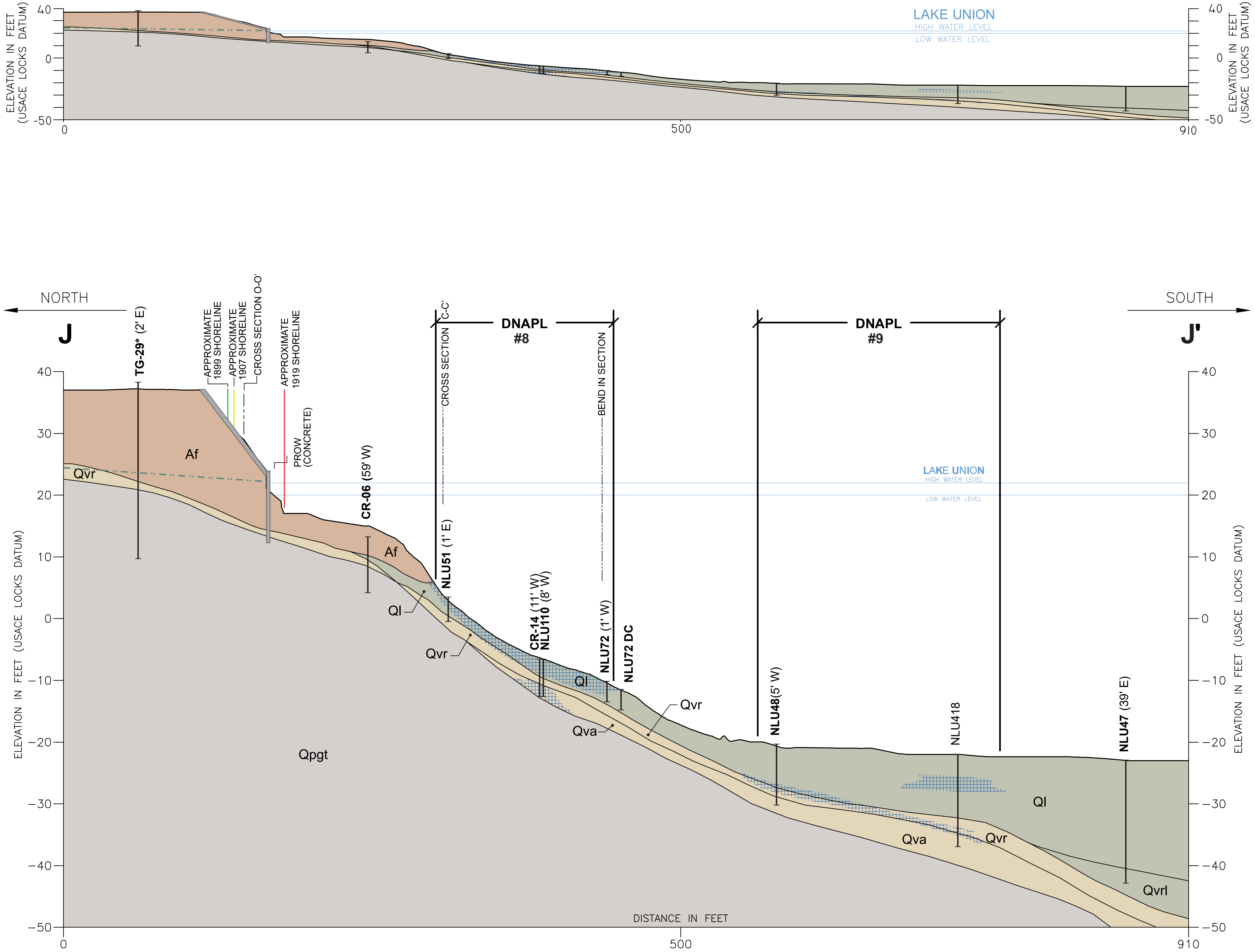
FEET

NAPL Cross Section I-I'

Gas Works Park Site
Seattle, Washington

GeoEngineers

Figure 5F-17

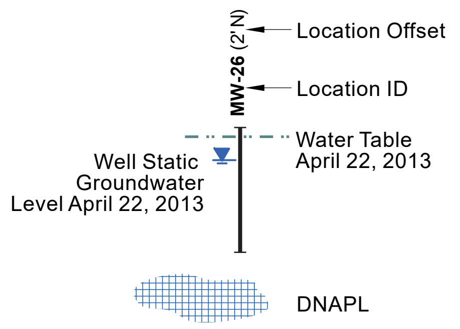


SCALE: 1"=80'

80 0 80

FEET

Legend



Notes:

1. * TG-29 was not used to interpret lithology.
2. The location and configuration of NAPL brackets depicted in this cross section are approximate, and interpretation is based on multiple data sources/types and field observations. In some cases, borings are projected onto the cross section and the presence of NAPL at a specific location is projected based on data from surrounding explorations.

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HORIZONTAL SCALE: 1"=80'

80 0 80

FEET

VERTICAL SCALE: 1"=16'

VERTICAL EXAGGERATION: 5X

16 0 16

FEET

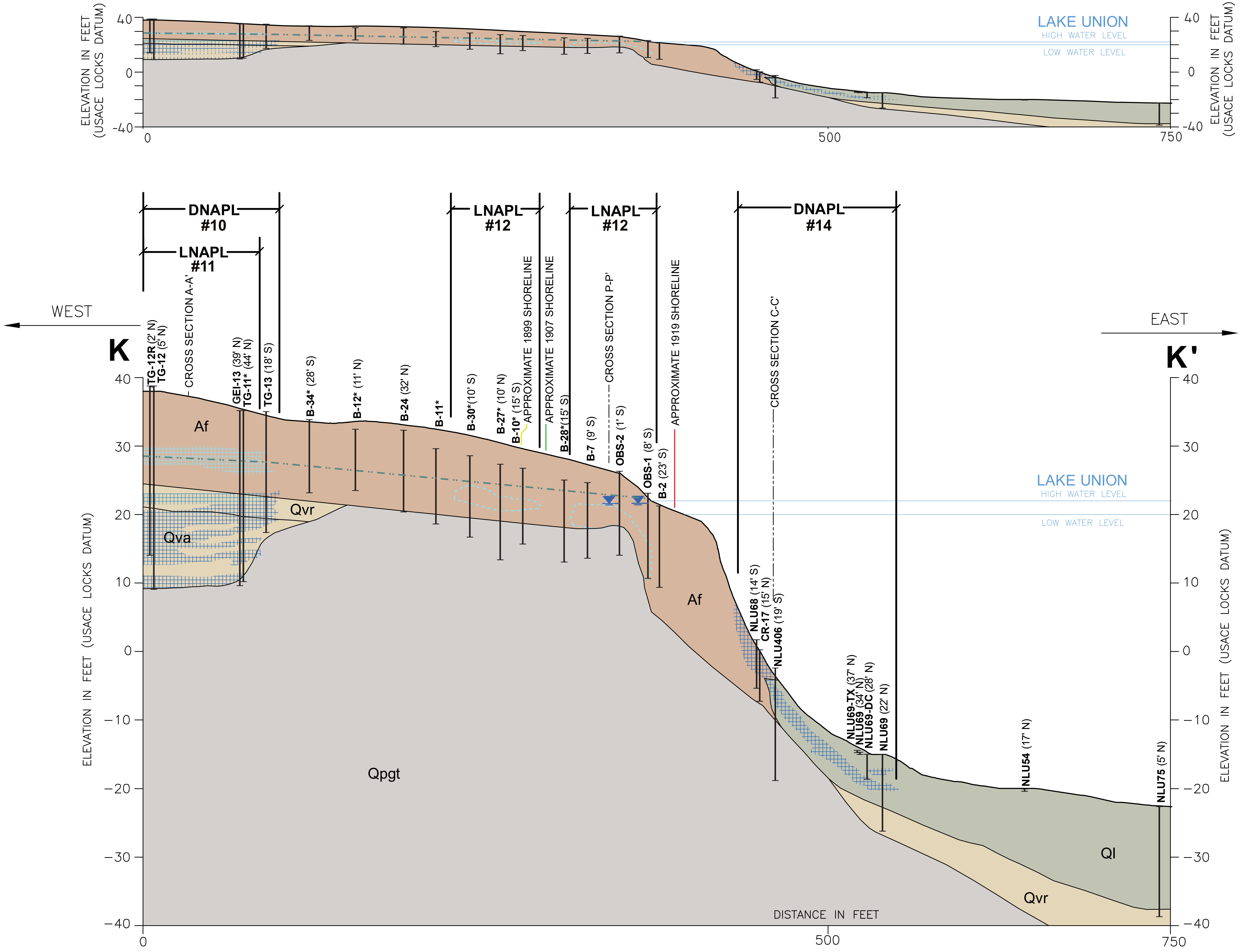
NAPL Cross Section J-J'

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Figure 5F-18

P:\0\0186846\Graphics_Misc\Figure 5F-18 - NAPL J-J.ai Exported 12/6/21 by spride



SCALE: 1"=80'

80 0 80

FEET

Legend

MW-26 (2' N)

Location Offset

Location ID

Water Table April 22, 2013

Well Static Groundwater Level April 22, 2013

▦ LNAPL

▦ DNAPL

▦ Mixed LNAPL/DNAPL

◌ Former LNAPL

Notes:

1. * TG-11, B-34, B-12, B-11, B-30, B-27, B-10 and B-28 were not used to interpret lithology.
2. The location and configuration of NAPL brackets depicted in this cross section are approximate, and interpretation is based on multiple data sources/types and field observations. In some cases, borings are projected onto the cross section and the presence of NAPL at a specific location is projected based on data from surrounding explorations.

