# GROUNDWATER/DNAPL SOURCE CONTROL FOCUSED FEASIBILITY STUDY

## NW NATURAL "GASCO" SITE

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# CERTIFICATION STATEMENT

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# 1 INTRODUCTION

This Draft Groundwater/Dense Non-Aqueous Phase Liquid (DNAPL) Source Control Focused Feasibility Study (GWFFS) evaluates and recommends interim groundwater source control removal actions for the NW Natural "Gasco" Site (Site) in Portland, Oregon. This former Manufactured Gas Plant (MGP) Site is located on the banks of the Lower Willamette River in Portland Harbor. The purpose of this GWFFS is to evaluate potential removal technologies to minimize the movement into the river of Site chemicals in groundwater and subsurface DNAPL, which are present due to historical MGP operations. After evaluating many potential removal technologies, this document concludes with a recommended set of removal technologies (called a removal alternative) for groundwater/DNAPL source controls for review and approval by the Oregon Department of Environmental Quality (DEQ).

A preliminary draft GWFFS was submitted to DEQ on October 12, 2007. A meeting was held between DEQ and NW Natural on October 23 to discuss the document. At that meeting DEQ asked NW Natural to revise the document. In the interest of facilitating revision and meeting the tight project schedule, it was agreed that NW Natural would revise the GWFFS based on the meeting discussions, without receiving formal written comments from DEQ. It was agreed that DEQ and other stakeholders would provide written comments after reviewing this revised GWFFS. For this version of the GWFFS, DEQ asked NW Natural to provide more detail on several topics. The primary topics are listed below.

- Hydraulic containment of DNAPL
- Placement of the vertical barrier on Siltronic property
- Depth of the vertical barrier related to DNAPL depth

The remaining sections of this document provide the following information relevant to this evaluation and recommendation for interim groundwater/DNAPL source controls:

1. Section 2 – Describes project context and how the proposed interim source controls fit into other studies and removal or remedial actions taking place on and around the Site.
2. Section 3 – Summarizes the Site conditions most relevant to making groundwater/DNAPL source control decisions, recently collected relevant data, as well as ongoing relevant investigations.
3. Section 4 – Defines the purpose and remedial goals that will be used to evaluate the effectiveness of potential source control alternatives.

4. Section 5 – Defines segments of the Site to facilitate the evaluation of source control alternatives across varying Site conditions.
5. Section 6 – Describes a wide range of potential source control technologies that could be applied and screens them down to a reasonable set of technologies for detailed evaluation.
6. Section 7 – Provides a detailed evaluation of source control technologies for one portion of the Site shoreline (Segment 1, as defined in Section 5).
7. Section 8 – Provides a detailed evaluation of source control technologies for a second portion of the Site shoreline (Segment 2, as defined in Section 5).
8. Section 9 – Summarizes the recommended source control alternative based on the evaluations in Sections 7 and 8.
9. Section 10 – Describes a general proposed schedule for design and implementation of the recommended alternative.
10. Section 11 – Briefly describes the operations, maintenance, and monitoring approaches that are envisioned for the recommended alternative.
11. Section 12 – Briefly describes the proposed path forward on interim source controls after this document is submitted to DEQ.

This report was prepared by Anchor Environmental, LLC (Anchor). S.S. Papadopulos (SSPA) developed aquifer parameters from the extraction well pump test data and prepared the ModFlow groundwater model. Advanced Remediation Technologies (ART) did the preliminary engineering for the groundwater treatment system and assisted with cost estimating.

# 2 PROJECT CONTEXT

## 2.1 Regulatory Context

NW Natural has undertaken this GWFFS to fulfill certain requirements of an August 8, 1994 Voluntary Agreement (DEQ No. ECVC-WMCVC-NWR-94-13) between NW Natural and DEQ) and as amended July 19, 2006. The Voluntary Agreement requires the completion of Remedial Investigation (RI), Risk Assessment (RA), and Feasibility Study (FS) activities at the Site in satisfaction of the requirements of Oregon Administrative Rules (OAR) 340-122-070 and 340-122-080. A revised final RI (HAI 2007a) and RA (Anchor 2004) were completed and submitted to DEQ in April of 2006 and December of 2004, respectively, and have not yet received comment or final approval from DEQ. This GWFFS is one step toward a complete upland FS for the Site, as described more below.

### *2.1.1 Integration with In-River Activities*

Historic MGP operations have chemically impacted both the uplands portion of the Site as well as the river sediments offshore of the Site. Pursuant to an interagency Memorandum of Agreement (MOU), DEQ is the lead agency for upland source control activities above the ordinary high water mark. Investigation of in-river areas below the ordinary high water mark near the upland Site, as well as the rest of Portland Harbor, is being conducted through the Portland Harbor Superfund Site Administrative Order on Consent (AOC; No. CERCLA-10-2001-0240) between the U.S. Environmental Protection Agency (EPA) and several public and private entities in the harbor including NW Natural. Collectively, these entities are known as the Lower Willamette Group (LWG).

Because of the regulatory division between upland and in-river work, the activities considered in this GWFFS are not intended to remediate any impacts to the river due to past source discharges, but only to control future sources to the river to an acceptable level as determined by DEQ and EPA. NW Natural conducted an in-river removal in 2005 of approximately 15,000 cubic yards of tar and sediment under an administrative order on consent with EPA. These materials were disposed of at Chemical Waste Management of the NW facility near Arlington, Oregon. NW Natural is currently conducting long-term monitoring of a pilot cap placed over the removal area under the same EPA order.

In addition, NW Natural has and is conducting some work offshore of the upland Site under direction DEQ for two purposes: 1) to assist in the evaluation of upland sources and their control by understanding the nature and extent of groundwater impacts near the upland Site and 2) to fill data gaps identified by the LWG related to potential in-water risks from upland groundwater discharges. These investigations are described more in Section 3.

DEQ has indicated in comment letters that various aspects of the offshore data collection support only the second purpose and that the data will not inform DEQ's decisions regarding the need for groundwater/NAPL source controls. NW Natural believes that much of this offshore work is valuable for understanding the potential need for and degree of upland groundwater source controls. Given recently collected offshore data, it is NW Natural's current view that Site groundwater/DNAPL source controls are necessary, and the question of the need for source controls has been settled. However, offshore information can still help inform the following:

- The potential effectiveness of groundwater/DNAPL source controls, a key evaluation criteria in this GWFFS
- The appropriate extent and magnitude of groundwater/DNAPL source controls.

Data uses for specific data types are discussed more in Section 3.

### 2.1.2 Integration with Wider Upland Investigations

Historically, the MGP operations associated with the Gasco Site extended approximately 400 feet beyond the current NW Natural southern property line (Figure 1). The area to the south of the current NW Natural property line is owned by the Siltronic Corporation (Siltronic). A portion of the Siltronic property along the current property line is known to be impacted by historical MGP activities directly, and some MGP wastes were re-distributed by others to other portions of the property, after NW Natural's predecessor sold the property in 1962 (HAI 2007a). Previous investigations conducted by NW Natural on the Siltronic property (HAI 2005 and Anchor 2003) focused on the evaluation of potential contaminant pathways to the Willamette River and were completed pursuant to an Order Requiring RI and Source Control Measures (DEQ No. ECVC-NWR-00-27), issued jointly to both Siltronic and NW Natural. Although these sampling and analysis activities provided some information, the exact nature and extent of these MGP-related wastes on the property is not yet entirely understood. Therefore, an RI related to MGP impacts at the Siltronic property is currently underway pursuant to NW Natural's Voluntary Agreement, as amended July 19, 2006. An RI Work Plan (HAI 2007b) for the MGP investigations at the Siltronic property is currently under review by DEQ.

Because the distribution of MGP-related impacts near the NW Natural/Siltronic property line is relatively well known based on information available to date, this GWFFS includes evaluation of groundwater/DNAPL source controls extending approximately 500 feet onto the Siltronic property, consistent with DEQ comments in a May 2, 2007 letter to NW Natural. Areas extending farther southward along the shoreline are not evaluated in this GWFFS because the nature and extent of MGP-related groundwater contamination that may have the potential to enter the river is of significantly lower magnitude, albeit less well understood at this time. Although DEQ has commented in the May 2, 2007 letter that groundwater source controls are warranted for this more southerly portion of the shoreline for multiple sources of contamination (including non-MGP related), NW Natural believes that this area needs further evaluation in light of additional data currently being collected to determine the need for and extent of any such source controls for MGP-related impacts. DEQ and NW Natural have agreed that such an evaluation will be conducted once data are available from August 2007 sampling of wells on the Siltronic property installed by Rhone-Poulenc. This source control evaluation of the southerly portion of the Siltronic shoreline is expected to be completed and submitted to DEQ in November 2007. The timing of these investigations and the source control evaluation of these data are described more in Sections 3 and 10.

It should also be noted that DEQ is currently working with Siltronic and Rhone-Poulenc under separate agreements to investigate, remediate, and provide necessary source controls for deep groundwater trichloroethylene (TCE) and dioxin/herbicide plumes, respectively. These remedial efforts are not within the scope of any NW Natural remedial or source control efforts on the Siltronic property or elsewhere.

## 2.2 Integration with Overall Site Remedy

Groundwater source controls are considered an "interim" action as part of the overall upland Site remediation. This GWFFS is being conducted prior to the initiation of the overall uplands FS, which will evaluate remedial alternatives for upland soils, groundwater, and surface water as necessary to attain acceptable risk levels. As described in the Portland Harbor Joint Source Control Strategy (JSCS; EPA and DEQ 2005), EPA and DEQ determined that river source controls for shoreline properties should be conducted in advance of overall upland remediation as necessary to prepare the Portland Harbor Superfund Site for in-river remedial design and remedial action, starting after the Record of Decision is issued by EPA. The most recent JSCS Milestone Report (DEQ 2007) indicates that source control measures are expected to be selected for high priority sites (Gasco is one such site) by mid-2008 and implemented by the end of 2009. NW Natural and DEQ have agreed upon a source control schedule that anticipates the initiation of implementation of upland groundwater source controls for Gasco in 2008.

Because source controls will be designed and implemented prior to full Site remediation, this GWFFS describes "interim" actions designed specifically to address the groundwater/ DNAPL source control portion of the overall Site remediation. Consequently, the later overall Site FS will evaluate remedial actions beyond this interim removal action to further ensure that groundwater/DNAPL sources to the river are controlled acceptably. Given the nature and scope of the interim actions contemplated by this GWFSS, however, NW Natural anticipates that this interim source control action will be a key component of the final Site remedy. Although all actions needed to complete remediation of the Site will be considered in the FS, it is expected that the focus of the future FS will be the remediation of upland soils and surface water as necessary to complete the remedial actions that will begin with the groundwater/DNAPL source controls.

## 2.3 Integration with Other Source Controls

Investigations and evaluations of other potential sources to the river are also underway. The primary components of these other investigations are potential riverbank erosion of soils and potential stormwater discharges.

### 2.3.1 Potential Riverbank Soil Source

The potential for erosion of riverbank soils containing chemicals into the river and proposed controls to address this potential source has been considered previously in a Bank Stabilization Alternatives Analysis submitted to DEQ in June 2003, which DEQ has not yet provided comment on. This Bank Stabilization Alternatives Analysis has been updated in light of more recent project developments and is resubmitted for DEQ's review and approval as Appendix F to this document. It is NW Natural's intent to conduct interim bank stabilization source controls shortly after implementation of groundwater/DNAPL source controls. The primary reason for this timing is that bank stabilization will require work below the ordinary high water line, which will trigger a much more lengthy aquatic permitting process (see schedule discussions in Section 10). The bank stabilization would be an interim action similar to the description above for groundwater/DNAPL controls. The overall upland FS will address to what extent the bank stabilization interim actions can be considered final or alternatively, need to be augmented for a final overall Site remediation. The bank stabilization alternatives considered in Appendix F have the potential in some shoreline areas to spatially overlap with the groundwater/DNAPL source control alternatives evaluated in detail in Sections 7 and 8 of this GWFFS. As explained in Section 10, the design of the selected alternative for groundwater source control will be directed to facilitate subsequent bank stabilization measures.

### 2.3.2 Potential Upland Stormwater Source

Source control for upland stormwater runoff to the river is also under evaluation. NW Natural submitted to DEQ a Source Control Data Gaps Work Plan to DEQ in July 2007 (Anchor and HAI 2007), and DEQ commented on this document in a letter to NW Natural dated August 15, 2007. The Work Plan proposed to fill several groundwater related data gaps (described more in Section 3), as well as stormwater sampling and analysis, to evaluate the need for any additional stormwater source controls on the Site. DEQ required the resubmittal of the stormwater portion of the plan for further consideration. It is anticipated that an acceptable plan for stormwater data needs will be negotiated between NW Natural and DEQ in time for sampling of stormwater in the fall or early winter of 2007.

# 3 SITE DESCRIPTION AND RELATED INVESTIGATIONS

This section describes Site characteristics and the findings of previous and ongoing investigations related to groundwater/DNAPL source controls. Because contamination closest to the river is most relevant to understanding potential groundwater/DNAPL sources to the river, this description focuses on the shoreline portions of the Site.

The Gasco RI (HAI 2007a) describes the Site and defines the nature and extent of MGP-impacted soil and groundwater. The Siltronic RI Work Plan (HAI 2007b) describes MGP-related issues within the northerly portion of the Siltronic property, which is the portion of that property included in this GWFFS. In addition, Anchor completed a Gasco/Siltronic Source Control Evaluation shoreline field sampling program in 2006 (Anchor 2007a) that included shoreline borings for groundwater and soil sampling along the entire length of the Gasco shoreline, as well as the northerly approximate 500 feet of the Siltronic property. This information was collected specifically to support this GWFFS and source control decisions. Below is a very brief summary of the most relevant findings of these documents.

## 3.1 Site Description

General site features are shown in Figure 1. The upland Site hydrogeology in the vicinity of the shoreline consists of three units including the surficial fill (approximately 2 to 30 feet thick), the alluvium (approximately 30 to 225 feet thick), and the underlying basalt bedrock (encountered from 36 to 225 feet below ground surface) (Figures 2 and 3). The top of the alluvium contains a silt layer, which is generally present throughout the uplands portion of the Site. The upper silt layer thins towards the river, is absent in some areas, and acts as a semi-confining unit across much of the Site. Below the silt layer, the alluvium consists primarily of fine to medium sand with silt interbeds. There are more silt interbeds in the upper alluvium than in the lower alluvium, as shown on Figures 2 and 3.

The upland RI report describes the nature and occurrence of groundwater at the Site. Figures 4a through 4c are groundwater elevation maps developed for the RI report. They represent groundwater elevations in the fill water bearing zone (WBZ), upper alluvium WBZ, and the lower alluvial WBZ. The potentiometric surface gradient in all three hydrogeologic units is toward the river.

MGP-related tars and DNAPL are present in the surficial fill and upper silt units throughout the former production areas of the historic gas plant, primarily in the former effluent settling pond and effluent discharge areas including the northerly most portions of the Siltronic property (Figure 1). In areas of the effluent settling pond and discharge areas, DNAPL has migrated vertically through secondary porosity features (e.g., root casts, partings), through the upper silt layer, and into the sands of the upper alluvium. The locations of DNAPL along the Site shoreline are described in the shoreline Source Control Evaluation Phase 1 report (Anchor 2007c) and updated cross sections including additional investigations described in Section 3.2 are shown in Appendices A and C. In addition, more recent DNAPL TarGOST subsurface profiling (a DNAPL-sensitive laser-induced fluorescence technology) was conducted in September 2007 and the findings of this evaluation are discussed in Section 3.2.3.2 and Appendix G.

The key chemicals of interest (COI) at the Site are polynuclear aromatic hydrocarbons (PAHs), benzene, and cyanide. Generally, the highest concentrations of PAHs and benzene in soil and groundwater at the Site correlate to locations at which MGP wastes and DNAPL are found and often exceed human health and ecological screening values at depth in the subsurface. Total cyanide is widespread throughout the Site in both soils and groundwater, however, free cyanide is much less frequently detected. The highest concentrations of total cyanide occur more often in soils and groundwater in the Former Spent Oxide area in the northeast corner of the Site. Although total cyanide in groundwater is often detected throughout the Site, free cyanide (the bioavailable form) is only infrequently detected at concentrations above conservative screening values (e.g., chronic ambient surface water criteria). Arsenic, cadmium, chromium, copper, lead, nickel, zinc, toluene, ethylbenzene, xylene, and certain phenols are also Site COIs, with the metals and phenols at levels above screening values found only at a subset of sample locations.

## 3.2 Recently Collected Data

In addition to the primary sources of information noted above, several investigations relevant to source control evaluation have been either recently completed or are still underway. Much of this recent information has not been reported previously, and this section provides a summary of recent findings, which in many cases includes unvalidated and/or preliminary chemistry data that are subject to change. This GWFFS will be followed by more detailed data reports for each of these recent investigations.

The recent investigations have been identified by DEQ and NW Natural to fill data needs to conduct this GWFFS and have included the primary efforts described below.

**Offshore Groundwater Investigations** – As noted in Section 2, the purpose of these investigations was to understand the nature and extent of groundwater discharges to the river and to help verify where (vertically and horizontally) groundwater/DNAPL source controls were needed, as well as fill LWG-identified data gaps. This study was planned in 2006 as a two-phase effort. The first phase focused on a series of shoreline borings, as described in Section 3.2.1, and was completed and reported to DEQ in May 2007 (Anchor 2007c). The second phase progressed further offshore and out into the river channel and was proposed in the same document (Anchor 2007c) and commented on by DEQ in a June 28, 2007 letter. This second phase is still underway and has proceeded in two steps: 1) a shallow transition zone water (TZW) and groundwater reconnaissance and 2) a deeper exploration of offshore groundwater focused on areas of discharge indicated by the step 1 effort. Only the preliminary results from the first step of Phase 2 are currently available for use in the GWFFS. It should be noted that these data have not been validated and are subject to change in whole or part.

**Groundwater Extraction System Pilot Studies –** This pilot study was proposed by NW Natural in 2006 (Anchor 2006a) and was refined in a series of DEQ comments and addenda so that the pilot study started in early in 2007. The purpose of the study was to better understand the feasibility and design parameters of a potential full-scale groundwater extraction system at the Site. The pilot study included the installation of pilot borings, chemical testing of groundwater from the borings, installation of extraction wells, pump testing of the extraction wells, chemical testing of groundwater from the wells, treatment system bench scale treatability testing of groundwater samples, and modeling and data analysis of extraction well pumping performance.

**Upland Groundwater/DNAPL Data Needs** – Upland monitoring wells for the entire Site have been routinely monitored since 1995. Regular monitoring was recently conducted in

June/July 2007 and is used in this GWFFS to augment the existing groundwater data set. In addition, NW Natural submitted a Source Control Data Gaps Work Plan to DEQ in July 2007 (Anchor and HAI 2007), and DEQ commented on this document in a letter to NW Natural dated August 15, 2007. The Work Plan proposed and DEQ approved installation and monitoring of eight additional wells across three stations along the approximate northern half of the Gasco shoreline to better understand cyanide concentrations in this shoreline area. A DNAPL-targeted laser-induced fluorescence (TarGOST) study was also conducted to better understand DNAPL distribution along the Site shoreline. To expedite data collection for this GWFFS, the additional well installation was described (Anchor 2007b) and approved by DEQ in a letter dated June 25, 2007. The additional wells were sampled in July 2007 and the TarGOST DNAPL study was conducted in August and September 2007. The results of these studies are described in Sections 3.2.1 through 3.2.3. In addition, some additional data collection efforts still underway, that may have some bearing on source control design are discussed in Section 3.3.

### *3.2.1 Offshore Groundwater Investigations*

#### *3.2.1.1 Offshore Phase I Findings*

##### 3.2.1.1.1 Geology

The geologic sequence encountered along the shoreline consisted of a thin surface cobble/riprap layer, underlain by river alluvium extending down to basalt bedrock. The geologic units are shown on the subsurface profile A-A', Figure 3. The primary difference between the shoreline geologic sequence and the upland geology is the absence of the fill layer, which overlies the alluvium in the upland portion of the Site.

The lithology of the river alluvium along the shoreline is essentially the same as present under the Site upland, consisting primarily of sand to silty-sand, interbedded with silt to sandy-silt. The upper alluvium generally consists of very fine to fine sand and the lower alluvium is predominantly medium sand.

A layer of alluvial gravel was encountered in several borings immediately above the contact with basalt bedrock. The depth to bedrock was highly variable at the north end of the shoreline. The highest bedrock elevation of about -70 feet mean sea level (msl; City of Portland datum) was encountered in boring GS-01, and the lowest bedrock elevation was about -190 feet, in boring GS-05. Southward along the shoreline from GS-05 the bedrock elevation rises gradually to about -175 feet at GS-12 on the Siltronic shoreline. In many of the borings, the alluvium/bedrock contact was characterized by a layer of highly weathered basalt.

#### 3.2.1.1.2 Groundwater Quality

Groundwater samples were obtained at the following planned depths below mudline in the shoreline GS borings: 4 to 6-foot, 9 to 11-foot, and at approximate 25-foot intervals to the bottom of each boring. The actual sample depth intervals varied slightly due to conditions at each boring location. Appendix D, Table 3, lists the lab test methods and the test results for the groundwater chemistry analyses. For the purpose of describing the nature and extent of MGP-related COIs, this summary focuses on benzene, naphthalene, total cyanide, amenable cyanide, and free cyanide as indicator chemicals.

The groundwater concentrations of benzene, naphthalene, total cyanide, amenable cyanide, and free cyanide are shown in Appendix C1, subsurface profiles C1-5a through C1-5e. The zones where tar or DNAPL were detected at any magnitude by field screening of the sediment cores are also shown on the Figure 5 profiles.

Review of the Appendix C1-5 groundwater chemistry subsurface profiles supports the conceptual site model (CSM) by relating the history of MGP-related materials management with the depth and concentration profile of target COPCs. The highest shoreline groundwater concentrations of petroleum-based COPCs, as indicated by benzene and naphthalene, are associated with the occurrence of shallow tar or DNAPL in borings GS-08 (tar), -09 and -10. The DNAPL and tar present in shallow shoreline sediments is sourced from MGP residuals that were discharged to a drainage to the river, as described in the upland RI report (HAI 2007a). This can also be seen in the high benzene and naphthalene concentrations of the shallow sediments, for example in Figures C1-6a (benzene) and C1-6b (naphthalene). The very high concentrations in sediments are mostly likely due to discharge of MGP residuals along the shoreline. Also, given the extensive dredge, fill, and movement of soils/sediments of this shoreline over time (see RI), these materials may have been relocated to varying sediment depths.

The concentrations and extent of cyanide species in shoreline groundwater are reflective of a somewhat different CSM than the DNAPL-sourced petroleum constituents. This is understandable because they occur in two different portions of the Site. Appendix C1 Figures 5c, 5d, and 5e show the highest concentrations of cyanide in shallow shoreline groundwater samples from borings GS-01 to -03 and GS-06 to -07. Whereas the highest concentrations of petroleum-derived COIs were associated with the presence of shallow tar or DNAPL in borings GS-08, -09 and -10, the highest cyanide concentrations are correlated with the former nearby upland spent oxide storage area (GS-01 to GS-03) or the former effluent discharge area (GS-06 to GS-07). The upland RI describes a former large spent oxide (e.g., gas purification waste) pile adjacent to the north shoreline. Erosion and runoff from this former spent oxide storage area may have caused spent oxide materials to concentrate along the shoreline, particularly in the areas of borings GS-01 to -03. Historical effluent discharges or overflows to the shoreline area north of the effluent settling ponds may be a cause for the observed elevated total cyanide concentrations at the GS-06 to -07 locations. Free cyanide was detected in only about 10 percent of the 92 groundwater samples tested and was detected at concentrations lower than the method reporting limit (MRL) of 10 micrograms per liter (μg/L). Lower total cyanide concentrations in deeper portions of the offshore plume appear to correlate with the total cyanide plume present in the upland shoreline monitoring wells, as shown on the cyanide plume profile A-31 in Appendix A.

In borings GS-01 through GS-06, benzene concentrations ranged from 1 to 100 μg/L in the 4 to 6-foot sample interval, but the concentrations were generally below detection or less than 1 μg/L below that depth (Appendix C1, Figure 5a). The highest benzene concentrations were detected in borings GS-08 through GS-10 located offshore of the former effluent settling pond area. Benzene concentrations up to 710 μg/L were measured in the 9 to-11 foot depth interval at these locations, while the 100-foot sample interval in borings GS-08, -09, and -10 had benzene concentrations ranging from 76 to 310 μg/L. Below the 100-foot interval, however, the concentrations consistently drop to less than 5 μg/L, or below detection.

Appendix C1 Figure 5b shows that the general pattern of naphthalene detections is very similar to benzene. In general the only naphthalene detections above 1 μg/L in borings GS-01 to GS-06 were in the 4 to 6- or 9 to 11-foot samples. As with benzene, the concentrations drop under 1 μg/L at depths below 100 feet in the GS-07 to -10 borings.

Amenable and free cyanide concentrations are shown on Appendix C1, Figures 5d and 5e. The amenable and free cyanide concentrations are a small fraction of the total cyanide concentrations. Figure C1-5c shows that total cyanide is present throughout the saturated thickness of the alluvium. Total cyanide does not attenuate as quickly with depth in the alluvium as benzene and naphthalene. The highest concentrations of total cyanide were detected in the 4 to 6- and 9 to 11-foot samples in borings GS-01 to GS-03 offshore of the former spent oxide storage area. Total cyanide concentrations ranging from 2 to 100 μg/L were detected at the base of the alluvium, just above the bedrock contact.

Of the 92 groundwater samples tested, only eight samples had detections of free cyanide. The free cyanide concentrations ranged from 5 to 9 μg/L, and averaged 6.5 μg/L. The highest free cyanide concentrations were detected in the upper alluvium at the north end of the shoreline, in borings GS-01 and GS-03.

#### *3.2.1.2 Offshore Phase 2 Investigation*

The Phase 2 investigation has been in progress during the summer of 2007 and is not complete as of the time of this report. All discussion of preliminary Phase 2 results is based on unvalidated data, which are subject to change in whole or part. Consequently, any discussions based on these data contained in this GWFFS are also subject to change. Step 2 of Phase 2 is still ongoing, but preliminary results are available for Step 1 of Phase 2, which included shallow TZW sampling along transects B, C, and D offshore of the upland Site and out into the river navigation channel.

The preliminary Step 1 results are summarized in figures in Appendix C. Appendix C2, Figures 1 through 6 are maps of the offshore sample TZW sample locations. Next to each offshore sample location the maps show the TZW porewater concentrations of target analytes free cyanide (Appendix C2, Figure 1), amenable cyanide (Appendix C2, Figure 2), total cyanide (Appendix C2, Figure 3), benzene (Appendix C2, Figure 4), naphthalene (Appendix C2, Figure 5), and toluene (AppendixcC2, Figure 6). These six target analytes were selected to represent the general distribution of Site COIs in offshore TZW. For a complete list of all TZW water quality data for all Site COIs, see the tables in Appendix D.

Overall, the preliminary shallow TZW data suggest that there is groundwater mediated discharge of at least some upland groundwater chemicals to the river. The presence of chemicals in TZW may be due to either groundwater discharge or bulk sediment contamination related to historically placed tar or DNAPL directly in the river. Consequently, it is useful to evaluate the shallow TZW results in the context of surface sediment chemistry as shown in Appendix C3. Appendix C3, Figures 1 through 4 contain maps of TZW porewater data and bulk sediment chemistry data for four target analytes: total cyanide (Appendix C3, Figure 1), benzene (Appendix C3, Figure 2), naphthalene (Appendix C3, Figure 3), and toluene (Appendix C3, Figure 4). The following discussion is for those four key chemicals of interest, and follow up data reporting will provide a presentation of all Phase 2 results once they are finalized.

For cyanide, it is notable that free cyanide is nearly absent in TZW, similar to the findings for upland groundwater as measured in shoreline monitoring wells (see Appendix A, Figure A-29). Total cyanide was found widespread in TZW throughout the offshore areas. In some areas, such as the downstream portion of the Site, these concentrations, due to the close correspondence with surface sediment concentrations, appear to be related to direct historical discharges of cyanide-containing wastes. However, upstream and further offshore of the Site, the presence of total cyanide appears to be more closely related to ongoing discharges of groundwater across this portion of the riverbed. This is consistent with the finding of increasing TZW total cyanide concentrations with depth found at a number of stations in this upstream area.

Benzene was frequently undetected or detected at low levels in the shallowest TZW samples, even in locations where benzene was detected in surface sediments. One exception is GS-C8, which had elevated concentrations of benzene in the same general area as found by the Siltronic offshore investigations. Preliminary evaluation of both data sets indicates there may be a localized area of benzene (and other MGP chemicals) discharge that is approximately coincident with a portion of the Siltronic TCE plume. It is unknown to what extent the elevated MGP chemical concentrations detected in this area is due to localized groundwater discharge or mobilization of MGP-related chemicals in offshore sediments by the TCE plume.

Shallow TZW naphthalene concentrations show a mixture of areas coincident with historical sediment contamination, as well as areas that may be more indicative of groundwater discharges. The potential sediment-related TZW concentrations appear to exist in nearshore areas near the tar body removal area and downstream along Transects B and C. Potentially groundwater-related TZW concentrations appear along the mid- to upstream portions of Transect C, including the TCE area noted above.

### 3.2.2 Groundwater Extraction System Pilot Studies and ModFlow Model

Pilot extraction wells PW4-85 and PW4-118 were installed and developed in July 2007. A pilot well report detailing extraction well installation, development, and aquifer testing is in progress and will be provided to DEQ following submittal of this GWFFS. Appendix E contains the extraction well construction diagrams. The two extraction wells were installed adjacent to existing monitoring wells MW-5 and MW-20. The extraction well locations and screen depths are shown on the Figure 2 geologic profile.

Following screen development, pump tests were completed in the extraction wells. Step tests and constant discharge tests were conducted in both PW4-85 and PW4-118. The tests were conducted between July 3 and July 26, 2007. The pump tests were generally conducted according to the protocols in the Groundwater/DNAPL Pilot Program Well and Performance Evaluation Design Report (Anchor 2007b), as amended by the Revision to Aquifer Test Plan (Anchor 2007c). During the tests water level changes were measured using pressure transducers installed in each of the extraction wells, plus the following eight monitoring wells:

- MW-05-32
- MW-05-100
- MW-05-175
- MW-19-125
- MW-19-180
- MW-20-120
- WS-14-125
- WS-14-161

Anchor field staff obtained groundwater samples from each of the extraction wells as required in the Work Plan. The samples were obtained prior to the test, during the pumping portion of the test, and after the pumping stopped. The samples were laboratory tested for Site COIs. Groundwater samples were also obtained by Maul, Foster & Alongi, Inc. (MFA) personnel from monitoring wells WS-14-125 and WS-14-161, located at the northern portion of the Siltronic property, for laboratory testing. The laboratory testing results will be provided in the pilot well report.

The water level data from the step tests and the constant rate pumping tests were evaluated by Anchor and SSPA. The findings of the pump test data analysis, including aquifer properties of the alluvium, are in Appendix E. The pump test data were used to derive aquifer parameters for input to the ModFlow model developed for the Site by SSPA. The ModFlow model was used to complete a preliminary design for the Site shoreline extraction well containment system alternative evaluations, as summarized below.

Appendix E contains a description of the ModFlow model findings. The model found that complete capture of groundwater occurs in Segments 1 and 2 with an array of extraction wells at 10 locations separated by an average distance of 200 feet along the shoreline. Model sensitivity analyses were run to determine the well discharge range that results in groundwater containment. The model shows that capture of groundwater in the alluvium down to bedrock is achieved at a flow rate of approximately 20 gallons per minute (gpm) per well location, for a total combined flow of 200 gpm in Segments 1 and 2. The sensitivity model runs showed that capture begins to deteriorate at about 14 gpm and that breakthrough occurs at about 12 gpm per well.

The ModFlow model was also used to determine required extraction well flow with and without the presence of a vertical barrier. The model was used to determine the optimum screen depth for the extraction wells, with and without a vertical barrier. The depth to bedrock is generally between approximately 80 and 115 feet below top of bank at the northern shoreline and generally between approximately 190 and 225 feet below top of bank across the remainder of the shoreline, which is too deep to reach with current barrier wall technology. The model results showed that the presence of a vertical barrier that is not tied into a low permeability layer does not significantly reduce the inflow of groundwater from the river shoreline into the extraction wells. This is because the majority of the groundwater entering the extraction wells is sourced from the Site uplands.

The model findings, as they apply to the analysis of source control alternatives, are discussed further in Sections 7 and 8.

### *3.2.3 Upland Groundwater/DNAPL Data Needs*

#### *3.2.3.1 2007 Monitoring Well Data*

In June and July 2007, Hahn Associates, Inc (HAI) conducted a comprehensive groundwater sampling round of the Site monitoring wells. This work was completed by HAI for NW Natural at the request of DEQ. Appendix B contains the groundwater quality data tables with the laboratory testing results. The data in Appendix B have not been validated and are subject to change in whole or part.

DEQ also requested that this GWFFS include subsurface profiles of the Site shoreline monitoring wells that display a comprehensive list of COI concentrations in groundwater. Appendix A contains subsurface profiles A-01 through A-41. The COI concentrations on the profiles are from the data tables in Appendix B, which have not been validated and are subject to change in whole or part. Although these data have not been validated, the concentrations are generally consistent with those found in previous sampling events. A separate subsurface profile exists for each of 41 Site COIs. The COIs include PAHs, cyanide compounds, benzene, toluene, ethylbenzene, and xylene (BTEX), volatile organic compounds (VOCs), selected semivolatile organic compounds (SVOCs), and selected metals. A list of the profiles with the corresponding COI is in Appendix A.

These Appendix A profiles include the results of the first sampling of the monitoring wells installed in June and July 2007 along the northern portion of the Gasco shoreline in Segment 2. These include new wells in the MW-01, MW-02, and MW-21 well clusters.

With data from the new Segment 2 monitoring wells, the Appendix A water quality profiles show that the concentration and extent of Site COIs in groundwater in Segments 1 and 2 are comprehensively defined.

#### *3.2.3.2 TarGost DNAPL Survey Findings*

Appendix G contains the subsurface borehole profiles generated during the TarGOST reconnaissance investigation conducted by HAI for NW Natural. DEQ required that cone penetrometer (CPT) and laser-induced fluorescence (LIF) logging systems (i.e., “tar-specific green optical screening tool” [TarGOST]) be used to further refine the CSM for occurrence of NAPL within the alluvium. TarGOST is a direct push-delivered LIF instrument that logs the fluorescence of PAHs at depth. The technology was developed with the objective being the identification of NAPL found at former MGP and wood treating sites by sensing the fluorescence of PAHs found in NAPL. Two maps in Appendix G show the locations of the TarGost borings completed.

In the presence of PAH-containing oil or tar within the soil matrix, the PAHs will absorb light and are delivered into an electronically excited state. As the PAHs return to ground state, they will fluoresce (they emit red-shifted light). The red-shifted light is collected by a mirror and delivered to the surface by a return fiber optic cable. The intensity and waveform shape of the returned red-shifted light may be used to qualitatively ascertain the magnitude of PAH presence across the depths being evaluated. High resolution depth-encoded data are presented on vertical logs in real time that may be viewed as the TarGOST is pushed through the subsurface.

The intensity and quality of the red-shifted light is meant to provide an indication of the type and magnitude of the PAH containing materials present. The greatest intensity red-shifts are delivered across those zones containing DNAPL. As reported by the technology developer, the TarGOST can be used to identify zones containing DNAPL versus zones containing no DNAPL. TarGOST results do not differentiate between free and residual forms of DNAPL.

Appendix G contains map Figures G-1 through G-4 showing the locations of the TarGOST borings completed. For the Gasco property Figure G-1 shows the areal extent of DNAPL above 100 feet bgs, and Figure G-2 shows that DNAPL is not present on Gasco below 100 feet bgs. For the Siltronic property Figure G-3 shows DNAPL above 100 feet bgs, and Figure G-4 shows DNAPL below 100 feet bgs. Figure 3 confirms previous Site data indicating the DNAPL is not present near the Siltronic shoreline at depths above 100 feet bgs.

Borings TG-1 through TG-8 were completed on the Gasco property and borings TG-1S through TG-6S were completed on the Siltronic property. The individual TarGOST profiles for each boring location are in Appendix G. The TarGOST instrument is deployed on a CPT drilling tool, and the individual CPT logs for each boring are also in Appendix G. Except where bedrock was encountered (TG-6), all borings were pushed to a depth of 150 feet bgs, corresponding to an elevation well below known DNAPL occurrence at either property. The TarGOST boring results confirmed the current DNAPL CSM and showed that DNAPL within the alluvium along the Gasco Shoreline in Segment 1 is present only in the upper alluvium and does not extend northward to or beyond the TG-1 location (near monitoring well MW-3).

Consistent with direct observation of soils collected from adjacent borings, DNAPL at the Gasco property in Segment 1 was detected at the TG-2 (28 to 30 feet bgs) and TG-3 (58 to 60 feet bgs) locations. Riverward of TG-2, direct observation of soil core from the MW-16 well location indicates DNAPL presence within the alluvium to be limited to depths above 44 feet bgs. The deepest occurrence of DNAPL at the Gasco property as identified by TarGOST was detected at a depth of 65 feet bgs at TG-5 (near monitoring wells MW-5). Observation of the soil core during the drilling of the MW-20 well location (approximately 20 to 40 feet riverward of TG-5 and the MW-5 locations) suggests the presence of DNAPL zone between 71 and 72.5 feet bgs, indicating a deepening of DNAPL occurrence toward the shoreline. The TarGOST study has confirmed the understanding that DNAPL occurrence within the shoreline alluvium at the Gasco property is limited to the Segment 1 area where the historical effluent discharge occurred and the effluent settling ponds were located.

At a meeting on October 23, 2007, DEQ asked for further discussion of two isolated occurrences of NAPL detected near the shoreline in Segment 2, specifically, if those two occurrences require source control beyond pump and treat containment. One occurrence is the presence of DNAPL in the fill at MW-21 (in the vicinity of the Former Spent Oxide Area), and the other occurrence is the presence of petroleum LNAPL detected in the FAMM basin. The following two paragraphs discuss these occurrences in detail.

**Former Spent Oxide Area**. DNAPL has been identified within the surficial fill unit in proximity to the former spent oxide storage area at the MW-1-22 and B-1 boring locations at the northern portion of the Gasco site. The zone of oil saturation was found to consist of an interval located immediately above the silt unit at depths ranging from 16 to 21 feet bgs (fill). Boring logs indicate that much debris had been deposited at this portion of the Site as fill, including concrete, bricks, and solid carbon pitch. As nearby borings MW-1-55, MW-1-82, B-2, B-3, B-4, B-5, and B-7 do not show indications of DNAPL, and are located between the area of observed oil and the primary oil source areas at the southwestern portion of the Site (e.g., former light oil plant/retort area), it appears that the identified DNAPL was likely mixed into fill at this portion of the Site as a component of the fill, is very limited in extent, and its presence is not a result of migration from other areas. With regard to the potential mobility of the observed product, it is noted that well MW-1-22 is screened directly across the zone of observed DNAPL saturation, and that no DNAPL has entered this well at any time during a 10-year monitoring period. Based on the preceding, it appears that the observed DNAPL at this portion of the Site is present only in the form of residual product and is not mobile.

**FAMM Containment Basin**. A small area of NAPL was observed in a narrow band of fill from a depth of 8.5 to 12 feet bgs in borings GT-1, MW-21-12, and MW-21-115. All of these borings are immediately adjacent (clustered) within the north end of the southern FAMM tank farm. The identified product had a diesel odor uncharacteristic of the oil encountered at the rest of the site. The very limited extent of the apparent diesel product in the subsurface has been confirmed because no product was identified at adjacent boring locations B-8, B-52, GT-2, MW-21-75, or MW-21-115, or in TarGOST boring TG-6, constructed through the entire thickness of fill and alluvium in the area. Further, no NAPL has entered well MW-21-12 to date, with this well being screened across the zone of NAPL occurrence. Based on the preceding, it appears that the observed NAPL at this portion of the Site is likely in the form of residual product and is therefore not mobile.

Based on the above findings the occurrences of NAPL at MW-21 and the FAMM basin are isolated pockets of NAPL that are not mobile and do not require a barrier wall to block migration to the river.

On the Siltronic property, TarGOST borings TG-1S and TG-2S were drilled closest to the shoreline and TG-4S was drilled about 200 feet from the shoreline. In TG-1S, a DNAPL zone was detected between 116 and 119 feet bgs, consistent with the findings from previous borings completed by MFA for Siltronic. No DNAPL was detected in TG-2S down to the maximum depth explored (150 feet bgs). In TG-4S, DNAPL was detected at 37 feet bgs (minor) and in intermittent zones between a depth interval of 62.5 and 100 feet bgs.

The TarGOST DNAPL detections are also displayed in subsurface profiles on Figures 5C through 5G and Figures 6A through 6B.

These TarGOST results are consistent with the current DNAPL CSM as presented by HAI in the Gasco RI report and indicates that DNAPL within the alluvium along the Siltronic shoreline in Segment 1 is present only in the lower alluvium (and below 116 feet bgs) near the northern corner of the property and does not extend southward beyond the TG-2S location (near monitoring wells WS-12).

In summary, DNAPL occurs in one or more discrete zones within shallow alluvium down to about 65 to 73 feet bgs on the Gasco portion of Segment 1, with the deepest occurrence being near the property line with Siltronic. DNAPL occurs below the depth of 116 feet bgs on the northern Siltronic shoreline and in intermittent zones primarily between 62.5 and 100 feet bgs, approximately 200 feet upland from the northern shoreline (TG-4S) and between approximately 33 and 78 feet bgs, approximately 500 feet upland from the shoreline (TG-3S). Existing data (TarGOST and core observation) indicate that DNAPL is not present in the upper alluvium on the Siltronic shoreline portion of Segment 1. The data also indicate that DNAPL is not present within the alluvium at or upstream of the TG-2S location.

### 3.3 Relevant Data Collection Underway

Data collection that in some cases was originally envisioned as supporting the GWFFS is ongoing. However, due to the logistics of planning, negotiating, revising, and mobilizing for these efforts, the data will not be available for use in this GWFFS. The following subsections describe ongoing studies that may be relevant to groundwater source control issues.

In some cases, these studies are expected to provide information that will help refine the design of the recommended source control alternative during the design phase of work[1], modifications to the recommended alternative may be necessary. In most cases, the ongoing study results will be available well prior to DEQ's expected timing for finalizing the preferred alternative for issuance to public comment, which is currently scheduled for January of 2008 (see Section 10 for schedule details).

### 3.3.1 Offshore Seepage Meters

NW Natural proposed in August 2007 (Anchor 2007d) the placement of six seepage meters in offshore areas including in the river channel, and DEQ commented in a September 14, 2007 letter accepting the plan with one additional meter proposed (for a total of seven). The purpose of the seepage meters is to better understand the variations and levels of groundwater seepage spatially along the Site shoreline and the potential relationship of groundwater seepage to chemical concentration gradients seen in the offshore TZW chemistry studies. The LWG conducted similar sampling with identical equipment in 2005, and the primary purpose of the current sampling is to fill data gaps in that sampling approach. It is not expected that this information would have a direct bearing on the design of upland groundwater source controls, but depending on the results, the data are expected to further identify the locations of groundwater discharges along the shoreline. This data collection is expected to occur in October 2007.

### 3.3.2 Offshore Tidal TZW Sampling

A tidal TZW influence study was developed by NW Natural in response to DEQ's June 28, 2007 comments to the Phase 2 Offshore Field Sampling Approach (Anchor 2007b). Based on those comments, it was NW Natural's understanding that DEQ would like additional information regarding the potential variability in measured shallow sediment TZW chemical concentrations offshore of the Site due to tidal fluctuations in the river. DEQ had stated that it believes this information will allow a determination of whether shallow TZW chemical concentrations measured during the Phase 2 offshore TZW sampling are tidally influenced, which will help DEQ in the interpretation of the Phase 2

[1] As noted previously, some of the offshore data is also expected to help fill in-river data needs identified by the LWG for the Portland Harbor Superfund Site.

offshore investigation TZW chemical concentration data. These data are not expected to have a direct bearing on the design of upland source controls.

### 3.3.3 River Water Surface Water Cyanide Sampling

NW Natural provided a Cyanide Surface Water Investigation Field Sampling Plan to DEQ in July 2007 (Anchor 2007e) containing the sampling approach for the collection of river surface water samples offshore of the Site for the analysis of speciated cyanide. DEQ commented on the plan in an August 30, 2007 letter, and the plan was revised and resubmitted to DEQ in late September. Currently, the plan calls for sampling of surface water for three species of cyanide (including free cyanide, the bioavailable form) and conventional parameters at 20 sampling stations offshore of and upstream/downstream of the Site under multiple tidal conditions. Existing Site information indicates that total cyanide is widely distributed in Site groundwater and offshore TZW. At the same time, the presence of free cyanide in these same samples is very limited. Given that some forms of total cyanide (i.e., iron cyanide complexes) are known to convert to free cyanide in the presence of light (Anchor 2007e), the purpose of the study is to understand the extent to which concentrations of total cyanide in shoreline groundwater could be resulting in free cyanide concentrations of concern in surface water.

