DNAPL REMOVAL PILOT PROGRAM

NW NATURAL GASCO SITE

Prepared for

NW Natural

Prepared by

Anchor Environmental, L.L.C.
6650 SW Redwood Land, Suite 333
Portland, Oregon 97224

October 2008

Figures

1 DNAPL REMOVAL PILOT PROGRAM

1.1 Introduction

On behalf of NW Natural, Anchor Environmental, LLC (Anchor) prepared the Preliminary Design Report Groundwater Source Control, NW Natural Gasco Site (June, 2008). Section 4.2 of the preliminary design report described the preliminary plan for a DNAPL Removal Pilot Program (DNAPL Pilot). The Oregon DEQ issued an August 22, 2008 letter containing comments on the June preliminary design report. Comments specific to the DNAPL Pilot plan are on page 3 of the August 22 letter. This report provides a revised DNAPL Pilot plan that addresses the DEQ comments.

1.2 DNAPL Program Objectives

In order to have a successful DNAPL recovery program it is necessary to identify objectives that have measurable criteria for determining completion (NRC, 2005). For this project it is important to recognize that the preliminary DNAPL Removal Pilot plan was designed to address issues posed by DEQ related to groundwater/DNAPL source control, not overall upland cleanup of the Site. The principal objective of the preliminary DNAPL Pilot plan was to answer DEQ's question of whether pumping of the source control shoreline extraction/containment wells would cause migration of DNAPL in the former effluent pond area. Secondarily the plan was intended to obtain information that could be used to design a DNAPL removal system in the former effluent pond area, if such a system was determined to be necessary to prevent DNAPL migration under the influence of the shoreline extraction wells.

It has not yet been determined if, or how, DNAPL removal in the former effluent pond area may fit into an overall upland cleanup plan. Such objectives for DNAPL removal will be considered in the upland Feasibility Study.

With regard to data collection objectives for the DNAPL Removal Pilot Program, DEQ had the following comments in the August 22 letter.

> *The data collection objectives of the pilot tests are too narrow for purposes of developing an approach to remove DNAPL from beneath the former effluent ponds (i.e., reduce DNAPL "head" beneath the ponds). More specifically, the pilot test should assess the occurrence of DNAPL at the base of the fill that could be feeding DNAPL migrating vertically downward*

through the silt and into the alluvium. Absent DNAPL controls in the fill water-bearing zone (WBZ), constructing and operating extraction wells through and/or below the silt unit has the potential for increasing downward vertical migration of DNAPL. Additionally, there is insufficient information provided in the Preliminary Design Report regarding how the pilot tests will achieve the two data collection objectives listed above. For example, discussions of how the data collected during the pilot tests will be used to assess DNAPL removal alternatives (e.g., trenches, vertical wells, horizontal wells); or estimate design parameters for DNAPL removal (e.g., radius of extraction well influence, the density, numbers, and locations of DNAPL recovery wells) should be provided. The pilot study should also discuss how installation of the pilot wells could influence interpretations of DNAPL accumulation rates.

To address the additional issues identified by DEQ in the August 22nd letter, the preliminary DNAPL Removal Pilot plan has been modified to provide information that will help answer the technical questions identified by DEQ. Specifically this revised plan is designed to provide data to address the following technical issues in the former effluent pond area.

1. Determine if pumping the shoreline source control extraction wells is likely to cause migration of DNAPL from the former effluent pond area
2. Assess whether pumping DNAPL from the pilot wells screened in the alluvium causes migration of DNAPL as measured in piezometers screened in the overlying fill
3. Assess DNAPL pumping methods and design parameters for pumping systems

Section 1.4.2 of this plan provides a discussion of how installation of the pilot wells and piezometers could influence the behavior of DNAPL.

DEQ has approved using the locations of TarGost borings TG-8 and TG-13 for installing pilot extraction wells. However, in the August 22 letter DEQ also asked that drilling and installation methods should consider the stratigraphy of the fill and alluvial units and further assess the occurrence of DNAPL at the base of the fill. Therefore this revised plan includes subsurface geologic profiles that display the distribution of DNAPL in conjunction with site geologic units. This plan describes how the drilling, field logging, and monitoring of piezometers in the fill WBZ will provide the needed information on Fill stratigraphy and DNAPL occurrence.