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HORIZONTAL SCALE: 1"=80'

80 0 80

FEET

VERTICAL SCALE: 1"=16'

VERTICAL EXAGGERATION: 5X

16 0 16

FEET

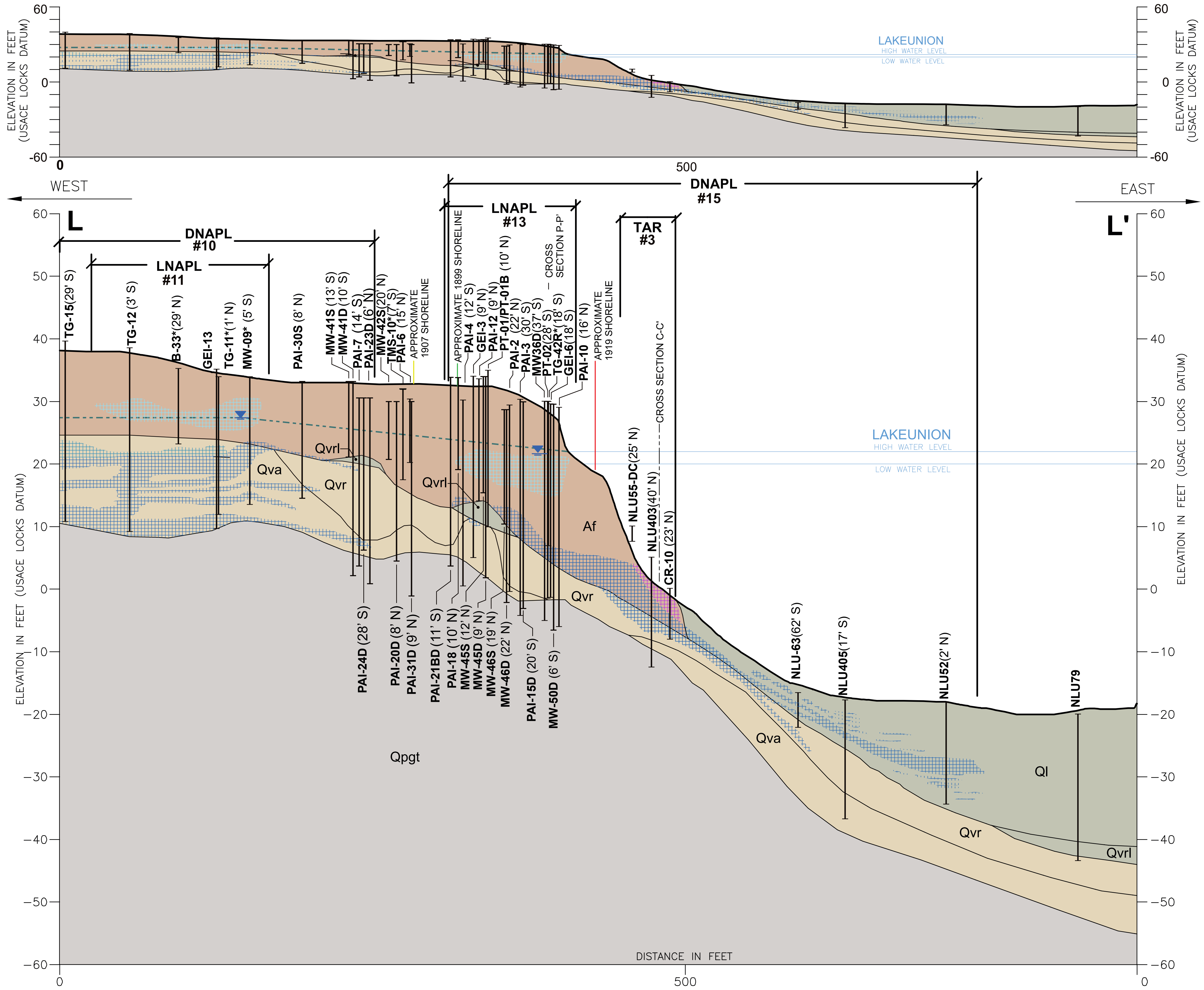
NAPL Cross Section K-K'

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Figure 5F-19

P:\0\0186846\Graphics_Misc\Figure 5F-19 - NAPL K-K.ai Exported 12/6/21 by spride



P:\0\0186846\Graphics_Misc\Figure 5F-20 - NAPL L-L.ai Exported 12/6/21 by spride

SCALE: 1"=80'

80 0 80
FEET

Legend

MW-26 (2' N) — Location Offset

— Location ID

Water Table April 22, 2013

Well Static Groundwater Level April 22, 2013

▨ LNAPL

▨ DNAPL

▨ Primarily LNAPL with DNAPL

▨ Tar

Notes:

1. *B-33, TG-11, MW-09, TMS-10 and TG-42R were not used to interpret lithology.

2. The location and configuration of NAPL brackets depicted in this cross section are approximate, and interpretation is based on multiple data sources/types and field observations. In some cases, borings are projected onto the cross section and the presence of NAPL at a specific location is projected based on data from surrounding explorations.

HORIZONTAL SCALE: 1"=80'

80 0 80
FEET

VERTICAL SCALE: 1"=16'
VERTICAL EXAGGERATION: 5X

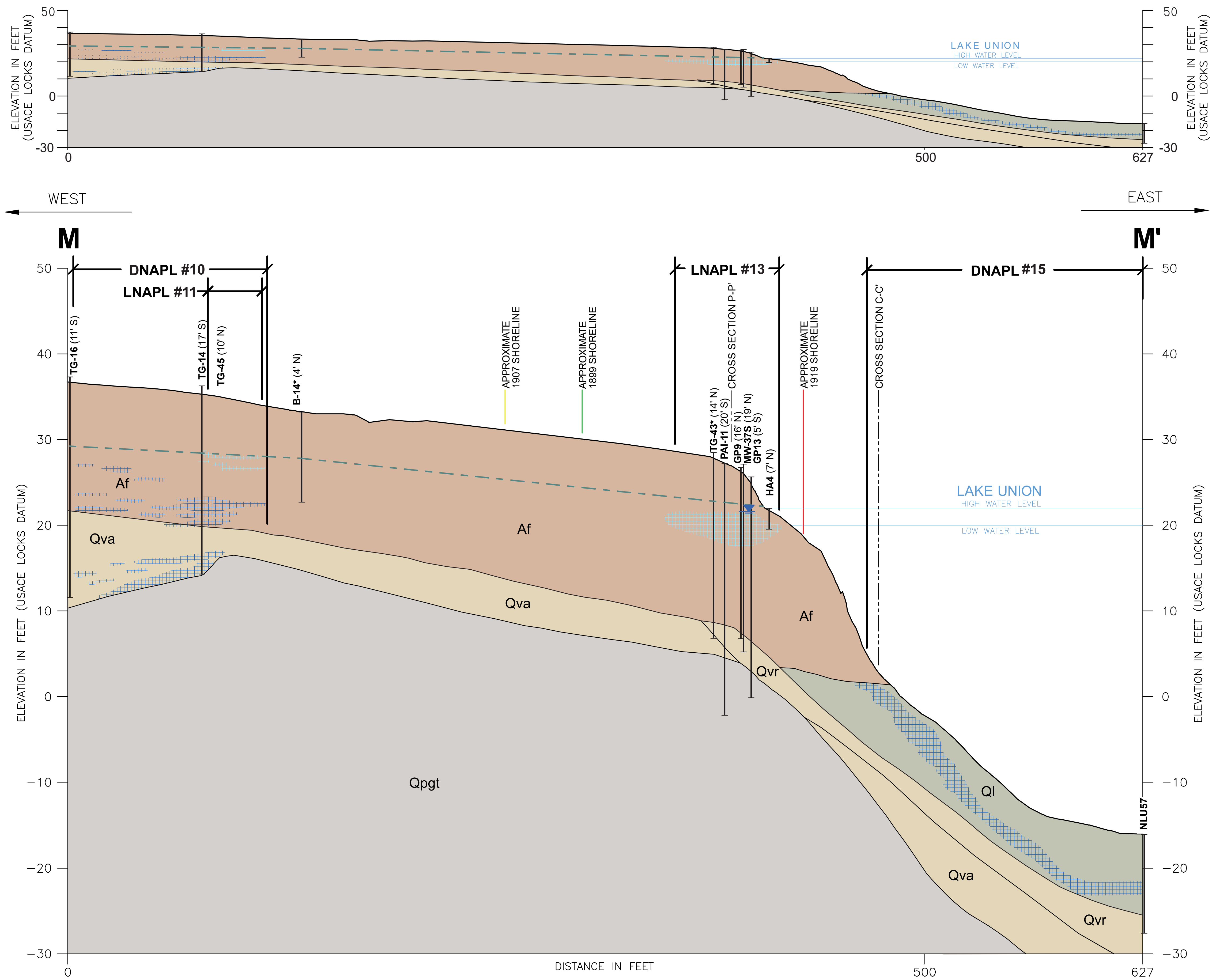
16 0 16
FEET

NAPL Cross Section L-L'

Gas Works Park Site
Seattle, Washington

GeoEngineers

Figure 5F-20

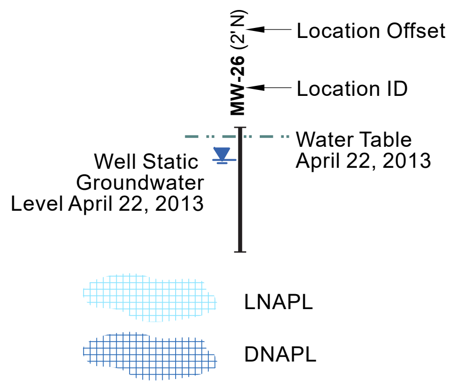


SCALE: 1"=60'

60 0 60

FEET

Legend



Notes:

1. * B-14 and TG-43 were not used to interpret lithology.
2. The location and configuration of NAPL brackets depicted in this cross section are approximate, and interpretation is based on multiple data sources/types and field observations. In some cases, borings are projected onto the cross section and the presence of NAPL at a specific location is projected based on data from surrounding explorations.