This study is expected to have a direct bearing on the design of source controls in the northern approximate half of the Gasco property (Segment 2), where shoreline DNAPL is generally not present and dissolved MGP-related chemicals are less prevalent in groundwater. Existing shoreline data indicate that the primary purpose of source controls along this portion of the shoreline would be for the control of cyanide discharges in groundwater. The impact of the surface water cyanide results on the source control design for this portion of the shoreline is highly dependent on the results of the study. If, for example, the study shows the absence of free cyanide in surface water, this could call into question the need for groundwater source controls in this area, or lead to a reevaluation of the specific objectives of such source controls. Other outcomes, such as the confirmation of free cyanide impacts to surface water are also possible, but the results may still have importance to refine the extent or magnitude of source control design in this area of the shoreline.

### 3.3.4 Vibration Studies

NW Natural has worked extensively with Siltronic on vibration issues during the preparation of this GWFFS. Siltronic has identified a number of feasibility issues related to its ongoing operations for installation of vertical barriers for DNAPL source control. These feasibility issues are evaluated in detail in Sections 7 and 8. One such issue is the potential that vibrations from the construction of a barrier wall could disrupt operation of delicate machinery within the fabrication buildings on the Siltronic property. Siltronic has suggested that such vibrations could require it to cease manufacturing activities for the duration of the construction, resulting in significant financial loss.

NW Natural has been working with Siltronic and DEQ to help identify the levels and types of vibrations that would be prohibitive to Siltronic's normal operations. The development of a study to mimic potential vibrations caused by potential source control technologies, particularly vertical barriers such as sheet pile walls, has also been discussed extensively. As of the date of this document, NW Natural has not been provided with specific vibration levels that must not be exceeded (or similar criteria to judge the impacts of potential vibrations), although it is our understanding Siltronic is working to develop such criteria. Until such time that effective vibration criteria and a vibration study acceptable to DEQ and Siltronic are determined, the design parameters of vertical barriers in particular, cannot be accurately defined. The conduct of a useful study with effective criteria would have a direct bearing on evaluating the type of vertical barrier technology that can be employed (e.g., sheet pile wall or slurry wall) and the distance from Siltronic buildings that they could be employed. Until these vibration issues are resolved, the feasibility, as well as the selection or design, of the recommended source control alternative for the Gasco and Siltronic properties, including possible vertical barriers, cannot be determined.

# 4 PURPOSE AND REMOVAL ACTION GOALS

This section defines the purpose and specific goals for the interim groundwater/ DNAPL source control actions evaluated in this GWFFS. Section 4.3 also defines the purpose and goals of the interim bank stabilization evaluation presented in Appendix F. The purpose and goals of the source controls determine the measures by which effectiveness of various evaluated alternatives are judged. Effectiveness of source control alternatives is a primary criterion under Oregon rules (ORS 465.200 et seq. and OAR 340-122-010 et seq.) and State FS guidance (DEQ 1998) as well as similar federal guidance (EPA 1988) including issues of:

- Overall Effectiveness
- Long Term Reliability and Permanence
- Use of Treatment and Compliance with Regulations
- River Recontamination Prevention
- Compatibility with In-water Remedial Action.

## 4.1 Purpose – Interim Groundwater/DNAPL Source Controls

The theoretical general purpose of interim groundwater/DNAPL source controls is to:

- Minimize chemical and DNAPL impacts to sediments, TZW, surface water, and biota of the river from upland sources to the extent practicable, under both current conditions and potential future remedial conditions.
- Where practicable, minimize impacts at or below the levels expected from in-river remediation goals set by the Portland Harbor Superfund process to protect in-river resources (human and ecological uses).

This purpose is theoretical because it is impossible to predict future conditions either of in-river remediation or the in-river remedial goals, which have not yet been determined. Consequently, there is a need for more practical and specific source control goals that are intended to attain this more general purpose.

## 4.2 Removal Action Goals – Interim Groundwater/DNAPL Source Control

For many projects, remedial goals are presented in terms of chemical concentration criteria. Several types of guidelines involving chemical concentrations have been used for various purposes in Portland Harbor both by EPA and DEQ. These guidelines are generally used to conduct various types of data screening to guide further investigations and are not used or intended as final determinations of risks in various media (e.g., sediments, water).

The JSCS contains guidelines that are sometimes used in these types of screening evaluations (EPA and DEQ 2005). The purpose of the strategy, as described in the strategy report, is to "identify, evaluate, and control sources of contamination that may reach the Willamette River…" The JSCS identifies screening level values (SLVs) for Portland Harbor. As stated in the JSCS:

> *An exceedance of an SLV does not necessarily indicate the upland source of contamination poses an unacceptable risk to human or ecological receptors, but does require the further consideration of source control efforts using a weight-of-evidence evaluation.*

In short, the SLVs are not source control remedial goals.

Perhaps more importantly, the JSCS (or any other Portland Harbor document) does not identify the point of compliance for the use of any chemical concentration guidelines to judge the success of source controls. For example, numeric guidelines for groundwater could be applied in the uplands or in the river surface water, or somewhere in between such as at the shoreline, at the surface water/sediment interface, within the sediment TZW, below the biologically active zone in sediments, etc. Depending on the point of compliance, the level and type of source controls needed to meet a numeric value could vary widely.

Consequently, in the absence of any numeric guidelines or points of compliance specific to source controls, the evaluation of source controls must use other primary types of goals, which are discussed in the next subsection. However, chemical concentrations will be used as supporting information to the primary removal action goals, as discussed in Section 4.2.2.

### 4.2.1 Primary Physical Removal Action Goals

Two primary goals are necessary, one for groundwater dissolved plumes and the other for DNAPL migration. These goals are defined as:

- Groundwater – Control upland groundwater gradients to result in near zero groundwater discharge to the river.

- DNAPL – Prevent the migration of upland DNAPL to the river.

This first goal recognizes that it may be nearly impossible to reduce Site groundwater discharges to zero. Further, such a level of control is not necessary to prevent dissolved plume migration to the river, as discussed more in the evaluation sections. This first goal also implies a preference for technologies that control movement of groundwater, as opposed to, for example, in-situ treatment of chemicals. This goal was defined for the purposes of this document after the screening of technologies discussed in Section 6. This approach provided the benefit of being able to define the removal goals more specifically and usefully for the project, given that some remedial technologies were screened out on a technical basis early in the process.

Implicit in the second goal is that DNAPL is defined as an “upland” source. Upland DNAPL is defined as DNAPL that currently resides shoreward of the high water mark at any depth below ground surface. Source controls that meet the DNAPL goal above will prevent continued migration of upland DNAPL in the shoreline area and beyond. DNAPL that is present river-ward of the high water mark will be evaluated and managed following the in-water regulatory processes described in Section 2.

Oregon FS guidance (DEQ 1998) indicates that an FS should assess residual risk of a remedial action. Residual risks are normally assessed through predicted reductions in chemical concentrations. Because the primary removal action goals are not chemical concentration based, there is no way to quantify residual chemical concentrations after the interim action is complete. However, the concept of residual risk is discussed qualitatively in Sections 7 and 8. In general, if an interim source control alternative meets the primary removal action goals, it can be assumed that virtually no residual risk from groundwater/DNAPL sources exists. If the alternative does not meet the goals in whole or part, then some residual risks from sources would exist.

The concept of residual risk from sources should not be confused with residual risks from other chemical impacts unrelated to upland source controls. As noted in Section 2, sediment remediation and wider upland remediation will proceed after this interim source control action, which is not intended to address these more widespread risks.

These more general risks should not be included in the assessment of residual risk for the source control interim action.

#### *4.2.2 Supporting Chemical Guidelines*

Source controls that meet the above primary removal action goals would by definition reduce the potential for chemical concentrations due to upland sources in either river water or river sediments/TZW to immeasurably low levels. For example, in the absence of any other sources, concentrations of chemicals in surface water would not be measurable because there would be near zero groundwater discharges into the river. Similarly, if DNAPL migration is prevented into the river, it cannot contribute to any chemical concentrations in the river.

Thus, meeting the primary removal action goals will ensure that almost any potentially applicable screening levels will be met for groundwater/DNAPL sources. In this context, JSCS screening values can be used as supporting guidelines that would be expected to be met in the river (in the absence of any other sources) once the primary goals are met including:

- Water
  - Human health fish consumption (EPA, DEQ, and Portland Harbor specific values)
  - Human health drinking water (Maximum Contaminant Levels and Tap Water Preliminary Remedial Goals [PRGs])
  - Ecological water quality guidelines from EPA, DEQ, and Oak Ridge laboratory
- Sediment
  - Ecological Probable Effects Concentrations and Sediment Quality Values
  - Ecological DEQ bioaccumulative sediment SLVs

The specific values for these guidelines are listed in Table 3-1 of the JSCS (EPA and DEQ 2005). As noted above, the point of compliance is an important issue, even when guidelines are only used in a supporting role. The most relevant point of compliance for water guidelines is river surface water, because each of these guidelines (except drinking water values) are intended for comparison to surface waters. For drinking water, surface water is also the most potentially relevant point of compliance[2], because there is no existing or reasonable future potential for drinking water wells on or near the Site (see the RI and RA for a broader discussion of potential future uses HAI 2007a and Anchor 2004). The most relevant point of compliance for sediment values is the biologically active zone of the river sediments, because this is where organisms that are intended to be protected by these guidelines would be exposed. The Portland Harbor Superfund process has defined the biologically active zone as the top 1 foot of sediments.

These values should not be confused with or necessarily used as post-interim action performance or monitoring criteria. Perhaps more importantly, these supporting guidelines cannot be used as performance criteria because other sources to the river surface water and sediment will continue to exist after the interim action is completed. Thus, compliance of groundwater discharges with these low level guidelines cannot be verified through river water and sediment monitoring due to the ongoing presence of contaminated sediments and other river sources, at least until these other sources are addressed. Even in the event that all other sources are completely eliminated, many of these supporting guidelines could not be used as performance criteria because they may be below even naturally occurring background levels. Long-term monitoring performance criteria for the source control interim action will need to focus on other approaches as discussed in Section 11.

### 4.3 Interim Shoreline Stabilization – Purpose and Goals

As discussed in Appendix F, the purpose of the bank stabilization interim action is to control erosion of riverbank soils potentially containing COIs into the river. Thus, the primary removal action goal is:

- Minimize riverbank soil particulate movement into the river.

Similar to the groundwater goals, this erosion goal is expressed in terms of preventing movement of soils, rather than the chemicals present in the soils. Also, the word minimize is used to recognize that even well stabilized soils (e.g., with large amounts of vegetation) may have some very low level of soil particulate loss over time. The evaluation of bank erosion source controls is presented in Appendix F.

[2] Untreated domestic water supply is not a designated beneficial use of the Willamette River. OAR 340-041, 340, Table 340A, note 1.

# 5 DIVISION OF SITE INTO SHORELINE EVALUATION SEGMENTS

To facilitate the evaluation of source control technologies, the Site has been separated into two shoreline segments. The primary factors determining these segments are:

- The general distribution of DNAPL and elevated concentrations of key chemicals of interest (i.e., PAHs, benzene, and cyanide) along the shoreline
- Shoreline physical features such as structures.

Variations in the nature and presence of contaminants in particular may indicate the need for potentially different source control alternatives across the two shoreline segments. Shoreline physical features are mainly useful for determining the exact location of the border between the segments. The segments used in this GWFFS are shown in Figure 1 and discussed more below.

## 5.1 Segment 1 – Upstream Gasco/Siltronic Segment

This segment includes approximately 690 feet of Gasco shoreline as delineated by the location where the upstream Koppers pipeline crosses the top of bank, plus approximately 500 feet of the northern Siltronic shoreline. The Segment 1 boundaries are shown on Figure 1. As shown in the data presentations in Section 3, the downstream end of this segment includes DNAPL on the Gasco property, as well as the vast majority of the MGP-related dissolved phase plume. The Siltronic portion of this segment includes the remaining DNAPL and MGP-related dissolved phase plume. The Koppers pipeline dock is a convenient downstream break point because this structure could be a logistical barrier impacting construction methods for some source control technologies and is generally coincident with the lateral extent of upland DNAPL.

It is important to note that the upstream extent of DNAPL in this segment is known to a certain spatial scale, and the end of this segment coincides with Siltronic boring WS-12, which is the last shoreline boring (within 200 feet of shore) showing no presence of DNAPL. The next nearest downstream boring, WS-11, shows the presence of deep DNAPL as described in Section 3. As shown on Figure 3, TarGOST boring TG-1S is located adjacent to Siltronic boring WS-11, and is approximately 250 feet north of WS-12/TG-2S. It is unclear where in this 250 feet gap between borings this DNAPL ceases to exist. Consequently, any source control technology targeting the DNAPL removal action goal will likely be conservative in length and cost, since it is assumed to cover this entire 250-foot length for the purpose of this GWFFS. This length could represent a significant additional cost for some DNAPL control technologies, and will need to be refined further during the design phase.

### 5.2 Segment 2 – Downstream Gasco Segment

The downstream Gasco segment covers the remaining approximately 930 feet from the Koppers upstream pipeline dock to the downstream property line at U.S. Moorings. The primary and most widespread MGP-related COI in this area is total cyanide as presented in Section 3.

# 6 IDENTIFICATION AND SCREENING OF SOURCE CONTROL TECHNOLOGIES

This section identifies and screens a range of potential groundwater/DNAPL source control technologies. Those technologies passing this initial screening are evaluated in more detail in Sections 7 and 8. The screening is based on a brief review of each technology as it relates to general effectiveness, cost, and feasibility issues.

## 6.1 Identification of Potential Technologies

Three general categories of source control technologies are identified for evaluation and screening.

- Containment
- In-Situ Treatment
- Ex-Situ Treatment

A comprehensive list of potential source control technologies is in Table 1. The technologies identified in Table 1 were derived from several sources, including, but not limited to the following.

- Groundwater Technologies Remediation Center, Pittsburgh, Pennsylvania, gwrtac@gwrtac.org
- Federal Remediation Technologies Roundtable, www.FRTR.gov
- CLU-IN, EPA Technology Innovation Program, www.clu-in.org
- Gas Technology Institute (GTI), www.gastechnology.org

Each of the potential technologies identified for this GWFFW is potentially applicable for of either dissolved groundwater COI source control or for DNAPL source control. As described later in this section, very few of these technologies are applicable to both the dissolved COIs and DNAPL, so it will be necessary to combine technologies where both dissolved COIs and DNAPL are present.

The identified technologies are evaluated for their applicability to the Site COIs and to the CSM identified in the RI report (HAI 2007a). The primary goal of the considered technologies is containment. Many of the containment technologies have contaminant removal and treatment as a component. Each technology is considered for implementability near the river shoreline. Some technologies, such as in-situ chemical treatment, may not be implementable because of the risk of potential release of treatment chemicals to the river. Such technologies may be suitable for future evaluation in the Site-wide FS.

**Table 1**
**Identification of Potential Groundwater/NAPL Source Control Technologies**
**Gasco/Siltronic Site**

| Technology | PAH + Benzene | Cyanide | NAPL |
|---|---|---|---|
| **Containment** | | | |
| Physical Barriers (slurry walls/sheet piles) | Yes | Yes | Yes |
| Groundwater Pumping | Yes | Yes | Yes |
| **In Situ Biological Treatment** | | | |
| Enhanced Biodegradation | Yes | Dissociable Cyanide | No |
| Natural Attenuation | Yes | Dissociable Cyanide | No |
| **In Situ Physical/Chemical Treatment** | | | |
| Chemical Oxidation | Yes | Dissociable Cyanide | No |
| Dual Phase Extraction | Yes | No | No |
| Thermal Treatment | Yes | Yes | No |
| Recirculating Groundwater Recovery Wells | Yes | No | No |
| Soil Vapor Extraction/Air Sparging | Yes | No | No |
| Stabilization /Fixation | Yes | Yes | No |
| Surfactant Enhanced/Cold Water Flooding | No | No | No |
| Steam Injection/Hot Water Flood | No | No | No |
| **Ex-Situ Biological Treatment** | | | |
| Bioreactors | Yes | Dissociable Cyanide | No |
| **Ex-Situ Physical/Chemical Treatment** | | | |
| Separation | No | No | Yes |
| Cyanide Forager | No | Dissociable Cyanide | No |
| Advanced Oxidation | Yes | Yes | Yes |
| Adsorption | Yes | No | Yes |
| Monitored Natural Attenuation | Yes | Yes | No |

## 6.2 Containment Technologies

### *6.2.1 Hydraulic Containment/Control*

Hydraulic control of groundwater and NAPL is a proven technology based on successful application at many sites across the United States. Hydraulic containment using extraction wells can be implemented on a predictable time schedule. An extraction well system can be designed to accommodate site-specific characteristics and for integration into future site-wide remedial measures.

To help understand how the operation of extraction wells will contain the Site DNAPL, this section includes a discussion of DNAPL occurrence and movement. The RI report describes the physical properties of MGP DNAPL and its behavior in the subsurface (HAI 2007a). For the Gasco RI, DNAPL samples were obtained and laboratory tested from five Gasco monitoring wells and two Siltronic monitoring wells. The Site DNAPL is oil with a specific gravity (density) ranging from 1.05 to 1.10, compared to water, which has a density of 1.0. The Site RI showed that following release, the DNAPL migrated downward under gravity forces to low permeability layers where it accumulated in pools or at residual concentrations. Because its density is slightly greater than water, the Site DNAPL is detected where it accumulates in the bottom of Site monitoring wells. This is in contrast to petroleum fuel sourced Light Non-Aqueous Phase Liquid, or LNAPL, which floats on the water table where it is detected in wells. Site monitoring wells were consistently assessed for the presence of MGP LNAPL during historic monitoring events, and no MGP LNAPL has been detected in Site monitoring wells.

Where monitoring wells have been screened in zones where the DNAPL is present above residual saturation; for example, at MW-16-45, the DNAPL flows into the well screen in response to slow pumping. This shows that the DNAPL can be recovered by pumping in some areas of the Site. The TarGOST survey results (Appendix G) confirm that the DNAPL occurs primarily in isolated thin sand lenses, separated by discontinuous silt interbeds. This is illustrated on Figure 2, which shows where the TarGOST survey detected thin lenses of DNAPL. The TarGOST survey and previous Site borings cover the Site comprehensively, and these results do not indicate that the Site DNAPL occurs in thick pools, but rather in thin, isolated lenses. Some of the isolated lenses may extend laterally via vertical stepping. Because of the thin-lensed nature of the DNAPL and the extensive study of DNAPL distribution at the Site, it is extremely unlikely that thick reservoirs of DNAPL are present anywhere that would provide a large hydraulic head source to drive further significant migration. DNAPL migration has been identified on Site where the ambient head conditions have been changed by installation of a monitoring well or where DNAPL pumping is being conducted by NW Natural.

Because the Site DNAPL is only slightly denser than water, the groundwater gradient changes induced by the extraction wells will also affect the DNAPL. Both groundwater and DNAPL will flow to the extraction wells. Where groundwater is being pumped from source control extraction wells for containment purposes the DNAPL hydraulic head will also be affected. The degree of head reduction in the DNAPL will be variable, depending upon distance from the extraction well, DNAPL viscosity, DNAPL saturation levels, interfacial tension forces, and other factors. Because the DNAPL density is only slightly higher than water it is concluded that the reduction in groundwater hydraulic head induced by the extraction wells will also act to contain further movement of the DNAPL. However, the degree of DNAPL containment under varying subsurface conditions at different distances from the extraction wells cannot be predicted with certainty.

DEQ has expressed interest in further evaluation of the effect of extraction well pumping on DNAPL movement. DEQ has presented two primary concerns related to this issue:

1. That migration of DNAPL from upland source areas to the shoreline area could occur under the influence of the extraction wells
2. That DNAPL already in the shoreline area will migrate past the shoreline into the alluvium below the river channel, regardless of the presence of the extraction wells.

Because hydraulic containment of groundwater using extraction wells is integral to source control at the shoreline (see Section 9), any groundwater source control alternative that is selected will be faced with questions related to DNAPL behavior under the influence of the extraction wells. Although a model could be prepared to try and predict DNAPL behavior under the influence of extraction wells, the number of estimated variables required for the model would result in findings that are not site-specific or reliable for predictive purposes.

Therefore, it is recommended that DNAPL hydraulic head and movement be monitored during operation of the extraction wells to try and measure the effects of the extraction wells. This monitoring program is also mentioned in Section 7.1.1, describing the groundwater pump and treat alternative.

In locations where a vertical barrier is installed, the hydraulic head reversal induced by the extraction wells will reverse the normal groundwater gradient and draw groundwater sourced from the river under the wall to the extraction wells. Because of this gradient (head) reversal, DNAPL that is currently near the wall will be prevented from migrating to the river. The extraction well capture zone will extend under the base of the barrier below the river channel. Within this capture zone the dissolved plume sourced from DNAPL near the shoreline will be contained and prevented from migrating further into the river channel alluvium and prevented from migrating upward into the river. The model diagrams in Appendix E and Figures 9a and 9b show the modeled capture zone extending under the river channel.

The only significant disadvantage of hydraulic containment technology at this Site is that the extraction well system will have to be operated for many years. However, there are no existing source control technologies that can be successfully implemented at the Site in a shorter time frame.

Extraction wells can be used alone or in combination with other technologies to contain dissolved groundwater COIs and DNAPL. Extraction wells can be used to modify the groundwater gradient along the shoreline to cause groundwater flow to the wells rather than to the Willamette River. Dissolved COIs in the groundwater would be extracted by the wells, thus reducing mass flux of chemicals to the river, although as noted in Section 4, quantitatively measuring flux reduction at the Site is likely infeasible. As explained previously, the gradient reversal will also prevent DNAPL from migrating to the river.

DNAPL containment, not removal, is a primary purpose of extraction wells if they are applied to this Site. Incidental DNAPL removal by the wells would be expected to occur in areas where mobile NAPL exists in the vicinity of the shoreline. The recent TarGOST investigation (see Section 3.2.3.2) has confirmed the Site CSM with regard to distribution of DNAPL near the shoreline. Section 7 contains a more detailed discussion of the findings of site-specific groundwater modeling that underlie the selection of extraction wells for hydraulic containment.

Extraction wells have been successfully pilot tested at the Site. The pilot test is described in Section 3.2.2 and the calculated aquifer parameters and groundwater flow model generated diagrams are presented in Appendix E. The groundwater and DNAPL extracted from the wells would be handled in an aboveground treatment system. The technologies considered for treatment are described in Section 6.4.

### 6.2.2 Vertical Barriers

DEQ has proposed that a vertical barrier be placed in Segment 1 as a DNAPL containment technology. Vertical barriers provide low-permeability obstacles to the movement of liquids, either water or DNAPL. Ideally, vertical barriers extend downward into a low permeability layer to block groundwater flow. Vertical barriers have depth limitations related to their installation methods, as discussed more below for each method. Vertical barriers installed for groundwater control require the use of hydraulic containment to prevent groundwater from migrating around the barrier.

The primary reason for considering vertical barriers as a containment technology is the occurrence of DNAPL in the upper alluvium in Segment 1. A vertical barrier placed directly in a potential DNAPL flow path will block migration. Therefore, the presence of a vertical barrier in a DNAPL flow path provides a higher degree of containment than hydraulic containment alone.

Where applicable, the purpose of a vertical barrier would be to block migration where DNAPL would otherwise have a direct downward flowpath into the river channel. Under ambient conditions, DNAPL that has already migrated below the river bottom elevation is prevented by gravitational forces from migrating back upward into the river channel. There are several vertical barrier technologies, including sheet pile, slurry wall, jet-grouted wall, and auger wall.

#### 6.2.2.1 Sheet Pile

Sheet pile walls are vertical barriers that consist of formed steel sheets driven into the ground. Sheet pile walls are a proven technology at MGP groundwater cleanup sites. Sheet piles can be fabricated in different dimensions and types of material to achieve a range of strength and durability characteristics. Sheets can be made from a variety of materials such as steel, vinyl, plastic, wood, recast concrete, and fiberglass. The edges of the sheets fit together with interlocking joints to form a continuous wall. Some interlocking designs include the addition of sealants to further minimize potential groundwater flow through the interlocking connections of individual sheet piles. Some sealants are sensitive to groundwater pH and other chemical characteristics, so bench testing of sealants would be required during design, if used. During construction, the sheet pile edges overlap and are driven to a design depth to form the wall. The sheets are generally installed by driving with impact or vibratory hammers hoisted from a crane assembly.

Sheet pile walls can be placed at different depths, depending upon the type of sheet, installation method, and the subsurface geologic conditions. Steel sheet pile was driven to depths up to 75 feet in the Willamette River alluvium at the McCormick & Baxter site across the river and just upstream of the Site, which has similar geology to the Gasco site. Pile refusal at depths less than 70 feet was encountered in a few localized portions of the McCormick & Baxter sheet pile wall. The refusal was determined to be due to increased soil skin friction in those local areas (Ecology and Environment, Inc. 2004). Based on the McCormick & Baxter application, 75 feet is considered to be the maximum practical depth for steel sheet pile at the Site. Using special pre-trench techniques, it may be feasible to install sheet pile as deep as 85 feet bgs. This deeper option is discussed in Section 7 Evaluation of Alternatives. Because of steel's strength and stiffness properties, it is likely that steel sheet pile can be driven deeper than other sheet pile materials, such as aluminum or vinyl.

#### *6.2.2.2 Slurry Wall*

A slurry wall is a low permeability barrier constructed by excavating a trench and simultaneously backfilling the trench with a slurry composed of site soil and clay amendment. Slurry walls are a proven technology at MGP groundwater cleanup sites. Slurry wall subsurface barriers are constructed using a long reach excavator equipped with a digging bucket. A vertical trench is excavated and simultaneously filled with slurry. The slurry hydraulically shores the trench to prevent collapse and retards groundwater flow. Most slurry walls are constructed of a soil, bentonite, and water mixture. The bentonite is used primarily for stabilization during trench excavation. A soil-bentonite backfill material is then placed into the trench (displacing the material) to create the barrier wall. This composition provides a barrier with low permeability and chemical resistance. Other compositions, such as cement/bentonite, pozzolan/bentonite, attapulgite, organically modified bentonite, or geomembrane composite, may be used if greater structural strength is required or if chemical incompatibilities between bentonite and site contaminants exist. The additives determined to be the best to use at the Site depend upon final permeability requirements, site soil type, and compatibility with site COIs. Some clays are sensitive to groundwater pH and other chemical characteristics, so bench testing of slurry additives would be required during design.

Slurry walls can be constructed to depths up to 100 feet and are generally 2 to 4 feet in thickness. Installation depths over 100 feet are implementable using clamshell bucket excavation, but the logistical and constructability difficulties increase significantly. At the McCormick and Baxter site across the river from Gasco, a slurry wall was installed to a maximum depth of about 84 feet below the top of bank, at an approximate deep elevation of -49 feet elevation NGVD (-47.5 Elevation COP, Site datum). At that site, an excavator with a 90-foot boom was used to construct a soil bentonite slurry wall. The McCormick and Baxter site remediation also included installation of a sheet pile wall in other portions of the site, as described in Section 6.2.2.1.

At the Gasco/Siltronic Site, the alluvial sand coarsens dramatically at depths ranging from 70 to 90 feet below top of bank. This increase in grain size with depth has been determined by conducting grain size analysis on samples from the GS shoreline borings and from the pilot borings conducted for the PW-01 and PW-4 extraction wells. The increase in grain size and reduced silt content causes the deep alluvium to have a hydraulic conductivity (K) in the range of 200 to 300 feet/day compared to the shallow alluvium with a K value of about 10 feet per day. This increase in K value is confirmed with the ModFLOW model results reported in Appendix E. The increase in hydraulic conductivity caused significant sand heave to occur during Sonic drilling of the GS shoreline borings and during installation of the PW-4 extraction wells.

The degree of sand heave that would occur in the deep alluvium during slurry wall trenching is much higher than in the shallow alluvium and the increased potential significantly reduces the feasibility of successful installation of a deep slurry wall barrier.  The highly permeable deep alluvial sands and proximity to the river means that controlling ground water inflow to the slurry wall trench and controlling sand heave during slurry placement will be difficult and hard to assure that continuous slurry is being achieved.

Based on these factors, it is considered that the 84 to 85-foot slurry wall depth achieved at the McCormick and Baxter site is the feasible maximum depth for a slurry wall at the Gasco/Siltronic Site.

These factors affecting the implementability of slurry wall construction at the Site are further discussed in Section 7.3.4.

The soil excavated during slurry wall trenching is stockpiled and either beneficially reused (which would be unlikely at this Site due to the chemical concentrations present in most Site soils) or disposed at an appropriate disposal facility.

Slurry wall advantages include that they may be able to be constructed to slightly greater depths than sheet pile walls, but with potentially substantial logistical considerations.  Disadvantages include the requirement for heavy construction, the need for controls to prevent release of contaminated slurry into the environment, contaminated soil management, transportation and disposal issues, and most significantly, the potential for degradation of the slurry over time or non-homogeneous construction resulting in permeability gaps.  Slurry wall construction costs are generally higher than sheet pile wall construction.  Even with construction quality control, slurry walls may not be vertically and horizontally continuous due to wall collapse during construction.  Post-construction testing may be required to determine if the wall is continuous.

#### *6.2.2.3 Jet Grouting and Large Diameter Auger*

Both of these vertical barrier technologies are installed by constructing overlapping boreholes and filling the boreholes with low permeability material. In the case of jet grouting, the borehole is backfilled with grout as the drill pipe is raised from the hole. In the case of large diameter auger, the soil removed by the auger is mixed into a clay slurry and reinjected into the hole. Auger soil/cement walls can be constructed to a depth of approximately 100 feet depending on equipment availability and subsurface hydrogeologic conditions.

Advantages of these two technologies are that they could potentially be installed deeper than a slurry wall or sheet pile wall. They could also potentially be installed in areas where there is restricted room for heavy construction equipment.

During Site construction of the pilot extraction wells and shoreline monitoring wells, significant sand heave into the well casing was encountered in the deep alluvium. This heave condition would likely make installation of deep auger or jet grouted borings infeasible.

These borehole technologies have not been widely used in the United States for groundwater control, so their status as a proven technology is uncertain. The potential for subsurface void formation during construction is higher than slurry wall construction. Continuity testing of the resulting wall may not be able to detect voids formed during construction. The chemical compatibility of the grout and slurry would have to be tested as described for the slurry wall. The potential for wall degradation over time is similar to the slurry wall.

## 6.3 In-Situ Treatment

A wide range of in-situ treatment technologies are identified and discussed for potential application at the Site. All in-situ treatment technologies have a shared technical limitation, which is related to hydrogeological conditions in the subsurface zone of groundwater contamination. The success of all in-situ treatment methods depends upon achieving complete contact of the introduced chemicals or bacteria with the contaminated subsurface soil and groundwater. Most technologies require multiple subsurface applications of introduced materials to be effective. Remedial investigations completed to date at the Gasco and Siltronic facilities have shown that the subsurface fill and underlying alluvial soil are heterogeneous, with discontinuous, interbedded silt and sand layers. The subsurface profiles on Figures 2 and 3 show that the upper alluvium in particular has a lot of interbedded silt layers within the alluvial sands, and that the lower alluvium has fewer silt interbeds. The interbedded layers would likely make uniform subsurface application of treatment chemicals, nutrients, or bacteria difficult, if not infeasible. However, in-situ options should not be discounted at this stage of the evaluation, based strictly on the heterogeneous nature of the Site subsurface materials.

The presence of DNAPL at the Site is a major factor to be considered when evaluating the effectiveness of in-situ treatment technologies. This FS identifies several in-situ technologies that have been used at other sites to remediate DNAPL. However, those in-situ DNAPL technologies have only been used at sites where the depth and lateral extent of DNAPL is smaller than this Site; and even on those smaller sites, complete removal of residual MGP DNAPL has not been demonstrated. For this reason, it is concluded that existing technology cannot completely remove the residual DNAPL at the Site.

### 6.3.1 In-Situ Biological Treatment

Natural attenuation of hydrocarbon compounds by indigenous Site subsurface bacteria is likely ongoing, but has not been evaluated to date. Natural attenuation at MGP sites is further discussed in Section 6.5. Natural attenuation has some potential in subsurface zones with lower contaminant concentrations that are not lethal to the bacteria, and would likely not be significant in areas adjacent to DNAPL. Enhanced biodegradation of certain PAH compounds, benzene, and dissociable cyanide is possible.

The bacteria and required conditions for biodegradation of petroleum derived compounds are not the same as those required for biodegradation of cyanide compounds. Review of the distribution and concentration of cyanide compounds at the Site indicates that attenuation is primarily due to groundwater advection. Given the depth and lateral extent of dissolved COIs in groundwater along the shoreline it would be very difficult to inject bacteria/nutrients in a way that achieves complete contact. We are not aware of any proven in-situ biodegradation technology that would be effective for both petroleum derived COIs and cyanide compounds.

### 6.3.2 In-Situ Physical and Chemical Treatment

Table 1 lists eight in-situ technologies that are reviewed for potential application at the Site. The technologies were identified on the basis of their potential use for treatment of either the petroleum derived COIs, the cyanide compounds, and/or the DNAPL.

#### 6.3.2.1 Chemical Oxidation

In-situ chemical oxidation (ISCO) involves injection of oxidizing chemicals into the subsurface to destroy selected COIs. Fenton's Reagant, persulfate, ozone, and permanganate are among the more commonly used oxidants for in-situ treatment. The petroleum derived COIs and dissasociable cyanide are potentially amenable to in-situ oxidation treatment. In-situ chemical oxidation has been used at MGP sites in the United States, primarily for soil treatment. ISCO has also been used for treatment of MGP NAPL, but has generally not achieved complete NAPL removal. Because DNAPL is a long-term source of dissolved COIs in groundwater, multiple injections would be required to prevent migration to the river. Given the depth and lateral extent of dissolved COIs in groundwater along the shoreline, it would be very difficult to inject oxidant in a way that achieves complete contact. The process of oxidizing cyanide compounds could generate cyanide gas, a significant human health risk to Site workers. Engineering controls would be required to prevent release of oxidant into the river.

#### 6.3.2.2 Dual Phase Extraction

Dual-phase extraction (DPE), also known as multi-phase extraction, vacuum-enhanced extraction, or sometimes bioslurping, uses pumps to remove various combinations of contaminated groundwater, separate-phase petroleum product, and hydrocarbon vapor from the subsurface. DPE is typically used for removal of VOCs at sites where petroleum LNAPL is present at the water table surface and smear zone. Extracted liquids and vapor are treated and collected for disposal, or reinjected to the subsurface.

DPE systems can be effective in removing separate-phase product (free product) from the subsurface, thereby reducing concentrations of petroleum hydrocarbons in both the saturated and unsaturated zones of the subsurface. DPE systems are typically designed to maximize extraction rates; however, the technology also stimulates biodegradation of petroleum constituents in the unsaturated zone by increasing the supply of oxygen, in a manner similar to that of bioventing.
The application of DPE also maximizes the effectiveness of soil vapor extraction (SVE) by lowering the water table and therefore increasing air-phase permeabilities in the vadose zone.

The extracted groundwater and vapor would be treated in an aboveground treatment system. This technology is most applicable to sites where contamination is primarily in the upper portion of the water table and the smear zone.

#### *6.3.2.3 Thermal Treatment*

Thermal treatment involves the use of subsurface heating to raise the temperature of soil and groundwater to volatilize COIs for removal by soil vapor extraction. Two forms of thermal treatment may be applicable: Electrical Resistance Heating (ERH) and In-Situ Thermal Desorption (ISTD). ERH uses heating elements placed in the soil to raise the vapor pressure of VOCs and SVOCs for removal by soil vapor extraction. ISTD uses an array of heater wells to volatilize hydrocarbons and drive them to extraction wells. ColThermal treatment has been used on a small scale at MGP sites in the United States, primarily for treatment of petroleum hydrocarbon COIs in soil. The extracted vapor would be treated in an aboveground treatment system. Engineering controls would be required to prevent the volatile compounds from migrating beyond the influence of the vapor extraction system. This technology could be effective for the petroleum-derived COIs, but not for the cyanide compounds. This technology is typically applied at sites where the contamination is near the top of the water table. Controlling the migration of volatile compounds generated from thermal treatment in deep groundwater would be difficult.

#### *6.3.2.4 Recirculating Groundwater Recovery Wells*

Recirculating Groundwater Recovery Wells (RGRW) are designed to establish a subsurface circulation system whereby groundwater is continuously pumped from one portion of the well and injected back out into the aquifer from another portion of the well. Each well has its own circulation system and the wells are designed so that the circulation cells of adjacent wells overlap with each other. RGRW systems can be designed so that groundwater is treated in situ in the well casing by air stripping. Alternatively a portion of the extracted groundwater can be pumped to an aboveground treatment system where amendments are added, which are reinjected into the aquifer and circulated through the groundwater at each well. Because petroleum derived COIs and cyanide compounds require different treatment methods, the application of RGRW at the Site would likely not be advantageous over a conventional pump and treat system. The presence of numerous silt interbeds in the upper alluvium at the Site would likely make establishment of RGRW circulation cells very difficult.

#### *6.3.2.5 Air Sparging/Soil Vapor Extraction*

Air sparging is an in-situ technology that reduces concentrations of volatile constituents in petroleum products that are adsorbed to soils and dissolved in groundwater. This technology involves the injection of contaminant-free air into the subsurface saturated zone, enabling a phase transfer of hydrocarbons from a dissolved state to a vapor phase. The air is then vented through the unsaturated zone.

Air sparging is most often used together with SVE, but it can also be used with other remedial technologies. When air sparging (AS) is combined with SVE, the SVE system creates a negative pressure in the unsaturated zone through a series of extraction wells to control the vapor plume migration. This combined system is called AS/SVE.

When used appropriately, air sparging has been found to be effective in reducing concentrations of VOCs found in petroleum products at underground storage tank (UST) sites. Air sparging is generally more applicable to the lighter gasoline constituents (i.e., BTEX), because they readily transfer from the dissolved to the gaseous phase. Air sparging is less applicable to diesel fuel and kerosene. Appropriate use of air sparging may require that it be combined with other remedial methods (e.g., SVE or pump-and-treat).

The extracted groundwater and vapor would be treated in an above ground treatment system. This technology is most applicable to sites where the groundwater contamination is primarily in the upper portion of the water table and smear zone.

Air sparging is generally not recommended in subsurface zones with NAPL, because it can cause groundwater mounding, potentially spreading the NAPL.

#### *6.3.2.6 Stabilization/Fixation*

This technology is included for its potential applicability to containment of the MGP mobile DNAPL. In-situ biogeochemical stabilization (ISBS) has been pilot tested for stabilization of creosote NAPL (Adventus 2007). Potassium permanganate is injected at the boundary of the NAPL. The goal is to stabilize the mobile NAPL residuals and enhance the natural attenuation process. Reaction of the permanganate causes formation of a mineral precipitate that stabilizes the NAPL. The permanganate also oxidizes and removes contaminant mass. Injection of oxidant for stabilization purposes has potential implementation problems similar to those described for ISCO in Section 6.3.2.1. This ISDS technology has not yet been proven at MGP sites.

#### *6.3.2.7 Surfactant Enhanced/Cold Water Flood*

This technology was developed to increase solubility and mobility of NAPL and enhance the removal rate that could be achieved with pumped groundwater. This technology has been used with limited success for NAPL removal on some MGP sites. Surfactants are chemical agents injected into the subsurface to increase NAPL solubility. Generally, a cold water flood is first injected to facilitate extraction well removal of easily recoverable mobile NAPL. A surfactant solution is then injected into the NAPL source zone. The surfactant/NAPL solution is further treated with an in-situ cold water flood, facilitating extraction well removal. The extracted fluids are treated in an aboveground treatment system.

The interbedded nature of the fill and alluvium make control of the surfactant migration pathways very difficult. Slow surfactant penetration of the low permeability layers would require multiple applications. The near proximity of the river to source control actions makes it difficult to prevent migration of contaminants mobilized by this technology to the river.

#### *6.3.2.8 Steam Injection/Hot Water Flood*

This is another technology for increasing solubility and mobility of NAPL. There are several technologies that use various combinations of steam injection, vapor extraction, hot water flooding, and well extraction. This technology has been used with limited success for NAPL treatment/removal on some MGP sites. The recovered steam and hot water are treated in an aboveground treatment system. The interbedded nature of the fill and alluvium make control of the steam/hot water migration pathways very difficult. Slow steam/hot water penetration of the low permeability layers would require multiple applications. The near proximity of the river to source control actions makes it difficult to prevent migration of contaminants mobilized by this technology to the river.

## 6.4 Ex-Situ Treatment

Ex-situ treatment occurs in an aboveground treatment system. Ex-situ treatment of dissolved contaminants in groundwater would be a component of an extraction well hydraulic containment system. The treatment technology must be able to handle all of the COIs present in Site groundwater, including petroleum derived VOCs and SVOCs, free cyanide, and metals. The evaluation of potential treatment technologies included a comprehensive review of technologies used for groundwater treatment at MGP sites nationwide, a review of the pollution engineering literature, and discussions with vendors of treatment equipment.

The analysis has determined that there is no single treatment technology that can remove all of the COIs. Therefore, the selected treatment system would include a combination of technologies. There are several technologies that have shown to be effective for selected COIs, as shown on Table 1.

Extraction wells operating in certain areas (MW-16, PW-01, MW-5) of the shoreline would likely remove some mobile DNAPL, at least in the early stages of system operation. An oil/water separator would be needed to remove the DNAPL from the extracted groundwater prior to treatment. The removed DNAPL could then be collected in a tank and recycled as is currently practiced with DNAPL recovered at the Site.

Sequential bioreactors could be designed to handle the full range of COIs. Separate reactors would be required to treat the petroleum-derived COIs and the free cyanide. This technology would also require multiple filtration steps and generate sludge for off-site disposal. Sequential bioreactors would require constant monitoring to respond to variations in groundwater chemistry resulting in significant labor costs.

Oxidation using ozone and hydrogen peroxide were identified as effective treatment for removal of free cyanide (Remediation Technologies 1990; Hayes 2002). Oxidation is also an effective treatment for the petroleum-derived COIs. Oxidation methods have the advantage of simultaneously destroying both the free cyanide and petroleum-derived COIs. Bench scale ozone and hydrogen peroxide treatment of Site groundwater has been conducted, and the method has proven capable of reducing free cyanide concentrations below 10 μg/L. Oxidation treatment would generate a sludge that would be filtered, stored, and disposed at an off-site landfill.

Cyanide forager® is an open-celled cellulose sponge incorporating an amine-containing chelating polymer that selectively absorbs dissolved heavy metals or cyanide. The forager can be specifically manufactured for cyanide absorption. The petroleum-derived COIs would have to be removed prior to treatment, otherwise they would clog the sponge matrix. There are no known applications where cyanide foragers have been used for MGP groundwater treatment.

Granular activated carbon (GAC) is a proven absorbent that will remove petroleum-derived organics and metals. GAC is currently used at the Site to treat groundwater from the LNG tank basin. Organoclay materials are also available as adsorbent for organics and metals. Filter mixtures of GAC and organoclay are commonly used for removal of organics and metals from groundwater.

### 6.5 Monitored Natural Attenuation

Ten former MGP sites were evaluated for natural attenuation of constituents of concern (RETEC 2003). Each of the 10 sites exhibited at least limited geochemical evidence of natural attenuation processes. Microbial evidence included the presence of VOC and PAH-degrading microbial populations, which were detected in at least some of samples collected from each site. The study concluded that evidence of natural attenuation was “strong” at four sites, “moderate” at four sites, and “weak” at two sites.

Monitored Natural Attenuation (MNA) relies on natural subsurface attenuation processes to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods (EPA 1999). Natural attenuation processes active in the MNA approach include physical, chemical, or biological processes that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil and groundwater. MNA is a component of remediation programs at many sites nationwide, especially sites contaminated with petroleum fuels and solvents.

Source control technologies that are feasible for reducing the mass discharge from the Site upland to the river may not be feasible for some areas beyond the transition zone.

Natural attenuation of dissolved contaminants through groundwater flow advection and dispersion is assumed to be occurring at the Site; however, the presence of other attenuation processes, such as adsorption and biodegradation is unknown at this time. MNA will be considered as a potential component of Segment 3 (not addressed in this GWFFS) source control and in the Site-wide upland FS.