1.3 Evaluation of DNAPL in Fill WBZ

In the August 22 letter and subsequent meetings, DEQ has requested that the plan be revised to consider the potential for downward DNAPL migration from the Fill WBZ to the Alluvial WBZ during the DNAPL Pilot. In revising the plan, the following three

factors were considered. The findings of the remedial investigation (HAI, 2007) indicated that the contaminant in the fill in the former effluent pond area is primarily solid to semi-solid tar, with only relatively minor amounts of viscous DNAPL associated with the tar. There is a thick layer of silt at the top of the alluvium at the TG-8 and TG-13 locations which would inhibit downward migration of mobile DNAPL, if present, during the testing. The RI report describes root macropores in the former effluent pond area that historically transmitted DNAPL through the silt in this area. DNAPL recovery efforts conducted to date at Gasco and the findings from MGP sites around the U.S. have shown that mobile DNAPL oil migrates very slowly (Gerhard, 2007), while the solid tar does not migrate at all. Therefore it is unlikely that DNAPL pilot pumping in the alluvium will have measurable effect on DNAPL in the Fill WBZ.

To evaluate this issue, this plan has been expanded to include the following additional items.

- Continuous soil cores obtained during drilling of the Fill and Alluvium borings will be examined in the field for the presence of potentially mobile DNAPL.
- One piezometer screened in the Fill WBZ will be installed at the TG-8 test location and one Fill WBZ piezometer will be installed at the TG-13 test location.
- Groundwater levels and DNAPL thickness (if present) in the Fill WBZ piezometers will be monitored prior to, during, and subsequent to operation of the DNAPL extraction well screened in the Alluvium WBZ.
- DEQ will be notified if monitoring data indicate that operation of the Alluvium WBZ extraction well causes drawdown of DNAPL in the Fill WBZ piezometer. At that time, a decision could be made to reduce the pumping rate in the extraction well, if necessary.

These changes to the plan are further discussed in the following sections.

1.4 DNAPL Extraction Well and Piezometer Design and Installation

1.4.1 Pilot Test Location

The TarGOST investigation results have been reviewed to evaluate possible test methods. Subsurface profiles located on Figure 1 have been prepared using the TarGOST boring logs for the former effluent pond area. The profiles on Figures 2

through 6 show that the DNAPL occurs in interbeds beneath the former tar pond. The interbeds generally occur at different elevations between borings, which may make the use of horizontal extraction wells infeasible. Therefore this plan utilizes conventional vertical screened wells for DNAPL removal. The findings from this assessment could be useful in determining the feasibility of using horizontal DNAPL extraction wells at the site.

TarGOST borings TG-8 and TG-13 appear to have suitable characteristics for pilot testing based on the following factors.

- The cumulative thickness of DNAPL containing interbeds is greater at these locations than at most of the other TarGOST borings
- These two borings are located on NW Natural property, allowing ease of access for pilot testing, compared to potential locations on the Siltronic property
- These two borings are far enough away from the Siltronic property line to reduce the potential that TCE impacted groundwater will be drawn into the wells, which would complicate treatment of recovered groundwater and recycling of the recovered DNAPL

The proposed pilot test locations adjacent to TG-8 and TG-13 are shown on Figure 7.

1.4.2 Pilot Extraction Well Design

A DNAPL extraction well will be constructed in the alluvium adjacent to each of the former TG-8 and TG-13 locations, as shown on Figures 6 and 7.

At each location, the extraction well will be constructed of 8-inch diameter steel casing with stainless steel wire wrapped screen and bottom sump. The screen slot size will be 0.035 inch, as was used in construction of the two PW-4 shoreline extraction wells. The annular sand pack will be 10/20 sand, as was used in constructing the PW-4 shoreline wells. The annular seal for the extraction wells and piezometers is planned to be a bentonite/organoclay grout. A variance to use this grout mixture is being considered by the Oregon Water Resources Department for the Gasco site. Each well will be equipped with a Blackhawk DNAPL recovery pump that draws DNAPL from the sump. Each

well will also contain an electric submersible pump located above the screen to remove groundwater and induce a hydraulic gradient. Figure 8 is a diagram showing the planned extraction well with upper submersible pump and lower Blackhawk DNAPL pump.

To confirm that the screen depths are appropriate, continuous cores will be obtained from the extraction well and piezometer borings at each location. Prior to construction of the extraction wells and piezometers, the cores will be photographed and logged in the field to confirm and refine the stratigraphy as it is shown on the subsurface profiles in this report.