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HORIZONTAL SCALE: 1"=60'

60 0 60

FEET

VERTICAL SCALE: 1"=12'

VERTICAL EXAGGERATION: 5X

12 0 12

FEET

NAPL Cross Section M-M'

Gas Works Park Site
Seattle, Washington

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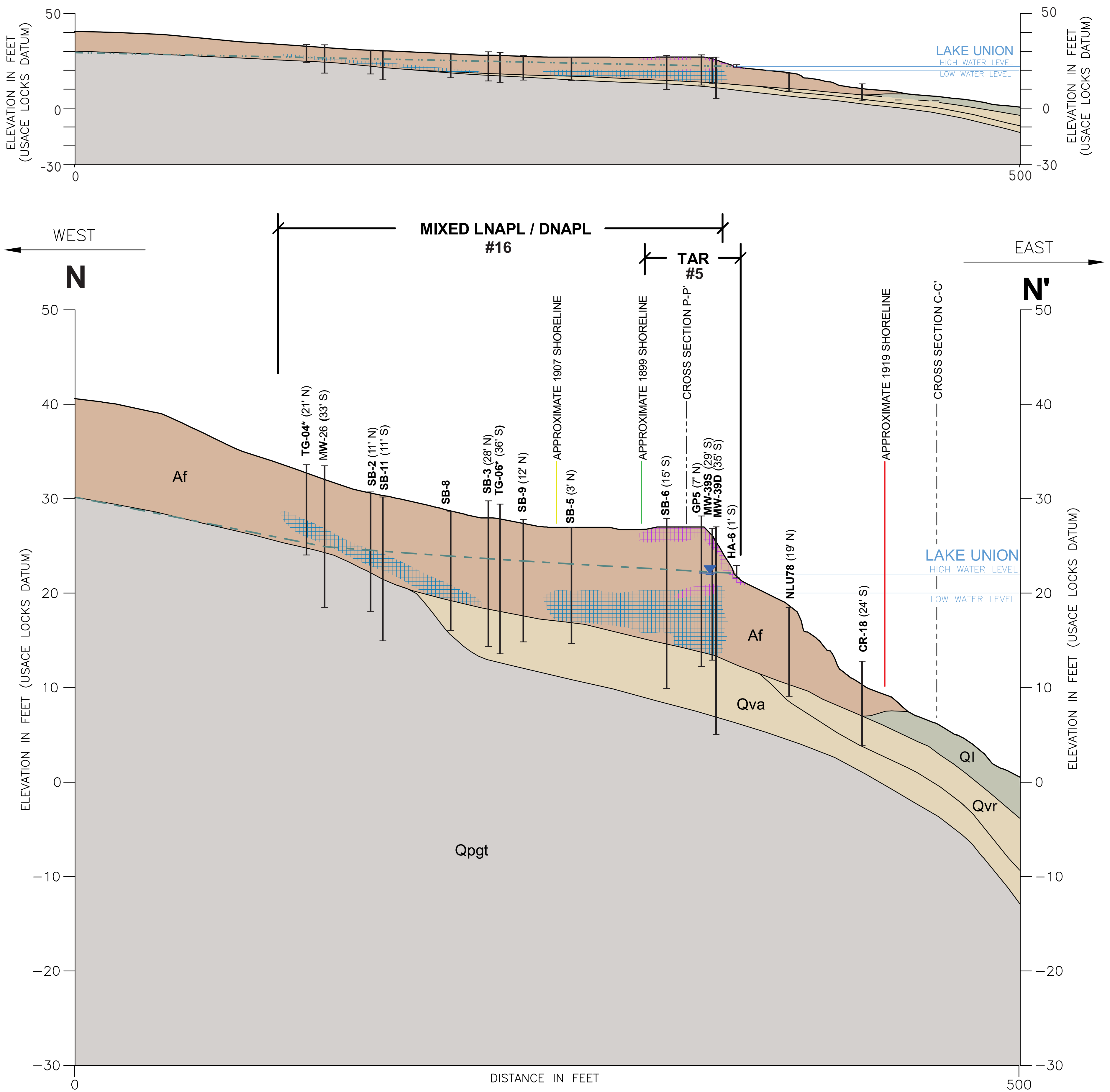
Figure 5F-21

P:\0\0186846\Graphics_Misc\Figure 5F-21 - NAPL M-M.ai Exported 12/6/21 by spride

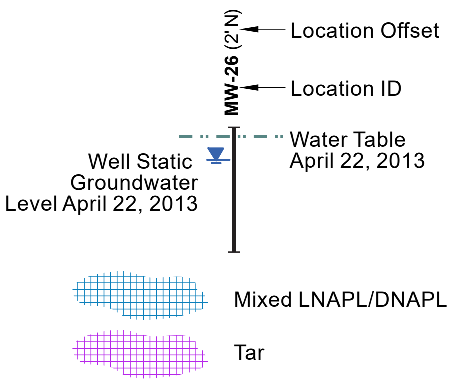


SCALE: 1"=60'

60 0 60

FEET

Legend



Notes:

1. * TG-04, TG-02 and TG-06 were not used to interpret lithology.
2. The location and configuration of NAPL brackets depicted in this cross section are approximate, and interpretation is based on multiple data sources/types and field observations. In some cases, borings are projected onto the cross section and the presence of NAPL at a specific location is projected based on data from surrounding explorations.

HORIZONTAL SCALE: 1"=60'

60 0 60

FEET

VERTICAL SCALE: 1"=12'
VERTICAL EXAGGERATION: 5X

12 0 12

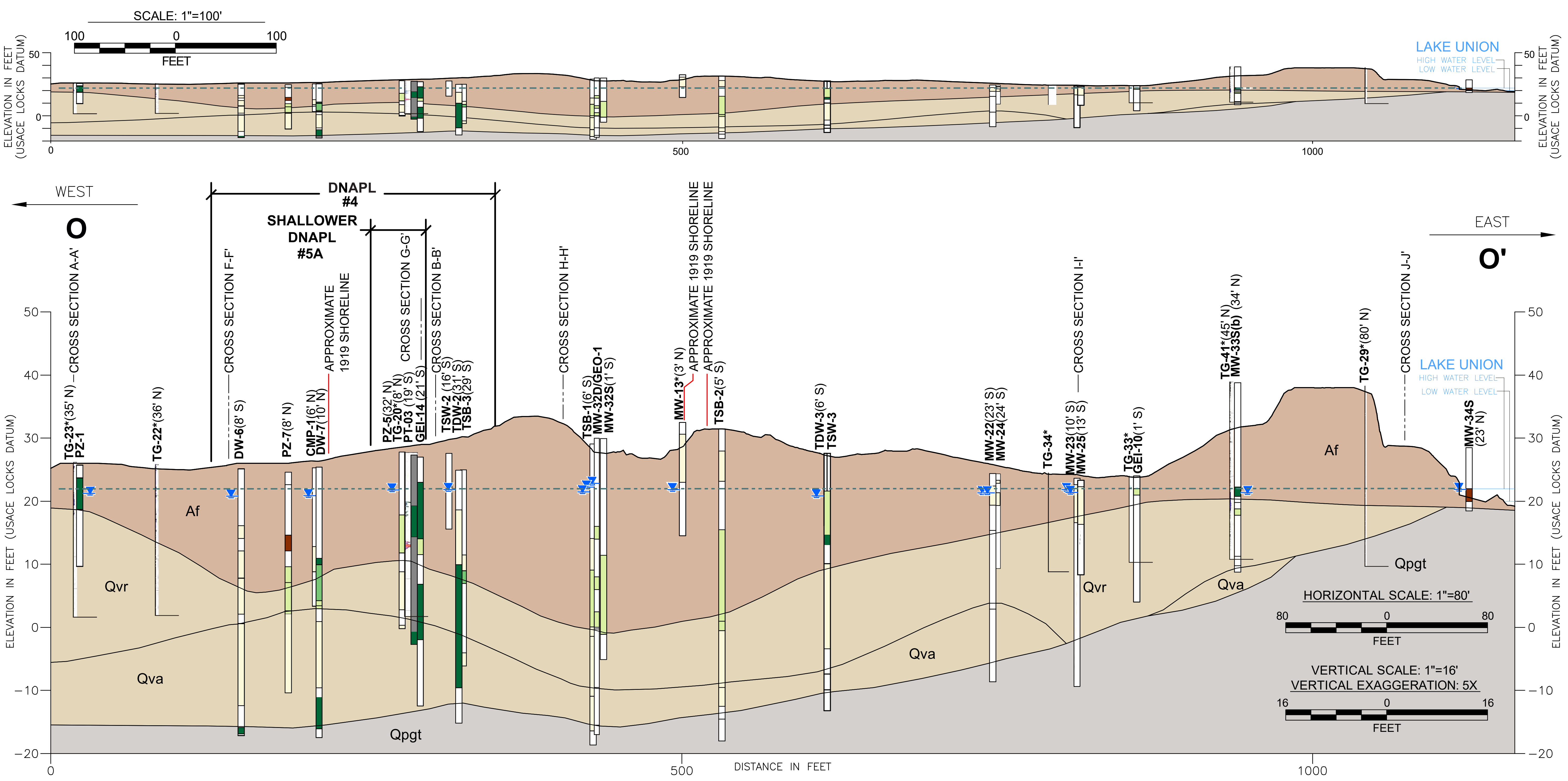
FEET

NAPL Cross Section N-N'

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Figure 5F-22



Notes:

1. * TG-23, TG-22, TG-20, MW-13, TG-34, TG-33, TG-41 and TG-29 were not used to interpret lithology.
2. The location and configuration of NAPL brackets depicted in this cross section are approximate, and interpretation is based on multiple data sources/types and field observations. In some cases, borings are projected onto the cross section and the presence of NAPL at a specific location is projected based on data from surrounding explorations.

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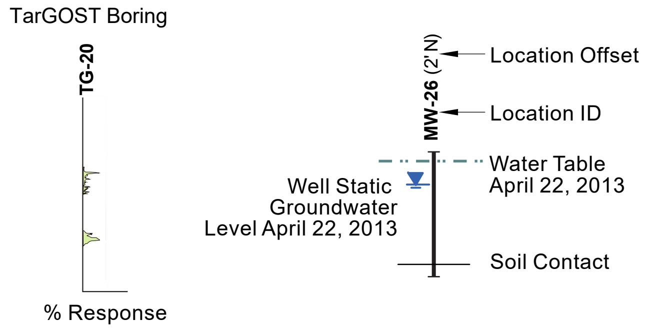
Legend

NAPL Occurance

- 🟫 Tar or Tar Impacted Interval
- 🟩 Heavy Sheen with NAPL
- 🟩 Heavy Sheen and/or Trace NAPL
- 🟨 Slight to Moderate Sheen
- ⬜ Staining and/or Odor
- ⬜ No Impacts
- ⬛ No Description



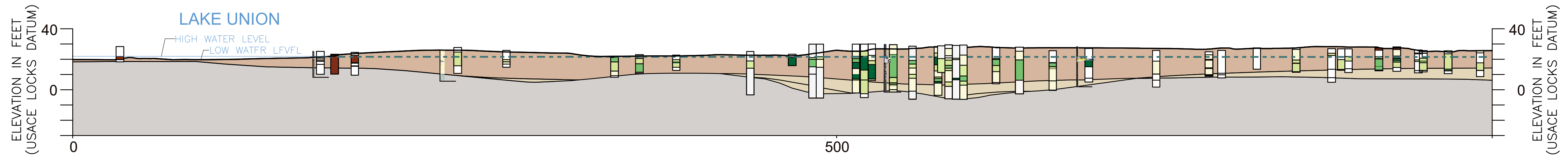
NAPL Cross Section O-O'