### 6.6 Screening of Technologies

Table 2 shows the results of screening the identified source control technologies against the criteria of effectiveness, implementability, and cost. Each technology was assigned a ranking of low (L), Moderate (M), or High (H), as indicated on Table 2. Each of the technologies are evaluated to determine if they should be retained for inclusion in the alternatives selected for detailed evaluation in Segment 1 (Section 7) and Segment 2 (Section 8).

**Table 2**
**Screening Groundwater/DNAPL Source Control Technologies**
**Gasco/Siltronic Site**

| Identified Remedial Technologies | Relevant Screening Criteria | | | Comments | Retained Yes/No |
|---|---|---|---|---|---|
| | Effectiveness L/M/H | Implementability L/M/H | Cost L/M/H | | |
| **Containment** | | | | | |
| Physical Barriers (slurry walls/sheet piles) | M | M | H | Can function where nearshore shallow NAPL has a direct flowpath down to the river channel | Yes |
| Groundwater Pumping | H | H | H | Will function to contain groundwater and NAPL | Yes |
| **In Situ Biological Treatment** | | | | | |
| Enhanced Biodegradation | L | L | H | Not proven effective for all COIs | No |
| Natural Attenuation | Unknown | Unknown | L | Further investigation warranted in shoreline zones with lower COI concentrations | No |
| **In Situ Physical/Chemical Treatment** | | | | | |
| Chemical Oxidation | L | L | H | Not implementable in nearshore zones due to heterogeneous geology and risk of release to river | No |
| Thermal Treatment | L | L | H | Not implementable in nearshore zones dues to heterogeneous geology, risk of containment of hazardous vapor, potential to spread NAPL | No |
| Recirculating Groundwater Recovery Wells | L | L | H | Technology not available for in-situ treatment of all Site COIs | No |
| Soil Vapor Extraction/Air Sparging | L | L | M | Not effective for non-volatile COI, potential to spread NAPL | No |
| Stabilization /Fixation | L | L | M | Potential application for NAPL stabilization, little effect on dissolved COIs | No |
| Surfactant Enhanced/Cold Water Flooding | L | L | H | Potential application for NAPL reduction, difficult to contain in nearshore zones | No |

| Identified Remedial Technologies | Relevant Screening Criteria | | | Comments | Retained Yes/No |
|---|---|---|---|---|---|
| | Effectiveness L/M/H | Implementability L/M/H | Cost L/M/H | | |
| Steam Injection/Hot Water Flood | L | L | H | Potential application for NAPL reduction, difficult to contain in nearshore zones | No |
| **Ex-Situ Biological Treatment** | | | | | |
| Bioreactors | L | L | H | Biological treatment of cyanide compounds difficult, high volume of sludge production, high manpower costs | No |
| **Ex-Situ Physical/Chemical Treatment** | | | | | |
| Separation | M | M | L | Oil water separator for NAPL removal | Yes |
| Cyanide Forager | M | M | M | Not proven for high flow conditions | No |
| Advanced Oxidation | H | H | H | Effective for petroleum derived COIs and free cyanide | Yes |
| Adsorption | H | H | H | Effective for post oxidation final polish of petroleum-derived organics | Yes |
| **Monitored Natural Attenuation** | Unknown | Unknown | L | Further evaluation warranted in shoreline zones with lower COI concentrations | No |

### 6.6.1 Containment

Both of the identified containment technologies, hydraulic containment and vertical barrier, are selected for development of source control alternatives. As discussed previously in this section, hydraulic containment is a required component of any feasible source control technology close to the river. Hydraulic containment is well proven at many cleanup sites nationwide and Site pilot studies have shown that the technology is effective and implementable.

Of the barrier technologies, sheet pile and slurry walls have been selected for further evaluation because they are both proven technologies applied to MGP sites. In contrast, jet grouting and large diameter auger are unproven technologies that have an even greater potential for allowing gaps in the barrier wall than slurry technology. Further, although the grouting and auger options have the capability to go deeper than sheet pile walls, they do not generally exceed the depths capable of slurry walls (which is an alternative selected for detailed evaluation). Finally, the additional depth allowed by grouting, auger, and slurry wall options is not a differentiating parameter for selection of the barrier wall options due to the fact that none of them have the ability to reach basalt at the Site. In the absence of the capability of integrating a wall into basalt, as noted above, there is no reason to extend any vertical barrier below the bottom of the river because once DNAPL is below the river bottom, it cannot counter gravity and enter the river.

In addition, a primary consideration for a barrier wall is where to install it relative to the shoreline bank. As noted in Section 4, an "upland barrier" is defined as stopping at the top of the shoreline bank. However, it is theoretically possible to place the barrier wall further out into the river possibly partway down the riverbank slope or even at the base of that slope. The advantages of such a location would be that it would contain more material and it could extend to a greater depth (because it would be driven through a land surface at a lower elevation). However, even at this lower starting elevation, it would be infeasible to construct the wall deep enough to contact the basalt. Consequently, there is no real advantage to this greater penetration depth as discussed above. One disadvantage is that if the wall were constructed partway down the riverbank slope or even at the base of the slope, there is a greater likelihood that the wall would encounter larger debris used to construct the shore berms. Another major and important disadvantage of this wall location is that it would require in-water construction, which presents both logistical and permitting issues including:

- Construction would be confined to certain times of year due to in-water work windows and construction within the next window (July to October 2008) is very likely too soon to implement
- Construction would have to contend with low water conditions in those periods, increasing the ranges and types of equipment that would have to be deployed
- Construction would have to work around existing shoreline structures, remediation areas, and barge docking traffic, which will create slower construction times
- In-water construction permits would have to be obtained, which typically take 18 months minimum. Thus, construction would be pushed to 2009 at a the earliest.

- Compliance with in-water permit requirements would require extensive water quality management integrated into construction, which will also increase the time and expense of implementation.

Consequently, all barrier wall technologies further evaluated in Sections 7 and 8 consist of an upland barrier wall installed at or near the top of the shoreline slope.

Combinations of extraction well and barrier wall technologies are identified in Section 6.7.

### 6.6.2 In-Situ Treatment

All of the eight in-situ treatment technologies identified in Section 6.3, have a low rank for potential effectiveness and implementability. Simultaneous enhanced biodegradation of both petroleum-derived COIs and cyanide has not been proven to be effective or implementable. The implementability of the in-situ chemical and physical treatment methods is reduced by the numerous silt interbeds in the upper alluvium, which would restrict injected air, hot water/steam, and vapors from uniform contact with the impacted subsurface soil and groundwater. Engineering controls would be required to prevent release of injected media to the nearby river shoreline. Pilot testing of in-situ treatment technology and engineering controls would be required prior to design and implementation. In-situ treatment is not selected for further evaluation for nearshore source control.

### 6.6.3 Ex-Situ Treatment

Ex-situ treatment of groundwater is a necessary component of hydraulic containment using extraction wells, which was selected for further evaluation. An oil/water separator would be needed to separate the DNAPL from groundwater pumped from the extraction wells. The use of chemical oxidation has been bench tested on Site groundwater and shown to be effective for treatment of petroleum-derived COIs and free cyanide. GAC is currently being used at the Site for removal of petroleum-derived COIs from groundwater. Organoclay filter material could be used in conjunction with GAC for final polish. Therefore, these technologies have been selected for further evaluation. These technologies are combined into a groundwater treatment system for further consideration in Sections 7 and 8. The preliminary design of the groundwater treatment system is further described in Section 7. Cyanide forager technology will be further considered during source control design as a potential component of the treatment system.

#### *6.6.4 Monitored Natural Attenuation*

MNA is not selected as an active source control technology for shoreline Segments 1 and 2. However, MNA is suitable for potential applicability in other areas of the Site, including offshore groundwater beneath the river channel, shoreline Segment 3, and in the Site-wide FS.

### 6.7 Summary of Resulting Alternatives for Detailed Evaluation

The following five source control alternatives are retained for separate consideration in shoreline Segments 1 and 2:

1. Groundwater Pump and Treat
2. Sheet Pile Wall
3. Slurry Wall
4. Pump and Treat with Sheet Pile Wall
5. Pump and Treat with Slurry Wall

As noted in Section 5, the Site has been broken down into two segments for this evaluation based on contaminant/DNAPL distribution and physical Site features. Source control alternatives in Segments 1 and 2 are discussed separately in Sections 7 and 8, respectively.

# 7 EVALUATION OF ALTERNATIVES – SEGMENT 1

This section presents a detailed evaluation of the selected removal action alternatives for Segment 1 as summarized in Section 6.7. First, each alternative for Segment 1 is described in Section 7.1 in more detail. Then each alternative is evaluated using the three general criteria categories of effectiveness, implementability (feasibility), and cost in Sections 7.2 through 7.4. At the start of each of these subsections is a definition of the criteria and/or any subcriteria that fall within that category, followed by an evaluation based on that definition and those subcriteria.

## 7.1 Description of Alternatives

### *7.1.1 Groundwater Pump and Treat*

Extraction wells can be used in Segment 1 to pump groundwater and create a capture zone that contains contaminated groundwater and DNAPL. Groundwater containment using pump and treat is commonly used where the goal is to prevent migration of impacted groundwater and NAPL from migrating off site to surface water bodies. Extraction wells PW4-85 and PW4-118 were installed and pump tested to develop aquifer properties for design of the extraction well system. The results of the PW4 extraction well tests are described in Section 3.2.2 and in Appendix E.

Figure 6A is a subsurface profile perpendicular to the Segment 1 shoreline. The profile shows the preliminary design location and screen depth of the extraction wells relative to other Site features. Figure 7 is a map of the Site shoreline showing the preliminary design of the extraction well locations. Figure 7 also shows the preliminary location of the transmission pipelines and treatment system. Figure 7 shows the location of a contingency treatment system for iron removal for groundwater to be withdrawn from the Siltronic property. This could be needed in the event that the Siltronic in-situ treatment program results in elevated iron concentrations in groundwater at the shoreline. Siltronic has conducted a pilot study of enhanced in-situ bioremediation of TCE and degradation products in groundwater (MFA 2007). This technology involves injection of hydrophilic carbon/zero-valent iron blend (EHC™) and anaerobic bacteria culture (KB-1™). The pilot study concluded that enhanced in-situ bioremediation will be successful in the Siltronic source area and could be implemented at the riverbank to reduce or eliminate TCE and degradation products in TZW.

The groundwater pump and treat system would be designed to be a component of the final cleanup plan for the Site. The system would be designed to be placed in semi-permanent operation for long-term protection of the river.

A ModFlow groundwater flow model was used to design an extraction well system for construction along the Site shoreline. Figure 7 shows the location of 10 extraction wells arrayed along the shoreline in Segments 1 and 2. The particle tracking diagram on Figure 8 shows that complete capture of groundwater at the shoreline will result from pumping the extraction wells at an average per well discharge rate of 20 gpm. Figure 9b shows the subsurface profile of the modeled capture zone with particle tracking.

The average per well pumping rate is 20 gpm, which will vary seasonally depending upon groundwater and river levels. A modeling sensitivity analysis was conducted to determine how much the pumping rate of 20 gpm could be reduced before breakthrough occurs. The sensitivity analysis shows that breakthrough occurs at about 12 gpm.

The 20 gpm per well discharge rate achieves complete capture of groundwater at the shoreline. We know that approximately 99 percent of the contaminant mass is in the portion of the alluvium above about -100 feet msl elevation, as shown on the subsurface profiles in Appendix A. We have previously considered designing the system to obtain capture down to the -100 feet elevation. However, monitoring and managing the extraction system to achieve capture to a specified elevation above bedrock requires more fine-tuning of the system than operating it for complete capture. Operating the system for complete capture provides a degree of conservatism to the system design and provides a higher degree of assurance that capture is occurring in the zone above -100 feet elevation, where most of the contaminant mass occurs.

Section 6.2.1 describes the ability of the extraction system to contain both groundwater and DNAPL and prevent both fluids from migrating to the river channel. DEQ has expressed concern that the behavior of DNAPL in the extraction well capture zone is not well understood and that the extraction wells may induce DNAPL to migrate from upland areas to the shoreline. DEQ is also concerned that the DNAPL currently near the shoreline could continue to migrate to the river channel regardless of the reversed groundwater gradient (hydraulic head) that will be induced by the extraction wells. If the DNAPL can be moved to the shoreline by extraction well pumping, then it can also be contained at the shoreline from migrating to the river channel. NW Natural believes that predicting DNAPL behavior by modeling will not be conclusive because of the large number of estimated variables required for such modeling. It is possible to design a monitoring program to assess the behavior of DNAPL under the influence of the extraction wells. This would include installation of monitoring wells that are screened in DNAPL to measure the head change in DNAPL that results from extraction well pumping. Monitoring wells would also be installed adjacent to known DNAPL zones to be used as sentinel wells to detect DNAPL migration. This monitoring program would be designed as part the source control design to be implemented following approval of this GWFFS. The monitoring program is further discussed in Section 11.2.

Although complete capture of groundwater will result in a higher discharge rate to the treatment system, the contaminant mass requiring treatment will be about the same. Therefore, treatment costs should be about the same, even with the higher flow rate required to attain complete capture.

Operating the system with a higher flow rate will result in a larger drop in groundwater elevation (i.e., a steeper potentiometric surface gradient, across the shoreline capture zone). The steeper gradient will be easier to monitor and will facilitate proving that capture is occurring.

The extraction system will be designed so that extraction well flow rates can be adjusted as needed to achieve capture. The extraction wells will have variable frequency drive motors so that the pump speed can be tuned to either achieve a specific water elevation in the pumping well, or to maintain a specific discharge rate under varying river and seasonal groundwater levels.

The planned ground water extraction and treatment system is shown on the process and instrumentation diagram (P&ID) on Figure 10. The treatment system components include the following:

- Contingency pretreatment system to remove iron and chlorinated solvents from Siltronic extraction wells
- Contingency pretreatment system to remove iron from north end of Segment 2 (as discussed below in Section 8)
- Oil/water separator to remove DNAPL (DNAPL to be recycled as fuel off site)
- Stage 1 oxidation using ozone
- Stage 2 oxidation with hydrogen peroxide
- Filtration with GAC/Organoclay

This system is designed to completely oxidize the petroleum-derived COIs and free cyanide. Petroleum-derived COIs that are not oxidized will be removed by the GAC/Organoclay filter. The system is designed to remove free cyanide to concentrations below 10 μg/L.

The extraction wells will be operated at pumping rates well below their potential maximum yield. This will minimize groundwater entrance velocity into the screens and reduce the potential for clogging of the screens with minerals and bacterial slimes.

### 7.1.2 Sheet Pile Wall

Two different sheet pile wall configurations are considered. The "Upper" sheet pile wall would extend to the depth of the river navigation channel, and the "Lower" sheet pile wall would extend to the depth of DNAPL present along the shoreline or the maximum constructible depth for such a wall. Each option is further discussed in the subsections below.

#### 7.1.2.1 Upper Sheet Pile Wall

Vertical barriers, such as sheet pile wall and slurry wall, are commonly used in conventional construction and on environmental cleanup projects as a component of a groundwater containment system. For most construction and environmental projects, a vertical barrier is only used if the bottom of the barrier can be tied into a low permeability layer at depth. If the bottom of the vertical barrier cannot be tied into a low permeability layer, as is the case in Site Segment 1, groundwater flow will be forced under the barrier, necessitating the use of extraction wells for groundwater containment. NW Natural and DEQ have discussed the possible use of a vertical barrier in several past meetings, and vertical barriers were evaluated for potential use in source control in the Groundwater Source Control Pilot Plan (Anchor 2006a).

Although DEQ and NW Natural have agreed that the use of vertical barriers is not ideal in Segment 1 because current technology is not available to extend a barrier to bedrock, DEQ has requested that vertical barriers be retained for consideration as a means to prevent DNAPL migration to the river.

Recent TarGOST subsurface investigations have been conducted to refine the nature and extent of DNAPL at the Site. The TarGOST boring profiles are in Appendix G and the TarGost investigation is discussed in Section 3.2.3.2. TarGOST borings TG-1, -2, -3 and -5 were located near the Gasco shoreline in Segment 1 as shown on the TarGOST boring location map in Appendix G. TarGost borings TG-4, -6, -7, and -8 were advanced approximately 200 feet from the shoreline to characterize DNAPL distribution farther upland.

The DNAPL zones detected by TarGOST are shown on the subsurface geologic profile B-B′ on Figure 2. This geologic profile is drawn through borings and wells completed near the top of bank along the Site shoreline, approximately where a vertical barrier would be installed, if selected. The TarGOST data show that potentially mobile DNAPL occurs at varying shallow depths on the Gasco portion of Segment 1, but at a maximum depth of 65 feet, as measured at TG-5 or 72.5 feet as observed in the soil core for well MW-20-120. This is consistent with the maximum detected depth of DNAPL as reported in the Gasco RI report (HAI 2007a).

TarGOST borings TG-1S through TG-6S were completed on Siltronic property and the profiles are also located in Appendix G. Subsurface profile 6B shows that DNAPL was detected from 116 to 118 feet bgs in TG-1S. DNAPL was not detected at all down to a depth of 150 feet bgs in boring TG-2S. TG-4S, located about 200 feet from the shoreline, had intermittent DNAPL detections at 37 feet (minor) and from 62 feet down to 100 feet bgs. At 500 feet from the shoreline (TG-3S), DNAPL was present within intermittent intervals between 33 and 78 feet bgs. The TarGOST findings on Siltronic therefore confirmed the presence of deep DNAPL near the shoreline, and shallower DNAPL farther upland on Siltronic property. The DNAPL along the Siltronic shoreline is well below the river channel elevation and is now prevented by gravitational forces from migrating upward into the river channel. See Section 6.2.1 for a discussion of DNAPL behavior in the subsurface. Therefore, construction of a vertical barrier on the Siltronic shoreline would not serve the purpose of blocking DNAPL migration pathway to the river.

However, DEQ has asked that a vertical barrier on the Siltronic property be retained as a source control alternative. Therefore, two vertical barrier options are presented in this FS, an upper barrier down to -40 feet elevation (river channel bottom equivalent), and a lower barrier down to -55 feet elevation. The -55 foot elevation lower barrier option is the maximum feasible depth that either a sheet pile wall or slurry wall can be installed given equipment and site conditions. The depth limitations for sheet pile installation were discussed in Section 6.2.2.1 and are further discussed in the evaluations of effectiveness and implementability in Sections 7.2 and 7.3.

The upper and lower wall options are identified by their target elevation depths (i.e., -40 and -55 foot elevation). This is used for reference purposes instead of a depth below ground surface, because the ground surface elevation of the top of bank varies almost 10 feet across Segment 1. For example, a sheet pile wall installed to a target bottom elevation of -40 feet, would have sheet depths ranging from 65 feet bgs to 74 feet bgs depending upon location along the top of bank in Segment 1. This is because the top of bank ground surface elevation on Segment 1 ranges from about 25 feet to 34 feet (City of Portland datum).

Subsurface profiles 5C through 5G show the TarGOST detected DNAPL, relative to the shoreline river profile. Figures 6A and 6B show the depths of the both the upper and lower barrier wall options in Segment 1 relative to DNAPL occurrence. The lower barrier wall option is further discussed in Section 7.1.2.2.

The primary purpose of a sheet pile barrier would be to block gravity flow of mobile DNAPL from upland source areas into the river. Considering the nature and extent of DNAPL in Segment 1, and the elevation of the river channel in this area (-40 feet msl), this upper wall alternative is evaluated to block potential DNAPL migration into the river channel. Therefore, a sheet pile vertical barrier alternative installed to an elevation of -40 feet (upper wall option) is considered along Segment 1. Although shallow DNAPL above the -40 feet river channel elevation is not present on the Siltronic shoreline, DEQ has requested that the vertical barrier be extended onto the Siltronic property. The upper wall depth and length are shown in profile on Figure 13. Because the bottom of the sheet pile wall will be at the elevation of the river bottom, this depth will block DNAPL from migrating into the river channel. The depth of the sheet pile barrier is also shown on subsurface profiles 6A and 6B.

Figure 9a shows a particle tracking capture profile including the extraction well system and a vertical barrier. As discussed in Section 6, DNAPL is prevented by gravity forces from migrating upward into the river channel from depths below the elevation of the river channel. This is particularly true along the shoreline where the extraction wells will create a groundwater capture zone that extends past the shoreline and below the river channel.

Design for the vertical barrier would include a geotechnical investigation to determine detailed subsurface conditions along the proposed barrier route. If necessary, a trench would be constructed along the wall alignment for removal of subsurface obstructions in the fill. The sheet pile would then be installed in the trench, avoiding the step of driving pile through the surficial fill layer.

#### *7.1.2.2 Lower Sheet Pile Wall*

In an October 23, 2007 meeting DEQ requested that NW Natural retain a vertical barrier alternative for further evaluation that would be installed to the maximum depth of existing DNAPL, or to the maximum feasible depth for vertical barrier construction. The maximum feasible depth for sheet pile is 85 feet bgs at this Site for reasons discussed in Section 6. As explained below, this depth can potentially be achieved by driving the pile into an open trench. DEQ also requested that the lower wall alternative be extended onto the Siltronic property. This lower barrier wall alternative is shown in profile on Figure 13. As shown on Figure 13, installing the wall down to -55 feet elevation does not extend the wall below the maximum depth of DNAPL on the Siltronic property (which is approximately -85 ft elevation).

Figure 13 shows that the bottom of the lower wall would be at approximately the -55 foot elevation, about 15 feet below the river channel bottom elevation. This deeper bottom wall elevation would be achieved by driving the sheet pile in an open trench constructed in the surficial fill. The implementation difficulties associated with this type of sheet pile construction are discussed in Section 7.2.

Based on the sheet pile experience at the McCormick & Baxter site, and discussion with construction contractors, the -55 foot bottom elevation is the maximum feasible sheet pile depth. The -55 foot elevation may not be reachable, depending upon subsurface conditions, friction between piles during driving, and other limiting factors. Therefore, the -55 foot elevation can be considered a feasible target depth, but reaching that depth in all locations along the proposed lower wall alignment cannot be assured because field conditions cannot be predicted with certainty.

### 7.1.3 Slurry Wall

#### 7.1.3.1 Upper Slurry Wall

The above discussion on the location and depths of a sheet pile wall also apply to a slurry wall alternative. Slurry walls are installed by excavating a trench and backfilling the trench with various types of soil mixtures. The three most common types of slurry walls are soil/bentonite (SB) walls, soil/cement/bentonite (SCB) walls, and cement/bentonite (CB) walls. The slurry components are determined during design based upon the desired permeability characteristics of the wall and on selecting amendments that are chemically compatible with the types of contaminants that are being contained. Various potential admixtures would be tested for compatibility with Site contaminants during design. An excavator is used to create the trench. The removed soil is mixed with either bentonite, cement, or other amendments to create a slurry. The process of excavating, mixing and pumping the slurry is carried out in a continuous process as the slurry wall is created. The excavated material is stockpiled and either beneficially reused (which would be unlikely at this Site due to the chemical concentrations present in most Site soils) or disposed at an appropriate disposal facility.

A soil bentonite slurry wall was installed at the McCormick and Baxter site across the river from Gasco. Most of the length of that slurry wall was installed to depths ranging from 40 to 70 feet bgs, but a short reach of the wall was installed to a depth of about 83 feet bgs (Ecology and Environment 2004). Based on professional judgment and the experience at McCormick & Baxter, the installation of a slurry wall to the -40 foot elevation is considered feasible.

#### *7.1.3.2 Lower Slurry Wall*

In an October 23, 2007 meeting DEQ requested that NW Natural retain a vertical barrier alternative for further evaluation that would be installed to the maximum depth of existing DNAPL, or to the maximum feasible depth. DEQ also requested that the lower wall alternative be extended onto the Siltronic property. This lower barrier wall alternative is shown in profile on Figure 13. As shown on Figure 13, the additional depth does not extend the wall below the maximum depth of DNAPL on the Siltronic property.

At the McCormick and Baxter site, the slurry wall was constructed using an excavator with a 90-foot boom. That excavator was able to construct the slurry wall to the maximum depth of 84 feet in a short reach of the wall. For reasons discussed in Section 6, the -55 foot elevation is considered to be the maximum feasible slurry wall target depth at the Gasco/Siltronic Site. The elevation of the bottom of the wall would be variable depending upon ground surface elevation at top of bank.

As with the sheet pile lower wall option, this option does not extend to the maximum depth of DNAPL, as shown on Figure 13.

## 7.2 Effectiveness

### *7.2.1 Definition of Criterion and Subcriteria*

#### *7.2.1.1 Overall Effectiveness*

Under OAR 340-122-090(3)(a)), each remedial action alternative shall be assessed for its effectiveness in achieving protection, by considering the following criteria, as appropriate:

- Magnitude of risk from untreated waste or treatment residuals
- Adequacy of engineering and institutional controls
- Restoration or protection of future beneficial uses of water (this criteria addresses hot spots in water)
- Adequacy of treatment technologies
- Time until remedial action objectives would be achieved
- Any other information related to effectiveness

#### *7.2.1.2 Long-Term Reliability*

Under OAR 340-122-090(3)(b) each remedial action alternative shall be assessed for long-term reliability by considering the following criteria, as appropriate:

- Reliability of treatment technologies in meeting treatment objectives
- Reliability of engineering and institutional controls necessary to manage the risk from treatment residuals and untreated hazardous substances
- Nature, degree, and certainties or uncertainties of any necessary long-term management (e.g., operation, maintenance, and monitoring)
- Any other information related to long-term reliability

#### *7.2.1.3 Implementation Risks – Short Term Effectiveness and Implementation Risks*

Under OAR 340-122-090(3)(d) each remedial action alternative shall be assessed for the risk associated with implementing the remedial action by considering the following criteria, as appropriate:

- Potential impacts on the community during implementation and the effectiveness of mitigation measures
- Potential impacts on workers during implementation and the effectiveness of mitigation measures

- Potential impacts on the environment during implementation and effectiveness of mitigation measures
- Time until the remedial action is complete
- Any other information related to implementation risk

Potential impacts to Siltronic's manufacturing operations during implementation are evaluated as implementation risks.

#### 7.2.1.4 River Recontamination Prevention

This subcriterion is added at the request of DEQ for the purpose of assessing the ability of the selected alternative to prevent recontamination of the river.

#### 7.2.1.5 Compatibility with In-water Remedial Action

This subcriterion is added at the request of DEQ for the purpose of assessing the ability of the selected alternative to be compatible with future in-water remedial actions, such as dredging and capping.

### 7.2.2 Groundwater Pump and Treat Effectiveness Evaluation

#### 7.2.2.1 Overall Effectiveness

The extraction test results and modeling demonstrate that the use of extraction wells to contain groundwater along the Site shoreline would be an effective technology. Per the removal action goals in Section 4, this alternative would permanently minimize the discharge of groundwater to the river and would also be expected to contain DNAPL due to these gradient changes.

#### 7.2.2.2 Long Term Reliability

Similar systems are in operation throughout the United States, and many have functioned reliably for decades.

#### 7.2.2.3 Implementation Risks

There are no significant implementation risks to the community that are inherent with pump and treat systems. Site workers involved in installation of the wells and transmission lines will be trained to manage short-term exposure to contaminated soil and groundwater, and these will be mitigated through implementation of the Site health and safety plan. Because Site soil and groundwater are already impacted, construction of the pump and treat system will not present any additional risk to Site soil and groundwater. An erosion control plan will be in place to prevent potential transport of soil during construction activities.

Construction of a pump and treat system on the Siltronic property portion of Segment 1 presents some implementation risks that could affect the ability to complete construction on a predictable schedule. Siltronic has identified the following risks to their operation that will have to be accounted for during design, construction, and operation of the pump and treat system:

- Noise from construction could impact Siltronic worker productivity and noise mitigation where construction activities are near Siltronic office buildings may be needed
- The pump and treat system could impact groundwater levels potentially affecting the foundations of Siltronic buildings located near the shoreline. An analysis of this potential would need to be conducted for design.

Other implementation risks related to Siltronic include the following:

- The Segment 1 extraction wells would remove groundwater that is impacted by TCE and breakdown products sourced from Siltronic. DEQ may interpret TCE contained in recovered groundwater to be a listed Resource Conservation and Recovery Act (RCRA) waste. This could cause treatment residuals (such as sludges) and/or treated groundwater to also be listed RCRA waste, potentially resulting in special handling, transport, and disposal measures.
- Construction and operation of the extraction system and pipelines on Siltronic property will require institutional controls, such as an easement and equitable servitude, and access agreements.

#### *7.2.2.4 River Recontamination Prevention and Compatibility*

The pump and treat system will also be a primary component of preventing recontamination of the river following the CERCLA in-water remedial action.

Groundwater from the Site will no longer be discharging to the river following implementation of the pump and treat system. The extraction well containment system will remove the hydraulic head that is currently driving upland groundwater into the river sediments along the shoreline. By removing the hydraulic head, the groundwater flux through river sediments should be greatly reduced or eliminated. This should remove the potential for groundwater recontamination of nearshore remediated sediments. Also, construction of this alternative has no direct impact on the shoreline or nearshore sediments and therefore should be compatible with the in-water remedial action.

### 7.2.3 Sheet Pile Wall Effectiveness Evaluation

#### 7.2.3.1 Overall Effectiveness

##### 7.2.3.1.1 Upper Sheet Pile Wall

Because the sheet pile wall would physically block the migration of DNAPL into the river channel it meets the DNAPL removal objective described in Section 4. The bottom of the river channel is approximately -40 feet elevation adjacent to the Gasco and Siltronic sites. For reference purposes, the river channel bottom elevation is projected to the subsurface profile on Figure 13.

In an October 23, 2007 meeting DEQ asked for further discussion of the ability of the upper sheet pile (-40 feet elevation) to prevent DNAPL migration to the river. Figure 13 shows that DNAPL is present above the bottom of the upper wall on Gasco property, except near the Siltronic property line, where DNAPL is present below the projected wall bottom. DNAPL is not present above the -40 foot elevation at the Siltronic shoreline, but is present at depths below -40 feet elevation. The upper wall will function as a DNAPL barrier for the DNAPL above -40 feet elevation due to its ability to prevent lateral flow of fluids. If shallow DNAPL on Gasco migrates to the wall and then moves downward along the wall, the DNAPL will be below the river bottom elevation. Since the wall bottom is below the river channel elevation, the DNAPL is prevented by gravity force from rising into the river channel.

Because the TarGOST and previous investigations have not identified DNAPL above elevation -40 ft on the Siltronic property, the upper wall would not function as a barrier to DNAPL migration to the river on Siltronic. DNAPL is present in the Siltronic upland area (away from the shoreline) below -40 feet elevation. The subsurface profile on Figure 6b shows that DNAPL is present at the shoreline at elevations well below -40 feet. Construction of a vertical barrier to the full depth of DNAPL on the Siltronic shoreline is not feasible, as explained in Section 6. The lower sheet pile wall option discussed in the next section is capable of blocking lateral movement of DNAPL between -40 and -55 ft elevation, but not the DNAPL present at deeper elevations. It is critical to note that lateral migration of upland DNAPL currently existing below the river channel elevation of -40 feet would be below the bottom of the river and would not intersect the river channel.

However, because a sheet pile wall cannot be tied into the bedrock, by itself it does not meet the groundwater removal objective in Section 4 and must be considered ineffective as a stand-alone technology.

#### 7.2.3.1.2 Lower Sheet Pile Wall

In an October 23, 2007 meeting DEQ asked that NW Natural retain a vertical barrier alternative that would extend to the maximum depth of DNAPL or to the maximum feasible wall construction depth. Figure 13 shows the lower wall alternative constructed to the bottom elevation of -55 feet. As explained in Section 7.1 this is the maximum feasible construction depth for sheet pile at the Site. This is about 15 feet lower than the river channel. This lower wall option does block lateral movement of the deep DNAPL present on the Gasco Site near well MW-20, as shown on Figure 13. However, that deep DNAPL on the Gasco Site would, in any case, be prevented from migrating upward to the river by gravity force, as well as the head reversal resulting from the construction and operation of a hydraulic containment system.

The lower wall does block lateral movement of some of the deeper DNAPL on the Siltronic property, but it would not extend to the depth of the deepest

DNAPL on Siltronic. However, the DNAPL on Siltronic that is below -40 feet elevation would not migrate to the river channel due to gravity forces. Consequently, the lower sheet pile wall is no more effective than the upper sheet pile wall.

#### *7.2.3.2 Long Term Reliability*

##### 7.2.3.2.1 Upper Sheet Pile Wall

The upper sheet pile barrier on Segment 1 would be designed to be a component of the final cleanup plan for the Site. The system would be designed to be placed in semi-permanent operation for long-term protection of the river. Similar systems are in operation throughout the United States, and many have functioned reliably for decades.

There are no standard methods for determining or evaluating the longevity of vertical barrier materials (Chien et. al. 2006). It is not possible to predict the longevity of sheet pile. Steel will oxidize in the subsurface environment. The length of time that a sheet pile will function as a groundwater/DNAPL barrier is unknown, but the barrier should function for decades. During design we would evaluate whether a vinyl sheet pile could be installed under Site conditions, and if vinyl longevity would exceed steel.

##### 7.2.3.2.2 Lower Sheet Pile Wall

The reliability of the upper and lower sheet pile options are the same. Refer to the previous discussion in Section 7.2.3.2.1.

#### *7.2.3.3 Implementation Risks*

##### 7.2.3.3.1 Upper Sheet Pile Wall

There are no significant implementation risks to the community that are inherent with the upper sheet pile wall. Site workers involved in installation of the sheet piles will have short-term exposure to contaminated soil and groundwater, and these will be mitigated through implementation of the Site health and safety plan. Because Site soil and groundwater are already impacted, construction of the sheet pile system will not present any additional risk to Site soil and groundwater. There is a possibility that vibrations caused by driving the piles could mobilize NAPL from shallow offshore sediment into the river. Sheen monitoring in the river during pile construction could determine if this is a problem. If necessary, a boom containment system could be placed near the pile driving area to mitigate this concern. An erosion control plan will be in place to prevent potential transport of soil during construction activities.

Construction and operation of a sheet pile barrier would involve heavy construction equipment, which can pose some implementation risks to workers. The contractor will be required to develop, implement, and maintain a construction health and safety plan during construction to address these risks.

Construction of a sheet pile barrier on Segment 1 presents some implementation risks to Siltronic that could affect the ability to complete construction on a predictable schedule. Siltronic has identified the following risks to its operation that will have to be accounted for during design and construction of a sheet pile wall:

- Vibrations from construction of the sheet pile wall could substantially impact the operation of some delicate equipment causing them to either shut down or incur damage to their products.
- Noise from construction could impact Siltronic worker productivity and noise mitigation where construction activities are near Siltronic office buildings may be needed

The duration of vibrations from pile driving is directly related to the depth and length of the sheet pile barrier. Therefore, increasing the depth or length of the sheet pile barrier increases the potential that construction of the barrier could affect Siltronic business operations. This applies to both the upper and lower sheet pile barrier wall alternatives.

Construction of a vertical barrier on Siltronic property would require institutional controls, such as an easement and equitable servitude, and access agreements. Siltronic has not, at this time, consented to institutional controls or to access for barrier construction.

NW Natural is working closely with Siltronic to try to resolve the issues in a timely manner. At this time, the implementation risk to Siltronic's operations is unknown, but Siltronic believes it may be significant enough to render the barrier wall infeasible. Further, the time required to resolve the above issues may affect the vertical barrier implementation or the schedule for construction on or near the Siltronic property.

##### 7.2.3.3.2 Lower Sheet Pile Wall

The implementation risks discussed in Section 7.2.3.3.1 for the upper sheet pile wall also apply to the lower sheet pile wall. Because extensive trenching will be required to enable the lower sheet pile depth to be achieved, there is a potential for a higher degree of construction worker exposure to contaminated soil during the trenching operations. The removed soil would be transported and stockpiled on site. It has not been determined if the excavated soil would have to be disposed off site at a commercial landfill, or could be placed permanently on site in a containment facility constructed in the trench excavation created for sheet pile construction. For example, contaminated spoils from trenching at the McCormick and Baxter site were permanently placed behind the containment barrier.

#### *7.2.3.4 River Recontamination Potential and Compatibility*

##### 7.2.3.4.1 Upper Sheet Pile Wall

The upper sheet pile wall would prevent recontamination of the river from shallow DNAPL seepage following the CERCLA in-water remedial action. However, by itself would not decrease the potential for recontamination due to ongoing groundwater discharges.

Because the wall would be installed at the top of the shoreline slope, there would be no major limitations to in-water remediation alternatives. In-water remediation that involved removal of shoreline bank materials would have to be phased and/or constructed in such a manner to limit bearing loads on the wall itself to prevent wall failure. For the same reasons, these shoreline removals would likely not extend any further shoreward than the top of the slope.

##### 7.2.3.4.2 Lower Sheet Pile Wall

The DNAPL present between elevations -40 and -55 feet is trapped by gravity force and cannot migrate upward into the river. Therefore, the lower sheet pile wall does not add a higher degree of protection for river recontamination and compatibility than is described in Section 7.2.3.4.1 for the upper sheet pile wall.

### *7.2.4 Slurry Wall Effectiveness Evaluation*

This section provides information on slurry wall barriers that could change the effectiveness of the barrier, compared to a sheet pile barrier.

#### *7.2.4.1 Overall Effectiveness*

##### 7.2.4.1.1 Upper Slurry Wall

The effectiveness of slurry walls is lower than sheet pile walls because there is a somewhat greater potential for gaps in the slurry wall due to unidentified failures of the trench during excavation.

##### 7.2.4.1.2 Lower Slurry Wall

The deeper slurry wall would be expected to be less effective than sheet pile walls. This is because there is a greater potential for gaps in the deep portion of the lower slurry wall due to the higher hydraulic conductivity of the deep alluvium and resulting sand heave that would likely occur during lower slurry wall construction. Similarly, the lower slurry wall is no more effective than the upper slurry wall, given that any DNAPL currently below the bottom of the river cannot migrate up into the river for reasons discussed earlier.

#### *7.2.4.2 Long Term Reliability*

##### 7.2.4.2.1 Upper Slurry Wall

The slurry wall barrier on Segment 1 would be designed to be a component of the final cleanup plan for the Site. The system would be designed to be placed in semi-permanent operation for long term protection of the river. Similar systems are in operation throughout the United States, and many have functioned reliably.

There are no standard methods for determining or evaluating the longevity of vertical barrier materials (Chien et. al. 2006). It is not possible to accurately predict the longevity of a slurry wall. Slurry wall components, such as bentonite, cement, or other amendments will deteriorate with time, resulting in an increase in wall permeability. The length of time that a slurry wall will function as a groundwater/DNAPL barrier is unknown. Some design manuals use 30 years as a predicted functional period for slurry walls (Chien et. al. 2006).

##### 7.2.4.2.2 Lower Slurry Wall

The deepest segment of the lower slurry wall has a higher potential for zones of high permeability due to gaps in the slurry caused by groundwater inflow and sand heave during construction.

#### *7.2.4.3 Implementation Risks*

##### 7.2.4.3.1 Upper Slurry Wall

There are no significant implementation risks to the community that are inherent with slurry wall barrier systems and it is similar to sheet pile risks in many respects.

However, much more earthwork is involved in slurry wall construction compared to sheet pile walls. Because of the proximity to the river, rigorous construction and containment procedures would have to be followed to prevent release of excavated soil or slurry to the river. An erosion control plan would also be in place to prevent potential transport of soil during construction activities. This increase in contaminated soils handling increases risks to Site workers, and increases the potential for an upland spill during transport to a suitable upland disposal facility as well. However, earth vibrations from slurry wall construction should be much lower than would occur during sheet pile driving, so there is less risk that vibration from slurry wall construction would mobilize DNAPL to be released into the river.

Construction of a slurry wall barrier on Segment 1 presents some implementation risks to Siltronic that could affect the ability to complete construction on a predictable schedule. Siltronic has identified the following issues that will have to be accounted for during design and construction of a slurry wall on the Gasco portion of Segment 1:

- Vibrations from construction of the slurry wall could substantially impact the operation of some delicate equipment causing them to either shut down or incur damage to their products. It would be expected that vibrations caused by a slurry wall construction would be less than that for a sheet pile wall. However, as noted above there are substantial uncertainties about the levels of vibrations that are acceptable. Therefore, slurry wall construction may have similar potential impacts to Siltronic operations.
- Noise from construction could impact Siltronic worker productivity and noise mitigation where construction activities are near Siltronic office buildings may be needed.

Construction of a vertical barrier on Siltronic property would require institutional controls, such as an easement and equitable servitude, and access agreements. Siltronic has not, at this time, consented to institutional controls or to access for barrier construction.

NW Natural is working closely with Siltronic to try to resolve the issues in a timely manner. At this time, the implementation risk to Siltronic's operations is unknown, but Siltronic believes it may be significant enough to render the barrier wall infeasible. Further, the time required to resolve the above issues may affect the slurry wall implementation or the schedule for construction near the Siltronic property.

##### 7.2.4.3.2 Lower Slurry Wall

The implementation risk for the lower slurry wall may be slightly higher than the upper slurry wall because an excavator with a longer boom would be required for the lower slurry wall. This would require more room to maneuver and potentially cause more subsurface vibration, which could be factors raising the level of implementation risk on the Siltronic property.

#### *7.2.4.4 River Recontamination and Compatibility*

##### 7.2.4.4.1 Upper Slurry Wall

A slurry wall is essentially identical to a sheet pile wall with regard to this subcriterion with the exception that recontamination potential due to DNAPL seepage is slightly higher for slurry walls due to potential gaps in the walls and long-term reliability issues as discussed above.

##### 7.2.4.4.2 Lower Slurry Wall

The DNAPL present between elevations -40 and -55 feet cannot migrate upward into the river. Consequently, the lower wall option is no more effective at preventing river recontamination than the upper wall option. As discussed previously, given the potential gaps in the lower slurry wall, this option may not effectively limit lateral migration of DNAPL at greater depths.

### *7.2.5 Pump and Treat with Sheet Pile Wall Effectiveness Evaluation*

As described in Section 7.1.1, the proposed extraction well hydraulic containment system is capable of groundwater and DNAPL containment in Segment 1. However, DEQ requested NW Natural to consider the use of a vertical barrier in Segment 1 to prevent DNAPL migration to the river. As noted in previous sections, vertical barriers (either sheet pile or slurry walls) by themselves do not meet the groundwater discharge removal action objective in Section 4 because they must be coupled with groundwater extraction to prevent groundwater from migrating around the barrier. The potential location and depth of both an upper and lower sheet pile vertical barrier was described in Section 7.1.2. This alternative adds the sheet pile vertical barrier to the extraction well hydraulic containment system.

Three sheet pile wall alternatives are considered in this section: 1) a lower wall extending onto both Gasco and Siltronic property, 2) an upper wall extending across all of Segment 1, and 3) an upper wall only on the Gasco portion of Segment 1. These alternatives are shown on Figure 13.

#### *7.2.5.1 Lower Sheet Pile Wall Including Siltronic*

For this alternative, the lower sheet pile wall described in Section 7.1.2.2 is combined with the pump and treat containment system. In this alternative the sheet pile extends to the -55 foot elevation maximum feasible depth wherever DNAPL currently exists below the -40 foot bottom elevation of the upper sheet pile wall. This option blocks lateral movement of DNAPL that currently exists between elevations -40 and -55 feet.

The extraction well system will reverse the hydraulic gradient and restrict DNAPL flow to the river throughout the vertical thickness of the alluvium. DEQ has expressed concern that DNAPL could migrate to the river channel regardless of the capture zone emplaced by the extraction wells . NW Natural believes that this is unlikely because DNAPL specific gravity only slightly exceeds the specific gravity of water. Therefore, reversing the hydraulic gradient with extraction wells would contain groundwater and restrict DNAPL migration. DEQ has also expressed a concern that a dissolved plume may be produced by DNAPL migrating below the barrier wall. However, with the addition of the extraction system to this alternative, a reverse gradient will exist from the river down to bed rock. Consequently, a dissolved plume from DNAPL at any depth will be captured by the extraction system.

In this alternative, the level of certainty that DNAPL is blocked from migrating to the river channel is increased with the addition of the sheet pile wall. Therefore, this alternative has a somewhat higher level of potential effectiveness than the groundwater pump and treat alternative evaluated in Section 7.2.2. However, given that the pump and treat system by itself is expected to contain DNAPL, the added effectiveness of the sheet pile wall is minimal and provides no improvement in effectiveness with regards to groundwater discharge, as noted previously. As is explained in Section 11, a performance monitoring program is proposed to assess the potential for DNAPL movement under the influence of the extraction wells.

Adding the vertical barrier would reduce the flow of river water into the extraction wells. However, modeling has shown that the reduction in flow is not significant because a substantial thickness of alluvium is present below the barrier.

With regard to the other effectiveness subcriterion, this alternative has the same combination of advantages and disadvantages described in Sections 7.2.2 and 7.2.3.

##### *7.2.5.2 Upper Sheet Pile Wall Including Siltronic*

This alternative provides the upper sheet pile across all of Segment 1, but does not include the lower wall extension across portions of the Gasco and Siltronic properties. The upper wall blocks lateral movement of DNAPL currently existing above -40 feet elevation on Gasco.