The proposed screen zones of the two extraction wells are shown at the TG-8 and TG-13 locations on the Figure 6 subsurface profile. The extraction wells are designed to be screened in the sand interbeds of the alluvium where the TarGost investigation identified the presence of DNAPL. The extraction well and piezometer screen zones will be constructed so that the screen zones do not cross the fill/alluvium boundary. The screen zone for the extraction wells at each location will not extend above the base of the silt layer at the top of the alluvium.

In the design of this test plan it is recognized that drilling boreholes and constructing wells or piezometers can create subsurface conditions that can alter DNAPL mobility in the vicinity of the borehole. However, some degree of disturbance is inherent in any subsurface investigation that includes drilling and well installation. For this evaluation we are minimizing the effect of the disturbance by not using rotary or hollow auger drilling methods, which tend to smear and disturb soil on the borehole wall more than other methods. We have selected sonic drilling as the preferred method for well and piezometer installation, because this method should result in minimal smearing or disturbance of the soils in the borehole wall. We are also using the same stainless steel screen slot size in the extraction wells and piezometers to reduce the potential variables that could affect NAPL movement through the screen and annular sand pack.

1.4.3 Piezometer Design

Figure 7 shows the location of two piezometers that will be installed in the alluvium near each extraction well to measure the gradient induced by the extraction well. The alluvium piezometers will be screened at approximately the same elevation as the extraction well. The screen depths are shown on the subsurface profile 6. The piezometers will be constructed of two inch diameter PVC casing and stainless steel wire wrapped screen. The screen will be wire-wrapped Johnson stainless screen with 0.035 inch slots, the same slot size planned for the extraction wells. The annular sand pack material and annular seal material for the piezometers will also be the same as the extraction wells.

To respond to DEQ's request to evaluate potential drawdown effects in the overlying fill, a piezometer screened in the fill will also be installed at each location. Figure 7 shows the estimated location of the Fill WBZ piezometer at each location. The Fill WBZ piezometer screen zone at each location will not extend below the base of the fill, as it is interpreted in the soil core. The bottom of the screen will be set at the approximate depth of the base of the fill, with the sump installed in the underlying alluvial silt. The subsurface profile on Figure 6 shows the planned screen depths for the extraction well, the two alluvium piezometers, and the fill piezometers at locations TG-8 and TG-13.

1.5 Test Plan

The test plan is divided into two phases. Phase 1 is designed to fulfill objectives 1 and 2 as described in Section 1.2. Phase 2 is designed to fulfill objective 3.
During Phase 1, we will determine the optimum DNAPL recovery rate using just the DNAPL product pump, then determine if the DNAPL recovery rate increases when the groundwater gradient is increased by pumping groundwater. During Phase 2 we will further increase the groundwater pumping rate in the extraction well to determine how that influences the rate of DNAPL extraction.

1.5.1 Phase 1

The Phase 1 pilot test at each location is planned to include the following steps.

Phase 1: Step 1

Following installation and development of the wells and piezometers, static measurements of the groundwater levels and DNAPL thickness will be made daily until stabilization. For the DNAPL thickness it may take several days to reach stable conditions. Following the period of static measurements the pumping tests will be initiated. The Blackhawk pump will be operated at each well for about two weeks with concurrent daily measurement of the volume of DNAPL recovered. During that time vary the pumping rate to determine the optimum rate of daily DNAPL recovery. The Blackhawk pump removes DNAPL that accumulates in the sump, which should result in minimal recovery of groundwater. Some amount of groundwater will also be removed by the Blackhawk pump, but the operating frequency will be adjusted to minimize the groundwater removal rate.

During Phase 1 Step 1 the following measurements will be made in the extraction wells and piezometers.

- Groundwater level fluctuations as measured by transducers
- Daily DNAPL thickness measurements
- Daily measurement of DNAPL volume recovered

Phase 1: Step 2

Continue to operate the Blackhawk pump at the optimum pumping rate determined in Step 1 and simultaneously operate the submersible pump to induce a groundwater hydraulic gradient. This purpose of the induced gradient is to evaluate the effect of pumping from the future shoreline extraction wells. The target pumping rate will be determined through ModFlow modeling, which will determine the drawdown necessary to produce the gradients that will be induced at the pilot test locations during future operation of the shoreline extraction wells. Continue to make daily measurements of DNAPL volume recovered. Step 2 is estimated to extend for about two weeks.