Gas Works Park Site
Seattle, Washington

GeoEngineers

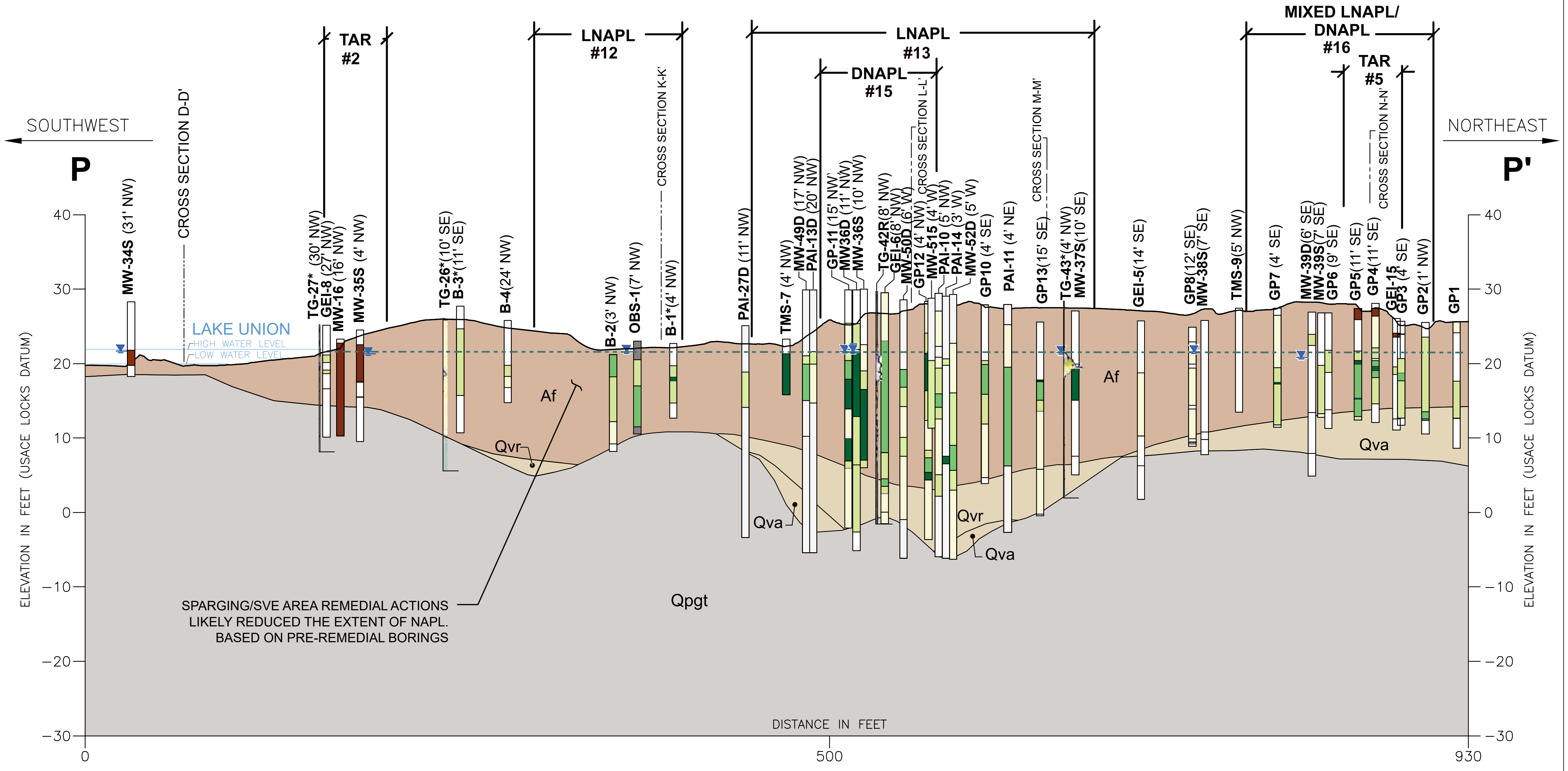
Figure 5F-23

P:\0\0186846\Graphics_Misc\Figure 5F-23 - NAPL O-O.ai Exported 12/6/21 by spride



SCALE: 1"=80'

80 0 80
FEET



HORIZONTAL SCALE: 1"=80'

80 0 80
FEET

VERTICAL SCALE: 1"=16'
VERTICAL EXAGGERATION: 5X

16 0 16
FEET

Notes:

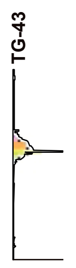
1. * TG-27, TG-26, B-3, B-1 and TG-43 were not used to interpret lithology.
2. The location and configuration of NAPL brackets depicted in this cross section are approximate, and interpretation is based on multiple data sources/types and field observations. In some cases, borings are projected onto the cross section and the presence of NAPL at a specific location is projected based on data from surrounding explorations.

Legend

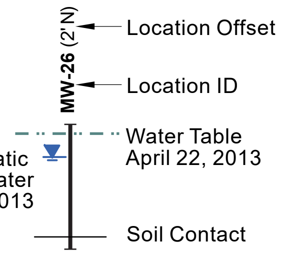
NAPL Occurance

- 🟫 Tar or Tar Impacted Interval
- 🟩 Heavy Sheen with NAPL
- 🟩 Heavy Sheen and/or Trace NAPL
- 🟩 Slight to Moderate Sheen
- 🟨 Staining and/or Odor
- ☐ No Impacts
- ▨ No Description

TarGOST Boring



% Response



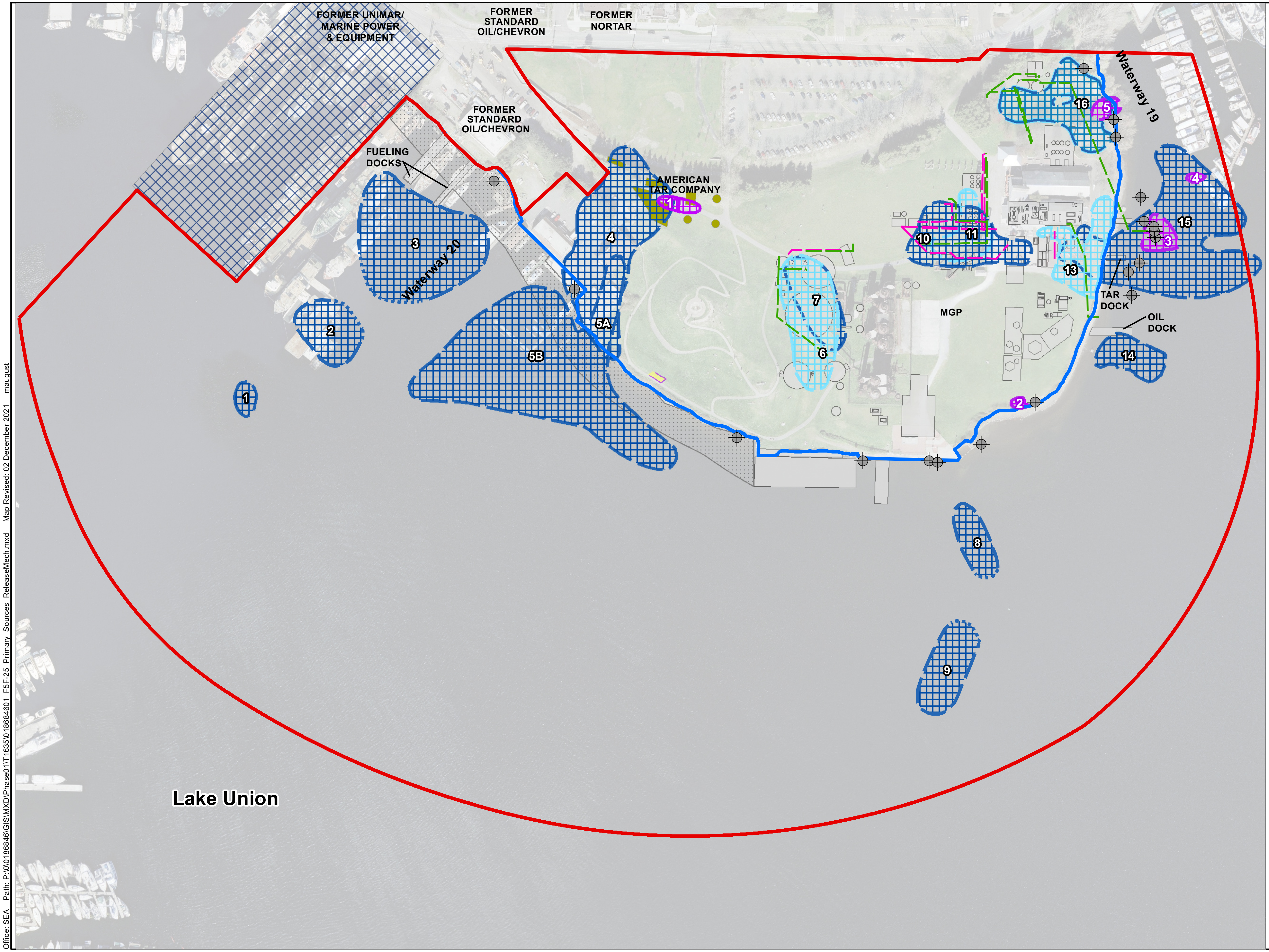
NAPL Cross Section P-P'

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Figure 5F-24

P:\0\0186846\Graphics_Misc\Figure 5F-24 - NAPL P-P.ai Exported 12/6/21 by spride



Legend

- Area of Investigation
- Shoreline (OHWM)

Historical Sources

- Oil Line
- Tar Line
- Potential MGP Historical Sources
- Tar Refinery Structures
- Historical Outfall
- Approximate location of former Wallingford Outfall
- Western Overwater Docking
- Shipyard Operations

NAPL/Tar Areas

- 1 NAPL Area
- 1 Tar Area
- Tar
- DNAPL
- LNAPL
- Mixed LNAPL/DNAPL
- Former Tar*
- Estimated Extent of NAPL—Greater Uncertainty

Notes:

1. *Tar Area 1 partially removed in 1997.
2. Reference Appendix 1B for structure names.
3. Basemap 2005 USGS aerial photograph. Does not show current conditions.
4. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Potential Historical Sources and NAPL/Tar Areas

Gas Works Park Site
Seattle, Washington

GEOENGINEERS

Figure 5F-25

ATTACHMENT 5F-1

UV Photographs and Petrophysical Results

Attachment 5F-1

UV Photographs and Petrophysical Results

SUB-ATTACHMENT 5F-1.1

WSA Shoreline Investigation Free Product Mobility Data 2007

PTS Laboratories

PTS File No: 36834
Client: Floyd Snider

FREE PRODUCT MOBILITY: INITIAL AND RESIDUAL SATURATIONS

PROJECT NAME: Gasworks Park
PROJECT NO: COS-GWSA-304D

		METHODS:	API RP 40		API RP 40	ASTM D425M, DEAN-STARK			
						PORE FLUID SATURATIONS, % Pv			
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	DENSITY		TOTAL POROSITY, %Vb	Initial Fluid Saturations		After Centrifuge at 1000xG	
			BULK, g/cc	GRAIN, g/cc		WATER (Swi) SATURATION	NAPL (Soi) SATURATION	WATER (Srw) SATURATION	NAPL (Sor) SATURATION
TSB2-21.3-21.8	21.5	V	1.61	2.69	40.3	71.7	5.6	26.0	2.4
TDW2-15.5-16.0	15.9	V	1.80	2.73	34.2	71.4	5.2	14.0	4.1
TDW2-16.8-17.3	17.1	V	1.70	2.72	37.5	66.2	2.1	11.5	0.1
TDW2-18.3-18.8	18.5	V	1.80	2.73	34.1	52.9	4.4	10.0	1.2

N/A = Not Analyzed. Vb = Bulk Volume, Pv = Pore Volume. (1) H = horizontal, V = vertical
Soi = Initial NAPL Saturation as received prior to centrifuging at 1000xG, Swi = Initial Water Saturation as received prior to centrifuging at 1000xG
Sor = Residual NAPL Saturation after centrifuging at 1000xG, Srw = Residual Water Saturation after centrifuging at 1000xG
Water =0.9996 g/cc, NAPL = 1.100 g/cc.