As noted earlier, DNAPL that is currently present below the -40 foot elevation, as shown on Figure 13, is trapped by gravity force from rising into the river channel. Thus, the upper sheet pile option is just as effective as the lower sheet pile option. The dissolved plume from the deep DNAPL will also be captured by the extraction wells as noted in the previous section. The upper wall would reduce the flow of groundwater from the river to the extraction wells, but as explained for the lower wall, the reduction in flow is not significant. Consequently, this alternative provides the same level of effectiveness as the combined extraction system and lower wall system described in the previous section.

With regard to the other effectiveness subcriterion, this alternative has the same combination of advantages and disadvantages described in Sections 7.2.2 and 7.2.3.

#### *7.2.5.3 Upper Sheet Pile Wall Excluding Siltronic*

This alternative provides the upper sheet pile wall on the Gasco portion of Segment 1. The wall would block lateral migration of DNAPL on Gasco that exists above -40 feet elevation (river bottom elevation). The wall is not extended onto Siltronic property in this alternative because DNAPL has not been detected on the Siltronic shoreline above -40 feet elevation. As explained above, DNAPL at depths greater than -40 feet elevation anywhere on the Site is not able to migrate to the river due to gravity forces.

The extraction well system will reverse the groundwater gradient near the shoreline and greatly reduce the potential for deep DNAPL on Siltronic from migrating past the river shoreline. In the unlikely event that deep DNAPL on Siltronic (currently below river channel elevation) does migrate laterally, the extraction well system will prevent the dissolved plume from migrating into the river alluvium similar to the previous options. This wall alternative will provide a small reduction in groundwater flow from the river to the extraction wells.

With regard to the other effectiveness subcriterion, this alternative has the same combination of advantages and disadvantages described in Sections 7.2.2 and 7.2.3.

### *7.2.6 Pump and Treat with Slurry Wall Effectiveness Evaluation*

As described in Section 7.1.1, the proposed extraction well hydraulic containment system is capable of complete groundwater and DNAPL containment in Segment 1. However, DEQ requested NW Natural to consider the use of a vertical barrier in Segment 1 to prevent DNAPL migration to the river. As noted in previous sections, vertical barriers (either sheet pile or slurry walls) by themselves do not meet the groundwater discharge removal action objective in Section 4 because they must be coupled with groundwater extraction to prevent groundwater from migrating around the barrier. The potential location and depth of both an upper and lower slurry wall vertical barrier was described in Section 7.1.2. This alternative adds the slurry wall vertical barrier to the extraction well hydraulic containment system.

Three slurry wall alternatives are considered in this section: 1) a lower wall extending onto both Gasco and Siltronic property, 2) an upper wall extending across all of Segment 1, and 3) an upper wall only on the Gasco portion of Segment 1. This alternative is a combination of the alternatives described in Section 7.1.1 and 7.1.3.

##### *7.2.6.1 Lower Slurry Wall Including Siltronic*

The lower slurry wall has similar advantages and disadvantages as those described for the lower sheet pile wall in Section 7.2.5.1. The greatest slurry wall disadvantage is that high permeability zones could result from sand heave and groundwater inflow during construction of the deepest portion of the wall. The resulting gaps deeper in the wall would allow lateral migration more than a lower sheet pile wall. Because the slurry wall option has a greater potential for gaps it is expected to be slightly less effective than the sheet pile wall.

##### *7.2.6.2 Upper Slurry Wall Including Siltronic*

The upper slurry wall including Siltronic has similar advantages and disadvantages as those described for the upper sheet pile wall in Section 7.2.5.2. The greatest disadvantage compared to a sheet pile wall is the potential that high permeability zones could result from wall caving during slurry wall construction. Thus, an upper slurry wall is judged to be slightly less effective than an upper sheet pile wall.

##### *7.2.6.3 Upper Slurry Wall Excluding Siltronic*

The upper slurry wall excluding Siltronic has similar advantages and disadvantages as those described for the upper sheet pile wall in Section 7.2.5.3. The greatest disadvantage compared to a sheet pile wall is the potential that high permeability zones could result from wall caving during slurry wall construction, making this slightly less effective than a sheet pile wall.

## 7.3 Implementability

### *7.3.1 Criterion Definition*

OAR 340-122-090(3)(c) requires that each remedial action alternative be assessed for ease or difficulty of implementing the remedial action, by considering the following criteria, as appropriate:

- Practical, technical, and legal difficulties and unknowns associated with construction and implementation of a technology, engineering, or institutional control, including potential scheduling delays
- The ability to monitor the effectiveness of the remedy
- Consistency with federal, state, and local requirements; activities needed to coordinate with other agencies; and the ability and time required to obtain authorization from other governmental bodies
- Availability of necessary services, materials, equipment, and specialists
- Any other information relevant to implementability

### 7.3.2 Groundwater Pump and Treat Implementability Evaluation

There are few practical or technical difficulties in implementing this system. Some of the practicalities of designing the system for optimal operation are described in Section 7.1.1. The alternative can be easily monitored to if determine the desired gradients are being achieved (see Section 11 for more details). There should be little difficulty in obtaining permits for installing the system, although the discharge permit for the treatment system may take considerable development time with DEQ. All of the equipment needed is commercially available, although the treatment systems must be ordered approximately 6 months in advance.

Several implementability issues have been raised by Siltronic for conduct of this alternative on their portion of Segment 1 including:

- Development of an access agreement for construction, long-term monitoring, operation, and maintenance
- Providing alternate access route for Siltronic equipment where construction activities restrict existing Siltronic roads
- Determining regulatory status (hazardous vs. non-hazardous waste) and management of recovered groundwater or DNAPL that may contain TCE or TCE breakdown products from Siltronic's release of RCRA listed (F002) spent solvent.

Other implementation risks related to Siltronic include the following:

- The Segment 1 extraction wells would remove groundwater that is impacted by TCE and breakdown products sourced from Siltronic. DEQ may interpret TCE contained in recovered groundwater to be a listed RCRA waste. This could cause treatment residuals (such as sludges) and/or treated groundwater to also be listed RCRA waste, potentially resulting in special handling, transport, and disposal measures.

- Construction and operation of the extraction system and pipelines on Siltronic property will require institutional controls, such as an easement and equitable servitude.

In addition, as noted in the effectiveness section, there is the potential for both noise and vibration impacts from operation of the pump and treat system that would have to be assessed in design and mitigated as necessary. Although NW Natural is working proactively with Siltronic to try to resolve these issues in a timely manner, the time required to resolve them may affect the implementation or schedule for construction and operation on the Siltronic property.

### 7.3.3 Sheet Pile Barrier Wall Implementability Evaluation

#### 7.3.3.1 Upper Sheet Pile Wall

The Segment 1 barrier location shown on Figure 11 has some potential constraints to construction that would be further assessed during design. Following is a list of feasibility issues that will be assessed and considered in barrier design:

- There are two outfalls that would intersect the sheet pile wall alignment that will need to be considered during construction.
- The shoreline dolphin/catwalk (Figure 11) will restrict equipment access along a portion of the shoreline.
- Fill along the barrier route is known to contain cobbles, boulders, or other shallow obstructions to pile penetration, which may require excavation of some fills prior to pile driving.

The proposed nearshore location of the sheet pile wall has inherent drawbacks from the standpoint of monitoring wall functionality. Since the barrier will not be keyed into a low permeability layer, extraction wells will be used to prevent upland groundwater from migrating under and around the wall. Water quality and water level fluctuations near the wall will be influenced primarily by the extraction well containment system, essentially masking the wall effects. The gradient effects of the extraction well system will make it infeasible to monitor the integrity of the wall using hydrology monitoring methods. Because groundwater is contaminated on both sides of the proposed wall location, water quality monitoring cannot feasibly be used to determine wall integrity. However, monitoring of groundwater gradients imposed by the extraction wells and modeling the resulting capture zone will be used to assess containment.

There appear to be no substantial implementability issues related to regulatory issues or timing and ability to obtain permits. The materials needed for construction are generally available.

However, construction of a vertical barrier on Siltronic property would require institutional controls, such as an easement and equitable servitude, and access agreements. Siltronic has not, at this time, consented to institutional controls or to access for barrier construction. This may present a legal difficulty in the implementation of a vertical barrier.

As requested by DEQ, the implementation risks to Siltronic presented by the vertical barrier are discussed in the effectiveness Section 7.2.3.3.

#### *7.3.3.2 Lower Sheet Pile Wall*

The lower sheet pile option has all of the implementability issues that apply to the upper sheet pile, as described in 7.3.3.1.

Constructing a sheet pile to -55 feet elevation would require pre-trenching and driving the sheets into the open trench. Depending on the trench method selected during design, this may require creating a trench wide enough to accommodate access for pile driving equipment. On both the Gasco and Siltronic properties, some reaches of the shoreline have restricted access for creating a wide trench. Trench construction will result in a large volume of excavated soil for stockpile, off-site disposal, or possible on-site storage. Even with trench construction, sheet pile refusal, as occurred at the McCormick and Baxter site, may prevent reaching the -55 foot elevation.

### 7.3.4 Slurry Wall Implementability Evaluation

#### 7.3.4.1 Upper Slurry Wall

The implementability issues for a slurry wall are similar to those for a sheet pile wall. In addition, design for the vertical barrier would include a geotechnical investigation to determine detailed subsurface conditions along the proposed barrier route. The excavator to be used for slurry wall construction should be adequate for removal of cobbles and small boulders that might be encountered in the surficial fill.

#### 7.3.4.2 Lower Slurry Wall

As explained in Section 6.2.2.2, the 84-foot slurry wall depth achieved at the McCormick and Baxter Site using an excavator with a 90-foot boom, is considered the maximum practical slurry wall depth feasible for the Site. This is primarily because of the expected high groundwater inflow that will occur in the medium to coarse sands of the deep alluvium. The use of an excavator or clam shell bucket to remove deep sand at the bottom of the trench will cause sand heave into the excavation as has occurred while installing deep extraction well screens at the Site. The sand heave can be controlled to some degree by keeping the water level in the trench above the groundwater level, but this method will have limitations in the highly permeable sands at the base of the trench. The potential for sand heave in the lower slurry trench option is higher than for the upper slurry trench option.

### 7.3.5 Pump and Treat with Sheet Pile Wall Implementability Evaluation

#### 7.3.5.1 Lower Sheet Pile Wall Including Siltronic

Because this alternative combines groundwater extraction and a sheet pile barrier, the implementability issues are essentially the same as those described in Sections 7.3.2 and 7.3.3. In terms of construction sequence, the vertical barrier would ideally be constructed first. If the extraction well system is installed first, the potential to damage the wells, controls, and pipeline system during wall construction would be significant.

Existing shoreline monitoring wells in the path of the barrier wall would have to be decommissioned prior to wall construction. Following wall construction, monitoring wells would be added in locations to facilitate evaluation of the performance of the extraction well containment system.

Construction of the lower sheet pile would result in a large excavation and consequent soil handling with disposal issues. The lower sheet pile target depth of -55 feet elevation may not be reachable due to pile refusal, even with pre-trenching.

#### 7.3.5.2 Upper Sheet Pile Wall Including Siltronic

A sheet pile of this depth was constructed at the McCormick and Baxter site, although pile refusal was encountered in some zones at depths above the target elevation for this option.

#### 7.3.5.3 Upper Sheet Pile Excluding Siltronic

A sheet pile of this depth was constructed at the McCormick and Baxter site, although pile refusal was encountered in some zones at depths above the target elevation for this option. Because this sheet pile would not be constructed on the Siltronic property, there is greatly reduced potential for effects to Siltronic operation, although vibration from wall construction could still be an issue.

### 7.3.6 Pump and Treat with Slurry Wall Implementability Evaluation

#### 7.3.6.1 Lower Slurry Wall Including Siltronic

Because this alternative combines groundwater extraction and slurry wall, the implementability issues are essentially the same as those described in Sections 7.3.2 and 7.3.4. In terms of construction sequence, the vertical barrier would ideally be constructed first. If the extraction well system is installed first, the potential to damage the wells, controls, and pipeline system during wall construction would be significant.

Existing shoreline monitoring wells in the path of the barrier wall would have to be decommissioned prior to wall construction. Following wall construction, monitoring wells would be added in locations to facilitate evaluation of the performance of the extraction well containment system.

As described in Section 7.3.4.2, the potential for high groundwater inflow and sand heave during construction of the deepest portion of the slurry trench are higher than would be encountered in the upper slurry wall option.

##### *7.3.6.2 Upper Slurry Wall Including Siltronic*

A slurry wall of this depth was constructed on the McCormick and Baxter site. The potential for wall collapse due to sand heave during construction is lower for the upper slurry wall option than the lower slurry wall.

##### *7.3.6.3 Upper Slurry Wall Excluding Siltronic*

Because the slurry wall would not be constructed on the Siltronic property, the potential for disruption of the Siltronic business operations is potentially reduced in this option.

## 7.4 Reasonableness of Cost

### *7.4.1 Definition of Criterion*

OAR 340-122-090(3) (e) requires that each remedial action alternative be assessed for reasonableness of cost, by considering the following criteria, as appropriate:

1. Capital costs
2. Annual operations and maintenance (O&M) costs
3. Costs of periodic review
4. Net Present Value of all of the above
5. Degree to which the costs of the action are proportionate to the benefits to human health and the environment created through risk reduction or risk management
6. With respect to hot spots, the degree to which the costs of the action are proportionate to the benefits created through restoration or protection of beneficial uses of water
7. Degree of sensitivity and uncertainty of the costs
8. Any other information relevant to cost-reasonableness

The costs developed for this GWFFW should be considered +/-30 percent conceptual design level costs. All costs include design, permitting, materials, equipment, construction, construction oversight, operation, and maintenance costs, where applicable. The primary purpose of developing these costs is to provide a rough estimate of the actual cost of each alternative for comparison with the cost of other alternatives.

### *7.4.2 Groundwater Pump and Treat*

The groundwater treatment system costs for design, capital equipment, construction, and startup were calculated for the combined system that will serve both Segments 1 and 2. The preliminary system layout is shown on Figure 10. The operation, maintenance, and monitoring costs for the entire system were also calculated for an operation period of 30 years. The system will likely have to operate longer than 30 years, but 30 years was selected because this time period is typically used for developing feasibility level groundwater remediation costs on CERCLA and RCRA cleanup projects. The primary uncertainty associated with this cost is the number of years that the system will be in operation. Given the nature and extent of MGP COIs on the Site, it is highly likely that the pump and treat system will be required to operate more or less permanently. This would mean that the cost of this system could be significantly more than the cost shown on Table 3.

The total costs as described above were further evaluated as they apply to Segments 1 and 2. Table 3 shows the total cost of each alternative for Segment 1. More detailed cost estimates are provided in Appendix H. To divide the groundwater treatment costs by Segment, the total costs were pro-rated by the ratio of each individual shoreline segment length to the total combined length of both segments. For this purpose, a shoreline length of 1,250 feet was used for Segment 1 and a length of 950 feet was used for Segment 2.

**Table 3**
**Summary Costs for Each Alternative for Segment 1**

| Evaluated Alternatives | Cost |
|---|---|
| Groundwater Pump and Treat | $7,800,000 |
| Upper Sheet Pile Wall | $6,900,000 |
| Lower Sheet Pile Wall | $7,300,000 |
| Upper Slurry Wall | $7,800,000 |
| Lower Slurry Wall | $8,100,000 |
| Pump and Treat with Upper Sheet Pile Wall Including Siltronic | $14,700,000 |
| Pump and Treat with Lower Sheet Pile Wall Including Siltronic | $15,100,000 |
| Pump and Treat with Upper Slurry Wall Including Siltronic | $15,600,000 |
| Pump and Treat with Lower Slurry Wall Including Siltronic | $15,900,000 |
| Pump and Treat with Upper Sheet Pile Wall Excluding Siltronic | $11,400,000 |
| Pump and Treat with Upper Slurry Wall Excluding Siltronic | $11,800,000 |

On the pro-rated basis described above, the estimated Segment 1 groundwater treatment costs are $7,800,000, including, capital, construction, and operation for 30 years.

### *7.4.3 Sheet Pile Barrier Wall*

#### *7.4.3.1 Upper Sheet Pile Wall*

The estimated cost of constructing a steel sheet pile 65 deep to a bottom elevation of -40 feet msl along the entire 1,250-foot length of Segment 1 is $6,900,000. Uncertainties associated with these costs are primarily related to constructability issues that will be further refined during design. For example, Siltronic vibration issues could require more expensive construction techniques. Cost estimates for upper and lower wall alternatives do not include potential Siltronic costs associated with possible vibration impacts during construction.

Closely spaced geotechnical borings will be completed during design to evaluate the properties of earth materials for design purposes.

Because of Siltronic issues, separate costs were developed for placing a vertical barrier on the Gasco and Siltronic portions of Segment 1. The depth and lateral extent of DNAPL are different on the Gasco and Siltronic portions of Segment 1, which affects the need for a vertical barrier for DNAPL containment. This is further discussed in Section 9.

##### *7.4.3.2 Lower Sheet Pile Wall*

The lower sheet pile cost is the sum of the upper sheet pile plus the cost of installing the 500-foot-long portion of the wall down to a target elevation of -55 feet. This lower sheet pile cost is estimated to be $7,300,000.

#### *7.4.4 Slurry Wall*

##### *7.4.4.1 Upper Slurry Wall*

The estimated cost of constructing a slurry wall 65 feet deep to a bottom elevation of -40 feet msl along the entire 1,250-foot length of Segment 1 was $7,800,000. Uncertainties associated with these costs are primarily related to constructability issues that will be further refined during design. For example, laboratory compatibility testing of potential slurry wall additives would be completed during design. Also, extraordinary construction techniques may be required in some areas where space for equipment access is limited.

##### *7.4.4.2 Lower Slurry Wall*

The lower slurry wall cost is the sum of the upper slurry wall plus the cost of installing the 500-foot long portion of the wall down to a target elevation of -55 feet. This lower slurry wall cost is estimated to be $8,100,000.

#### *7.4.5 Pump and Treat with Sheet Pile Wall*

##### *7.4.5.1 Lower Sheet Pile Wall Including Siltronic*

The cost for this alternative is simply the combined cost of the pump and treat and sheet pile wall alternatives. As described in Section 7.4.2, a primary uncertainty is the length of time that the pump and treat system will operate. Because the pump and treat system will likely operate longer than 30 years, the actual costs will probably be significantly more than the costs shown on Table 3.

The total cost for lower sheet pile with pump and treat, including Siltronic, is estimated to be $15,100,000.

Because of Siltronic issues, separate costs were developed for placing a vertical barrier on the Gasco and Siltronic portions of Segment 1. The depth and lateral extent of DNAPL are different on the Gasco and Siltronic portions of Segment 1, which affects the need for a vertical barrier for DNAPL containment. This is further discussed in Section 9.

#### 7.4.5.2 Upper Sheet Pile Wall Including Siltronic

The total cost for upper sheet pile with pump and treat including Siltronic is estimated to be $14,700,000.

#### 7.4.5.3 Upper Sheet Pile Wall Excluding Siltronic

The total cost for upper sheet pile with pump and treat excluding Siltronic is estimated to be $11,400,000.

### 7.4.6 Pump and Treat with Slurry Wall

#### 7.4.6.1 Lower Slurry Wall Including Siltronic

The cost for this alternative is simply the combined cost of the pump and treat and slurry wall alternatives. The total cost for lower slurry wall with pump and treat, including Siltronic, is estimated to be $15,900,000. As described in Section 7.4.2, the primary uncertainty is the length of time that the pump and treat system will operate. Because the pump and treat system will likely operate longer than 30 years, the actual costs will probably be significantly more than the costs shown on Table 3.

#### 7.4.6.2 Upper Slurry Wall Including Siltronic

The total cost for upper slurry wall including Siltronic with pump and treat is estimated to be $15,600,000.

#### 7.4.6.3 Upper Slurry Wall Excluding Siltronic

The total cost for upper slurry wall excluding Siltronic with pump and treat is estimated to be $11,800,000.

# 8 EVALUATION OF ALTERNATIVES – SEGMENT 2

This section presents a detailed evaluation of the selected removal action alternatives for Segment 2 as summarized in Section 6.7. First, each alternative for Segment 2 is described in Section 8.1 in more detail. Then each alternative is evaluated using the three general criteria categories of effectiveness, implementability (feasibility), and cost in Sections 8.2 through 8.4. Definitions of the criteria and/or any subcriteria that fall within that category were described previously in Section 7.

In general, in the evaluation of alternatives the advantages and disadvantages of each alternative are similar to those for the Segment 1 evaluation, unless otherwise noted.

## 8.1 Description of Alternatives

### *8.1.1 Groundwater Pump and Treat*

Extraction wells can be used in Segment 2 to pump groundwater and create a capture zone that contains contaminated groundwater. As described in Section 3.2.3.2, based on the findings of the remedial investigation and recent TarGOST assessment, mobile DNAPL is not present in alluvium in Segment 2. A thin layer of DNAPL was observed in shallow fill during drilling of the MW1 monitoring well, but NAPL has never migrated into the MW1-22 well screen in the fill. The RI investigation found that there is no mobile MGP-related NAPL in Segment 2. Therefore, DNAPL containment is not a goal in Segment 2. Groundwater containment using pump and treat is commonly used where the goal is to prevent migration of impacted groundwater from migrating off site to surface water bodies. Extraction wells PW4-85 and PW4-118 were installed and pump tested to develop aquifer properties for design of the extraction well system. Based on the similarities of the geologic units, including grain size, between Segments 1 and 2, the findings of the PW-4 pump tests are applicable for design of the extraction well system in Segment 2. The results of the PW-4 extraction wells tests are described in Section 3.2.2 and the findings are in Appendix E.

Figure 6B is a subsurface profile perpendicular to the Segment 2 shoreline. The profiles show the preliminary design location and screen depth of the extraction wells relative to other Site features. Figure 7 is a map of the Site shoreline showing the preliminary design of the extraction well locations. Figure 7 also shows the preliminary location of the transmission pipelines and treatment system. Figure 7 shows the location of a contingency treatment system for iron removal for groundwater to be withdrawn from the northern portion of Segment 2. Existing data indicate that iron concentrations in Segment 2 groundwater are elevated, probably from the spent oxide material that was historically stored there.

### 8.1.2 Sheet Pile Wall

As noted in Section 7, for most construction and environmental projects a vertical barrier is only used if the bottom of the barrier can be tied into a low permeability layer at depth. The depth to bedrock along Segment 2 ranges from about 100 to 200 feet below top of the bank and is generally below the feasible depth for a vertical barrier. NW Natural and DEQ have discussed the possible use of a vertical barrier in several past meetings, and vertical barriers were evaluated for potential use in source control in the Groundwater Source Control Pilot Plan (Anchor 2006a).

Although DEQ and NW Natural have agreed that the use of vertical barriers is not ideal in Segment 2 because current technology is not available to extend a barrier to bedrock, DEQ has requested that vertical barriers be retained for consideration.

There is no mobile DNAPL present in Segment 2 (see below), so a vertical barrier would provide no benefit with regards to preventing DNAPL migration. Although a vertical barrier keyed into an impermeable unit could have the potential benefit of reducing the inflow of groundwater from below the river channel, thereby reducing pump and treat costs, the ModFLOW modeling demonstrates that the addition of a vertical barrier here does not significantly reduce flow to the extraction wells. As a result, no significant pump and treat operational savings would be realized if a barrier wall was constructed.

Recent TarGOST subsurface investigations have been conducted to refine the nature and extent of DNAPL at the Site. The TarGOST boring profiles are in Appendix G and the TarGOST investigation is discussed in Section 3.2.3.2. TarGOST borings TG-1,- 2, -3, and -5 were located near the Gasco shoreline in Segment 1 as shown on the TarGOST boring location map in Appendix G. TarGost borings TG-5, -6, -7, and -8 were drilled approximately 200 feet from the shoreline to characterize DNAPL farther upland. The

DNAPL zones detected by TarGOST and as identified by visual observations during boring and well drilling activities are shown on the subsurface geologic profile B-B′ on Figure 2. This geologic profile is drawn through borings and wells completed near the top of bank along the Site shoreline, approximately where a vertical barrier would be installed, if selected. The Gasco remedial investigation in conjunction with TarGOST and Segment 2 well installation activities has demonstrated that mobile DNAPL does not exist in Segment 2.

The primary difference between implementation risk associated with construction of a sheet pile wall in Segment 2 (as compared to Segment 1) is the much larger number of shoreline structures and activities that could interfere with and complicate the installation of a sheet pile wall in this segment. These items include two pipelines and associated docks and a very narrow access area near the Fuel and Marine Marketing (FAMM) basin and facilities.

#### *8.1.3 Slurry Wall*

The discussion in Section 8.1.2 on the potential location, depth, and purpose of a sheet pile vertical barrier also applies to a slurry wall barrier. Therefore, those discussions are not repeated here.

Slurry walls are installed by excavating a trench and backfilling the trench with various types of soil mixtures. The three most common types of slurry walls are soil/bentonite (SB) walls, soil/cement/bentonite (SCB) walls, and cement/bentonite (CB) walls. The slurry components are determined during design, based upon the desired permeability characteristics of the wall and on selecting amendments that are chemically compatible with the types of contaminants that are being contained. Various potential admixtures would be tested for compatibility with Site contaminants during design. An excavator is used to create the trench. The removed soil is mixed with either bentonite, cement, or other amendments to create a slurry. The process of excavating, mixing, and pumping the slurry is carried out in a continuous process as the slurry wall is created.

### 8.2 Effectiveness

See Section 7.1 for a description of the effectiveness factors.

### 8.2.1 Groundwater Pump and Treat

The pilot test results demonstrate that the use of extraction wells to contain groundwater along the Site shoreline would be an effective technology. The overall effectiveness of such a system would be similar to that described for Segment 1 including the subcriterion descriptions. Because mobile DNAPL is not present in this segment, the pump and treat system would only have to perform as it relates to the groundwater discharge removal action goal (not the DNAPL containment goal) in Section 4.

The implementability risk issues as it relates to Siltronic operations do not apply for this segment because of its distance from the Siltronic property.

### 8.2.2 Sheet Pile Barrier Wall

As discussed above, the primary purpose of a sheet pile barrier would be to block gravity flow of mobile DNAPL from upland source areas into the river. Because mobile DNAPL is not present in Segment 2, there is no significant containment advantage added by placing a vertical barrier. Further, as discussed in Section 7, a vertical barrier that is not tied into bedrock provides no reduction in groundwater discharge to the river. Therefore, this alternative is not effective for the groundwater discharge remedial removal action objective in Section 4. Thus, a vertical barrier, by itself in Segment 2 would be an ineffective alternative.

Construction of a sheet pile barrier on Segment 2 presents some implementation risks to FAMM operations that could affect the ability to complete construction on a predictable schedule. The following issues would have to be accounted for during design and construction of the sheet piles on the FAMM portion of Segment 2:

- Equipment access near the aboveground storage tank (AST) containment basins
- Equipment access near overhead pipelines and dock structures

NW Natural believes that the above implementation risks could be mitigated by working closely with FAMM to resolve the issues in a timely manner. However, the time required to resolve the above issues may affect the sheet pile implementation schedule for construction near the FAMM lease.

The vibration issues related to Siltronic operations noted in Section 7 may also exist for driving of sheet pile in Segment 2. Until a vibration study that is acceptable to Siltronic can be devised, including effective vibration criteria, it is impossible to tell whether sheet pile driving would be limited or feasible in Segment 2. It is only known that the vibration levels would likely be less in Segment 2 due to the greater distance from the Siltronic property.

### 8.2.3 Slurry Wall

This section provides information on slurry wall barriers that could change the effectiveness of the barrier, compared to a sheet pile barrier. The primary purpose of a sheet pile barrier would be to block gravity flow of mobile DNAPL from upland source areas into the river. Because mobile DNAPL is not present in Segment 2, there is no significant containment advantage added by placing a vertical barrier. In addition, the wall would provide no reduction in groundwater discharges and therefore, is considered ineffective by itself.

Construction of a slurry wall barrier on Segment 2 presents some implementation risks to FAMM that could affect the ability to complete construction on a predictable schedule. The following issues would have to be accounted for during design and construction of a slurry wall on Segment 2:

- Slurry wall construction requires a wider access area than a sheet pile wall. The additional space requirements are for excavation equipment, soil handling, slurry mixing, and piping.
- Some portions of Segment 2 adjacent to the FAMM lease do not appear to have enough space to accommodate slurry wall construction. In those areas, a sheet pile or other type of vertical barrier would have to be integrated into the slurry wall. This issue would be resolved during wall design.

NW Natural believes that the above implementation risks could be mitigated by working closely with FAMM to resolve the issues in a timely manner. However, the time required to resolve the above issues may affect the slurry wall implementation schedule for construction near the FAMM lease.

As with the Segment 1 slurry wall, it is likely that the vibration issues as they relate to Siltronic operations are likely less than for sheet pile walls. This, combined with the greater distance of Segment 2 from Siltronic, likely indicates that slurry wall installation in Segment 2 would not likely create vibration issues for Siltronic. However, this is not certain until a vibration study with effective criteria is established by Siltronic.

### *8.2.4 Pump and Treat with Sheet Pile Wall*

As described in Section 8.2.1, the proposed extraction well hydraulic containment system is capable of complete groundwater containment in Segment 2. However, DEQ requested NW Natural to consider the use of a vertical barrier in Segment 2. The potential location and depth of a sheet pile vertical barrier was described in Section 8.1.2. This alternative essentially adds the sheet pile vertical barrier to the extraction well hydraulic containment system.

The extraction well system will reverse the hydraulic gradient and prevent groundwater flow to the river. The remedial investigation showed that mobile DNAPL does not exist in Segment 2. Therefore, the addition of a vertical barrier in Segment 2 would not add significantly to the containment capability of the pump and treat system. Therefore, this alternative is not more effective than the pump and treat system by itself. As noted above, the wall would provide no significant reduction in pump and treat rates, and would have no added benefit in this regard.

### *8.2.5 Pump and Treat with Slurry Wall*

The effectiveness of this combination alternative is the same as for the previous one. That is, the addition of a slurry wall to a pump and treat system provides no additional reduction in groundwater discharge, no prevention of DNAPL movement (because it does not exist in Segment 2), and no significant reduction in pump and treat costs. Consequently, this alternative is not more effective than pump and treat by itself.

## 8.3 Implementability

### *8.3.1 Groundwater Pump and Treat*

The technology and factors affecting implementability of the Segment 2 pump and treat system are the same as those discussed in Section 7.2.1 for Segment 1.

### *8.3.2 Sheet Pile Barrier Wall*

A vertical barrier on Segment 2 would have potential constraints to construction that would be further assessed during design. Unless otherwise noted, the implementability issues for Segment 2 are the same as those for Segment 1. Following is a list of conditions that will be assessed and considered in barrier design:

- The shoreline dolphin/catwalk near the FAMM administration building (Figure 11) will restrict equipment access.
- The overhead pipeline supports and catwalks that connect the top of bank to the offshore loading dock (Figure 11) will restrict equipment access.
- Fill along the barrier route is known to contain cobbles, boulders, or other shallow obstructions to pile penetration.
- The access along the FAMM basin and structures is very narrow and may require specialized pile driving equipment to be employed.

Design for the vertical barrier would include a geotechnical investigation to determine detailed subsurface conditions along the proposed barrier route. If necessary, a trench would be constructed along the wall alignment for removal of subsurface obstructions in the fill. The sheet pile would then be installed in the trench, avoiding the step of driving pile through the surficial fill layer. However, the ability to dig a trench of this type along the narrow FAMM basin area may be limited.

### *8.3.3 Slurry Wall*

A vertical barrier on Segment 2 would have potential constraints to construction that would be further assessed during design. Unless otherwise noted, the implementability issues for Segment 2 are the same as those for Segment 1. The same list of implementability issues exist as discussed for sheet pile walls in Segment 2. However, the amount and access area of equipment needed for slurry walls is much greater than for sheet pile walls. Thus, the access and structure issues noted above would be even greater for slurry walls.

### *8.3.4 Pump and Treat with Sheet Pile Wall*

Since this alternative combines groundwater extraction and sheet pile barrier, the implementability issues are essentially the same as those described in Sections 8.3.1 and 8.3.2. In terms of construction sequence, the vertical barrier would ideally be constructed first. If the extraction well system is installed first, the potential to damage the wells, controls, and pipeline system during wall construction would be significant.

### *8.3.5 Pump and Treat with Slurry Wall*

Since this alternative combines groundwater extraction and slurry wall, the implementability issues are essentially the same as those described in Sections 8.3.1 and 8.3.3. In terms of construction sequence, the vertical barrier would ideally be constructed first. The construction sequence issues are the same as for pump and treat with a sheet pile wall as discussed above.

## 8.4 Reasonableness of Cost

The cost criterion for Segment 2 alternatives are the same as those described for Segment 1 in Section 7.4.1. The costs developed for this GWFFS should be considered +/- 30percent conceptual design level costs. All costs include design, permitting, materials, equipment, construction, construction oversight, operation, and maintenance costs, where applicable. The primary purpose of developing these costs is to provide a rough estimate of the actual cost of each alternative for comparison with the cost of other alternatives.

Because the alternatives evaluated for Segment 2 use the same technology as those evaluated for Segment 1, the factors affecting cost and uncertainty of cost are generally the same as those described in Section 7.4 and are not repeated in this section. This section focuses on presenting the estimated cost for the Segment 2 alternatives and describes cost factors where they differ from those presented in Section 7.4. Table 4 summarizes the costs for the different Segment 2 alternatives. More detailed cost estimates are provided in Appendix H.

**Table 4**
**Summary of Costs for Each Alternative for Segment 2**

| Evaluated Alternatives | Cost |
|---|---|
| Groundwater Pump and Treat | $6,000,000 |
| Sheet Pile Wall (65-foot) | $4,600,000 |
| Slurry Wall (65-foot) | $4,900,000 |
| Pump and Treat with Sheet Pile Wall (65-foot) | $10,700,000 |
| Pump and Treat with Slurry Wall (65-foot) | $11,000,000 |

### 8.4.1 Groundwater Pump and Treat

Section 7.4.2 describes how the combined Segment 1 and Segment 2 groundwater treatment system costs were developed. That section also describes how the individual segment costs were calculated by pro-rating the total system cost by the ratio of the length of each segment.

On the pro-rated basis described above, the estimated Segment 2 groundwater treatment costs are $6,000,000, including, capital, construction, and operation for 30 years.

The same uncertainties described for groundwater treatment costs in Segment 1 apply to Segment 2.

### 8.4.2 Sheet Pile Barrier Wall

The estimated cost of constructing a steel sheet pile 65 feet deep to a bottom elevation of -40 feet msl along the entire 950-foot length of Segment 2 is $4,600,000. The cost uncertainties described for Segment 1 apply to Segment 2. The constructability and equipment access issues are even more difficult for Segment 2 because of the narrow space available between the FAMM tank basin and the riverbank, and by the larger number of overhead pipelines and pier supports in Segment 2.

### 8.4.3 Slurry Wall

The estimated cost of constructing a slurry wall 65 feet deep to a bottom elevation of -40 feet msl along the entire 950 feet length of Segment 2 is $4,900,000. The cost uncertainties described for Segment 1 apply to Segment 2. The constructability and equipment access issues are even more difficult for Segment 2 because of the narrow space available between the FAMM tank basin and the riverbank, and by the larger number of overhead pipelines and pier supports in Segment 2. Because slurry wall construction equipment and methods require more space than sheet pile methods, the narrow space along the top of the bank presents more uncertainty for slurry wall costs than for sheet pile costs.

### 8.4.4 Pump and Treat with Sheet Pile Wall

The cost for this alternative is simply the combined cost of the pump and treat and sheet pile wall alternatives. The total estimated cost for sheet pile with pump and treat is estimated to be $10,700,000. As described in Section 7.4.2, the primary uncertainty is the length of time that the pump and treat system will operate. Because the pump and treat system will likely operate longer than 30 years, the actual costs will probably be significantly more than the costs shown on Table 4.

### 8.4.5 Pump and Treat with Slurry Wall

The cost for this alternative is simply the combined cost of the pump and treat and slurry wall alternatives. The total estimated cost for slurry wall with pump and treat is estimated to be $11,000,000. As described in Section 7.4.2, the primary uncertainty is the length of time that the pump and treat system will operate. Because the pump and treat system will likely operate longer than 30 years, the actual costs will probably be significantly more than the costs shown on Table 4.

# 9 RECOMMENDED ALTERNATIVE

## 9.1 Summary of Alternatives Evaluation

Sections 7 and 8 describe the evaluation of each of the alternatives for Segments 1 and 2, respectively. Tables 5a and 5b, summarize this evaluation on a comparative basis for Segments 1 and 2, respectively.

These tables provide a score from 1 to 3 for each alternative as compared to each of the three major criteria of effectiveness, reasonableness of cost, and implementability. The subcriteria for effectiveness (overall effectiveness, long term reliability, implementation risks, river recontamination prevention, and compatibility with in-river cleanup) are scored individually, and then these subcriteria scores are averaged to obtain an overall effectiveness score. Using this approach, each of the three major criteria of effectiveness, cost, and implementability are weighted equally in the scoring. These three equally weighted scores are then summed in the "Total Score" row of the tables. However, as is often the case, effectiveness is likely to be the most important criteria for this project to ensure that the overall purpose of source control to the river is attained. Consequently, we have provided an additional row to the table "Total with Effectiveness 1.5x Weighted," which provides an additional 50 percent weighting to effectiveness as compared to the other two major criteria. This final row of scores best reflects and summarizes the findings of the discussions in Sections 7 and 8 on a comparative basis.

In summary, Table 5a illustrates that for Segment 1, the stand alone wall alternatives are ineffective because they do not prevent dissolved plume migration to the river. Thus, they score low. The combination wall/well alternatives are considered slightly more effective in preventing DNAPL migration to the river as compared to stand alone pump and treat, but potentially greater implementation risks, implementability issues, and higher costs result in only the Upper Partial Segment 1 with Pump and Treat Alternative (i.e., no wall on Siltronic score higher than the stand alone Pump and Treat Alternative. Thus, the partial wall combined with pump and treat across the entire segment appears to be the best overall alternative.

In summary, Table 5b illustrates that for Segment 2, that stand alone Pump and Treat is the best alternative primarily because the wall alternatives provide no added benefit over this portion of the Site. This is because the walls do not help control dissolved plume migration and there is no mobile DNAPL in this segment to control.

## 9.2 Summary of Recommended Alternative

### *9.2.1 Segment 1 Pump and Treat with Upper Sheet Pile Excluding Siltronic*

The alternatives analysis in Section 7 shows that groundwater pump and treat would be an effective and implementable containment technology for groundwater and DNAPL in Segment 1. Pump and treat is a proven technology that has been successfully pilot tested at the Site. The cost of pump and treat is high, including both capital and O&M costs, but there are no feasible containment alternatives that do not require pump and treat methods. The ModFLOW model results show that extraction wells will provide complete capture of groundwater along the shoreline. Therefore, groundwater pump and treat is selected for Segment 1. The extraction well array will be approximately as shown on Figure 12.

The Section 7 alternatives analysis also showed that a vertical barrier has a potential advantage where the goal is to prevent gravity drainage of shallow upland DNAPL down into the river. Therefore, a vertical barrier is selected to be located on the Gasco portion of Segment 1 in the location shown on Figure 12. Figure 14 shows the barrier in subsurface profile. The barrier would extend down to an elevation of -40 feet msl, which is equivalent to the bottom of the Willamette River navigation channel. The depth and location of the barrier are shown on Figure 6A. This barrier will provide an added degree of confidence that shallow DNAPL on the Gasco portion of Segment 1 cannot migrate to the river channel.

ModFLOW modeling has shown that the addition of a vertical barrier will cause an insignificant reduction in total groundwater flow to the treatment system. The capture zone profiles on Figures 9a and 9b show that the vertical barrier has little effect on particle tracking from the river to the extraction well system. Therefore, the vertical barrier will not provide a significant groundwater treatment cost savings. The only potential benefit of the wall is to block the flow of shallow DNAPL to the river.

**Table 5a**
**Segment 1 Evaluation Summary**

| Evaluation Criteria | Alt. 1 | Alt. 2 | Alt. 3 | Alt. 4 | | | Alt. 5 | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Sheet Pile Wall with Pump and Treat | | | Slurry Wall with Pump and Treat | | |
| | | | | Alt. 4A | Alt. 4B | Alt. 4C | Alt. 5A | Alt. 5B | Alt. 5C |
| | Pump and Treat | Sheet Pile Wall | Slurry Wall | Wall 65/85 ft Depth - Full Segment 1 | Wall 65 ft Depth - Full Segment 1 | 65 ft Depth Wall - Partial Segment 1 | Wall 65/85 ft Depth - Full Segment 1 | Wall 65 ft Depth - Full Segment 1 | Wall 65 ft Depth - Partial Segment 1 |
| **Effectiveness*** | 2.2 | 1.2 | 1.2 | 2.8 | 2.8 | 3.0 | 2.0 | 2.0 | 2.0 |
| Overall Effectiveness | 2 | 1 | 1 | 3 | 3 | 3 | 2 | 2 | 2 |
| Long Term Reliability | 2 | 1 | 1 | 3 | 3 | 3 | 2 | 2 | 2 |
| Implementation Risks | 3 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 2 |
| River Recontamination Prevention | 2 | 1 | 1 | 3 | 3 | 3 | 2 | 2 | 2 |
| Compatability with In-River Cleanup | 2 | 1 | 1 | 3 | 3 | 3 | 2 | 2 | 2 |
| **Reasonableness of Cost** | 3 | 3 | 3 | 1 | 1 | 2 | 1 | 1 | 2 |
| **Implementability** | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 2 | 2 |
| **Total Score**** | 7.2 | 6.2 | 5.2 | 4.8 | 5.8 | 7.0 | 4.0 | 5.0 | 6.0 |
| **Total with Effectiveness 1.5x weighted***** | 8.3 | 6.8 | 5.8 | 6.2 | 7.2 | 8.5 | 5.0 | 6.0 | 7.0 |

**Note:**

*Average of effectiveness subcriteria.

**Sum of Effectiveness, Cost, and Implementability Scores.

***Effectiveness x 1.5 plus sum of Cost and Implementability Scores.

Recommended Alternative

**Table 5b**
**Segment 2 Evaluation Summary**

| Evaluation Criteria | Alt. 1<br>Pump and Treat | Alt. 2<br>Sheet Pile Wall | Alt. 3<br>Slurry Wall | Alt. 4<br>Sheet Pile Wall with Pump and Treat | Alt. 5<br>Slurry Wall with Pump and Treat |
|---|---|---|---|---|---|
| **Effectiveness*** | 3.0 | 1.2 | 1.2 | 2.8 | 2.8 |
| Overall Effectiveness | 3 | 1 | 1 | 3 | 3 |
| Long Term Reliability | 3 | 1 | 1 | 3 | 3 |
| Implementation Risks | 3 | 2 | 2 | 2 | 2 |
| River Recontamination Prevention | 3 | 1 | 1 | 3 | 3 |
| Compatability with In-River Cleanup | 3 | 1 | 1 | 3 | 3 |
| **Reasonableness of Cost** | 2 | 3 | 3 | 1 | 1 |
| **Implementability** | 3 | 2 | 1 | 2 | 1 |
| **Total Score**** | 8.0 | 6.2 | 5.2 | 5.8 | 4.8 |
| **Total with Effectiveness 1.5x weighted***** | 9.5 | 6.8 | 5.8 | 7.2 | 6.2 |

Note:

*Average of effectiveness subcriteria.

**Sum of Effectiveness, Cost, and Implementability Scores.

***Effectiveness x 1.5 plus sum of Cost and Implementability Scores.

Recommended Alternative

DNAPL is not present on the Siltronic shoreline portion of Segment 1 at elevations above -40 feet msl. Because the upland DNAPL on Siltronic is currently well below the river channel elevation, there is no pathway for that deep DNAPL to migrate up into the river channel. Although there is shallow DNAPL farther upland on Siltronic property, that material will likely not be mobilized by the extraction well system because the increased groundwater gradient in those areas will be too low. In addition, there are significant implementation risks related to placement of a vertical barrier on Siltronic property, as described in Section 7.

For these reasons a vertical barrier is not recommended on the Siltronic portion of Segment 1. The performance monitoring program will include assessment of potential migration of DNAPL under the influence of the extraction wells, see Section 11. Monitoring wells are planned to be added on the Siltronic property to monitor the possible migration of DNAPL under the influence of the pump and treat system. If those DNAPL monitoring wells indicate that DNAPL could migrate to the river, the need for a vertical barrier on Siltronic can be re-evaluated.