During Phase 1 Step 2, the following measurements will be made in the extraction wells and piezometers.

- Groundwater level fluctuations as measured by transducers
- Daily DNAPL thickness measurements

- Daily measurement of DNAPL volume recovered

During Step 2, the daily DNAPL recovery data will be compiled and evaluated for the purpose of comparing recovery rates with and without groundwater pumping. This comparison should provide a reasonable assessment of the increase in DNAPL recovery due to hydraulic gradient increases induced by shoreline extraction wells. The information from the Phase 1 pilot test will be reviewed to see if the plan for Phase 2 testing should be modified.

1.5.2 Phase 2

During Phase 2, we will increase the groundwater discharge rate from the extraction wells to determine how that affects the rate of DNAPL recovery from the extraction wells. These test procedure will be somewhat similar to the method used in conducting step pumping tests in water wells for assessing properties of groundwater aquifers.

In this case we will pump groundwater from the two extraction wells at higher pumping rates than were used in the Phase 1 tests. At this time we plan to increase the pumping rates in three steps. Each step is planned to increase the pumping rate by approximately 1/3 higher than the rate used in Phase 1, Step 2.

For example, if the Phase 1, Step 2 pumping rate is 6 gpm, the Phase 2, Step 2 pumping rates would be approximately 8 gpm, 10 gpm, and 12 gpm. Pumping at each step will continue for about 3 days for a total step pumping period of about 9 days. During each step the following measurements will be made.

- Groundwater level fluctuations as measured by transducers
- Daily DNAPL thickness measurements
- Daily measurement of DNAPL volume recovered

1.6 Data Evaluation

During Phase 1 and Phase 2 testing, the groundwater elevation and DNAPL thickness data from the Fill WBZ piezometers will be assessed for trends to determine if pumping the extraction wells is having a measurable effect on the Fill WBZ. If the data suggest the possibility that the pilot test is causing DNAPL in the Fill WBZ to migrate vertically

down into the alluvium, we will notify DEQ. It is considered very unlikely that measurable downward migration of DNAPL will occur during the test for the reasons described in Section 1.1.3. However, if the data trends suggest the possible downward migration of DNAPL, we will confer with DEQ on the possible need for mitigation steps, such as reducing the extraction well pumping rate.

The Phase 1 data will be used to evaluate if pumping the proposed shoreline extraction wells will induce DNAPL migration in the former effluent pond area. The Phase 1 groundwater elevation and DNAPL thickness data trends will be assessed to determine how pumping from the extraction wells affects DNAPL migration. The daily DNAPL recovery rate measured during Phase 1 Step 1 will be compared with the rate measured during Step 2 to determine if inducing the groundwater gradient caused an increase in DNAPL recovery. The DNAPL thickness trend in the piezometers will also be considered.

The Phase 2 groundwater elevation and DNAPL thickness data trends will be compared for each pumping step. The data will be used to try and correlate the groundwater and DNAPL pumping rates with radius of influence as measured at the piezometers. If pumping the extraction wells causes measurable changes in DNAPL thickness in the piezometers, this data could be used to aid future design of a DNAPL removal system.

Furthermore, this pilot test provides an opportunity to see how efficiently conventional pumping systems in vertical extraction wells perform with regard to DNAPL recovery at the Site. The extraction wells are being installed in optimum locations with respect to DNAPL thickness, based on the TarGost boring data. Therefore, vertical extraction wells operated at the TG-8 and TG-13 locations offer a best-case scenario to help determine the feasibility of DNAPL removal using vertical extraction wells.

2 REFERENCES

Anchor Environmental, LLC. 2008. Preliminary Design Report Groundwater Source Control NW Natural Gasco Site. Prepared for NW Natural.

Environment Agency. 2003. An Illustrated Handbook of DNAPL transport and fate in the subsurface. Rio House.

Hahn Associates, Inc. 2007. Remedial Investigation Report NW Natural Gasco Facility, Portland, Oregon. Prepared for NW Natural.

Gerhard, J.I., TiWee Pang, Kueper, B. H. 2007. Time Scales of DNAPL Migration in Sandy Aquifers Examined via Numerical Simulation. Ground Water, Vol 45.

McDade, J.M. McGuire, T.M., Newell, J.C. 2005. Analysis of DNAPL Source Depletion Costs at 36 Field Sites. Wiley Periodicals Inc.