PTS Laboratories
ENVIRONMENTAL SERVICES

36834

CHAIN OF CUSTODY RECORD

PAGE 1 OF 1

COMPANY: FLOYD SNIDER
ADDRESS: 601 UNION ST #600
CITY: SEATTLE WA
ZIP CODE: 98101
PROJECT MANAGER: JANE FISHER 206-292-2078
PROJECT NAME: GASWORKS PARK
PHONE NUMBER: 206-682-7867
PROJECT NUMBER: COS - GWSA - 3040
FAX NUMBER:
SITE LOCATION: SEATTLE
SAMPLER SIGNATURE:

PO# COS-GWSA

TURNAROUND TIME
24 HOURS ☐ 5 DAYS ☐
48 HOURS ☐ NORMAL ☒ (2 WEEKS)
72 HOURS ☐
OTHER: ______

SAMPLE INTEGRITY (CHECK):
INTACT ____ ON ICE ____

PTS QUOTE NO.

PTS FILE:

ANALYSIS REQUEST

SAMPLE ID NUMBER	DATE	TIME	DEPTH, FT	NUMBER OF SAMPLES	SOIL PROPERTIES PACKAGE	HYDRAULIC CONDUCTIVITY PACKAGE	PORE FLUID SATURATIONS PACKAGE ×	TCEQ/TNRCC PROPERTIES PACKAGE	CAPILLARITY PACKAGE	FLUID PROPERTIES PACKAGE	PHOTOLOG: CORE PHOTOGRAPHY	MOISTURE CONTENT, ASTM D2216	POROSITY: TOTAL, API RP40	POROSITY: EFFECTIVE, ASTM D425M	SPECIFIC GRAVITY, ASTM D854	BULK DENSITY (DRY), API RP40 or ASTM D2937	AIR PERMEABILITY, API RP40	HYDRAULIC CONDUCTIVITY, EPA9100, API RP40, D5084	GRAIN SIZE DISTRIBUTION, ASTM D422/4464M	TOC: WALKLEY-BLACK	ATTERBERG LIMITS, ASTM D4318	PORE FLUID SAT'N API RP 40	FREE PRODUCT MOBILITY ~~ASTM D425M~~ / API RP40			COMMENTS
✓ TSB2-21.3-21.8	9/22	1010	21.3																			x	x			
✓ TSB2-22.5-23.0	9/22	1020	22.5																							
✓ TSB2-25.7-26.2	9/22	1047	26.0																							
✓ TDW3- 9.5-10.0	9/26	1306	9.5																							
✓ TDW3- 11.5-12.0	↓	1316	11.5																							
✓ TDW3-14.5-15.0	↓	1345	14.5																							
✓ TDW3- 17.0-17.5	↓	1353	17.0																							
✓ TDW2- 15.5-16.0	9/28	1207	15.5																			x	x			
✓ TDW2- 16.8-17.3	↓	1219	16.8																			x	x			
✓ TDW2- 18.3-18.8	↓	1231	18.3																			x	x			
✓ TDW2- 21.5-22.0	9/28	1330	21.5																							