At this time a sheet pile wall is the preferred construction method for a barrier wall, based on the technical evaluations provided in Section 7. As previously noted, there are certain construction risks that remain unresolved (e.g., vibration issues). The resolution of these issues will be incorporated into the design process, which may result in reevaluation of the preferred construction method or, potentially, in a determination that construction of a barrier wall is infeasible.

Table 6 shows that the total estimated cost of the selected alternative for Segment 1 is $11,400,000.

**Table 6**
**Summary of Costs for Recommended Alternatives by Segment**

| Recommended Alternatives | Segment 1 | Segment 2 |
|---|---|---|
| Pump and Treat with Upper Sheet Pile Wall Excluding Siltronic* | $ 11,400,000 | NA |
| Pump and Treat | NA | $ 6,000,000 |

*Does not include wall on Siltronic portion of Segment 1

### 9.2.2 Segment 2 Pump and Treat

The alternatives analysis in Section 8 shows that groundwater pump and treat would be an effective and implementable containment technology for groundwater in Segment 2. Pump and treat is a proven technology that has been successfully pilot tested at the Site. The cost of pump and treat is high, including both capital and O&M costs, but there are no feasible containment alternatives that do not require pump and treat methods. The ModFlow model results show that extraction wells will provide complete capture of groundwater along the shoreline. Therefore, groundwater pump and treat is selected for Segment 2. The extraction well array will be approximately as shown on Figure 7.

Although pump and treat is currently selected for Segment 2, NW Natural plans to assess this source control decision in light of the future findings of the October 2007 surface water cyanide study. In the event that those studies show that river water quality is not impacted by free cyanide from (or converted from total cyanide) groundwater discharge offshore of Segment 2, it may be appropriate to re-evaluate the need for active source control in Segment 2. Alternatively, these results may suggest that reduced pumping rates or otherwise less robust variations on the selected alternative may be effective.

Mobile DNAPL is not present on Segment 2, which is the primary reason for considering a vertical barrier on this Site. Also, a vertical barrier will not reduce pump and treat discharge rates or further reduce groundwater discharges. Therefore a vertical barrier is not recommended for addition to the selected pump and treat alternative for Segment 2.

Table 6 shows that the total estimated cost for the selected alternative for Segment 2 is $6,000,000.

### 9.3 Expected Design Refinements

Source control design will begin upon receipt of agency approval of the selected alternatives for Segments 1 and 2. This GWFFS identified the following significant issues that will be resolved during design:

1. Vertical barrier technology
   - Geotechnical conditions along the cutoff wall alignment
   - Sheet pile or slurry wall depending on resolution of construction risk issues
   - If sheet pile, select material (i.e., steel, vinyl, or aluminum)
   - Need for sheet pile sealant and if so, sealant material type
   - If slurry wall, select type (i.e. soil bentonite, cement bentonite; this would require bench testing)
2. Treated groundwater discharge permit plan
   - What type of discharge permit
   - Permit conditions
   - Permit discharge limits (i.e., specific numeric limits; these are needed before groundwater treatment method can be finalized)
3. City of Portland Greenway requirements

# 10 GENERAL SCHEDULE FOR DESIGN AND CONSTRUCTION OF RECOMMENDED ALTERNATIVE

The overall project schedule is shown on Figure 15. This schedule provides context for how the design and construction of the recommended alternative will fit into the overall project. Within this schedule is a breakout of tasks related to design and construction of the recommended alternative. Specifically, the following approximate timelines are anticipated:

**Groundwater/DNAPL Source Control Design**

| | |
|---|---|
| 1. Prepare Source Control Design | Dec. 07 through Feb. 08 |
| a. Conduct Design Level Studies | Nov. 07 through Jan. 08 |
| 2. DEQ/EPA Review of Design | Mar. 08 through May 08 |
| 3. Finalize Source Control Design | June 08 through July 08 |
| 4. Obtain Construction Permits | Dec. 07 through July 08 |

**Construction of Groundwater DNAPL Source Controls**

| | |
|---|---|
| 1. Order Sheet Piles and other critical materials | Apr. 08 |
| 2. Order Treatment System | June 08 |
| 3. Mobilize Material/Equipment | July 08 |
| 4. Start Installation of Wells and vertical barrier | Aug. 08 |
| 5. Install Treatment System | Nov. 08 |
| 6. Complete Installation of Walls | Dec. 08 |

Design level studies potentially include, but are not limited to, vibration studies, exploratory studies to refine the extent and location of vertical barrier and well locations, final treatability studies, and sheet pile/slurry wall compatibility studies. The permitting process assumes that only upland related permits are necessary. Section 404 or related aquatic permits are not required for these upland activities, and therefore, there is no federal nexus for triggering an Endangered Species Consultation for the recommended alternative.

This design and construction schedule is very aggressive in several respects. Key points of coordination will be:

- Design level studies must be sufficiently identified and agreed to early in the design process to allow them to inform the design before the design completion deadline.

- Discussions during the design must be sufficient to ensure that DEQ/EPA comments do not alter the design to such an extent that additional studies are needed or major new technologies are required, which would cause the schedule to slip.
- The design must be sufficiently agreed to during the DEQ/EPA comment period such that major equipment and materials can be ordered.
- Discussions during design revisions based on DEQ/EPA comments must be sufficient to ensure that construction can proceed almost immediately after the final design is submitted to DEQ/EPA.

As discussed previously, the recommended bank stabilization alternative in Appendix F is expected to take place after the groundwater/DNAPL source controls are constructed. A detailed schedule for bank stabilization will be prepared and submitted to DEQ after the general concept is approved. It is anticipated that the primary activities related to bank stabilization in 2007 and 2008 will be obtaining permits and refining designs based on the permit agency and DEQ/EPA comments. Given typical shoreline permitting processes, bank stabilization could not proceed until 2009 at the earliest.

# 11 GENERAL O&M/PERFORMANCE MONITORING APPROACH FOR RECOMMENDED ALTERNATIVE

This section summarizes the general O&M and performance monitoring approach for the recommended alternative summarized in Section 9. The design will include a more detailed plan for both these aspects of the recommended alternative.

## 11.1 Operations and Maintenance

Once installed, vertical barriers, either sheet pile wall or slurry walls, will require little to no ongoing operation or maintenance. The pump and treat systems will be largely automated, but will still require daily inspection by an on-site treatment system operator. The design report will provide details on required treatment system O&M. O&M protocols will include testing and disposal of sludges, precipitates, spent carbon, or other treatment residuals. Discharge of treated groundwater will occur under a permit. The permit and required treatment system monitoring protocols will be detailed in the permit to be issued by DEQ. The extraction well screens will be inspected with a downhole camera during the first months of operation to evaluate the rate of mineralization and/or slime formation. If necessary, a periodic well screen maintenance program will be implemented to maintain well efficiency.

## 11.2 Performance Monitoring

Because the removal action goals for the project (Section 4) are based on physical measures rather than chemical measures, performance monitoring will be designed to show that hydraulic and DNAPL containment is achieved. Performance monitoring will consist of water level measurements at a network of monitoring wells throughout the upland capture area. It is expected that a system will be established that allows continuous monitoring of well water levels and monitoring of those levels remotely via telemetry. Transducers will be placed in selected monitoring wells to evaluate the hydraulic gradient being maintained by the system. The extraction well system will be constructed so that the extraction well flow rate can be set based on water levels in the extraction wells or water levels in surrounding monitoring wells. The water levels will be input to the ModFlow model to determine if capture is being achieved, and the results will be used to potentially modify extraction well pumping rates accordingly.

A DNAPL migration monitoring program will also be conducted as part of the performance monitoring. The details of this monitoring program will be included in the source control design. The current concept is that monitoring wells will be used to measure the change in DNAPL head that results from operation of the extraction system. This may require the installation of monitoring wells with very short screens in certain DNAPL saturation zones. Monitoring wells would also be used to determine if DNAPL is migrating under the influence of the extraction wells. This may require the installation of sentinel monitoring wells located just beyond the known boundary of upland DNAPL zones. Data from the DNAPL wells and sentinel wells would be used to determine where DNAPL is migrating under the influence of the extraction wells. This data would be assessed in the context of the Site-wide feasibility study to determine what additional action, if any, is needed for DNAPL source control, which could include operation of upland product recovery systems in areas where increased DNAPL mobility is identified during monitoring.

Chemical monitoring of groundwater is not proposed to assess the performance of the source controls because the removal action goals are not defined in terms of chemistry. Further, because it is known that chemical contamination exists on both sides of the hydraulic and physical barriers, there would be no clear way to differentiate whether the system was causing reductions in mass flux of chemicals toward the river. (As noted above, contamination on the CSM side of the source controls will be remediated through in-river remediation process.)

Performance per the DNAPL seepage removal action goal will be determined through visual regular inspections of the shoreline area (particularly at times of low water) to determine if any DNAPL seeps are present, as well as observations from monitoring wells to determine if any new movement of DNAPL on the upland side of the controls is occurring. It should be noted that the presence of DNAPL seeps along the shoreline may not be a direct indication of any loss of containment, but would likely relate to movement of DNAPL that is present on the CSM side of the vertical barrier. Consequently, if DNAPL seepage is observed, it is expected that this would initiate subsurface sampling events (exploratory borings) to understand and trace the source and origin of any DNAPL seepage along the shoreline.

## 12 PATH FORWARD

This document was submitted to DEQ in early October 2007. From this point forward, the expected sequence of events related to review of this GWFFS, design, and construction are detailed in Figure 15. In summary, the following milestones are expected to occur as the project moves to design and construction:

- DEQ and EPA complete review and comments on this GWFFS Dec. 07
- DEQ completes selection of source control interim action Jan. 08
- Public notice period on interim action is completed Feb. 08
- Design level studies (surface water, vibration, etc.) complete Jan. 08
- Draft source control design completed Mar. 08
- DEQ and EPA review of draft design complete May 08
- Final source control design completed July 08
- Construction permits obtained July 08
- Construction begins Aug. 08

As with any project, unexpected delays may occur for unforeseen or uncontrollable reasons. It is NW Natural's intent to initiate construction of source controls within 2008 and to work proactively with DEQ and EPA on any issues within NW Natural's control to adhere to this timeline.

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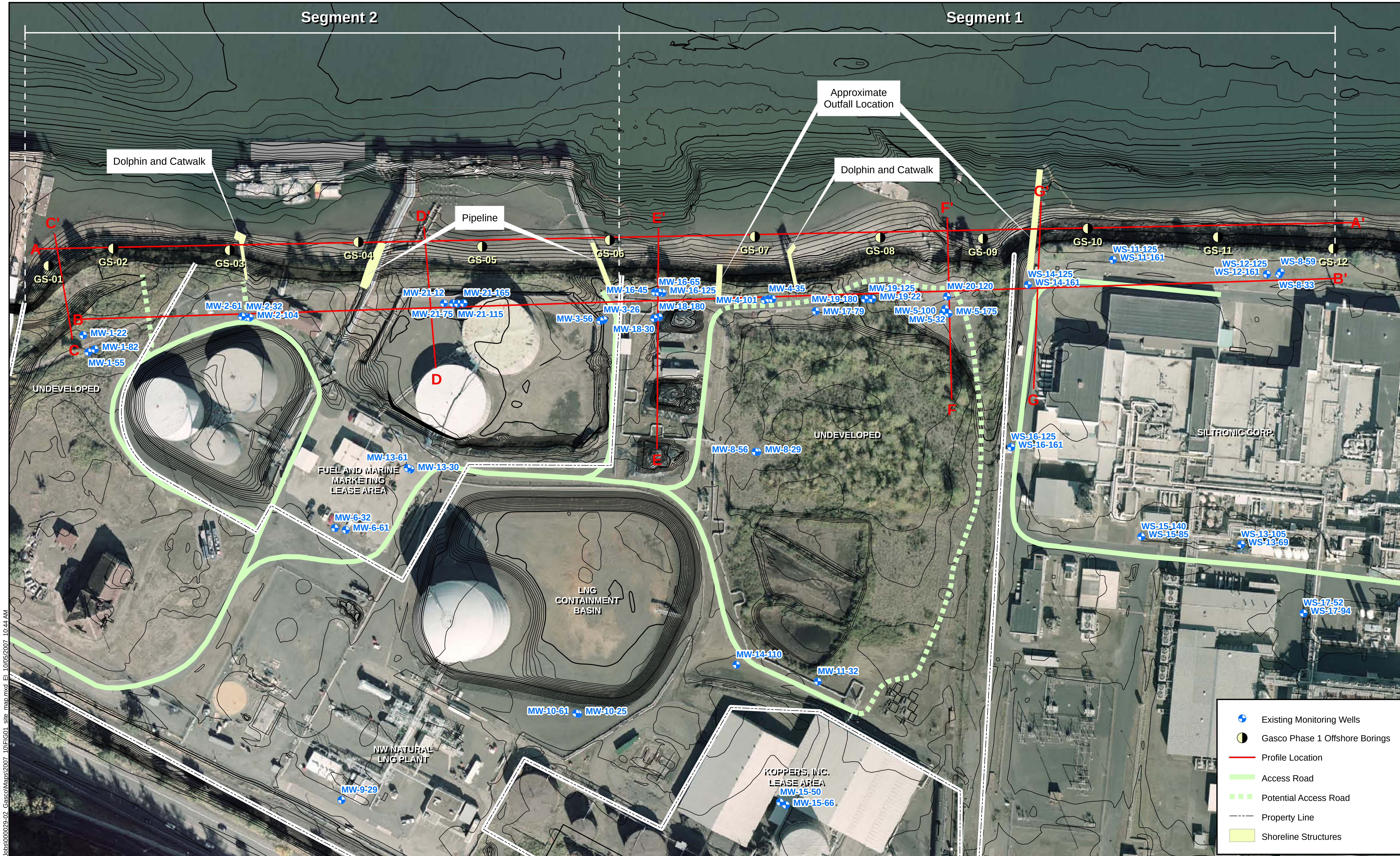
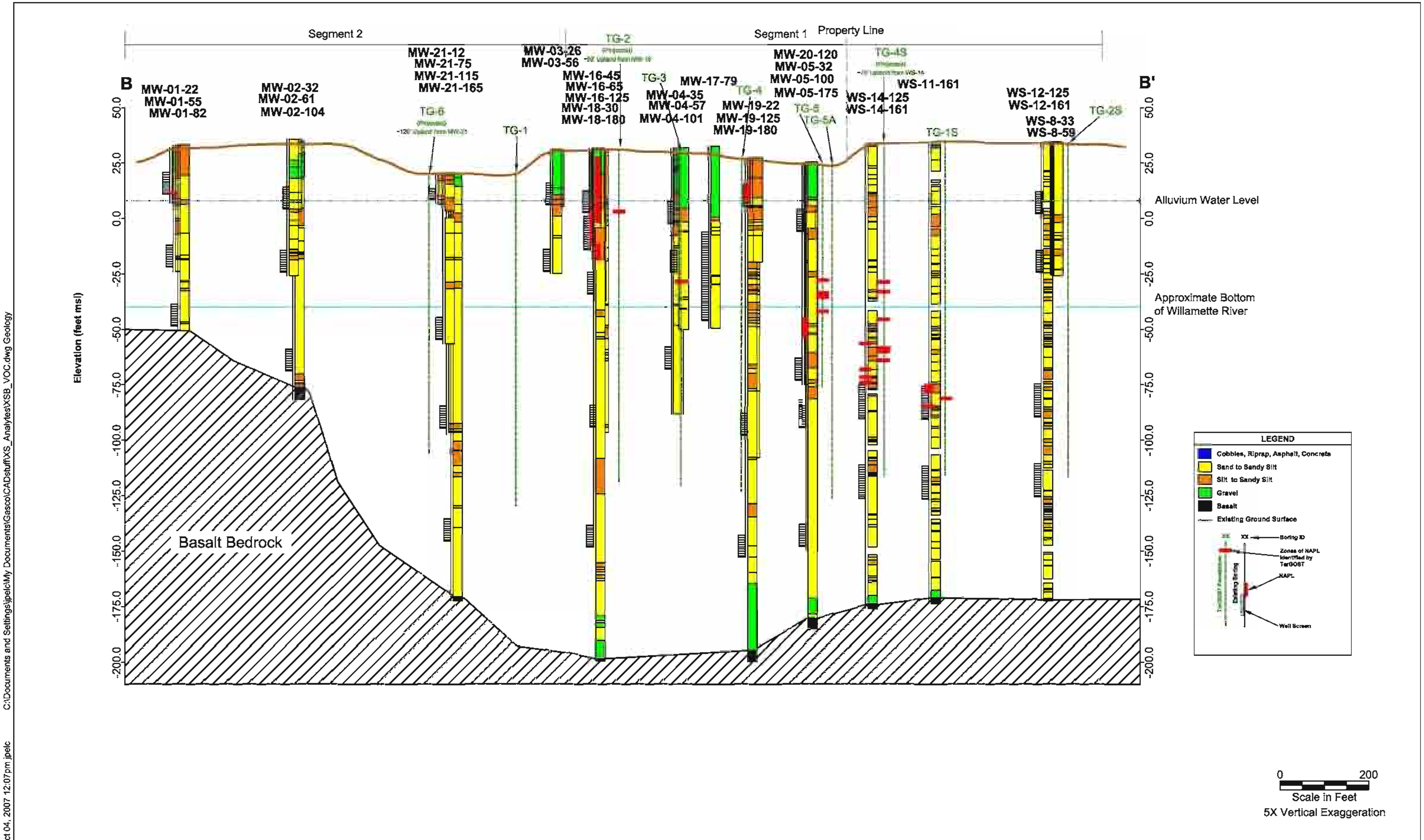
# Figures



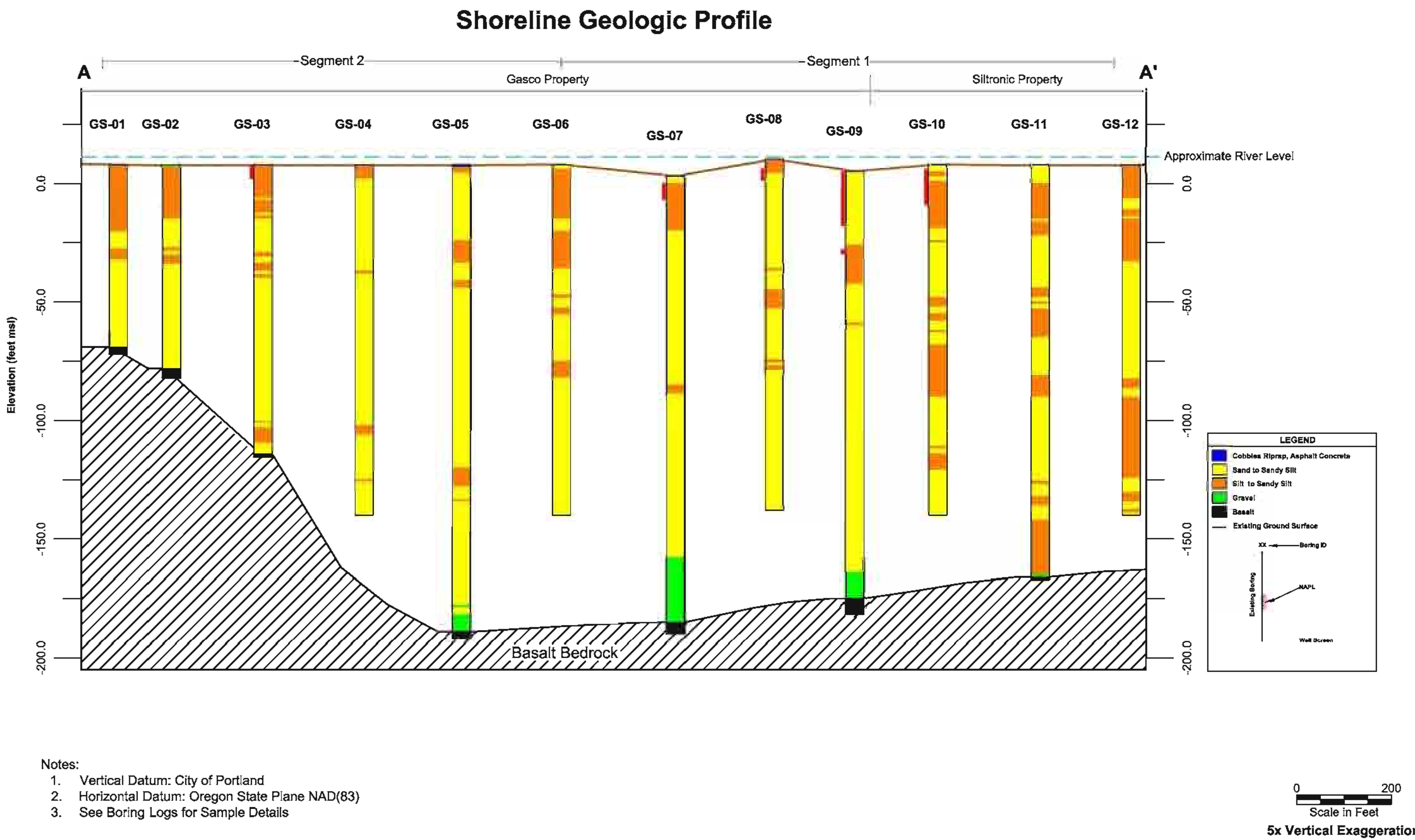

ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 1**
Site Map
Gasco/Siltronic
Portland, Oregon




ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 2**
Geologic Profile B-B'
Top of Bank
Gasco/Siltronic, Portland, Oregon




Notes:
1. Vertical Datum: City of Portland
2. Horizontal Datum: Oregon State Plane NAD(83)
3. See Boring Logs for Sample Details

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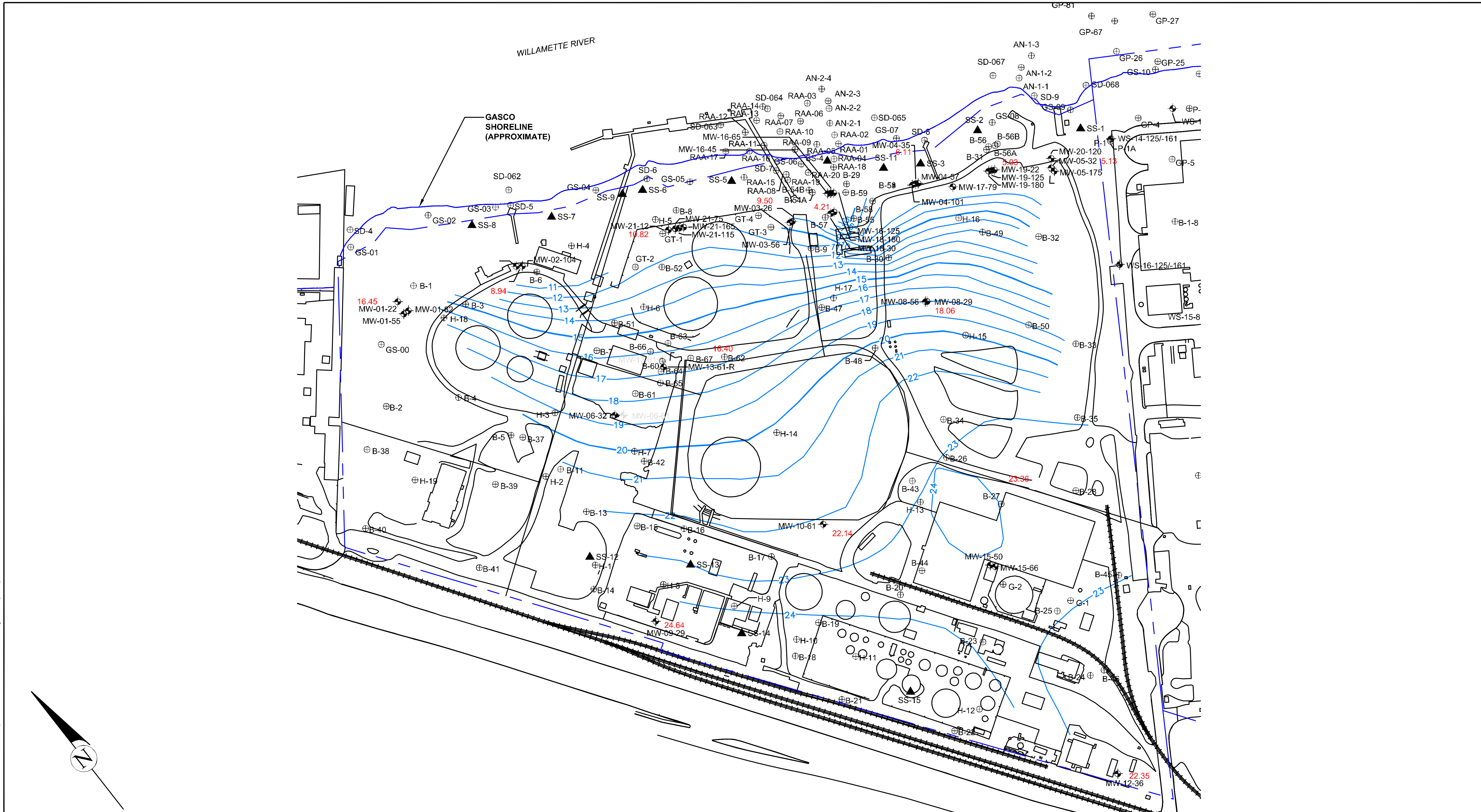
ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 3**
Geologic Profile A-A'
Shoreline
Gasco/Siltronic, Portland, Oregon




# LEGEND

- Monitoring Well
- Soil Boring
- Property Line (Approximate)
- Isocontour Line - Groundwater Elevation
- 23.79 Groundwater Elevation (feet MSL, City of Portland Datum)

## HAHN AND ASSOCIATES, INC.

ENVIRONMENTAL CONSULTANTS
434 NW 6th AVENUE, SUITE 203
PORTLAND, OREGON 97209
503-796-0717

Scale: 1 inch = 200 feet

200 0 200 400 feet

Project No. 2708-5237 REV. SEPTEMBER 2007

# FIGURE 4A

## GROUNDWATER ELEVATION MAP

Surficial Fill WBZ Wells
September 6, 2007

NW Natural Gasco Facility
7900 NW St. Helens Road
Portland, Oregon

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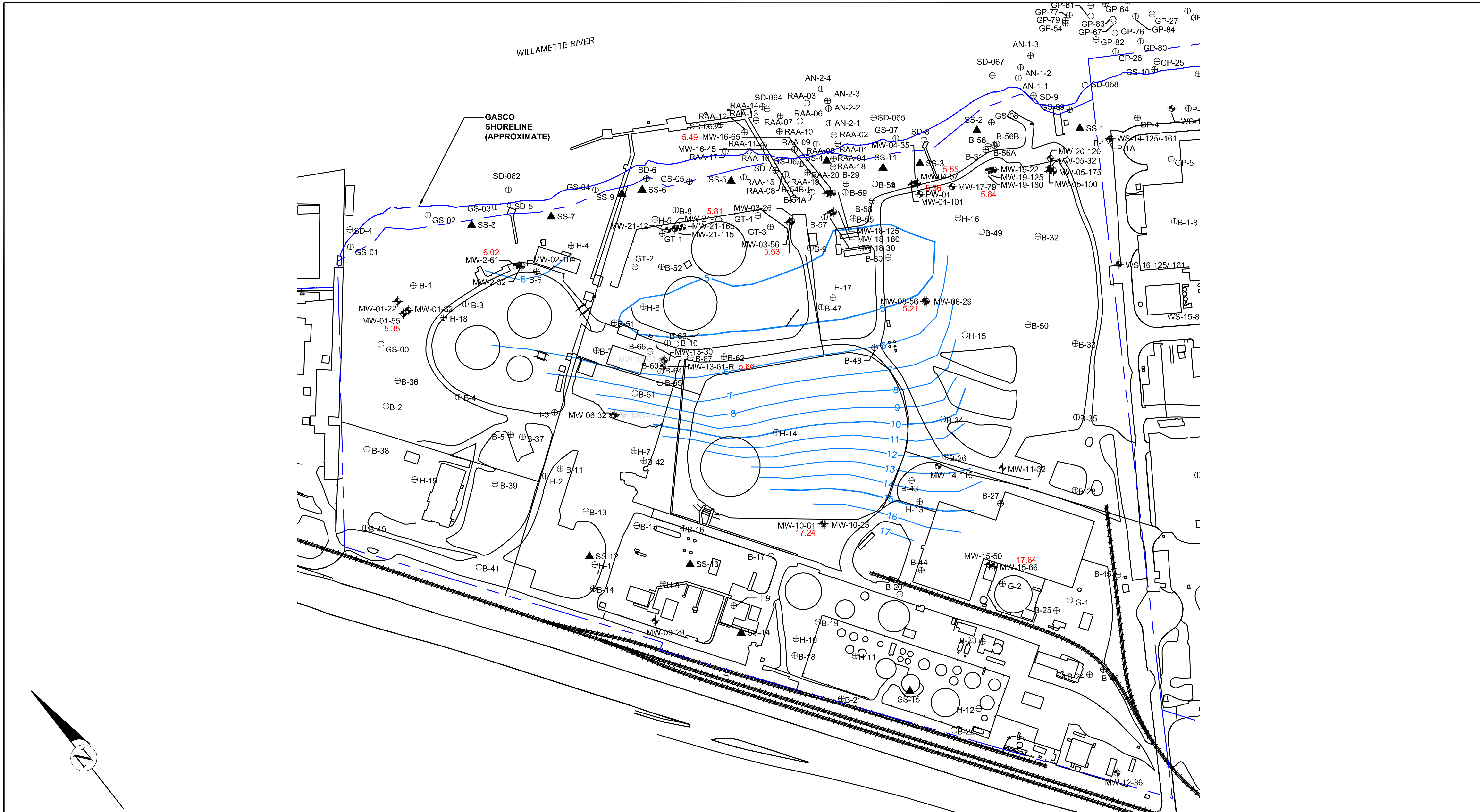


# LEGEND

- Monitoring Well
- Soil Boring
- Property Line (Approximate)
- Isocontour Line - Groundwater Elevation
- 23.79 Groundwater Elevation (feet MSL, City of Portland Datum)

**HAHN AND ASSOCIATES, INC.**

ENVIRONMENTAL CONSULTANTS
434 NW 6th AVENUE, SUITE 203
PORTLAND, OREGON 97209
503-796-0717

Scale: 1 inch = 200 feet

200 0 200 400 feet

Project No. 2708-5237 REV. SEPTEMBER 2007

# FIGURE 4B

## GROUNDWATER ELEVATION MAP

## Alluvial WBZ Wells - to 85' BGS (UPPER) - September 6, 2007

NW Natural Gasco Facility
7900 NW St. Helens Road
Portland, Oregon

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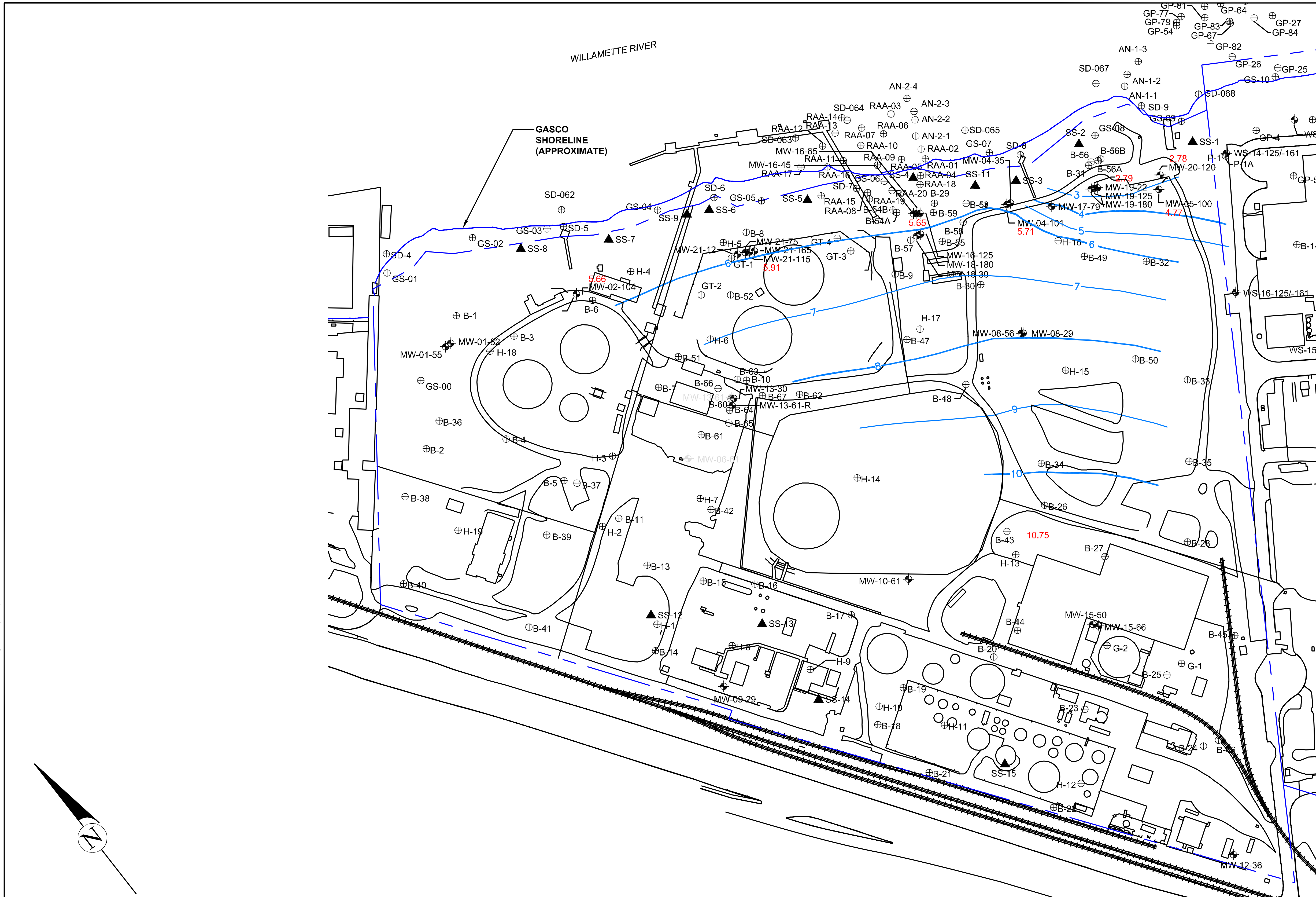


LEGEND

- Monitoring Well
- Soil Boring
- Property Line (Approximate)
- Isocontour Line - Groundwater Elevation
- 23.79 Groundwater Elevation (feet MSL, City of Portland Datum)

HAHN AND ASSOCIATES, INC.

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434 NW 6th AVENUE, SUITE 203
PORTLAND, OREGON 97209
503-796-0717

Scale: 1 inch = 200 feet

200 0 200 400 feet

Project No. 2708-5237 REV. SEPTEMBER 2007

# FIGURE 4C

## GROUNDWATER ELEVATION MAP
## Alluvial WBZ Wells - 85 to 125' BGS (Intermediate) September 6,2007

NW Natural Gasco Facility
7900 NW St. Helens Road
Portland, Oregon

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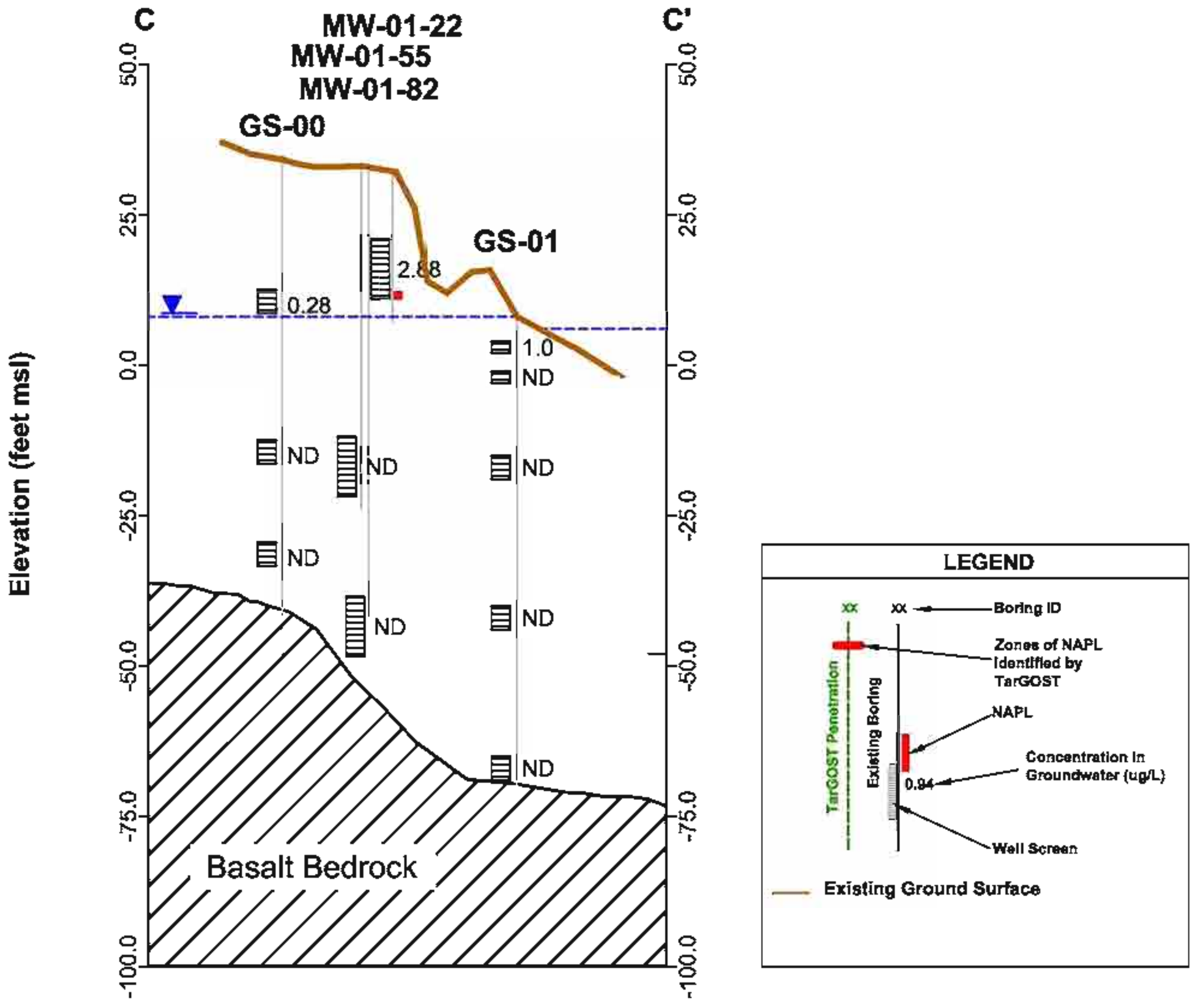


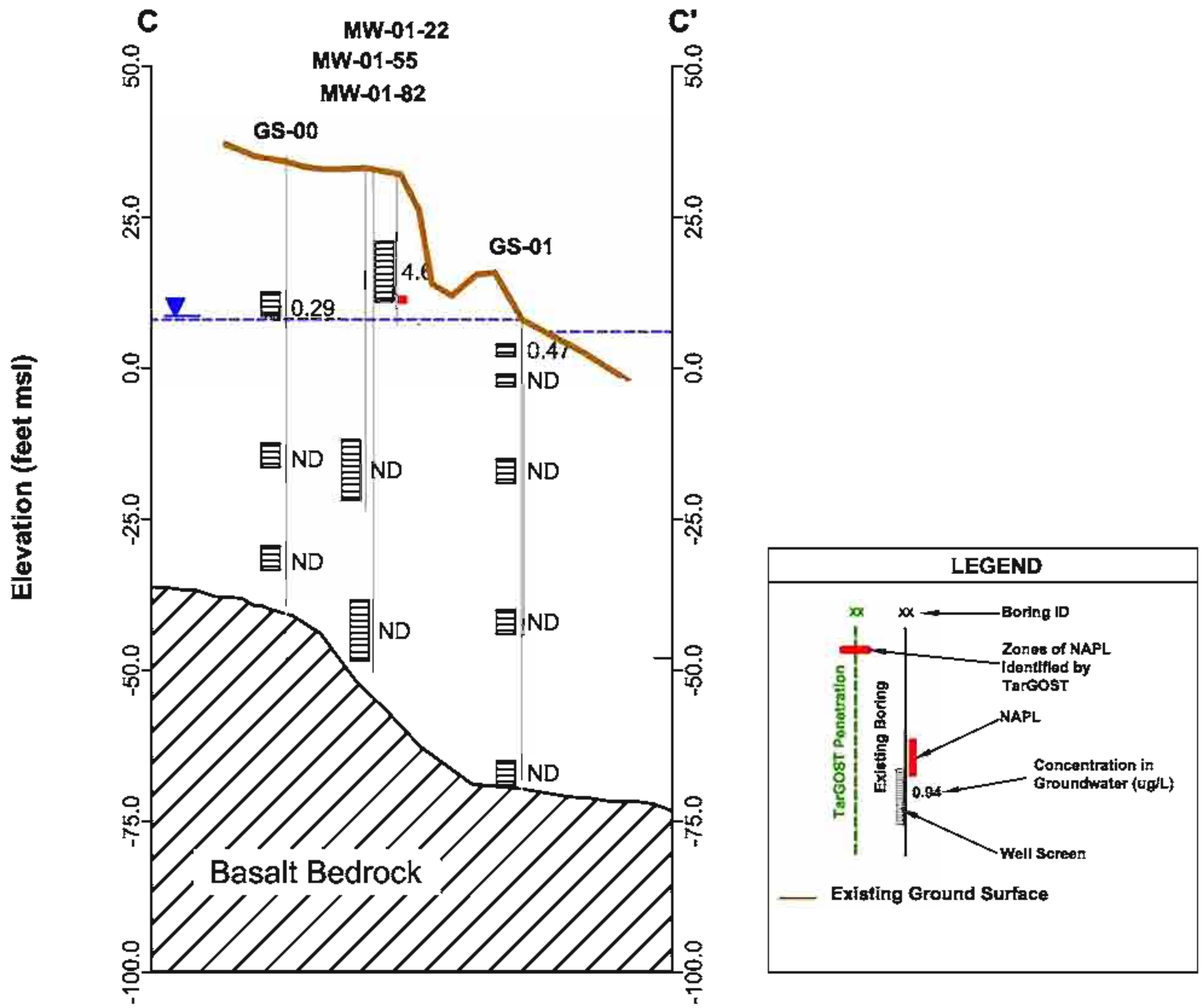

Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum



ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-C1**
C-C' Benzene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon



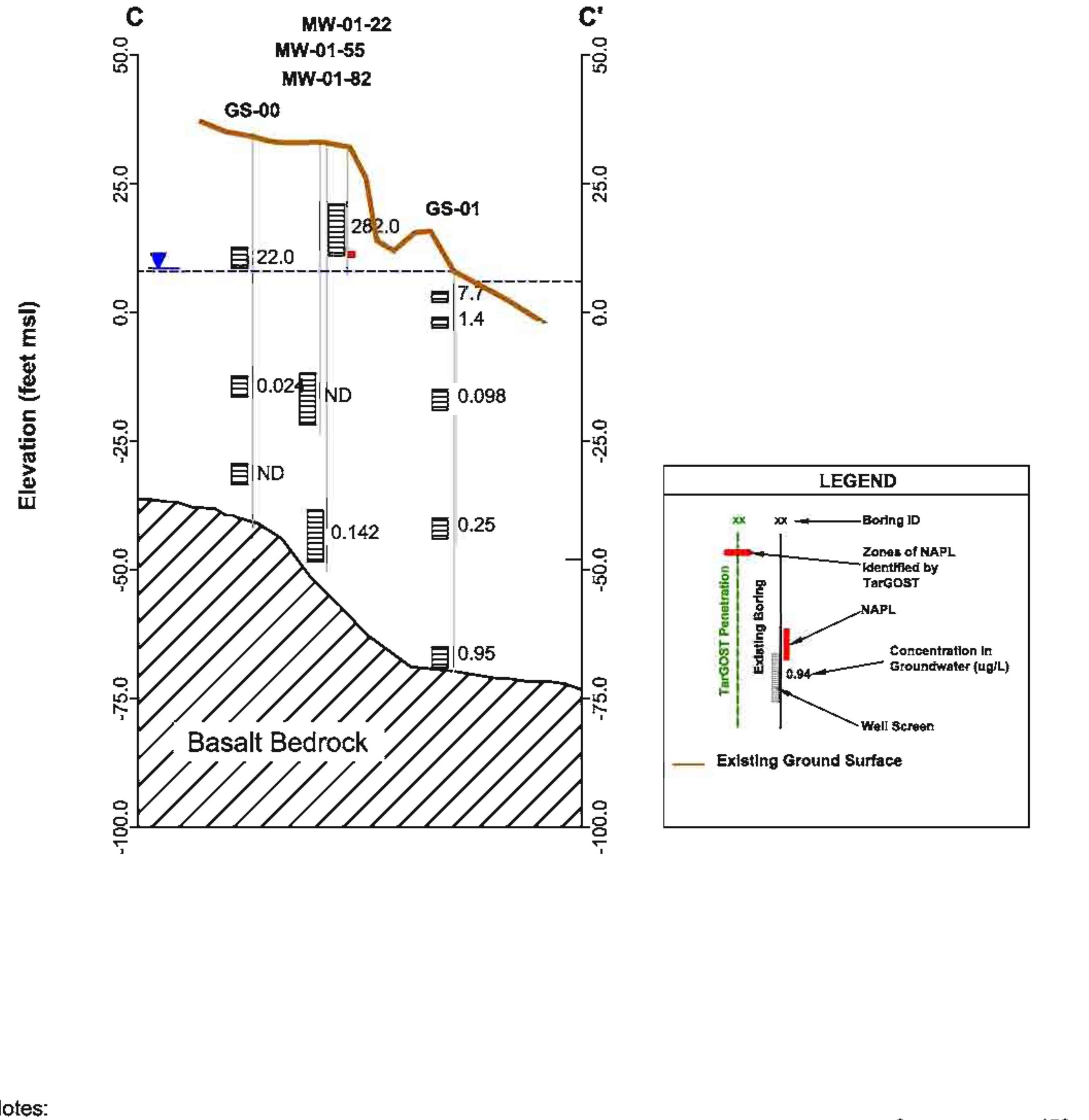

Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

Oct 03, 2007 9:46am jpelc C:\Documents and Settings\jpelc\My Documents\Gasco\CADstuff\XS_Analytes\XSC.dwg Toluene

ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-C2**
C-C' Toluene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon



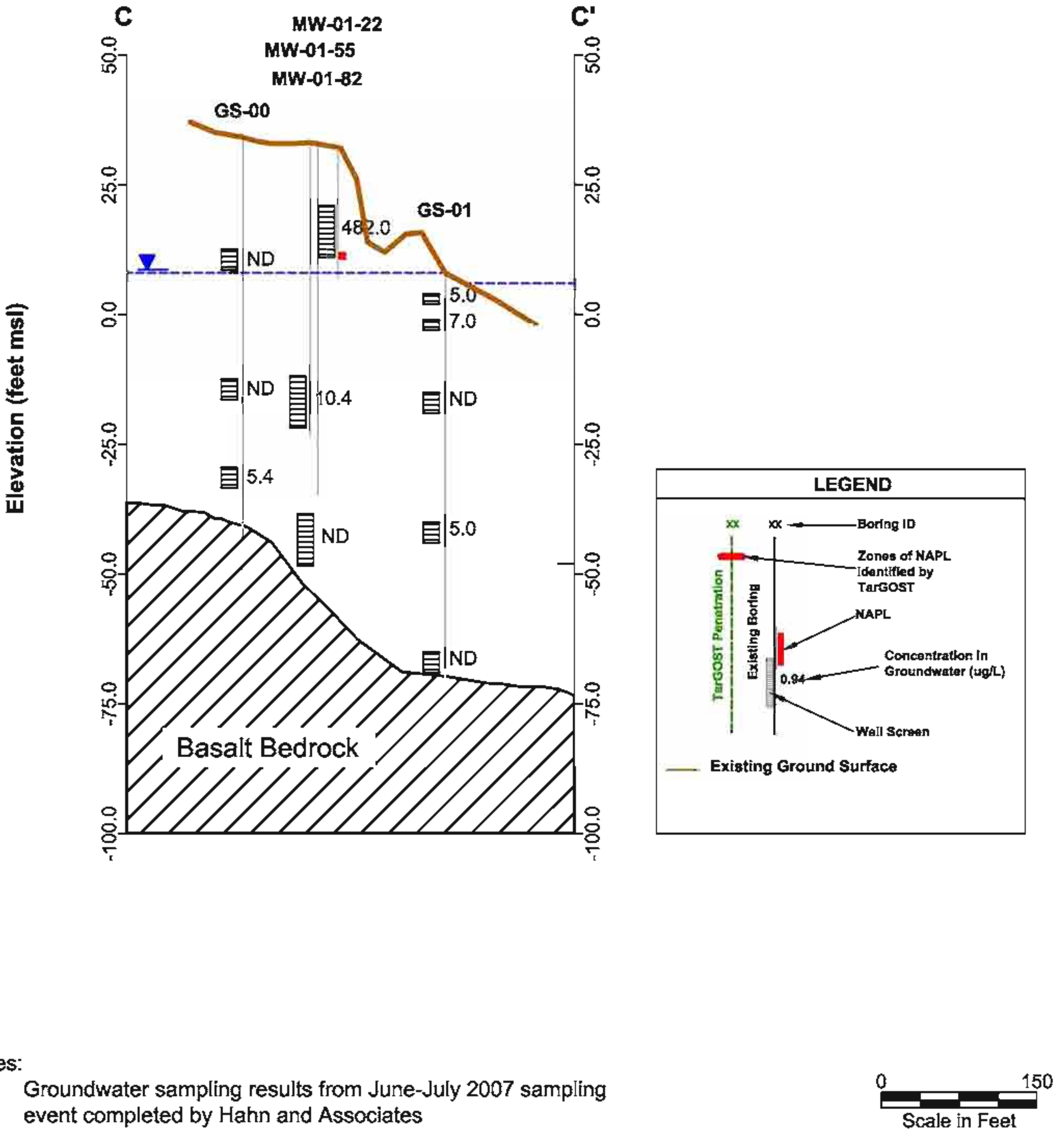

Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

Oct 03, 2007 9:46am jpelc C:\Documents and Settings\jpelc\My Documents\Gasco\CAD\stuff\XS_Analytes\XSC.dwg Naphthalene

ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-C3**
C-C' Naphthalene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon




Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

5X Vertical Exaggeration

Oct 03, 2007 9:47am jpelc C:\Documents and Settings\jpelc\My Documents\Gasco\CADstuff\XS_Analytes\XSC.dwg Free Cyanide

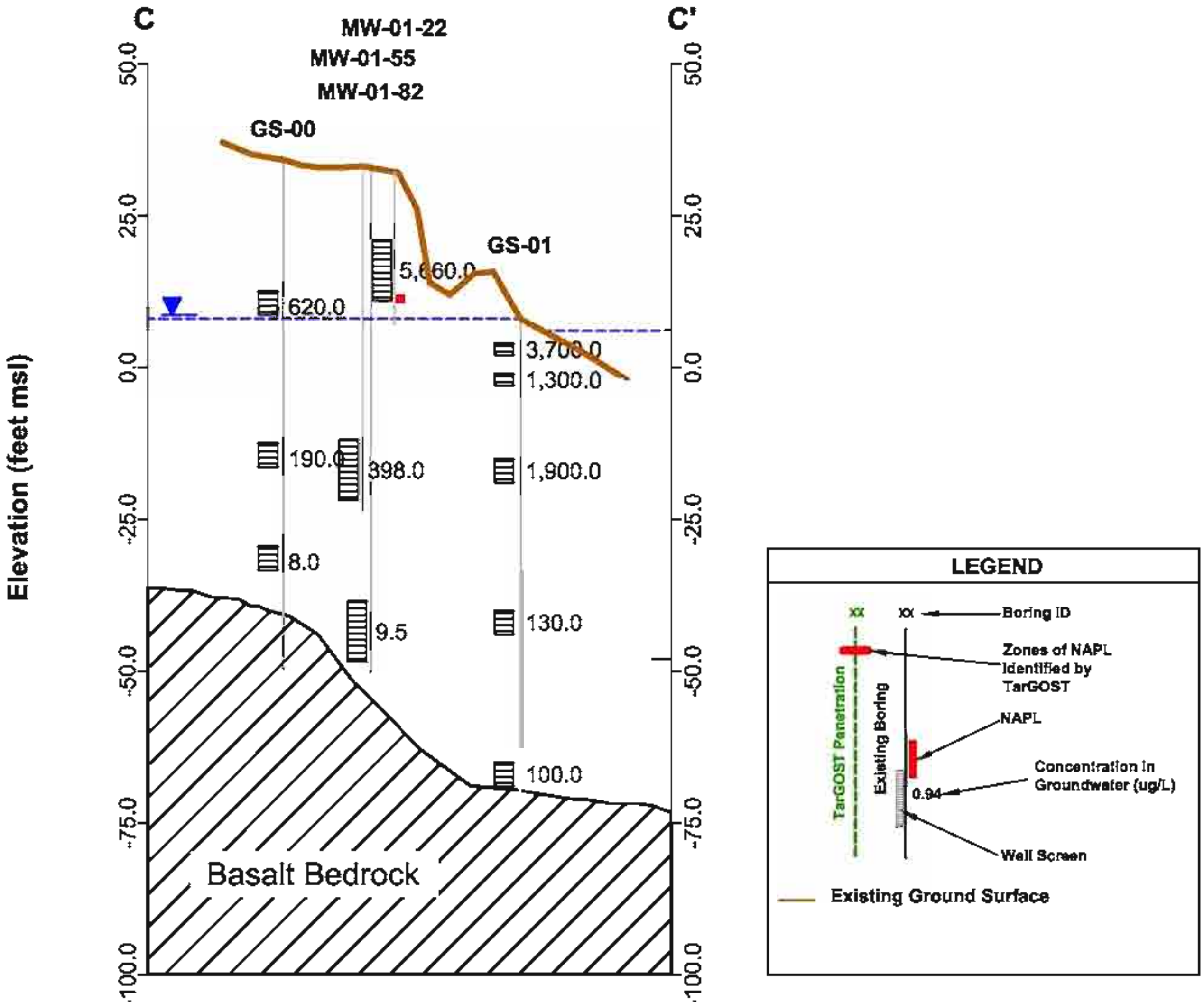
ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-C4**

C-C' Free Cyanide in Groundwater

Groundwater Focused Feasibility Study

Gasco/Siltronic, Portland, Oregon



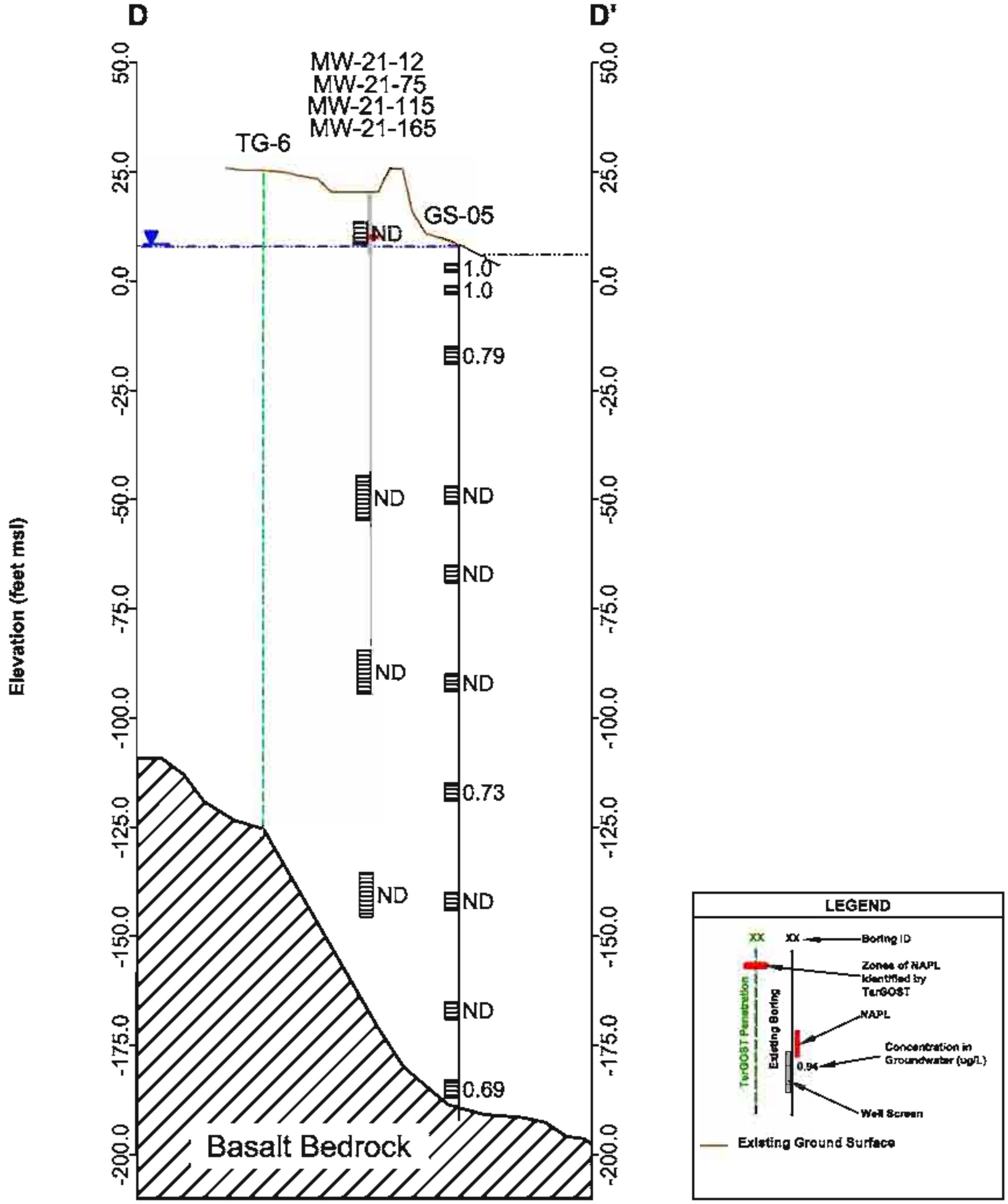

Notes:
1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum


5X Vertical Exaggeration



ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-C5**
C-C' Total Cyanide in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon








Notes:

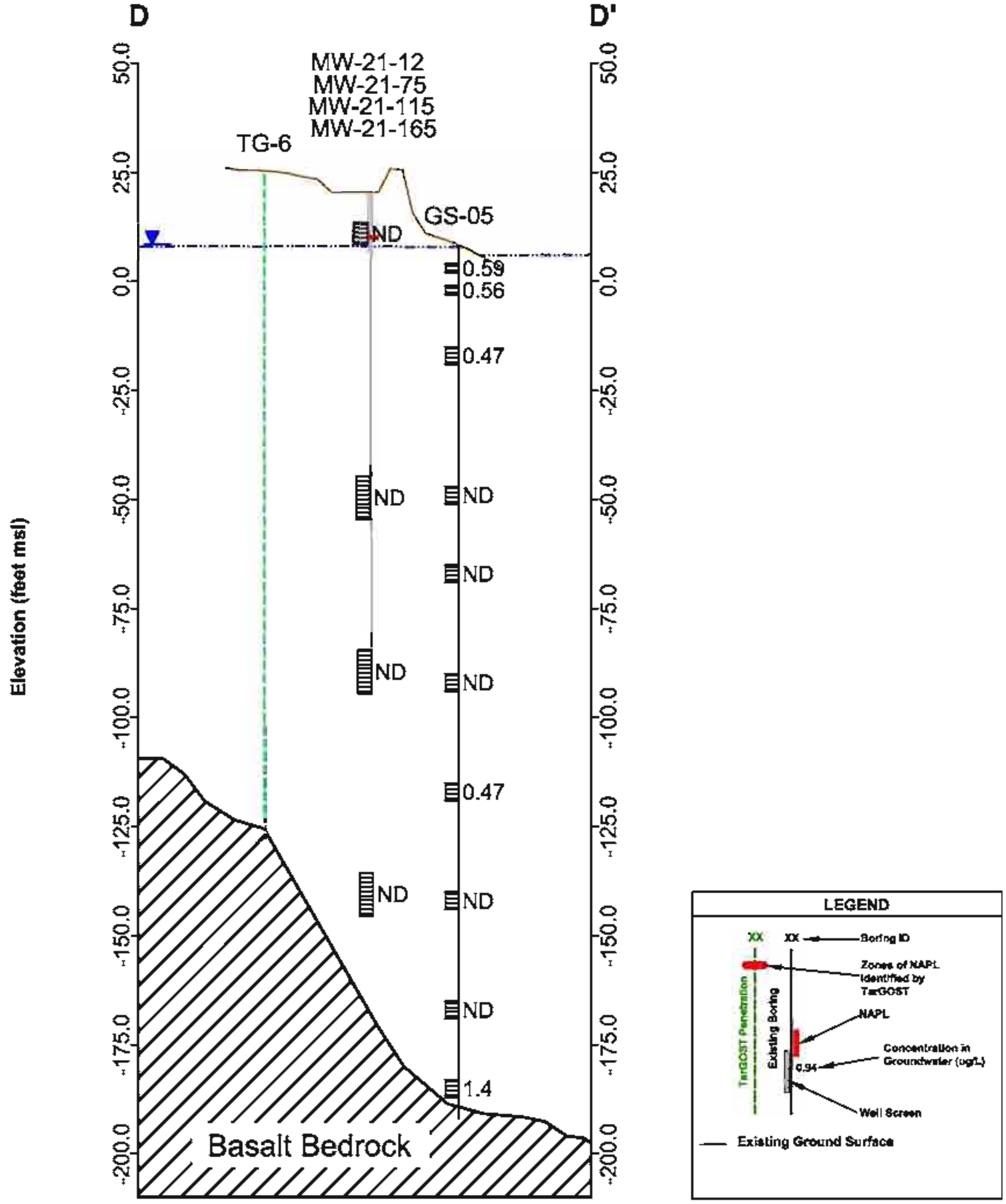
1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

0 200
Scale in Feet

5X Vertical Exaggeration

ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-D1**
D-D' Benzene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon




Notes:
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2. City of Portland vertical datum

0 200
Scale in Feet

5X Vertical Exaggeration

C:\Documents and Settings\jpelc\My Documents\Gasco\CADstuff\XS_Analytes\XSD.dwg Toluene

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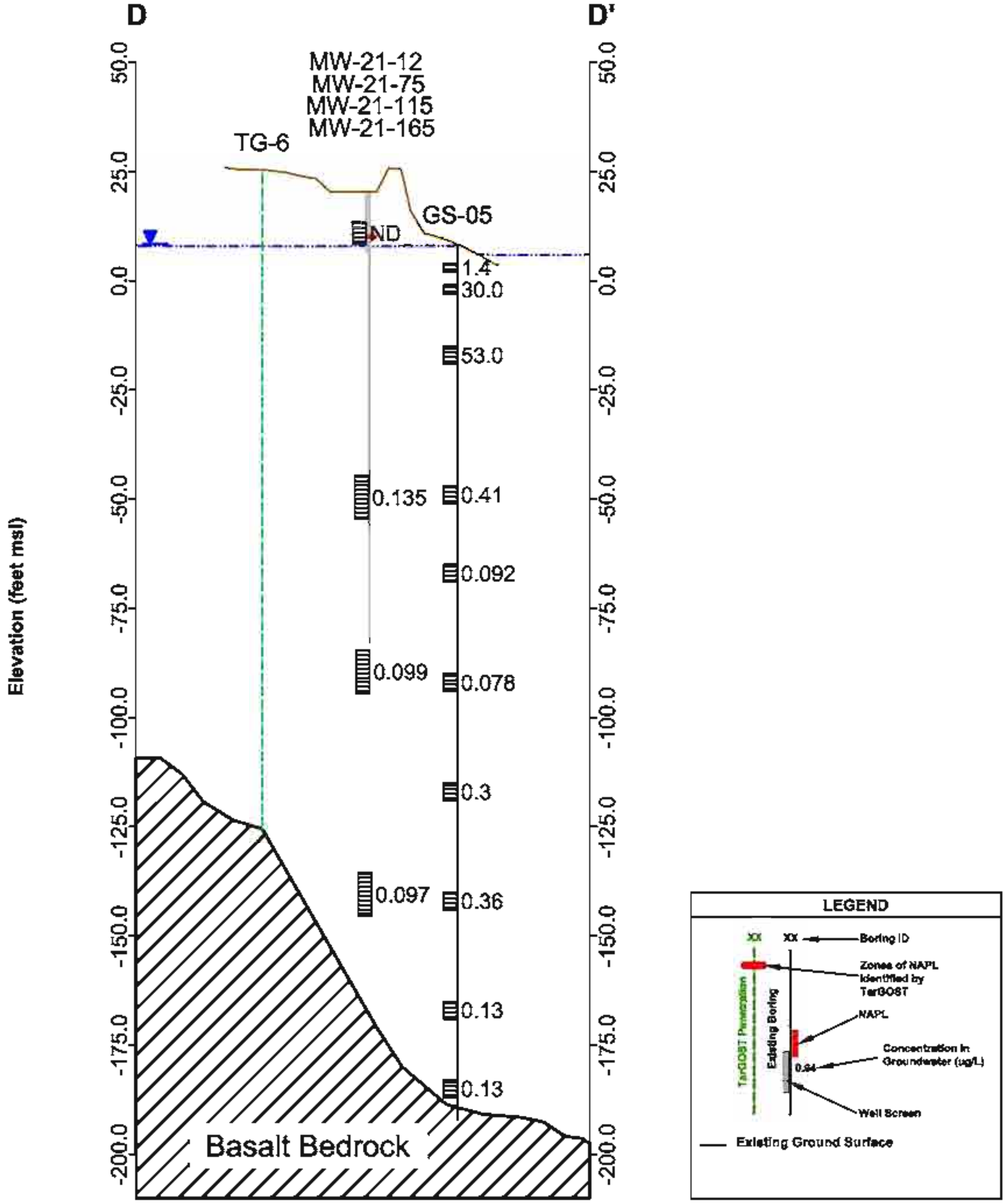
ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-D2**
D-D' Toluene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon



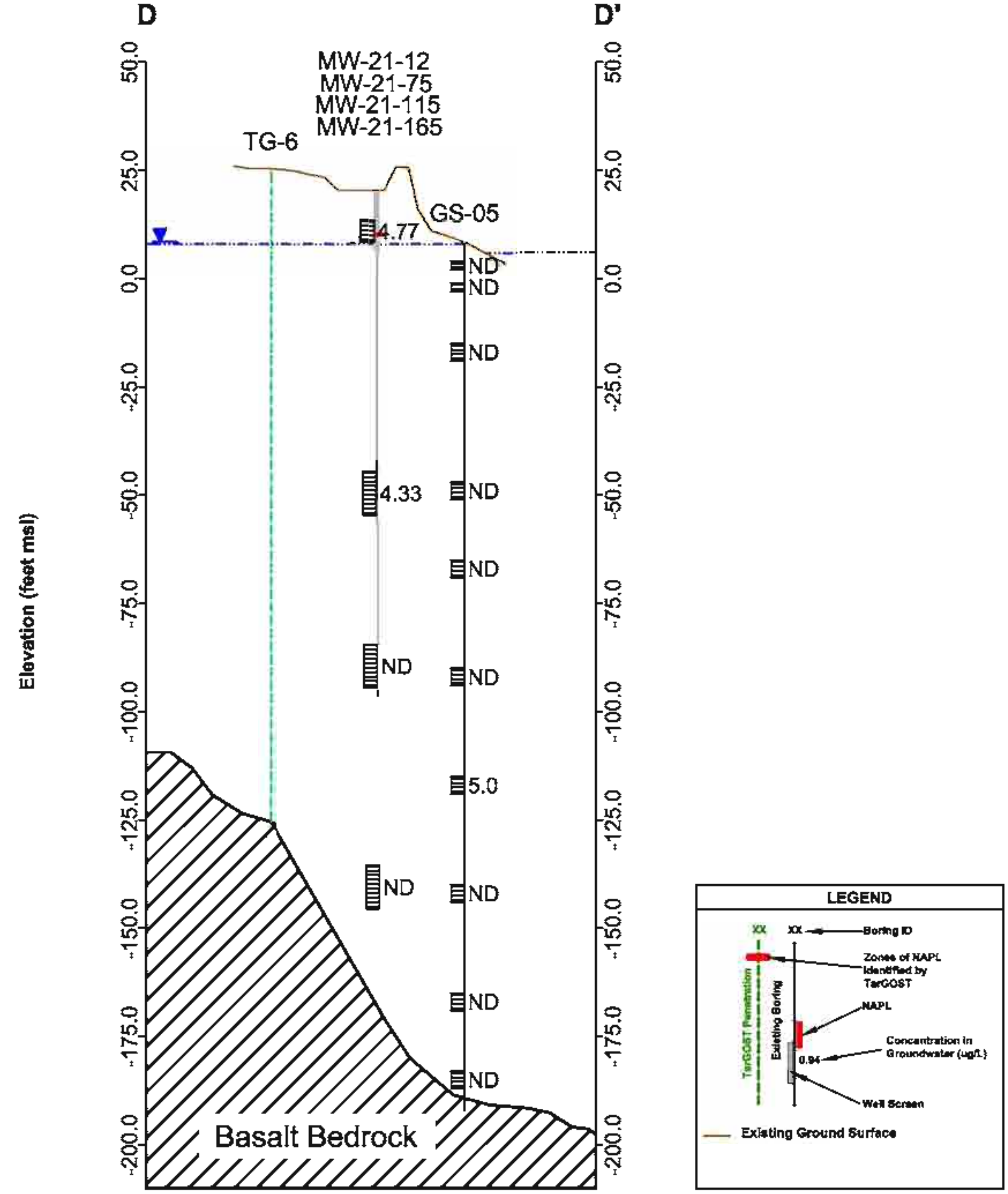

Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

5X Vertical Exaggeration

**Figure 5-D3**
D-D' Naphthalene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon

ANCHOR ENVIRONMENTAL, L.L.C.




Notes:

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2. City of Portland vertical datum

0 200
Scale in Feet

5X Vertical Exaggeration

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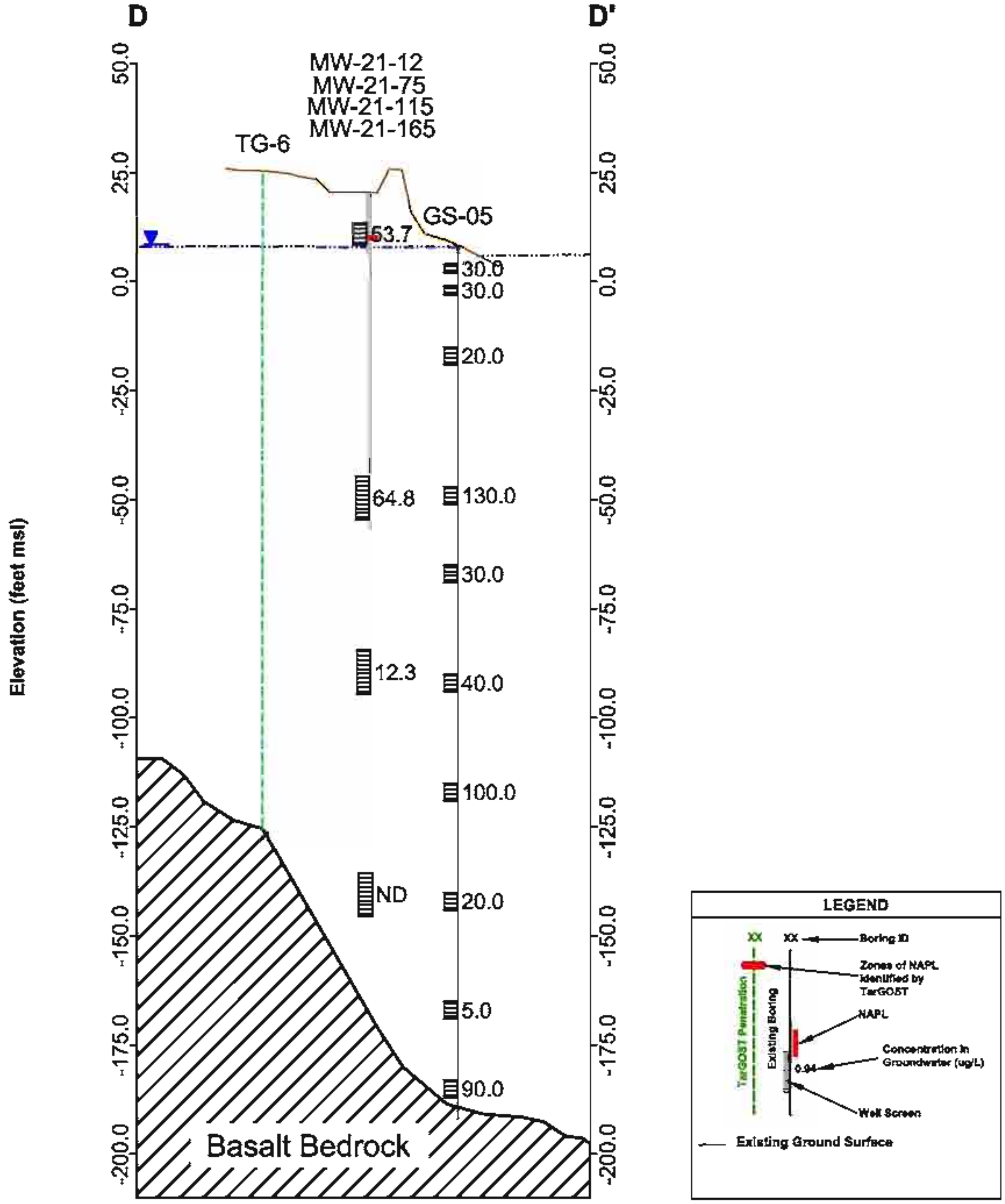
Oct 03, 2007 9:49am jpelc

**Figure 5-D4**
D-D' Free Cyanide in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon

ANCHOR ENVIRONMENTAL, L.L.C.








Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

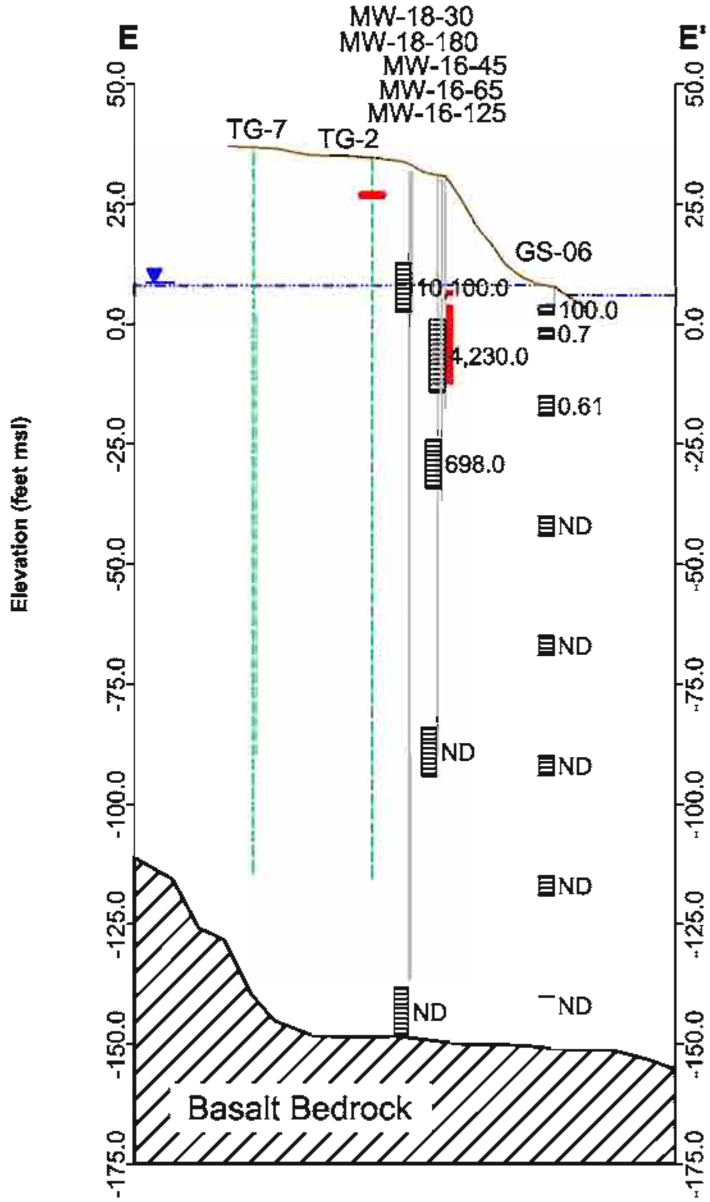
**Figure 5-D5**

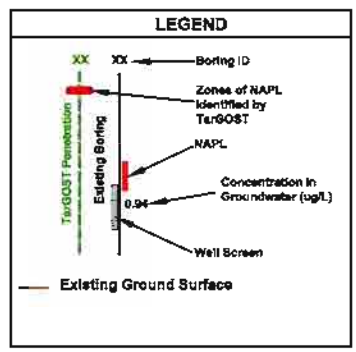
D-D' Total Cyanide in Groundwater

Groundwater Focused Feasibility Study

Gasco/Siltronic, Portland, Oregon

ANCHOR ENVIRONMENTAL, L.L.C.




Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

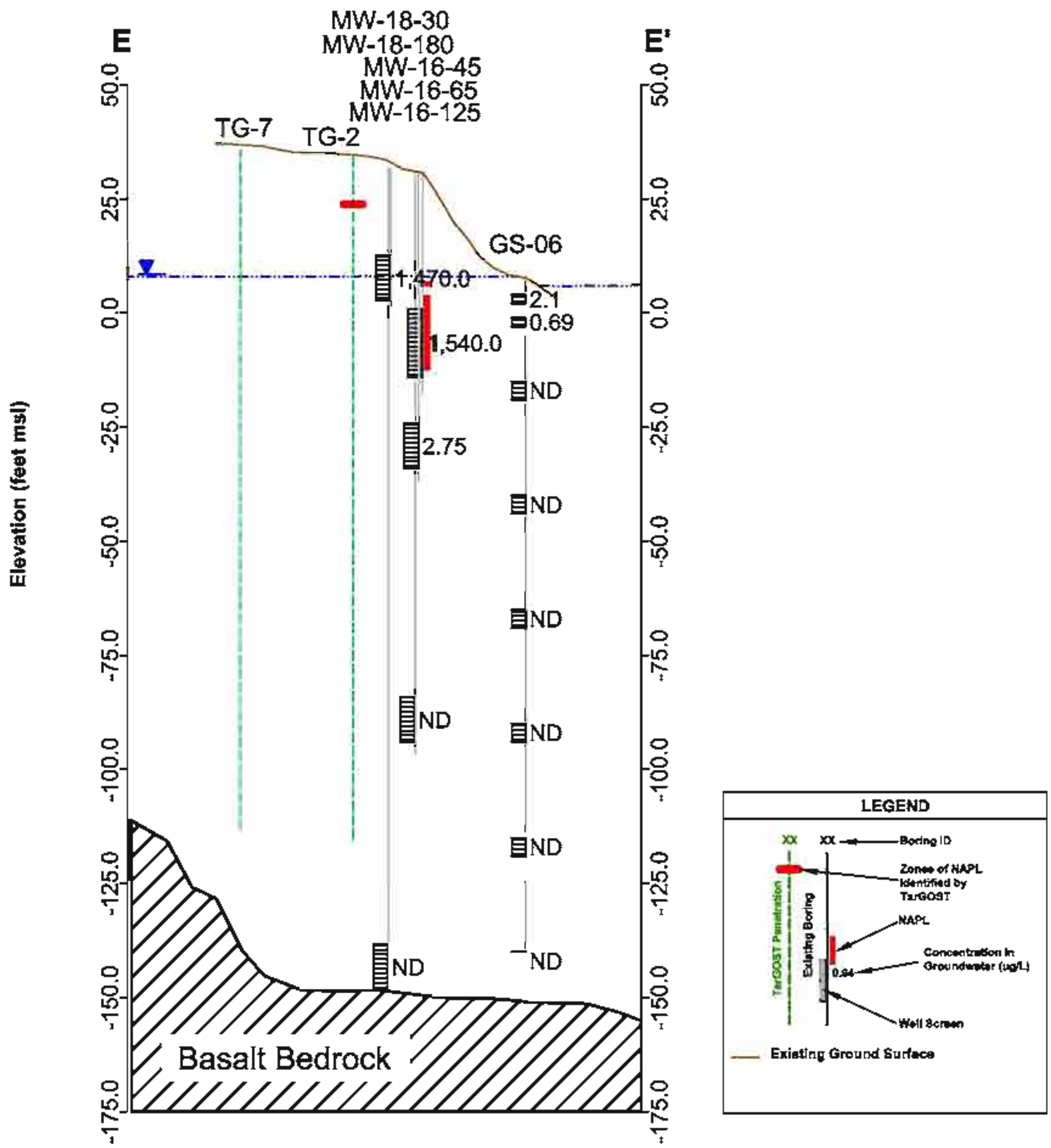
0 200
Scale in Feet

5X Vertical Exaggeration



ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-E1**
E-E' Benzene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon





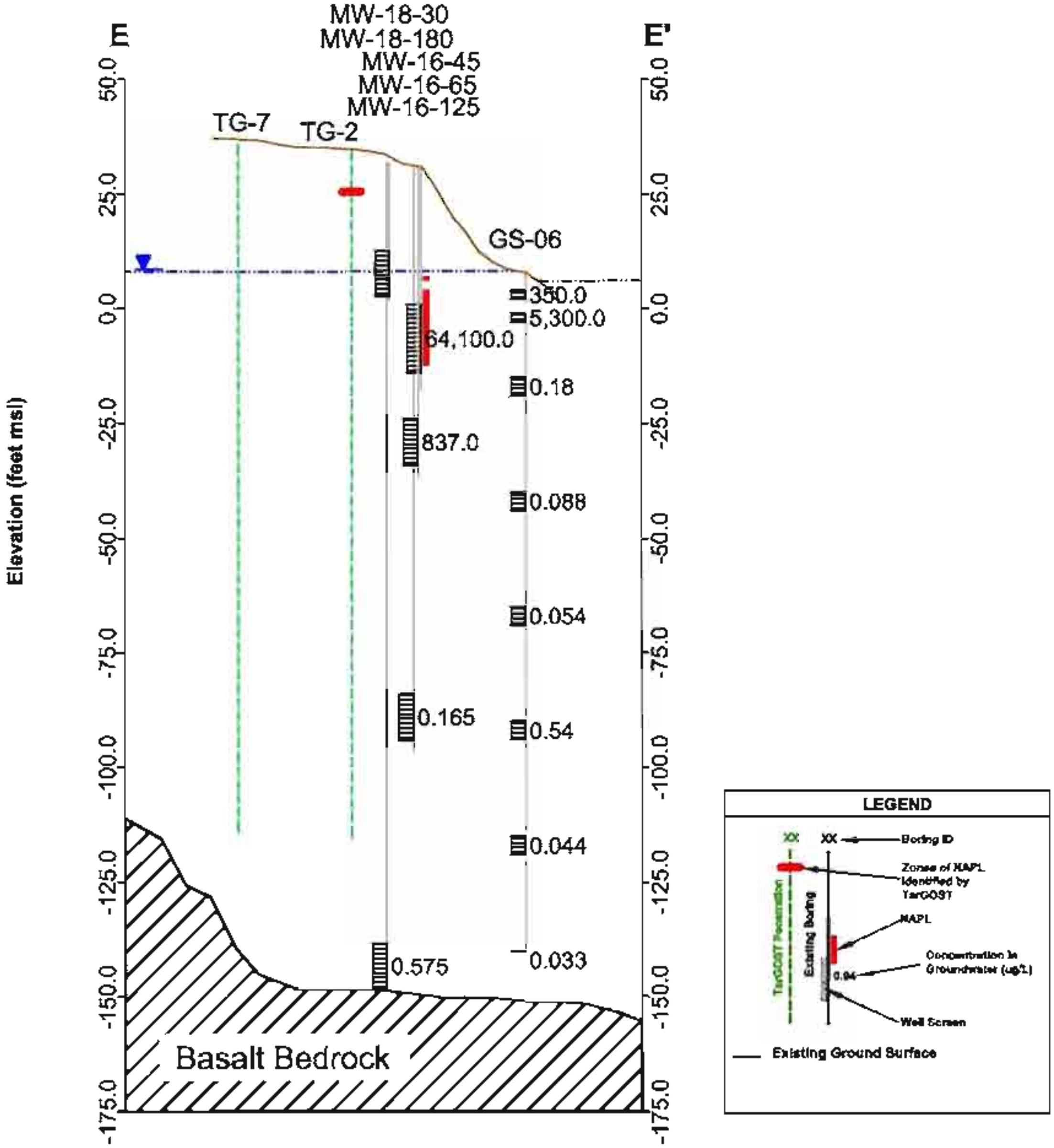

Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum


5X Vertical Exaggeration

ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-E2**
E-E' Toluene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon

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Notes:

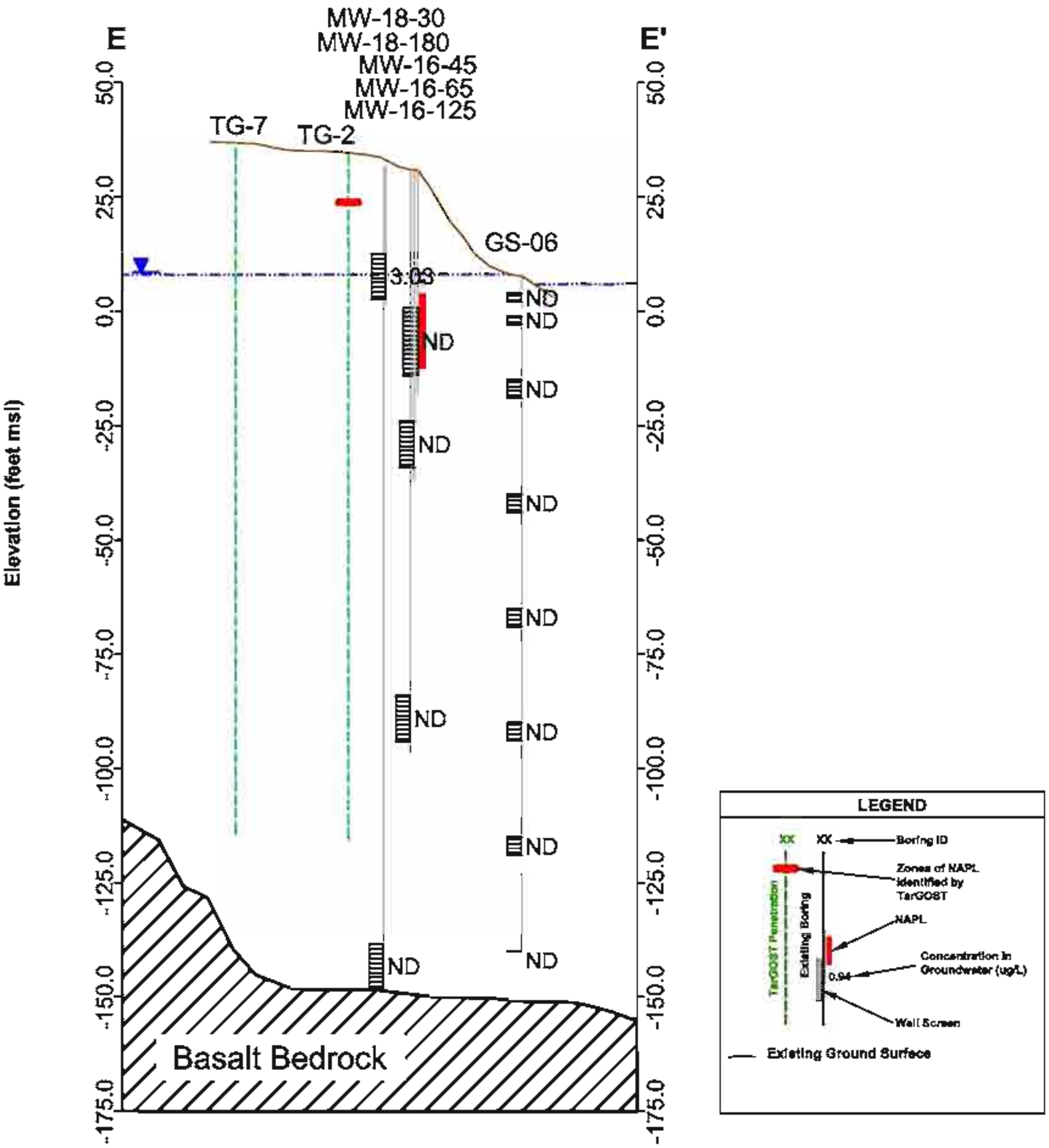
1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

0 200
Scale in Feet

5X Vertical Exaggeration

ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-E3**
E-E' Naphthalene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon

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Oct 05, 2007 8:29am jpelc

Notes:

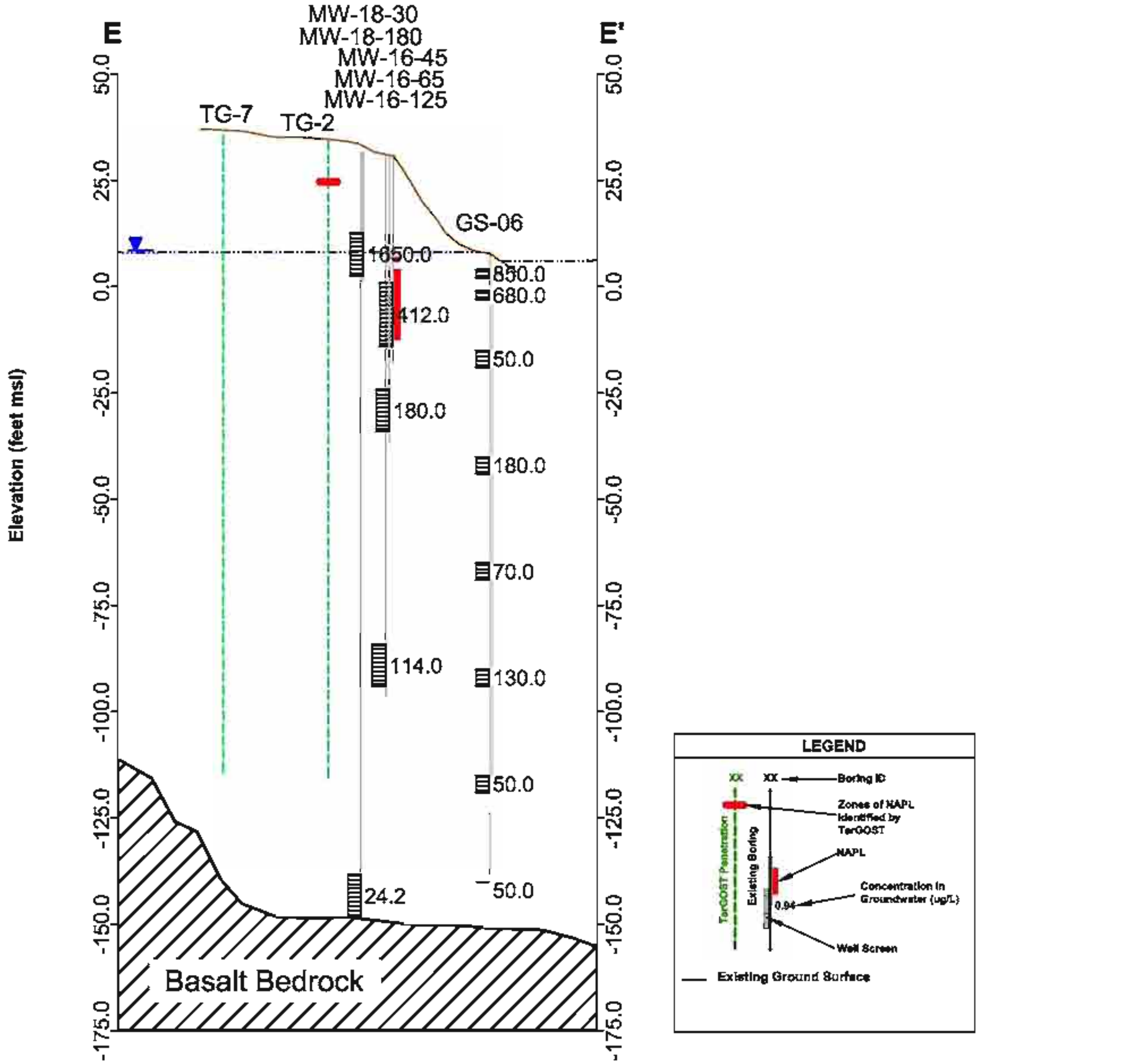
1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

0 200
Scale in Feet

5X Vertical Exaggeration

ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-E4**
E-E' Free Cyanide in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon

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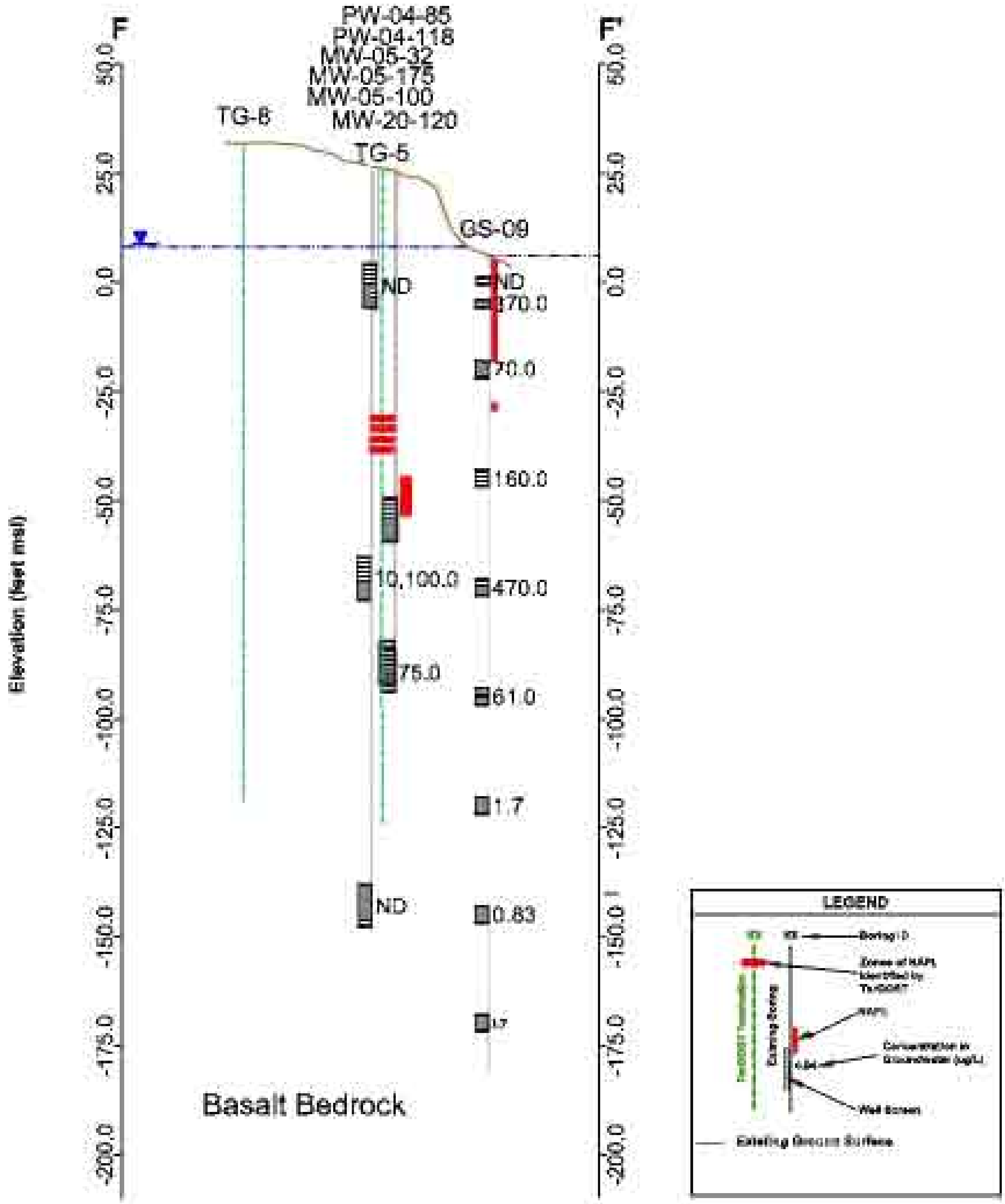
Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-E5**

E-E' Total Cyanide in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon




Notes:

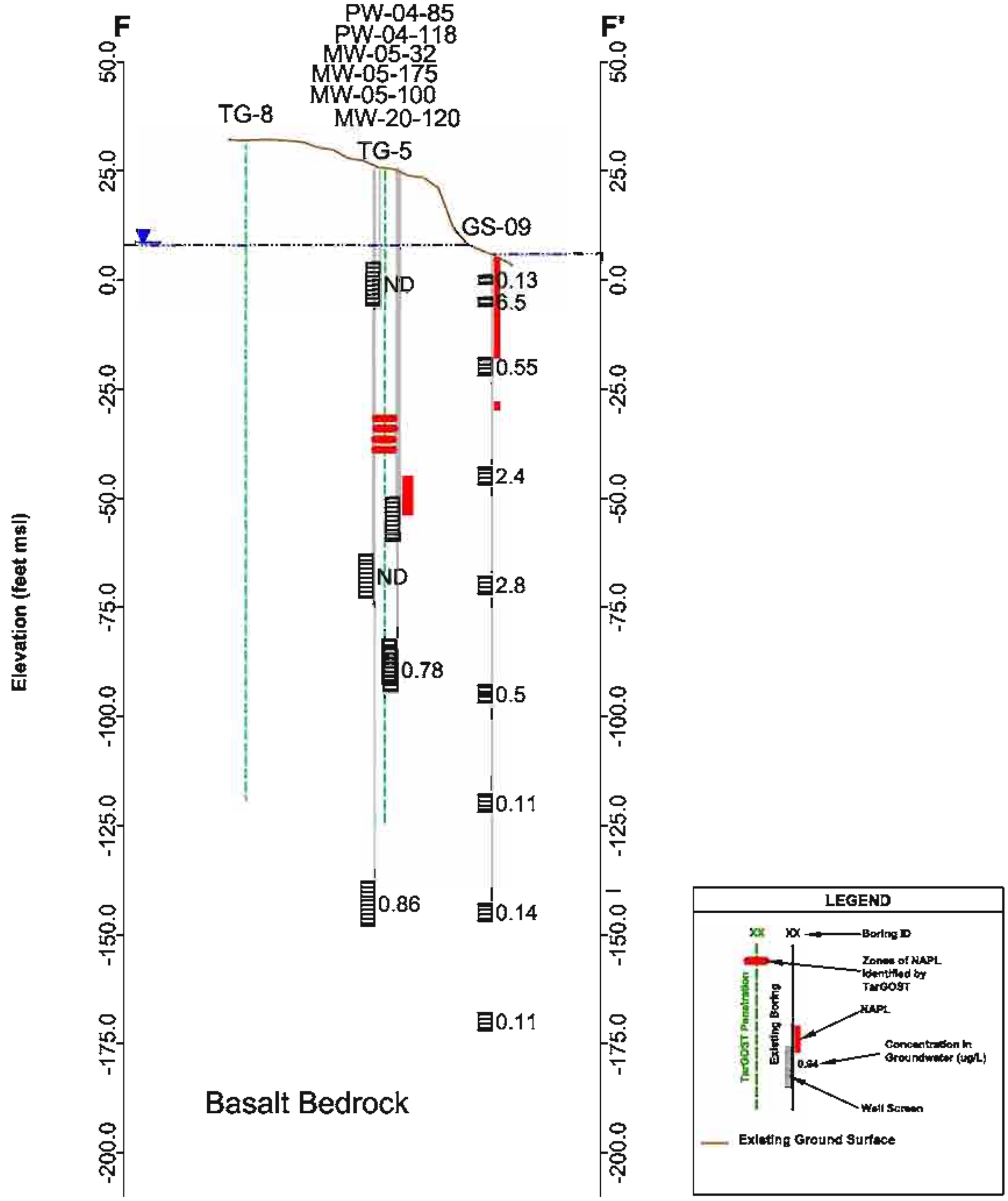
1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum


5X Vertical Exaggeration



ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-F1**
F-F' Benzene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon




Notes:
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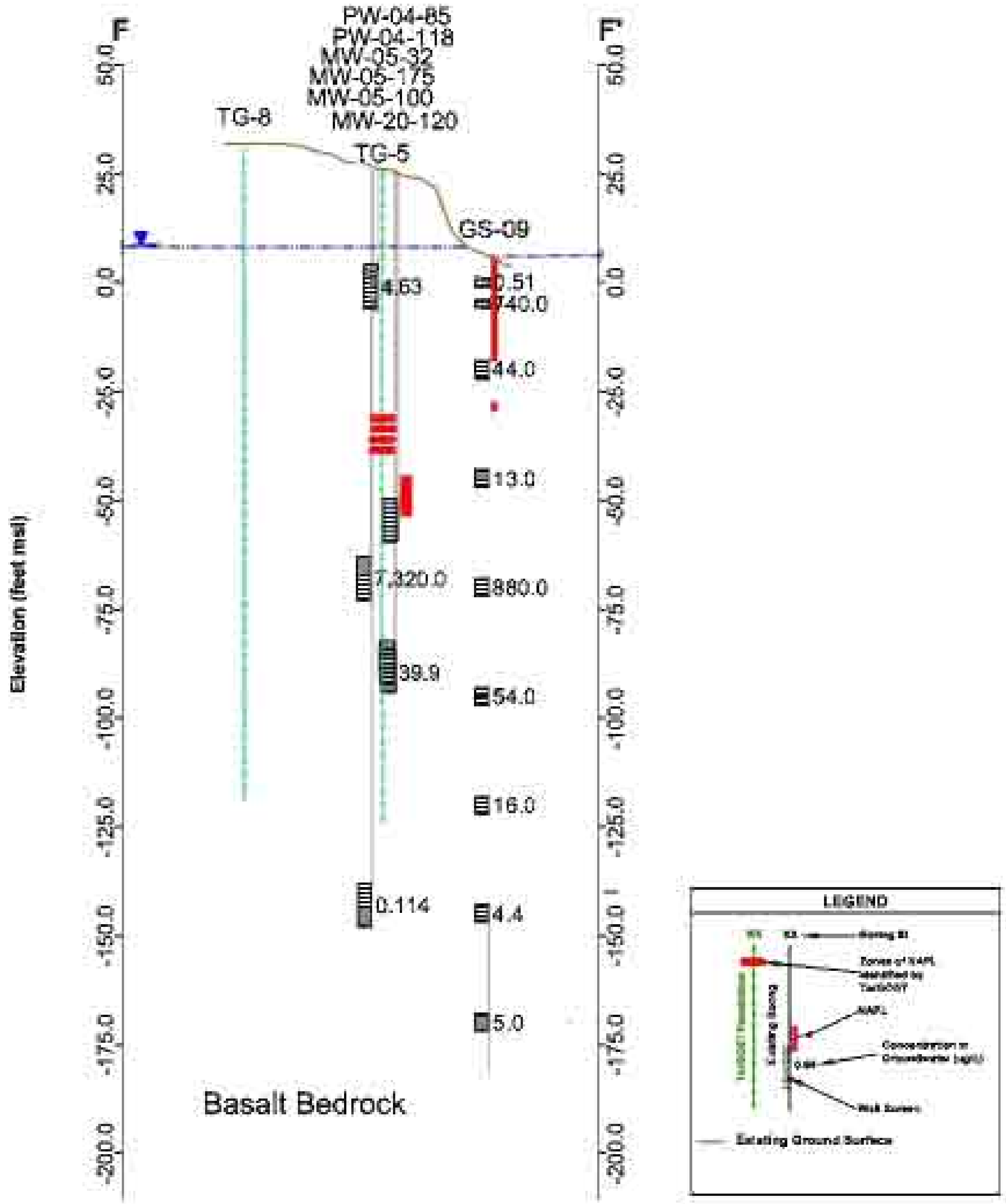
2. City of Portland vertical datum

0 200
Scale in Feet

5X Vertical Exaggeration

ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-F2**
F-F' Toluene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon




Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

0 200
Scale in Feet

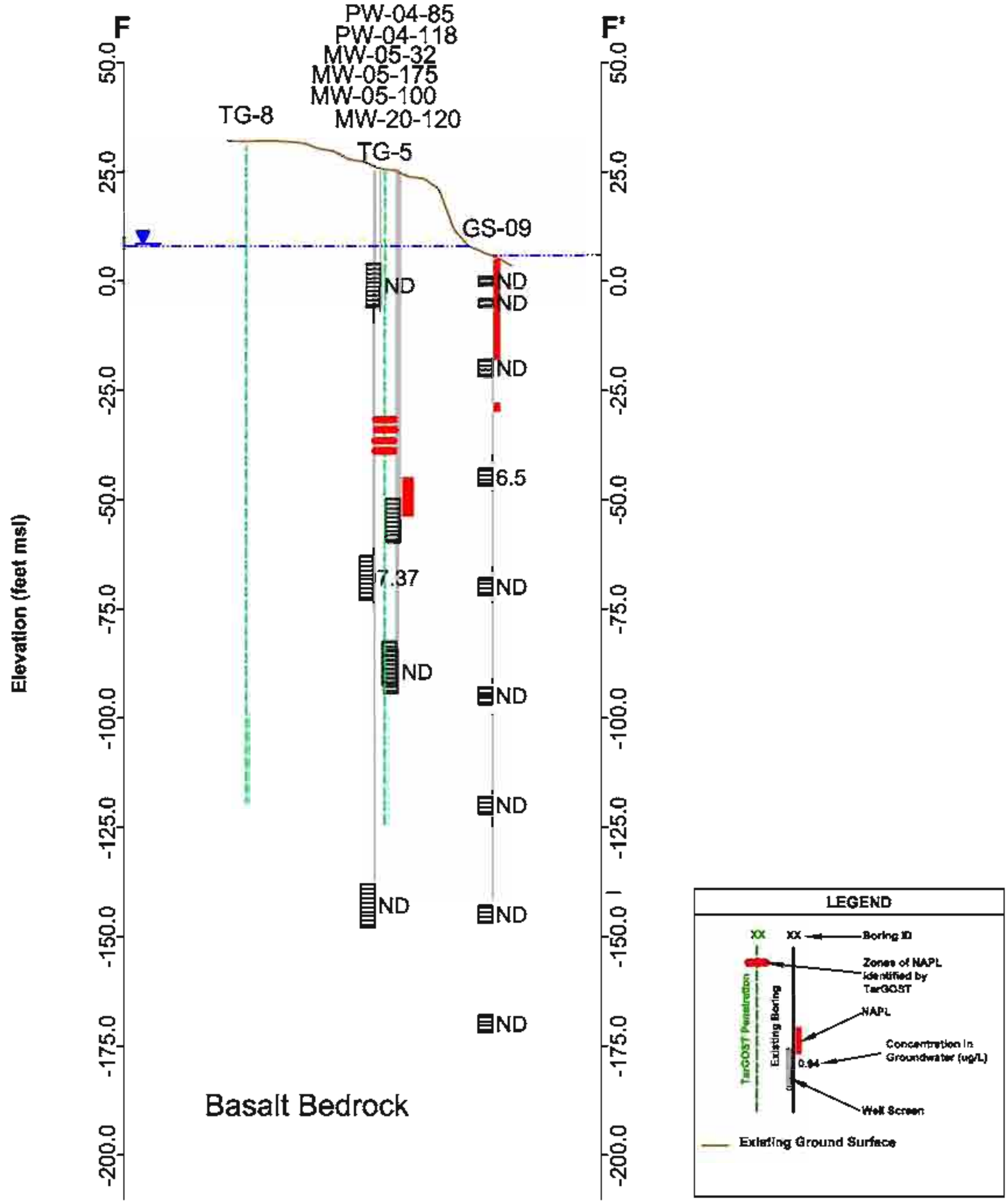
5X Vertical Exaggeration

C:\Documents and Settings\jpelc\My Documents\Gasco\CADstuff\XS_Analysis\XSF.dwg Naphthalene

Oct 03, 2007 8:56am jpelc

ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-F3**
F-F' Naphthalene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon




Notes:

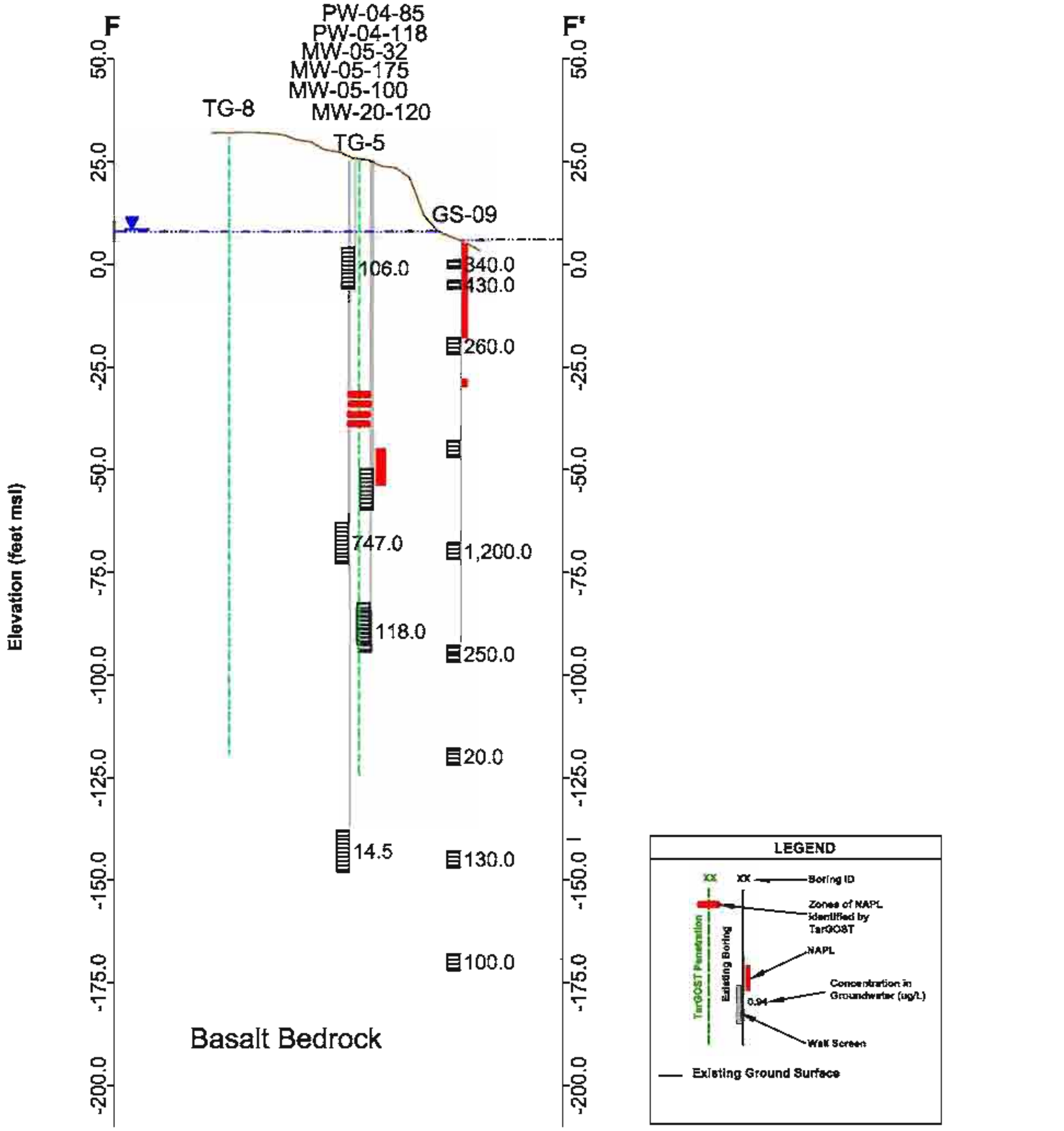
1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

0 200
Scale in Feet

5X Vertical Exaggeration

ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-F4**
F-F' Free Cyanide in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon



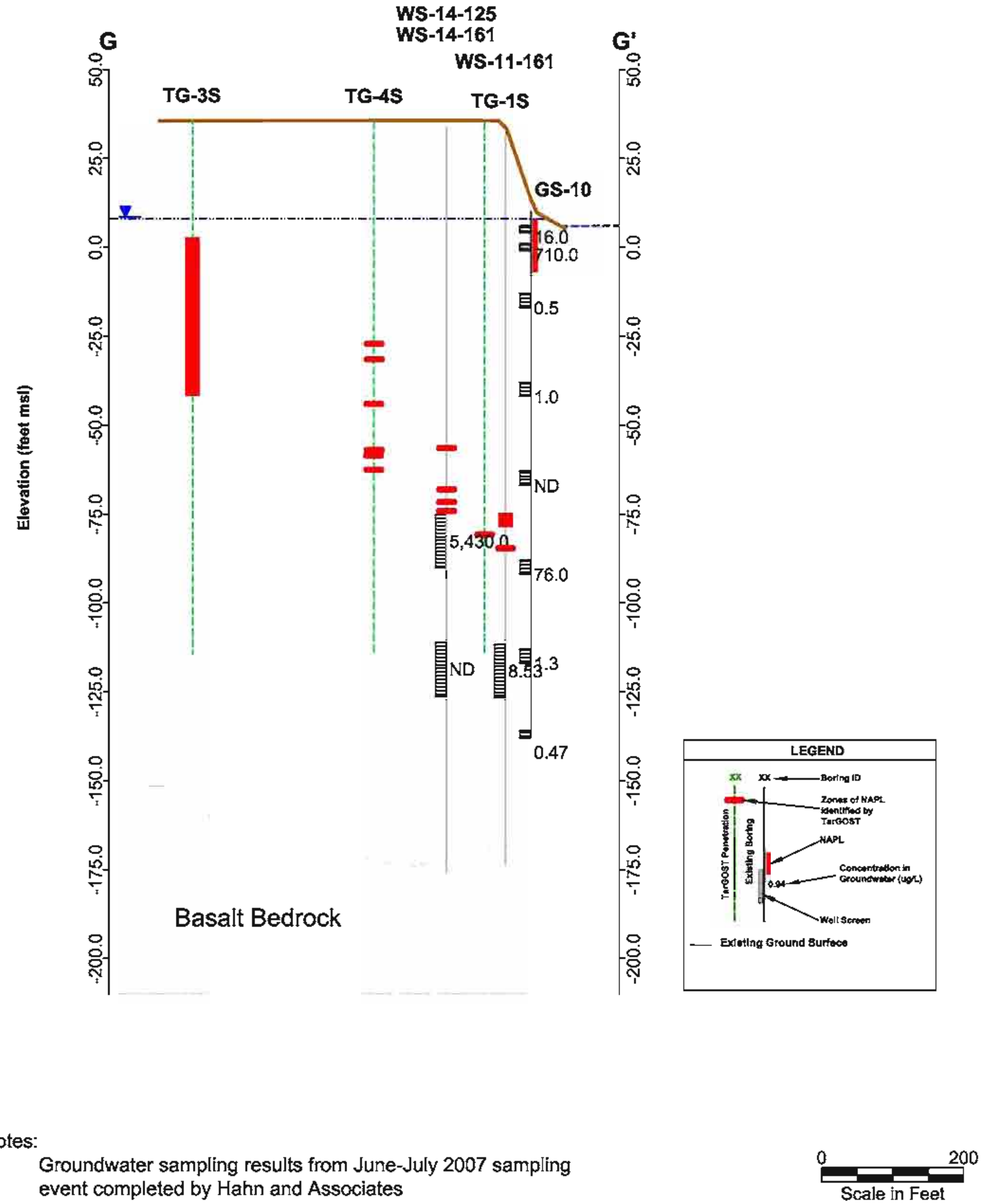

Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

**Figure 5-F5**

F-F' Total Cyanide in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon

ANCHOR ENVIRONMENTAL, L.L.C.




Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

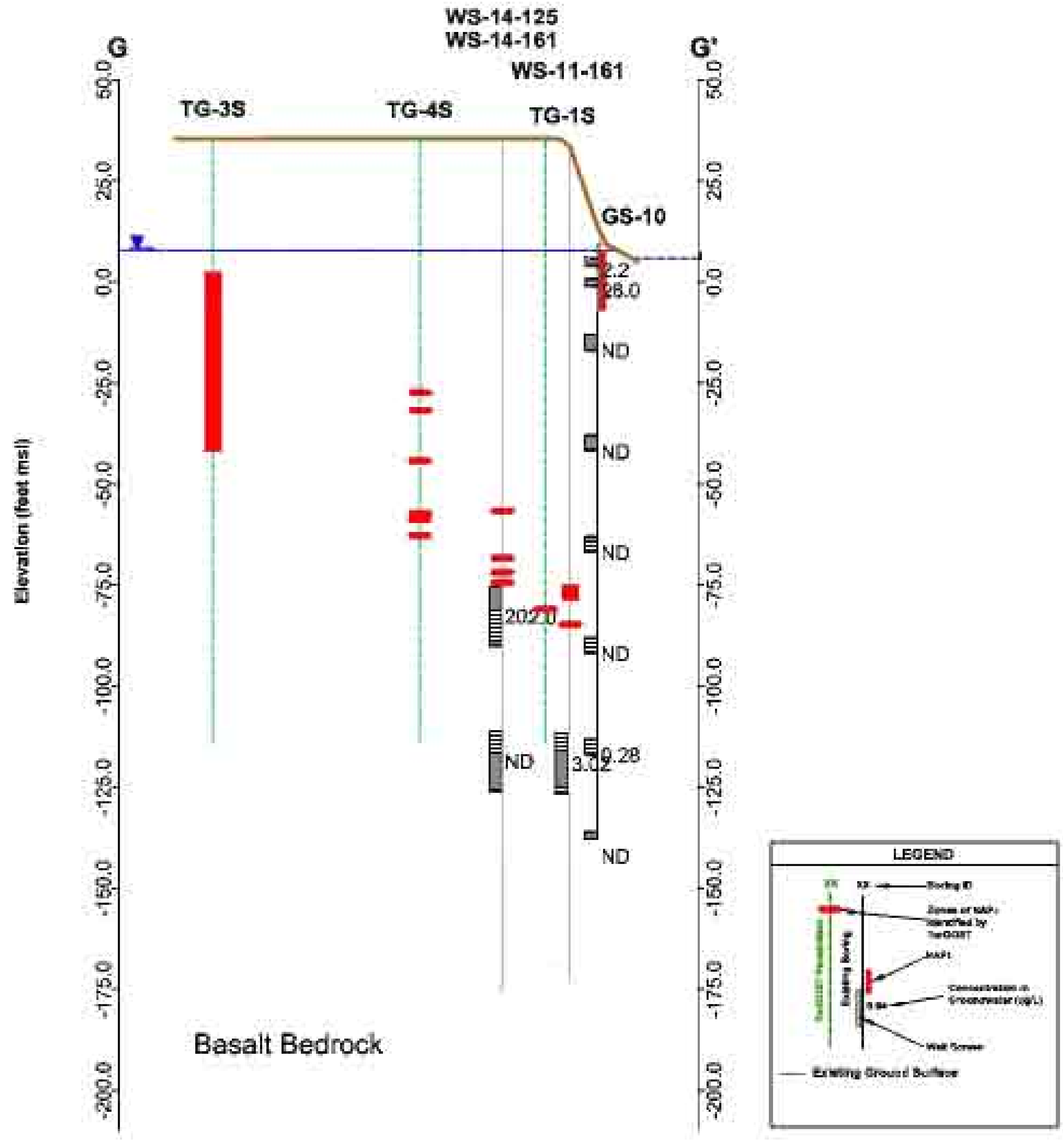
5X Vertical Exaggeration

C:\Documents and Settings\jpelc\My Documents\Gasco\CADstuff\XS_Analytes\XSG.dwg Benzene

Oct 08, 2007 8:12am jpelc

ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 5-G1**
G-G' Benzene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon




Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

0 200
Scale in Feet

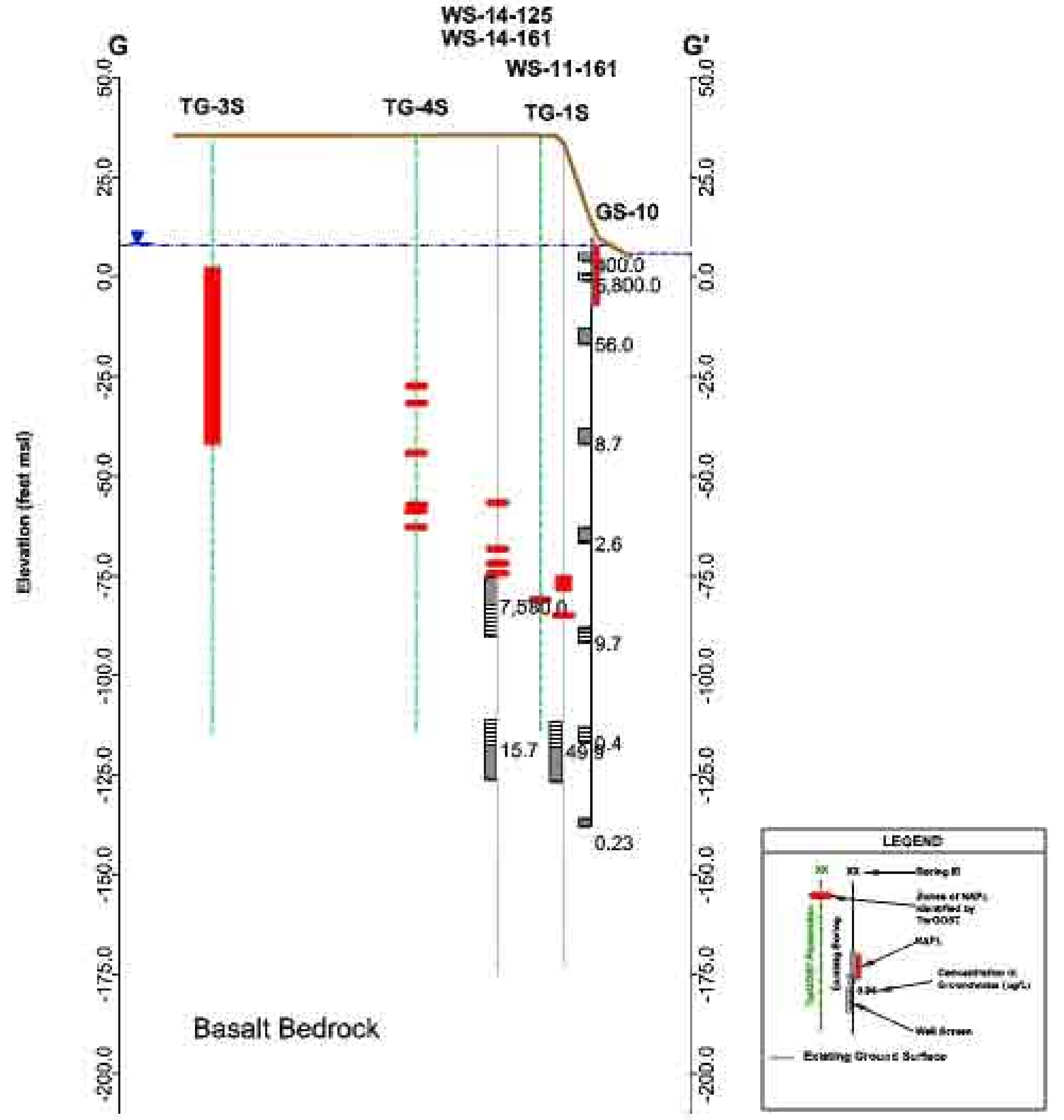
5X Vertical Exaggeration

C:\Documents and Settings\jpaic\My Documents\Gasco\CADs\um\XS_Analytes\XSG.dwg Toluene

Oct 06, 2007 8:12am jpaic

**Figure 5-G2**
G-G' Toluene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon

ANCHOR ENVIRONMENTAL, L.L.C.




Notes:

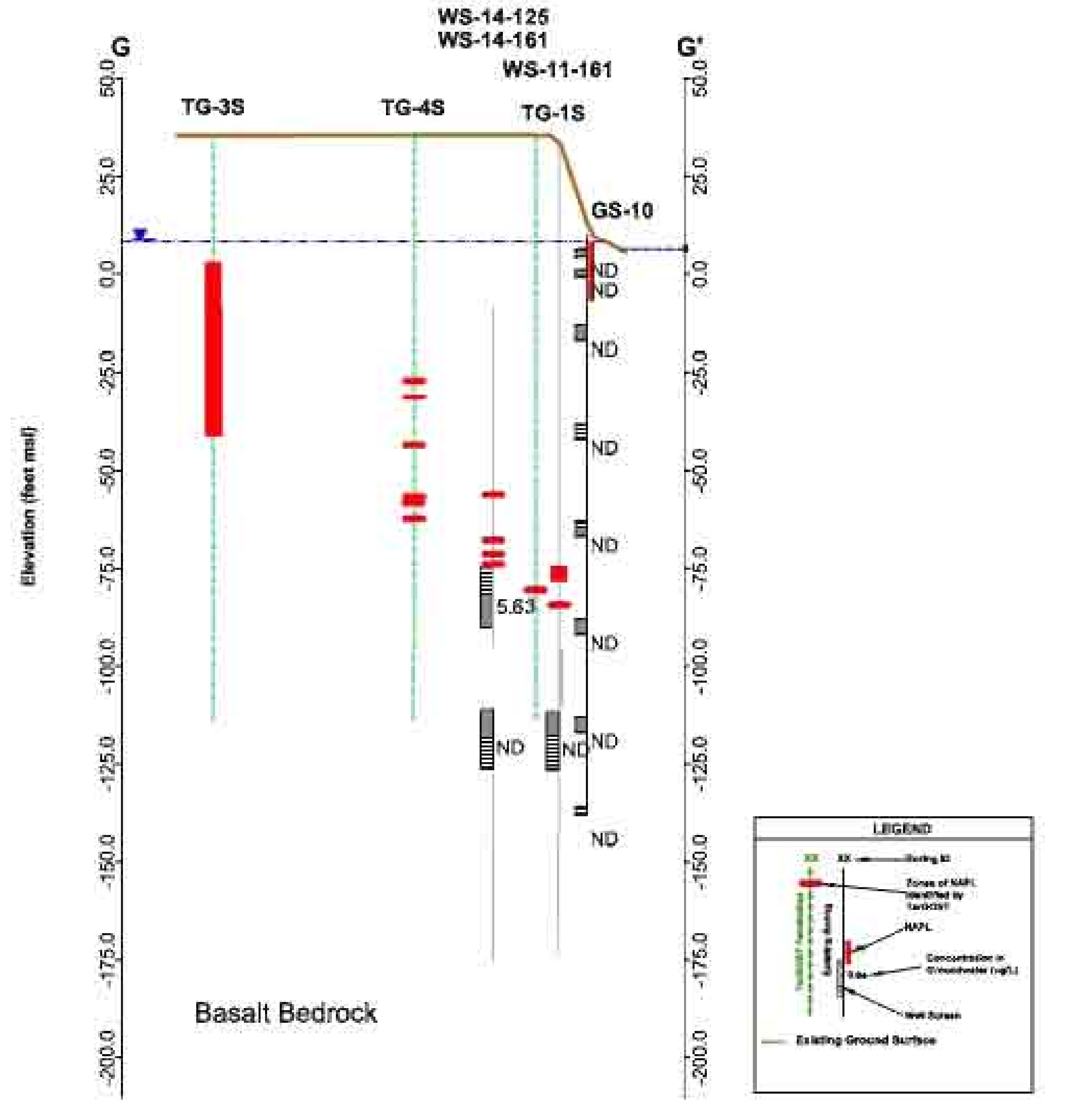
1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

0 200
Scale in Feet

5X Vertical Exaggeration

**Figure 5-G3**
G-G' Naphthalene in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon

ANCHOR ENVIRONMENTAL, L.L.C.




Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

0 200
Scale in Feet

5X Vertical Exaggeration

C:\Documents and Settings\jpeic\My Documents\Gasco\CAD\stuff\XS_Analyses\XSG.dwg Free Cyanide

Oct 08, 2007 8:13am jpelc

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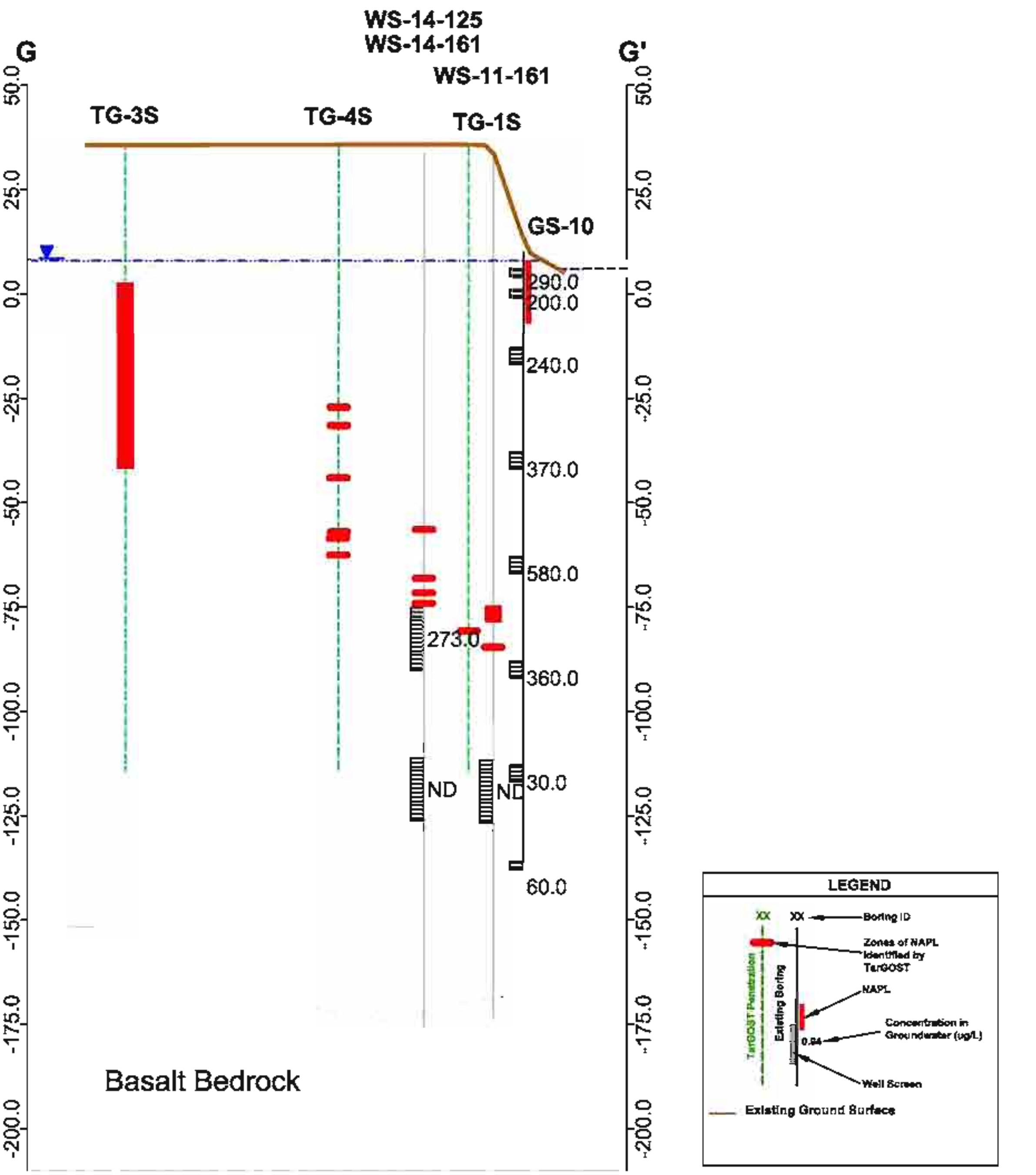
**Figure 5-G4**
G-G' Free Cyanide in Groundwater
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon




Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

C:\Documents and Settings\jpelc\My Documents\Gasco\CADstuff\XS_Analytes\XSG.dwg Total Cyanide

Oct 08, 2007 8:13am jpelc

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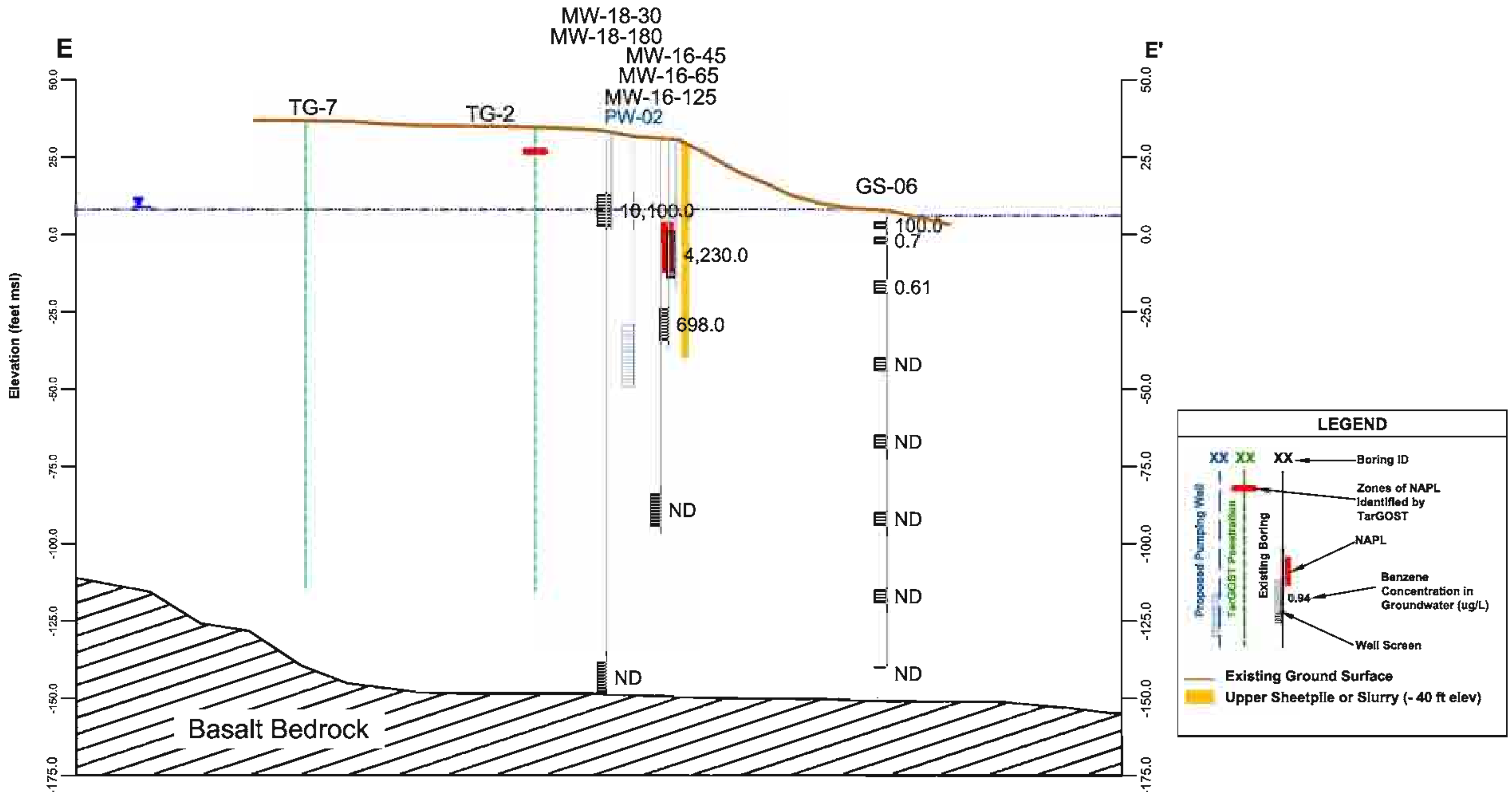
**Figure 5-G5**

G-G' Total Cyanide in Groundwater

Groundwater Focused Feasibility Study

Gasco/Siltronic, Portland, Oregon




Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

B:\Projects\0029_Gasco\000029-02_Gasco\CADstuff\XS_Analytes\XSE.dwg 6a

Nov 07, 2007 12:24pm jpelc

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**Figure 6a**
Subsurface Profile with Containment Measures
Groundwater Focused Feasibility Study
Gasco/Siltronic, Portland, Oregon

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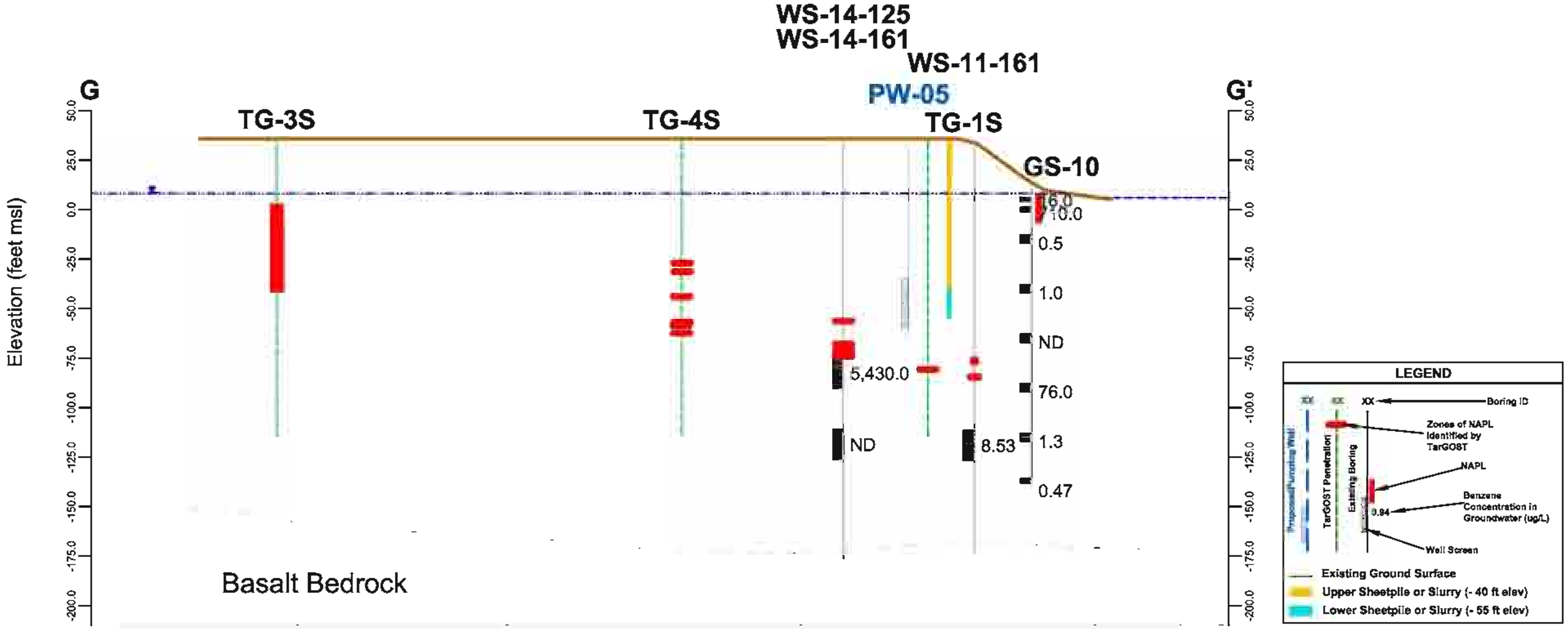
Nov 07, 2007 12:25pm jpelc




Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

0 120

Scale in Feet

0.6 X Vertical Exaggeration

ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 6b**

Vertical Profile with Pumping Well

Groundwater Focused Feasibility Study

Gasco/Siltronic, Portland, Oregon


**GASCO, NW Natural**

**FOCUSED FEASIBILITY STUDY, GROUNDWATER**

PORTLAND, OREGON

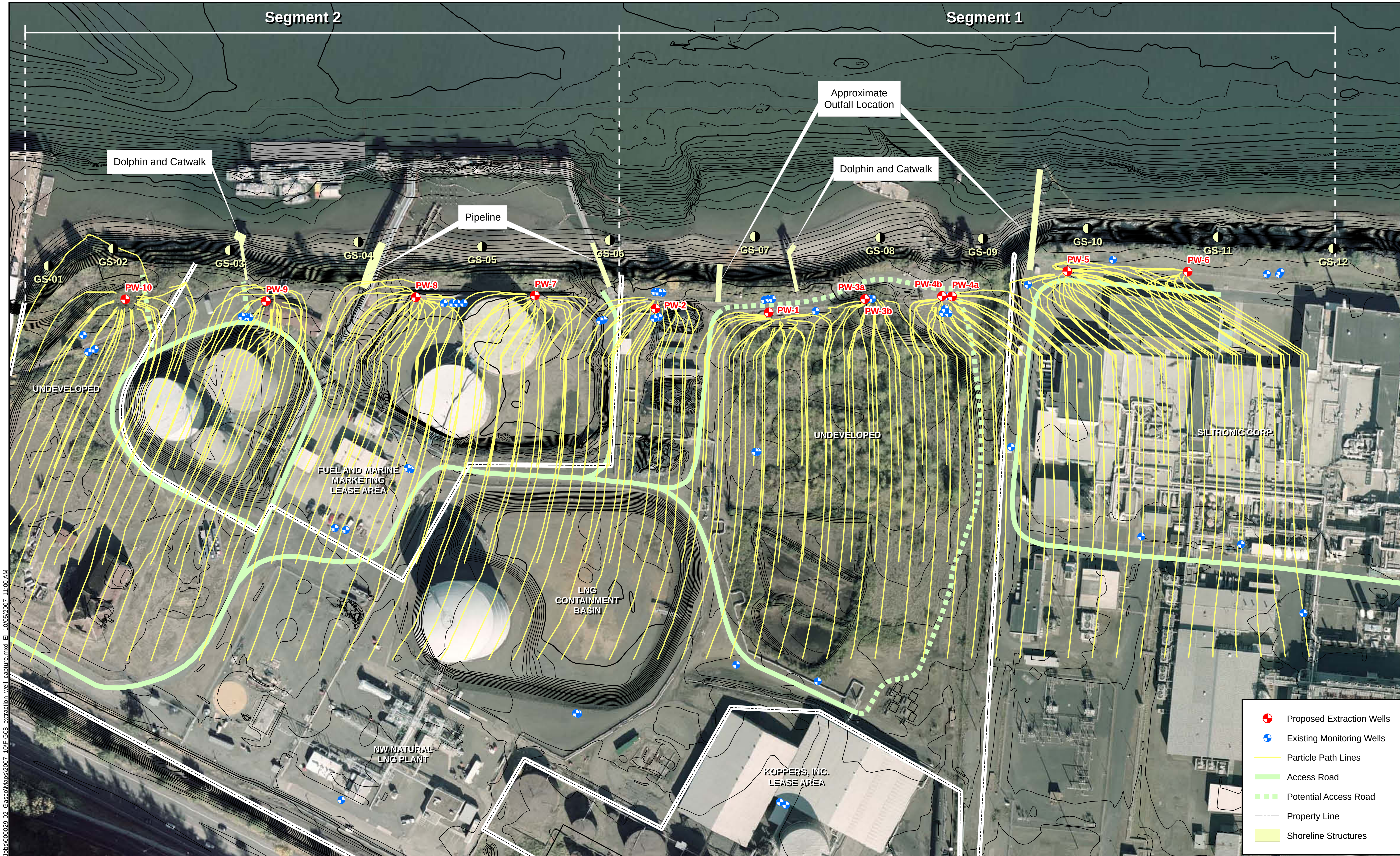
**EXTRACTION WELLS & WATER TREATMENT LAYOUT**

"PARTNERS IN SERVICE"

Advanced Remediation Technologies Co.

690 NW 1st Ave., Suite 104, Canby, OR 97013
Phone: 503-266-2122 Fax: 503-266-4724

FIGURE 7

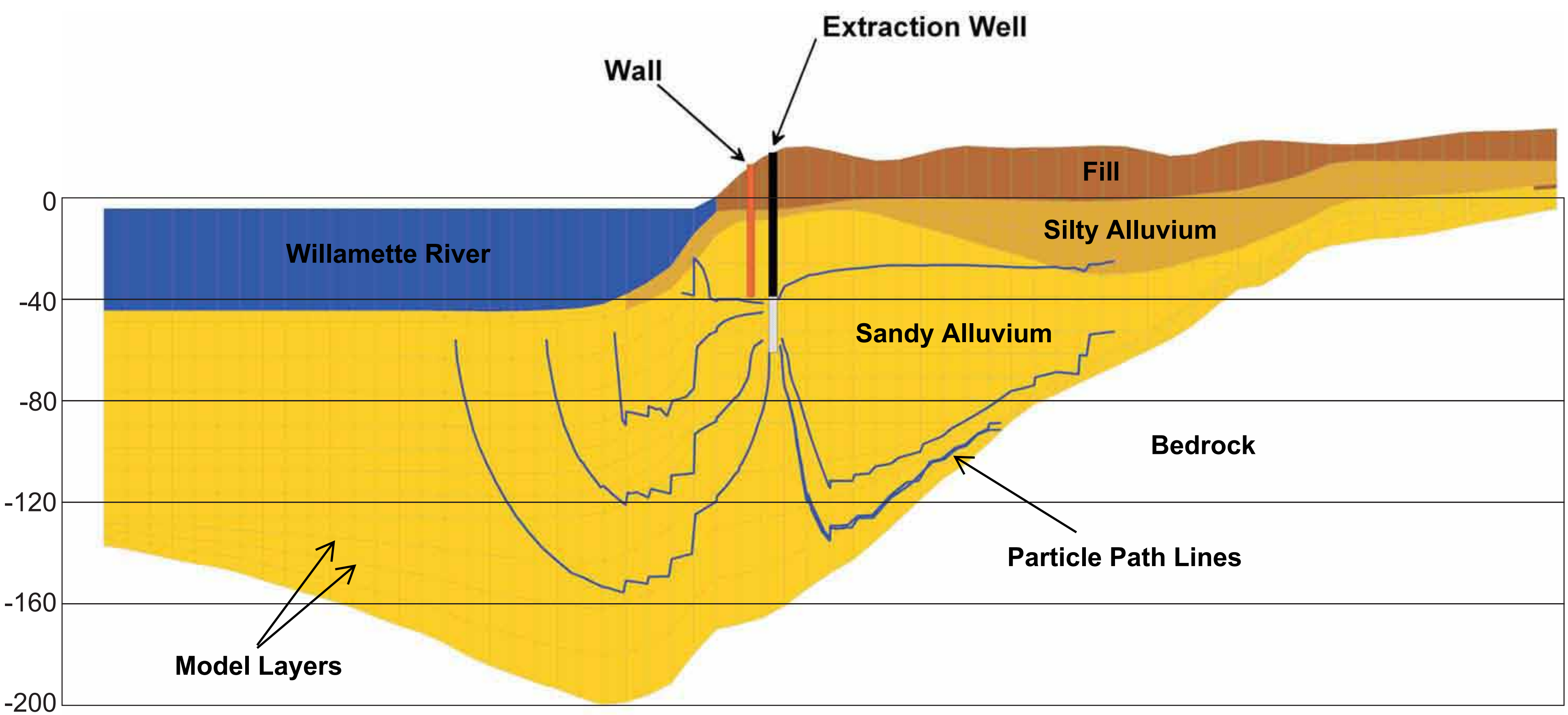



J:\Jobs\000029-02 Gasco\Maps\2007_10\FIG08_extraction_well_capture.mxd EI 10/05/2007 11:00 AM

ANCHOR ENVIRONMENTAL, L.L.C.

0 150
Scale in Feet
1 inch equals 150 feet

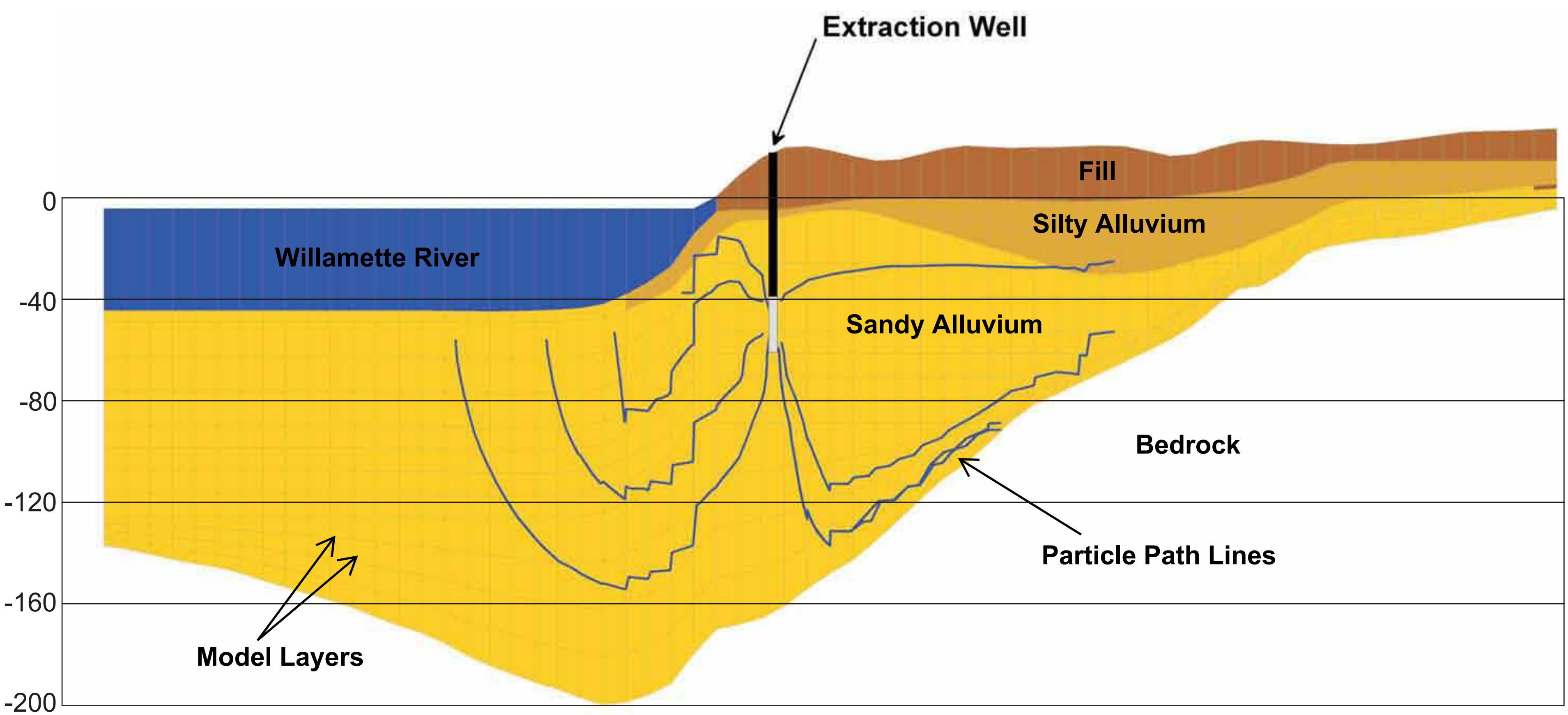
**Figure 8**
Extraction Well Capture Zone Map
Gasco/Siltronic
Portland, Oregon




9/27/07 jjr P:\Projects\GASCO\Groundwater Source Control\GWFFS\Draft Figures\Figure 9.cdr

ANCHOR ENVIRONMENTAL, L.L.C.

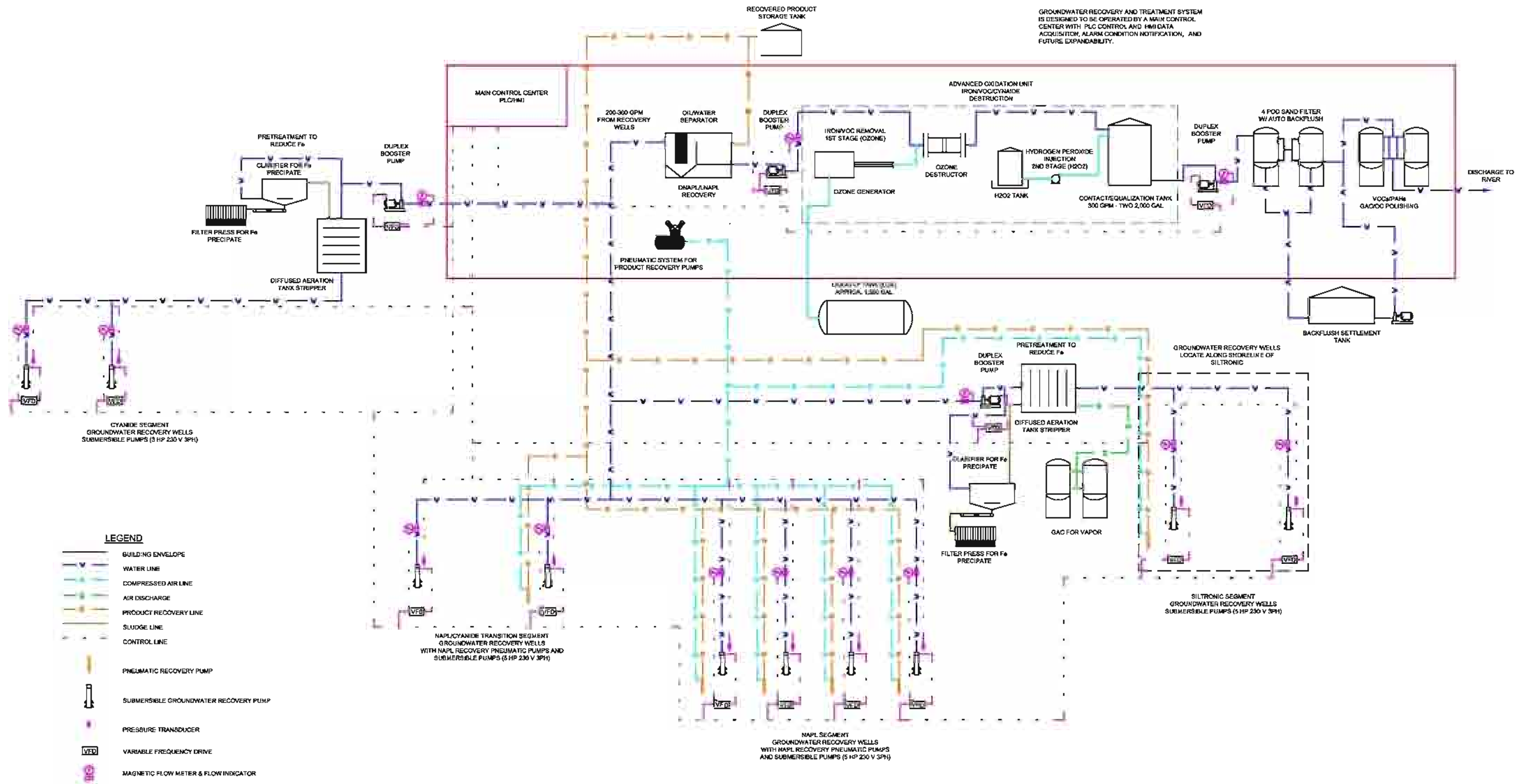
**Figure 9a**
Extraction Well Capture Profile with Barrier Wall
Groundwater Focused Feasibility Study
Gasco, Portland, Oregon




9/27/07 jjr P:\Projects\GASCO\Groundwater Source Control\GWFFS\Draft Figures\Figure 9.cdr

ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 9b**
Extraction Well Capture Profile without Barrier Wall
Groundwater Focused Feasibility Study
Gasco, Portland, Oregon




| REVISION INFORMATION | | |
|---|---|---|
| MILESTONE | DATE | REVIEWING AGENCY |
| PRELIMINARY FFS | 09/26/07 | CLIENT |

"PARTNERS IN SERVICE"

**Advanced Remediation Technologies Co.**

690 NW 1ST AVE, STE 104 CANBY, OREGON 97013
PHONE: (503) 266-2122 fax: (503) 266-4724

**ANCHOR ENVIRONMENTAL**
**GASCO, NW NATURAL**
PORTLAND, OREGON

**GROUNDWATER TREATMENT P&ID, FIGURE 10**

| | |
|---|---|
| DATE | 09/07/07 |
| DRAWN | LAD |
| DESIGN | LAD |
| CHECK | KAD |
| SCALE | NTS |

P&ID

SHEET 1 OF 1


ANCHOR ENVIRONMENTAL, L.L.C.

**Figure 11**
Vertical Barrier Location Map
Gasco/Siltronic
Portland, Oregon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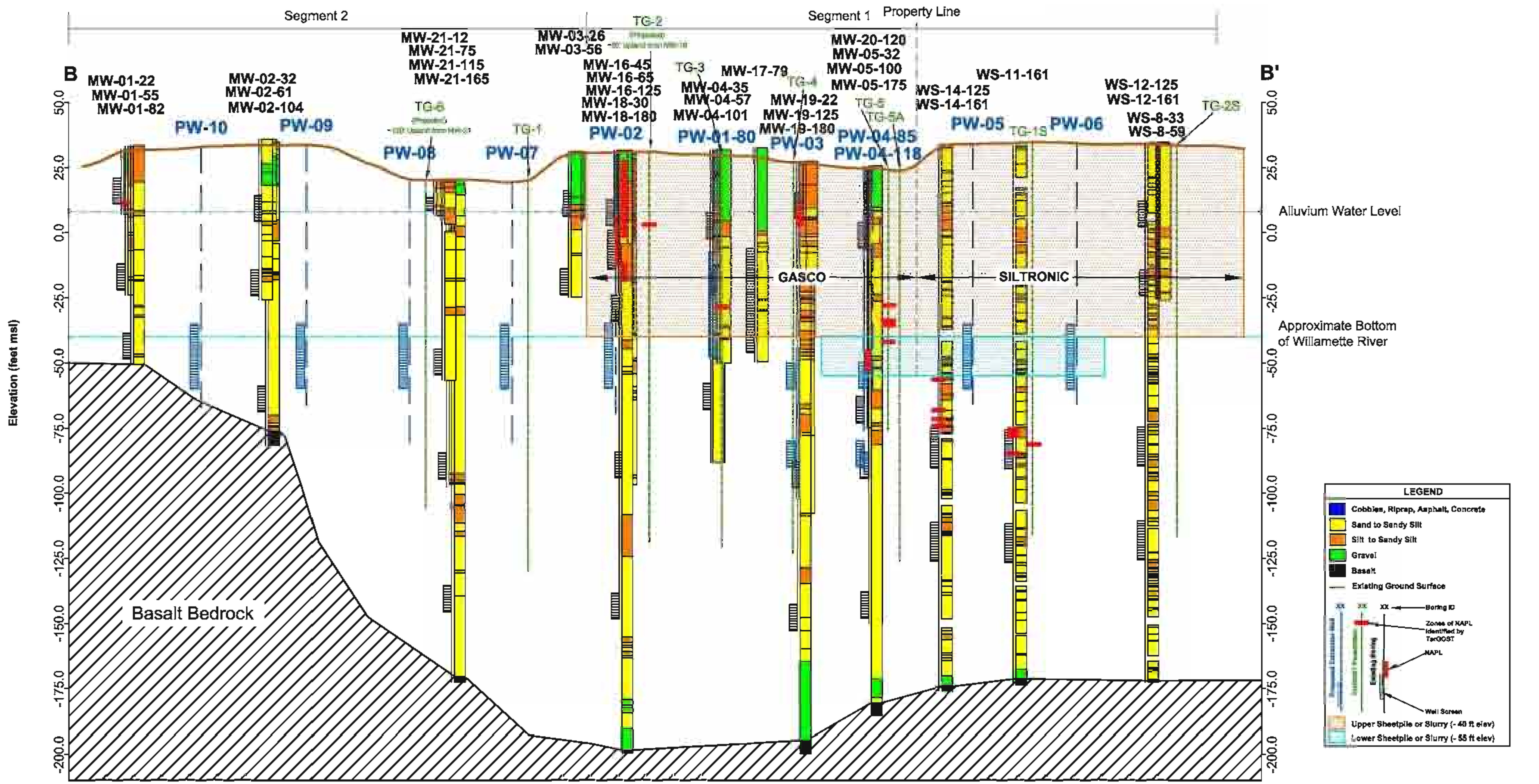
ANCHOR ENVIRONMENTAL, L.L.C.

0 150
Scale in Feet
1 inch equals 150 feet

**Figure 12**
Selected Alternative Extraction Well Vertical Barrier Map
Gasco/Siltronic
Portland, Oregon




Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

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Nov 08, 2007 2:24pm jpelc

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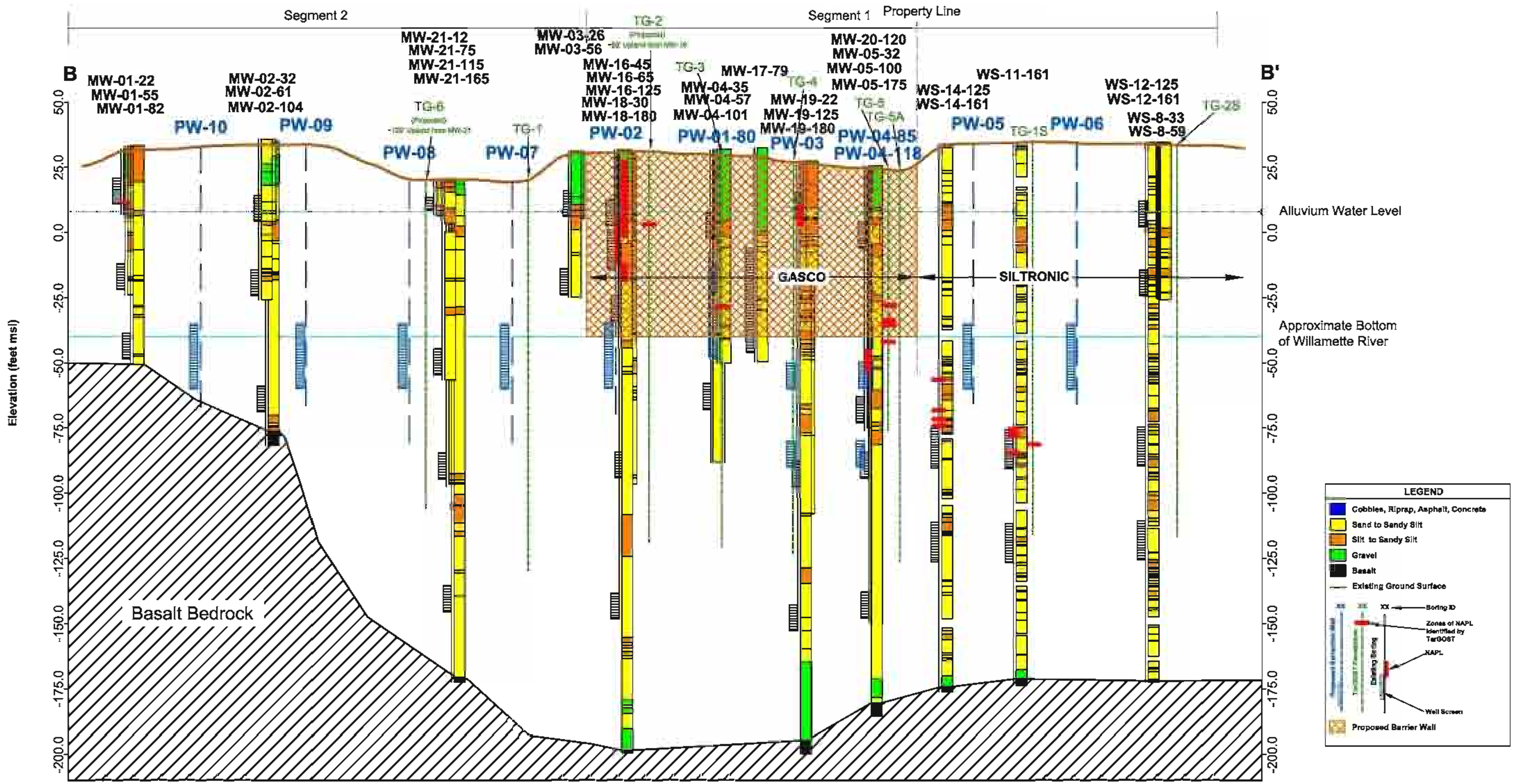
**Figure 13**

Upper and Lower Barrier Wall Alternative Subsurface Profile

Gasco/Siltronic, Portland, Oregon




Notes:

1. Groundwater sampling results from June-July 2007 sampling event completed by Hahn and Associates
2. City of Portland vertical datum

0 200
Scale in Feet
5X Vertical Exaggeration

Nov 08, 2007 2:24pm jpelc
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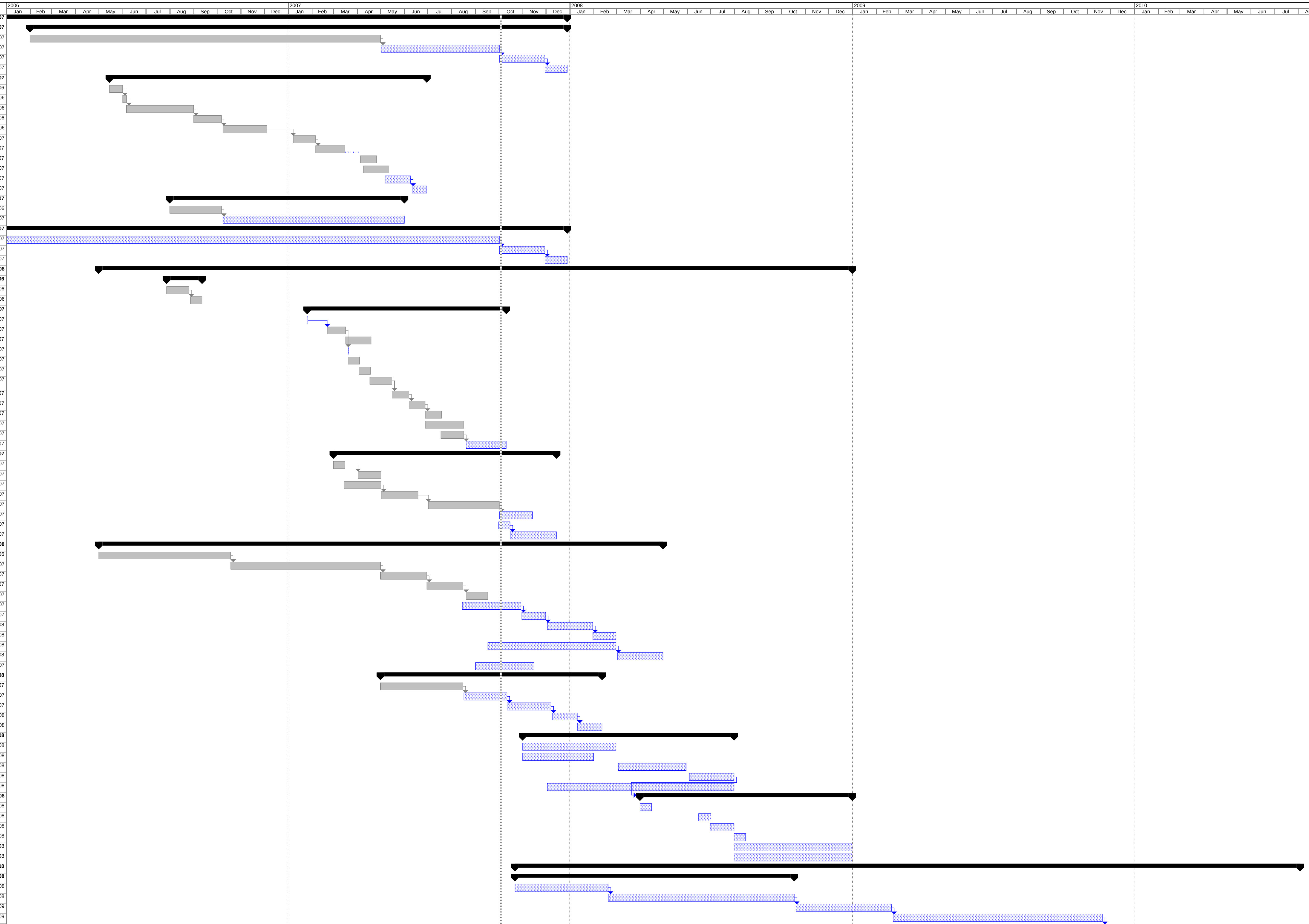
**Figure 14**
Selected Alternative, Subsurface Profile
Gasco/Siltronic, Portland, Oregon

Gasco Site RI/FS Planning Schedule
as of Wed 10/3/07

| ID | Task Name | Start | Finish |
|---|---|---|---|
| 1 | **Upland RI Activities** | **Mon 1/3/05** | **Fri 12/28/07** |
| 2 | **Gasco Site Final RI** | **Wed 2/1/06** | **Fri 12/28/07** |
| 3 | Gasco Site Final RI | Wed 2/1/06 | Mon 4/30/07 |
| 4 | DEQ Review Final RI | Wed 5/2/07 | Mon 10/1/07 |
| 5 | Final RI Revision and Submittal | Tue 10/2/07 | Thu 11/29/07 |
| 6 | DEQ Review and Approval of Revised Final RI | Fri 11/30/07 | Fri 12/28/07 |
| 7 | **MW-13 Area DNAPL Investigation** | **Mon 5/15/06** | **Fri 6/29/07** |
| 8 | Work Plan Development | Mon 5/15/06 | Wed 5/31/06 |
| 9 | DEQ Review and Approval of Work Plan | Thu 6/1/06 | Mon 6/5/06 |
| 10 | Conduct Phase I Investigation and MW-13 Abandonm | Tue 6/6/06 | Thu 8/31/06 |
| 11 | Tech Memo and Phase II Investigation Plan | Fri 9/1/06 | Fri 10/6/06 |
| 12 | DEQ Review and Approval of Phase II Plan | Mon 10/9/06 | Mon 12/4/06 |
| 13 | Phase II Investigation Activities | Mon 1/8/07 | Mon 2/5/07 |
| 14 | Tech Memo and MW-13 Replacement Plan | Tue 2/6/07 | Wed 4/4/07 |
| 15 | DEQ Review and Approval | Thu 4/5/07 | Wed 4/25/07 |
| 16 | MW-13 Replacement/Sampling Activities | Mon 4/9/07 | Fri 5/11/07 |
| 17 | MW-13 Investigation Report | Mon 5/7/07 | Fri 6/8/07 |
| 18 | DEQ Review and Approval of Investigation Report | Mon 6/11/07 | Fri 6/29/07 |
| 19 | **Supplemental Koppers Air Report** | **Tue 8/1/06** | **Thu 5/31/07** |
| 20 | Develop and Submitt Report to DEQ | Tue 8/1/06 | Fri 10/6/06 |
| 21 | DEQ Review and Approval | Mon 10/9/06 | Thu 5/31/07 |
| 22 | **Finalize Risk Assessment** | **Mon 1/3/05** | **Fri 12/28/07** |
| 23 | DEQ Complete Review of RA (Submittted Dec 2004) | Mon 1/3/05 | Mon 10/1/07 |
| 24 | Final RA Revision and Submittal | Tue 10/2/07 | Thu 11/29/07 |
| 25 | DEQ Review and Approval of Revised Final RA | Fri 11/30/07 | Fri 12/28/07 |
| 26 | **Source Controls** | **Mon 5/1/06** | **Wed 12/31/08** |
| 27 | **Groundwater Pilot Study** | **Fri 7/28/06** | **Mon 9/11/06** |
| 28 | Groundwater Pilot Study Plan Add. 2 | Fri 7/28/06 | Fri 8/25/06 |
| 29 | DEQ Review and Approval of GW Pilot Study Plan Ac | Mon 8/28/06 | Mon 9/11/06 |
| 30 | **Groundwater Pilot Study Implementation** | **Fri 1/26/07** | **Wed 10/10/07** |
| 31 | Finalize Pilot Boring Plan | Fri 1/26/07 | Fri 1/26/07 |
| 32 | Install Pilot Borings and Monitoring Wells | Wed 2/21/07 | Fri 3/16/07 |
| 33 | Soil Sieve Testing | Fri 3/16/07 | Wed 4/18/07 |
| 34 | Sample New Wells | Tue 3/20/07 | Tue 3/20/07 |
| 35 | Test Groundwater Samples Key Parameters | Tue 3/20/07 | Tue 4/3/07 |
| 36 | Extraction Well Design | Tue 4/3/07 | Tue 4/17/07 |
| 37 | Extraction Well and Performance Evaluation Design Report to DEQ | Tue 4/17/07 | Tue 5/15/07 |
| 38 | DEQ Review and Approve Extraction Well Design Rep | Wed 5/16/07 | Wed 6/6/07 |
| 39 | Install/Develop Extraction Wells | Thu 6/7/07 | Wed 6/27/07 |
| 40 | Pump Test New Extraction Wells | Thu 6/28/07 | Wed 7/18/07 |
| 41 | Lab Test Extraction Well Groundwater Samples | Thu 6/28/07 | Thu 8/16/07 |
| 42 | Aquifer Test Analysis and Groundwater Modelling | Wed 7/18/07 | Thu 8/16/07 |
| 43 | Extraction Well Performance Report to DEQ | Mon 8/20/07 | Wed 10/10/07 |
| 44 | **Offshore Groundwater/Geotech Sampling** | **Thu 3/1/07** | **Fri 12/14/07** |
| 45 | Receive All Phase 1 Lab Results | Thu 3/1/07 | Thu 3/15/07 |
| 46 | Draft Phase 1 Tech Memo to DEQ | Mon 4/2/07 | Tue 5/1/07 |
| 47 | Phase II Work Plan to DEQ | Thu 3/15/07 | Tue 5/1/07 |
| 48 | DEQ, EPA, and Stakeholder Review of Phase II Work | Wed 5/2/07 | Mon 6/18/07 |
| 49 | Conduct Phase II Work Plan Investigation | Mon 7/2/07 | Mon 10/1/07 |
| 50 | Phase I and Phase II Results Report to DEQ | Tue 10/2/07 | Tue 11/13/07 |
| 51 | Conduct Seepage/Tidal TZW/Surface Water Monitorin | Mon 10/1/07 | Mon 10/15/07 |
| 52 | Prepare Seepage/Tidal TZW Surface Water Report to | Tue 10/16/07 | Fri 12/14/07 |
| 53 | **Source Screen Update and Data Gaps I.D.** | **Mon 5/1/06** | **Wed 4/30/08** |
| 54 | Screen and I.D. Data Gaps Report | Mon 5/1/06 | Wed 10/18/06 |
| 55 | DEQ Review Approve Data Gaps | Thu 10/19/06 | Mon 4/30/07 |
| 56 | Data Gaps SAP (as needed) | Tue 5/1/07 | Fri 6/29/07 |
| 57 | DEQ Revew and Approval SAP (as needed) | Sat 6/30/07 | Wed 8/15/07 |
| 58 | Source Data Gaps Sampling (as needed) non-storm w | Mon 8/20/07 | Sun 9/16/07 |
| 59 | Stormwater SAP Revisions | Wed 8/15/07 | Mon 10/29/07 |
| 60 | DEQ Review and Approval of Stormwater SAP | Wed 10/31/07 | Fri 11/30/07 |
| 61 | Stormwater Sampling | Mon 12/3/07 | Wed 1/30/08 |
| 62 | Stormwater Report to DEQ | Thu 1/31/08 | Fri 2/29/08 |
| 63 | Source Screen Addendum | Mon 9/17/07 | Fri 2/29/08 |
| 64 | DEQ Review and Approval of Screen Addendum | Mon 3/3/08 | Wed 4/30/08 |
| 65 | Segment 3 Source Evaluation | Sat 9/1/07 | Thu 11/15/07 |
| 66 | **Groundwater/NAPL Source Control FFS** | **Tue 5/1/07** | **Mon 2/11/08** |
| 67 | FFS Scoping | Tue 5/1/07 | Wed 8/15/07 |
| 68 | GW/NAPL FFS Development | Fri 8/17/07 | Thu 10/11/07 |
| 69 | DEQ and EPA Review and Comment on FFS | Fri 10/12/07 | Fri 12/7/07 |
| 70 | DEQ Selection of Source Control Removal Action | Mon 12/10/07 | Thu 1/10/08 |
| 71 | Public Notice and Comment | Fri 1/11/08 | Mon 2/11/08 |
| 72 | **Groundwater/DNAPL Souce Control Design** | **Thu 11/1/07** | **Thu 7/31/08** |
| 73 | Prepare Source Control Design | Thu 11/1/07 | Fri 2/29/08 |
| 74 | Conduct Design Level Studies | Thu 11/1/07 | Thu 1/31/08 |
| 75 | DEQ/EPA Review Design | Tue 3/4/08 | Fri 5/30/08 |
| 76 | Finalize Source Control Design | Wed 6/4/08 | Thu 7/31/08 |
| 77 | Obtain Construction Permits | Mon 12/3/07 | Thu 7/31/08 |
| 78 | **Construction of Groundwater DNAPL Source Controls** | **Tue 4/1/08** | **Wed 12/31/08** |
| 79 | Order Sheet Piles and other critical materials | Tue 4/1/08 | Tue 4/15/08 |
| 80 | Order Treatment System | Mon 6/16/08 | Tue 7/1/08 |
| 81 | Mobilize Material/Equipment | Tue 7/1/08 | Thu 7/31/08 |
| 82 | Start Installation of Wells and Walls | Fri 8/1/08 | Fri 8/15/08 |
| 83 | Install Pump and Treatment System | Fri 8/1/08 | Wed 12/31/08 |
| 84 | Install Walls | Fri 8/1/08 | Wed 12/31/08 |
| 85 | **Site-Wide Upland FS and Remedy** | **Mon 10/22/07** | **Tue 8/3/10** |
| 86 | **Site-Wide FS** | **Mon 10/22/07** | **Fri 10/17/08** |
| 87 | FS Data Gathering | Mon 10/22/07 | Tue 2/19/08 |
| 88 | FS Write Up | Wed 2/20/08 | Fri 10/17/08 |
| 89 | **Upland Remedy Selection** | Mon 10/20/08 | Fri 2/20/09 |
| 90 | **Upland Remedy Design** | Mon 2/23/09 | Fri 11/20/09 |
| 91 | **Implement Upland Remedy** | Mon 11/23/09 | Tue 8/3/10 |




Project: Gasco RIFS Planning Schedu
Date: Wed 10/3/07

Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Milestone | Rolled Up Progress | Split | Completed Tasks | Project Summary | Group By Summary | Deadline



Figure 15
Gasco RI/FS Project Schedule