1. RELINQUISHED BY:
COMPANY: FLOYD SNIDER
DATE: OCT 3, 2006 TIME: 1109

2. RECEIVED BY:
COMPANY: PTS LABS
DATE: 10/4/06 TIME: 11:24

3. RELINQUISHED BY:
COMPANY:
DATE: TIME:

4. RECEIVED BY:
COMPANY:
DATE: TIME:

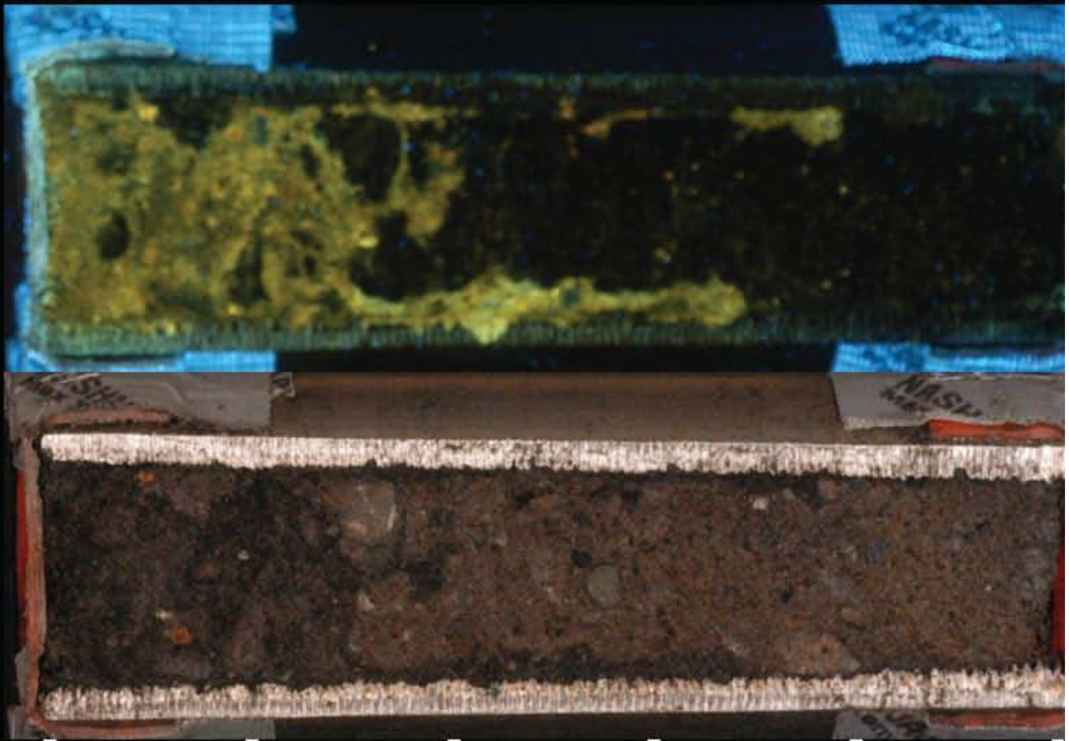
SUB-TTACHMENT 5F-1.2

Northeast Corner Petrophysical Laboratory Report 2008

UV Photographs

PTS Laboratories
ENVIRONMENTAL SERVICES

PTS File No.: 37801

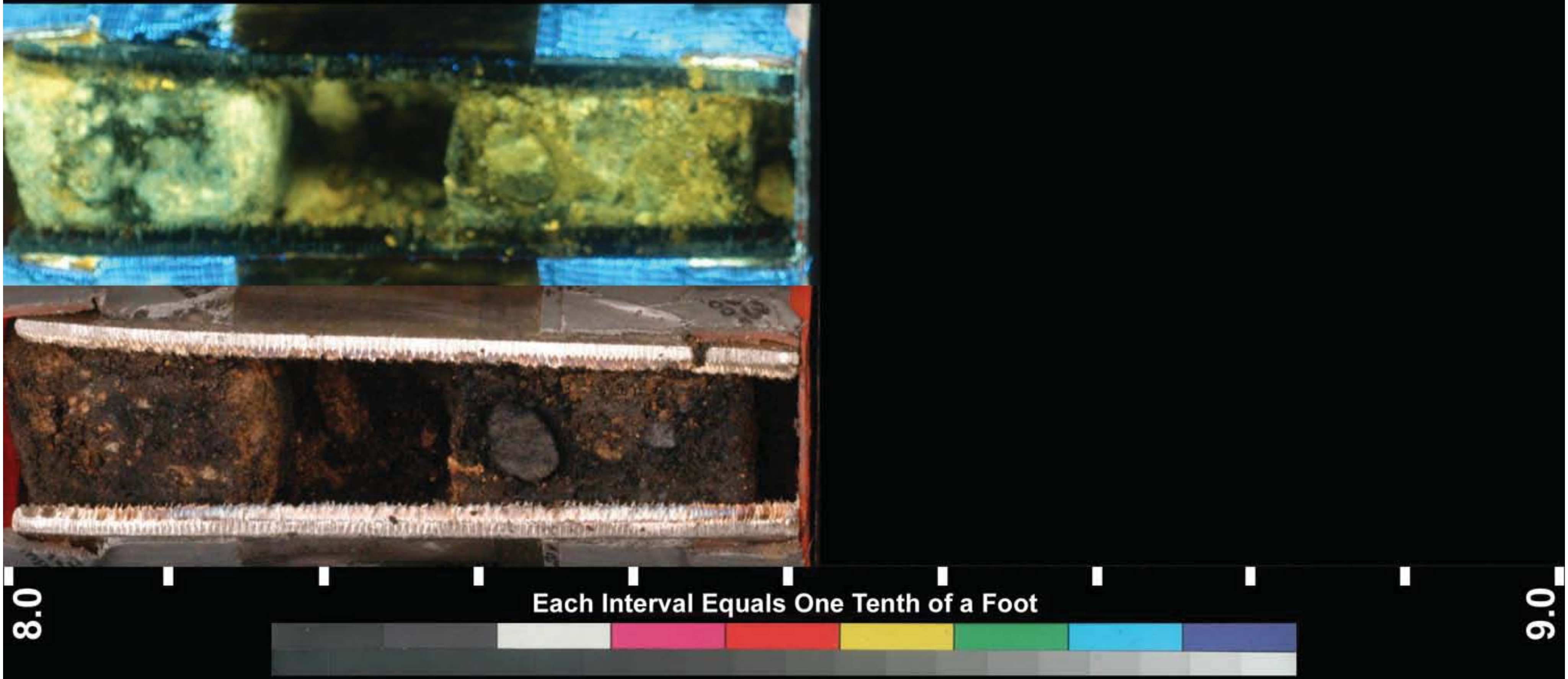


6.0

7.0

Each Interval Equals One Tenth of a Foot

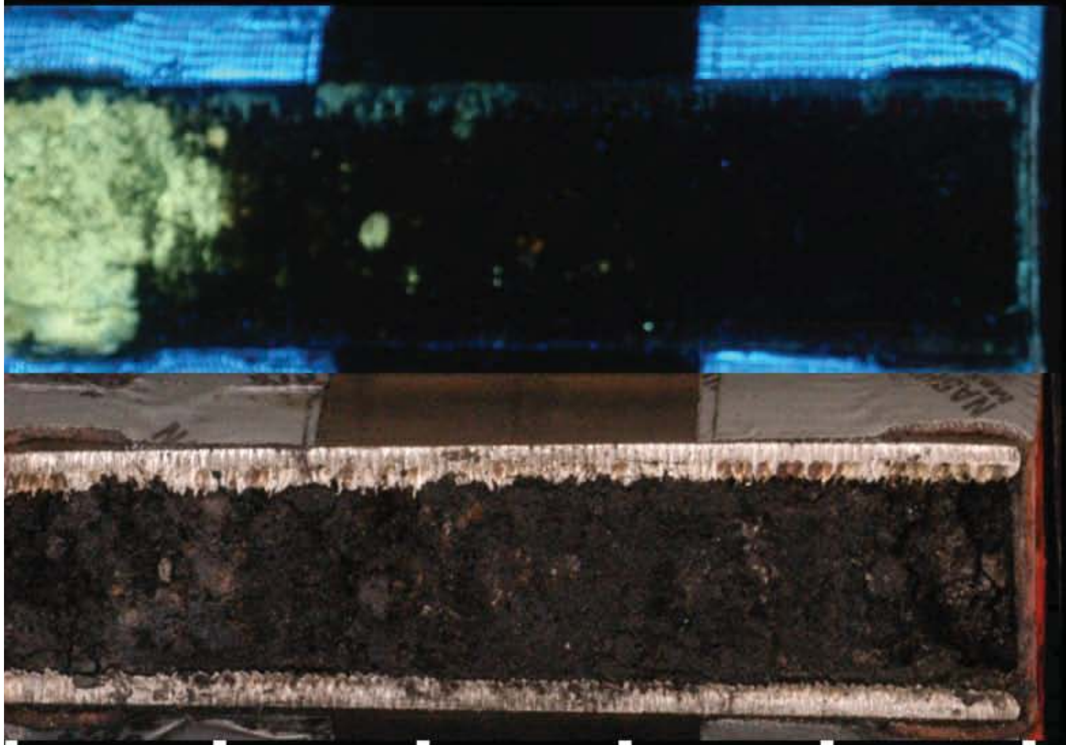
Project: Gas Works NE Corner   Boring ID: SB2-S4
Project No.: T6010 COS-GWSA

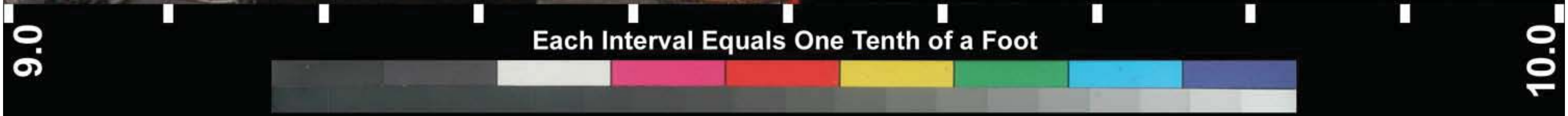


Project: Gas Works NE Corner   Boring ID: SB2A-S1
Project No.: T6010 COS-GWSA

PTS Laboratories
ENVIRONMENTAL SERVICES

PTS File No.: 37801

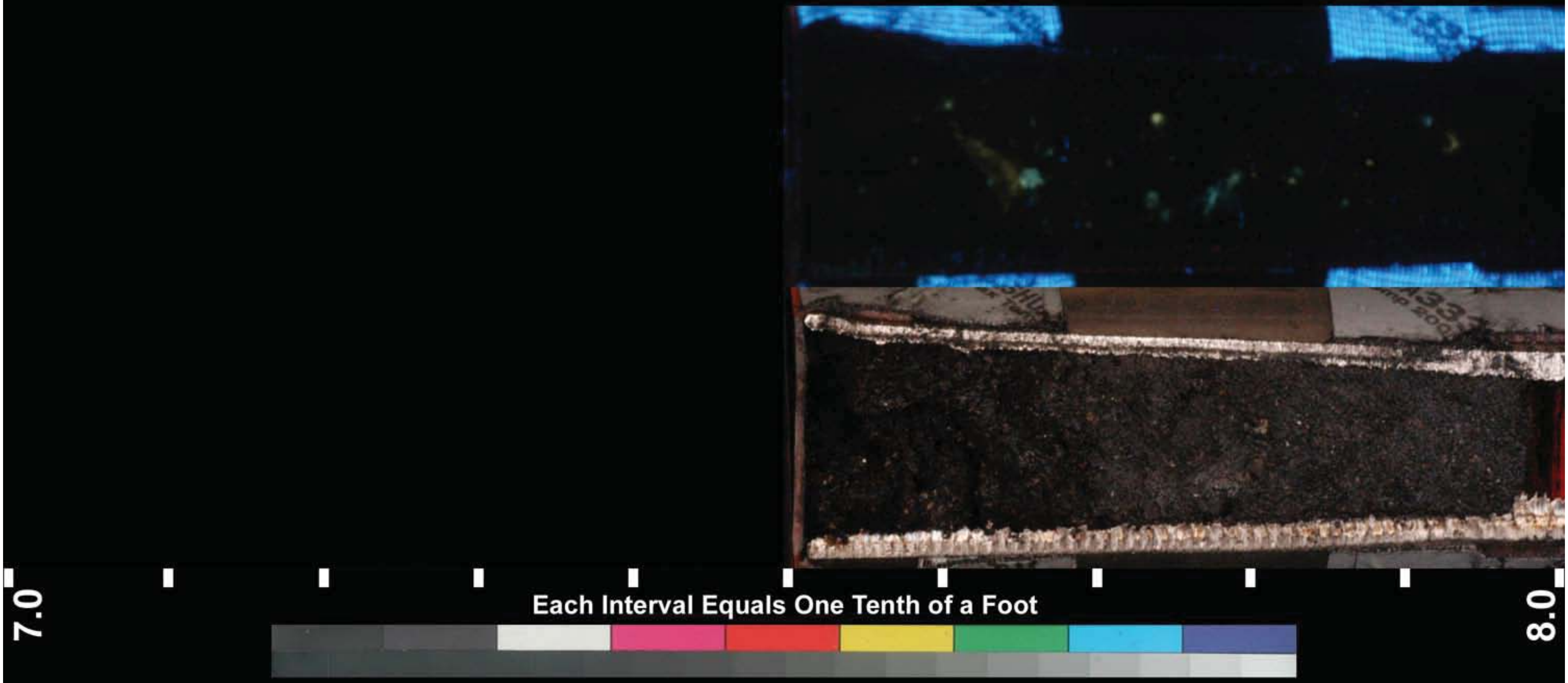




Project: Gas Works NE Corner Boring ID: SB 3A
Project No.: T6010 COS-GWSA

PTS Laboratories
ENVIRONMENTAL SERVICES

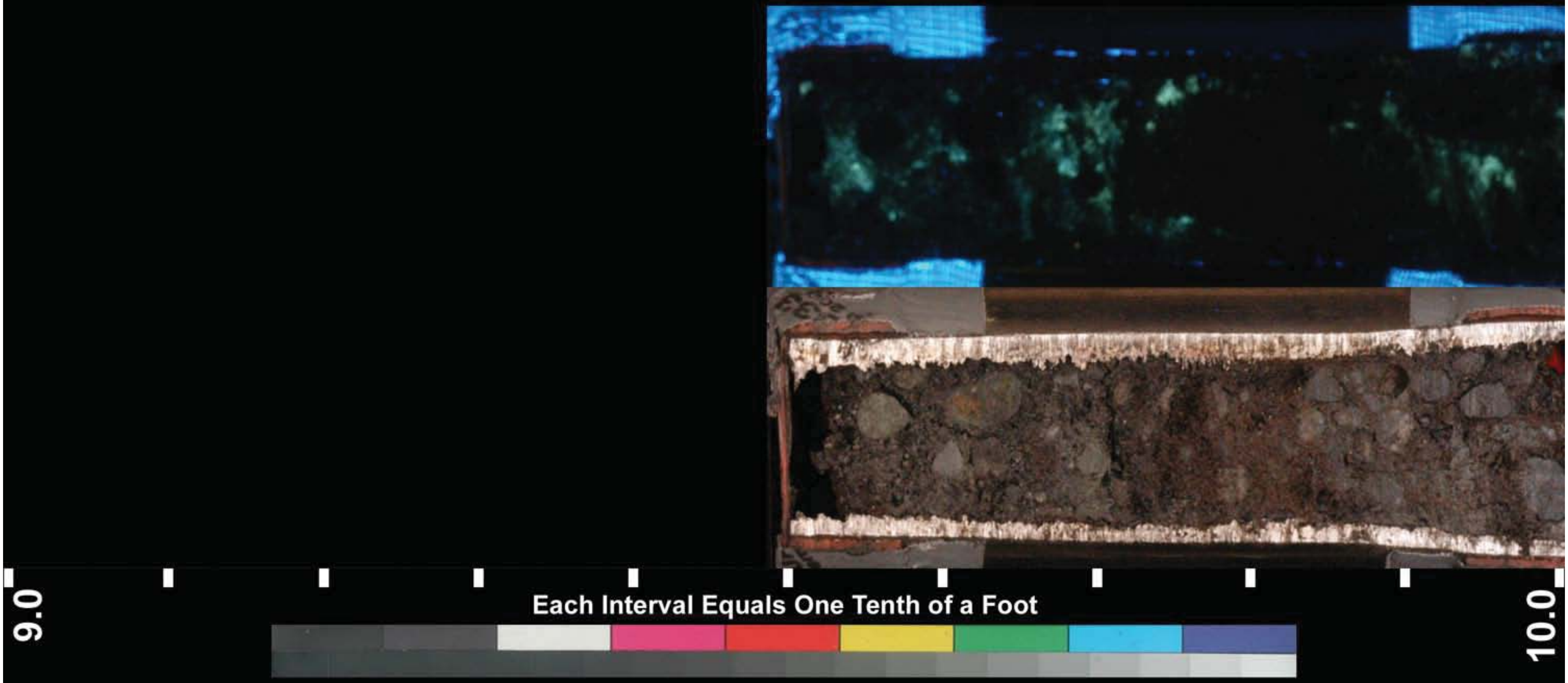
PTS File No.: 37801



Project: Gas Works NE Corner   Boring ID: SB5-S5
Project No.: T6010 COS-GWSA

PTS Laboratories
ENVIRONMENTAL SERVICES

PTS File No.: 37801

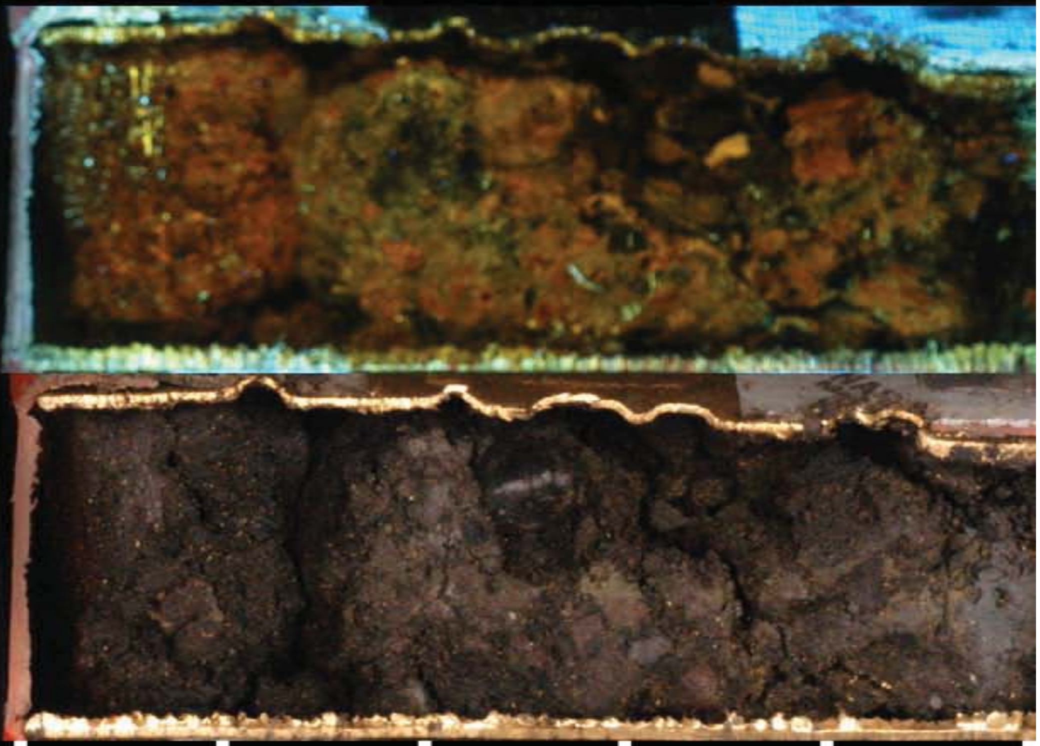


Each Interval Equals One Tenth of a Foot

Project: Gas Works NE Corner   Boring ID: SB8-S5
Project No.: T6010 COS-GWSA

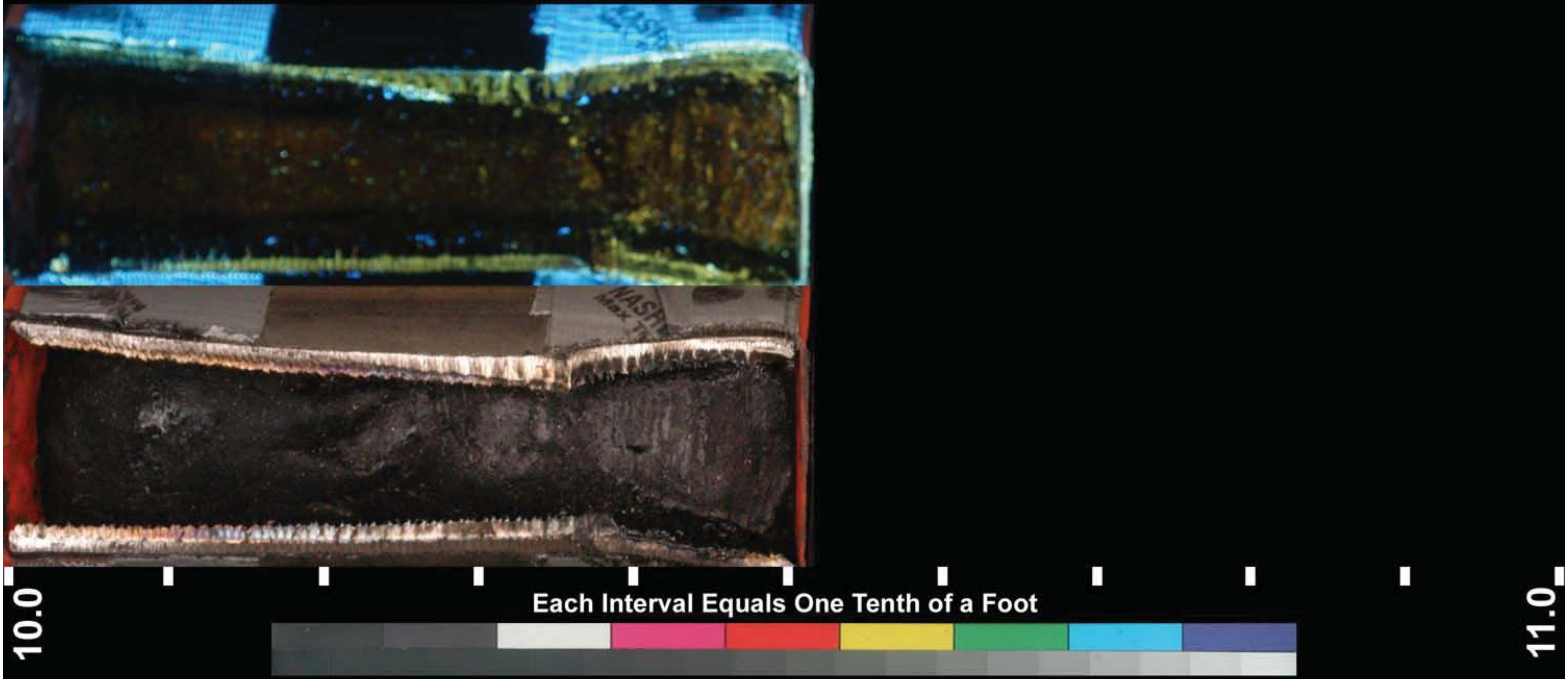
PTS Laboratories
ENVIRONMENTAL SERVICES

PTS File No.: 37801



Each Interval Equals One Tenth of a Foot

Project: Gas Works NE Corner   Boring ID: SB12A-S4
Project No.: T6010 COS-GWSA



Project: Gas Works NE Corner Boring ID: SB12A-S6
Project No.: T6010 COS-GWSA

Petrophysical Data

PTS File No: 37801
Client: Floyd Snider

PTS Laboratories

PHYSICAL PROPERTIES DATA - PORE FLUID SATURATIONS

PROJECT NAME: Gas Works NE Corner
PROJECT NO: T6010 COS-GWSA

		METHODS:	API RP 40 / ASTM D2216	API RP 40		API RP 40		API RP 40	
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	MOISTURE CONTENT, % weight	DENSITY		POROSITY, %Vb (2)		PORE FLUID SATURATIONS, % Pv (3)	
				BULK, g/cc	GRAIN, g/cc	TOTAL	AIR FILLED	WATER	NAPL
SB2-S4	6.65-6.8	V	19.2	1.59	2.64	39.7	9.0	72.7	4.5
SB2A-S1	8.0-8.15	V	15.0	1.42	2.65	46.4	25.1	41.0	4.9
SB 3A	9.15-9.3	V	41.1	1.09	2.26	51.8	6.4	74.5	13.2
SB12A-S4	6.65-6.8	V	18.8	1.64	2.64	37.8	6.9	76.0	5.8
SB12A-S6	10.2-10.35	V	152.8	0.44	1.55	71.4	0.6	9.9	89.3

(1) Sample Orientation: H = horizontal; V = vertical (2) Total Porosity = no pore fluids in place; all interconnected pore channels; Air Filled = pore channels not occupied by pore fluids (3) Water = 0.9996 g/cc, Hydrocarbon = 0.9600 g/cc; Vb = Bulk Volume, cc; Pv = Pore Volume, cc; ND = Not Detected

PTS File No: 37801
Client: Floyd Snider

FREE PRODUCT MOBILITY: INITIAL AND RESIDUAL SATURATIONS

PROJECT NAME: Gas Works NE Corner
PROJECT NO: T6010 COS-GWSA

		METHODS:	API RP 40		API RP 40	ASTM D425M, DEAN-STARK			
						PORE FLUID SATURATIONS, % Pv			
			DENSITY			Initial Fluid Saturations		After Centrifuge at 1000xG	
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	BULK, g/cc	GRAIN, g/cc	TOTAL POROSITY, %Vb	WATER (Swi) SATURATION	NAPL (Soi) SATURATION	WATER (Srw) SATURATION	NAPL (Sor) SATURATION
SB2-S4	6.5-6.65	V	1.65	2.59	36.1	61.9	6.7	39.4	6.7
	NOTE:	**No visible NAPL produced. Produced water clear with no hydrocarbon odor.**							
SB2A-S1	8.3-8.4	V	1.84	2.69	31.8	62.1	7.0	31.4	7.0
	NOTE:	**No visible NAPL produced. Produced water clear with no hydrocarbon odor.**							
SB 3A	9.0-9.15	V	1.21	2.45	50.7	57.4	17.6	22.6	16.1
	NOTE:	**Dark brown LNAPL produced. Produced water clear.**							
SB12A-S4	6.5-6.65	V	1.73	2.62	34.0	83.4	13.0	53.0	13.0
	NOTE:	**No visible NAPL produced. Produced water clear with faint hydrocarbon odor.**							

N/A = Not Analyzed. Vb = Bulk Volume, Pv = Pore Volume. (1) H = horizontal, V = vertical
Soi = Initial NAPL Saturation as received prior to centrifuging at 1000xG, Swi = Initial Water Saturation as received prior to centrifuging at 1000xG
Sor = Residual NAPL Saturation after centrifuging at 1000xG, Srw = Residual Water Saturation after centrifuging at 1000xG
Water =0.9996 g/cc, NAPL = 0.9600 g/cc.

FREE PRODUCT MOBILITY: INITIAL AND RESIDUAL SATURATIONS

(Samples spun under water.)

PROJECT NAME: Gas Works NE Corner
PROJECT NO: T6010 COS-GWSA

		METHODS:	API RP 40		API RP 40	ASTM D425M, DEAN-STARK			
						PORE FLUID SATURATIONS, % Pv			
		SAMPLE	DENSITY		TOTAL	Initial Fluid Saturations		After Centrifuge at 1000xG	
SAMPLE ID.	DEPTH, ft.	ORIENTATION (1)	BULK, g/cc	GRAIN, g/cc	POROSITY, %Vb	WATER (Swi) SATURATION	NAPL (Soi) SATURATION	WATER (Srw) SATURATION	NAPL (Sor) SATURATION
SB12A-S6	10.35-10.5	V	0.54	1.61	66.8	9.9	88.7	8.1	87.8

NOTE: NAPL produced from top and bottom of sample. Produced water clear. Sample compressed slightly during centrifuging.

N/A = Not Analyzed. Vb = Bulk Volume, Pv = Pore Volume. (1) H = horizontal, V = vertica
Soi = Initial NAPL Saturation as received prior to centrifuging at 1000xG, Swi = Initial Water Saturation as received prior to centrifuging at 1000xG
Sor = Residual NAPL Saturation after centrifuging at 1000xG, Srw = Residual Water Saturation after centrifuging at 1000xG
Water =0.9996 g/cc, NAPL = 0.9600 g/cc.

DATE PTS FILE# 37801 CHAIN OF CUSTODY RECORD PAGE 1 OF 1

COMPANY
FLOYD SNIDER

ADDRESS
601 UNION ST. STE 600, SEATTLE, WA 98101

PROJECT MANAGER
KATE SNIDER / MEGAN KING

PROJECT NAME
GAS WORKS NE CORNER

PHONE NUMBER
206-292-2078

PROJECT NUMBER
T6010 COS-GWSA

FAX NUMBER

SITE LOCATION
GAS WORKS PARK, SEATTLE WA

SAMPLER SIGNATURE

PO#

SPECIAL HANDLING
24 HOURS 5 DAYS
72 HOURS [✓ NORMAL]
OTHER

SAMPLE CONDITIONS
RECEIVED ON ICE YES/NO
SEALED YES/NO
OTHER YES/NO

ANALYSIS REQUEST

SAMPLE ID NUMBER	DATE	TIME	DEPTH, FT	PHYSICAL PROPERTIES PACKAGE, API RP40	MOISTURE CONTENT, ASTM D2216	POROSITY, API RP40	GRAIN DENSITY, API RP40	BULK DENSITY, API RP40	AIR PERMEABILITY, API RP40	SPECIFIC RETENTION/YIELD ASTM D425	CAPILLARY PRESSURE, ASTM D425M	SOIL pH, EPA 9045	GRAIN SIZE: DRY: 400 MESH	GRAIN SIZE: SIEVE & LASER	GRAIN SIZE: LASER; 1 MICRON	HYDRAULIC CONDUCTIVITY, EPA 9100, API RP40	TOC: WALKLEY-BLACK	HYDRAULIC CONDUCTIVITY PACKAGE	ATTERBERG LIMITS, ASTM D4318	TNRCC PROPERTIES PACKAGE	White light + UV Photography	Digital imaging - CDs	PORE FLUID SATURATION PACKAGE		NUMBER OF SAMPLES	COMMENTS
SB2-S4	9/17/07	-	6.5-8.0		✓		✓	✓													✓		✓			HOLD PORE
SB2A-S1	9/17/07	-	8.0-9.5		✓		✓	✓													✓		✓			FLUID SAT. PKG
SB 3A	9/19/07	-	9.0-10.5		✓		✓	✓													✓		✓			+ PHYSICAL
SB5-S5	9/18/07	-	7.5-9.0		✓		✓	✓													✓		✓			PROPERTIES
SB8-S5	9/18/07	-	9.5-10.0		✓		✓	✓													✓		✓			PENDING
SB12A-S4	9/20/07	-	6.5-8.0		✓		✓	✓													✓		✓			RESULTS OF
SB12A-S6	9/20/07	-	10.0-10.2		✓		✓	✓													✓		✓			UV + WHITE LT.
																										PHOTOGRAPHY

1. RELINQUISHED BY
COMPANY FLOYD SNIDER
DATE 9/24/07 TIME 3:00 PM

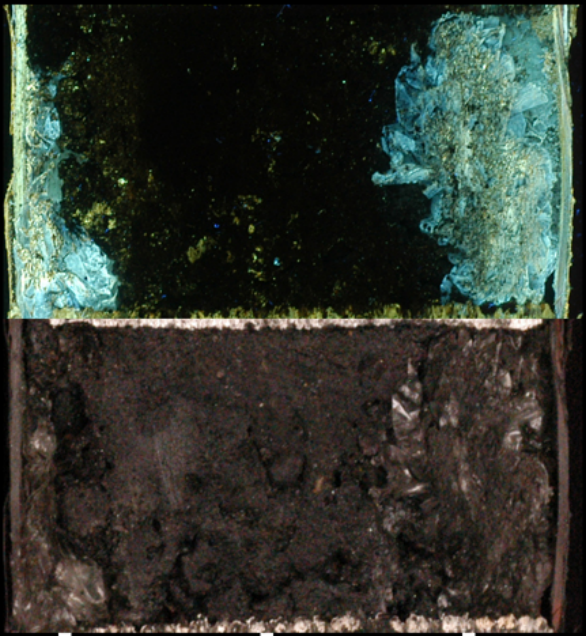
2. RECEIVED BY
COMPANY PTS Labs
DATE 9/25/07 TIME 1310

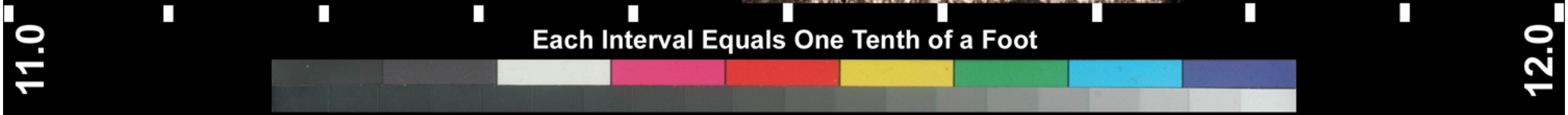
3. RELINQUISHED BY
COMPANY
DATE TIME

4. RECEIVED BY
COMPANY
DATE TIME

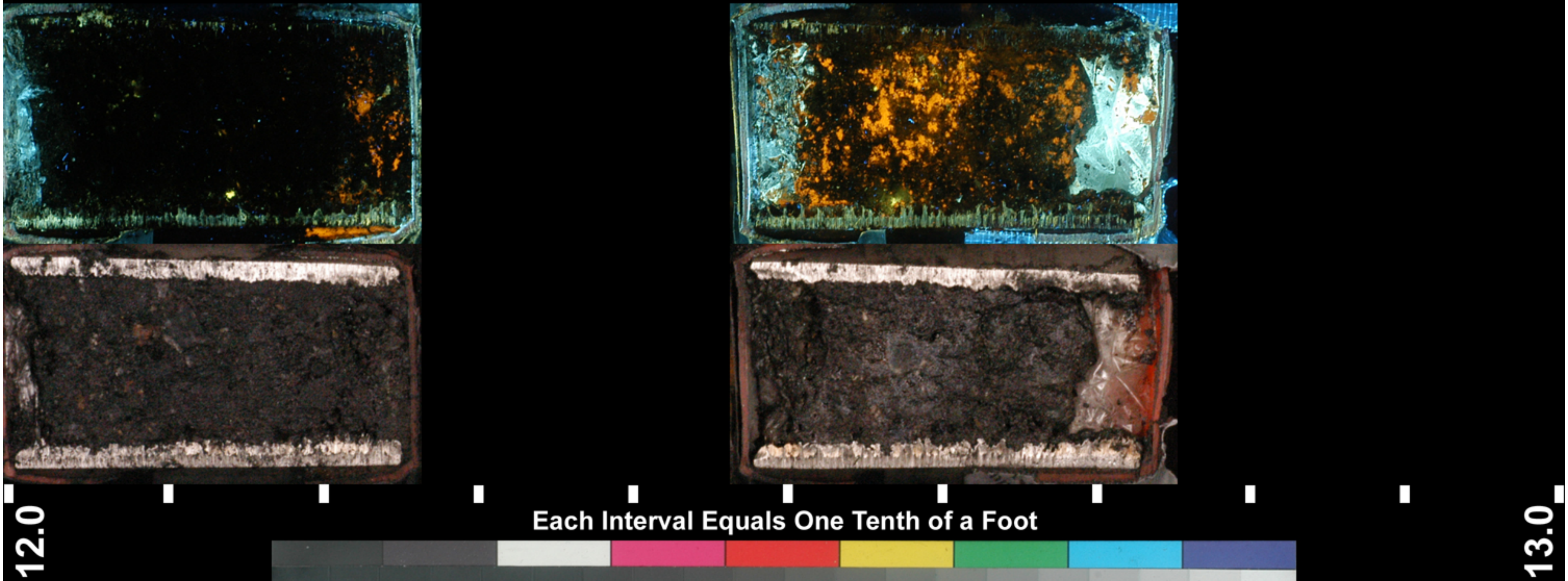
SUB-ATTACHMENT 5F-1.3
Eastern Shoreline Petrophysical Laboratory Report 2008

UV Photographs





Project: North Lake Union   Boring ID: GP-02
Project No.: 37769



Each Interval Equals One Tenth of a Foot

Project: North Lake Union **Boring ID: GP-02**
Project No.: 37769

PTS Laboratories
ENVIRONMENTAL SERVICES
PTS File No.: 37769

Each Interval Equals One Tenth of a Foot

Project: North Lake Union   Boring ID: GP-04
Project No.: 37769