National Research Council, 2005. Contaminants in the Subsurface, Source Zone Assessment and Remediation. National Academies Press.

WILLAMETTE RIVER

GS-01 GS-02 GS-03 GS-04 GS-05 GS-06 GS-07 GS-08 GS-09 GS-10 GS-11 GS-12

MW-1-22 MW-1-55 MW-1-82 MW- 2-61 MW- 2-32 MW- 2-104 MW-21-75 MW-21-125 MW-21-165 MW-21-115 TG-6

MW- 16-45 MW- 16-65 MW- 16-125 B-1 B-5 B-2 B-8 MW- 4-101 MW- 4-35 MW- 4-57 MW-16-196 MW- 3-26 TG-1 MW- 3-56 TG-9 MW-18-30 TG-2 PW-1-80 TG-15 TG-A TG-D TG-3 MW-17-79 TG-4 MW- 5-100 TG-11 TG-B TG-7 TG-8 TG-12 P-38 TG-A' TG-B'

MW-19-180 TG-10 B-7 B-3 MW-19-125 MW-18-30 PW-4-85 MW- 5-32 MW-20-120 B-4B B-4 PW-4-118 MW- 5-175 TG-5A TG-5 TG-4S TG-E TG-E'

TG-12S TG-1S TG-7S WS-14-161 WS-14-125 WS-13-125 WS-13-161 WS8-55 WS8-33 TG-2S TG-8S

MW- 8-56 MW- 8-29 TG-C TG-16 TG-3S TG-C'

MW- 13-61; MW-13 MW- 13-30 TG-13 TG-5S TG-6S

TG-14 TG-E TG-D TG-9S

MW-11 MW- 10-61 MW- 10-25 MW- 15-50 MW-9 TG-10S TG-11S

Legend

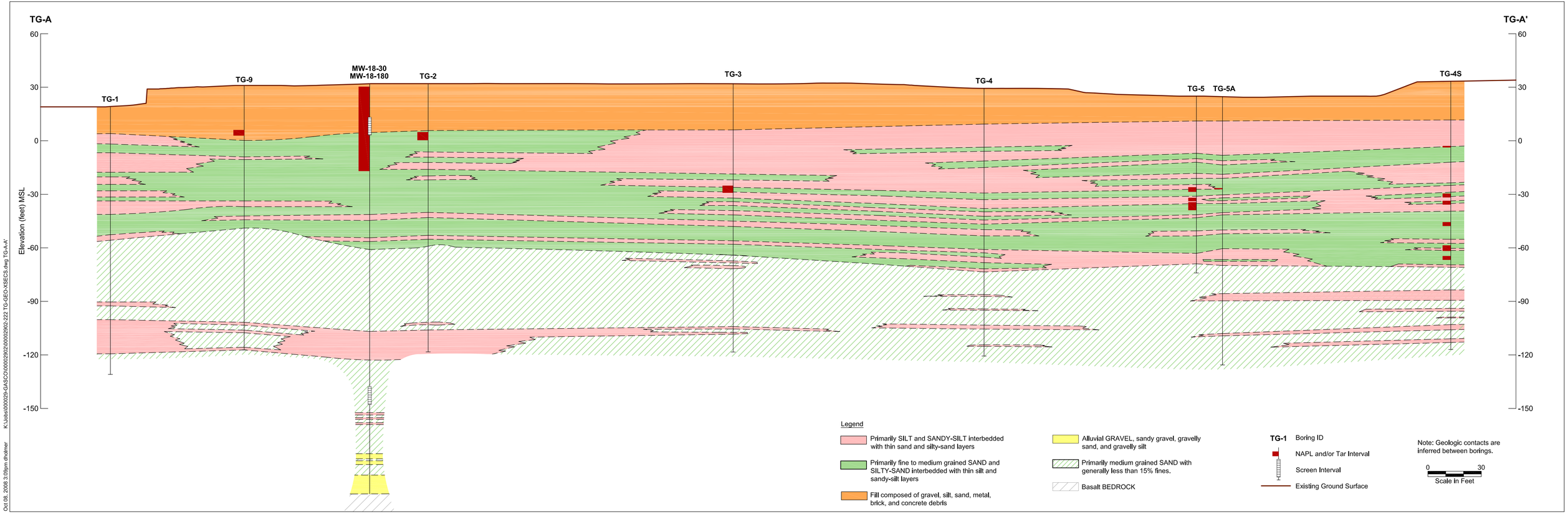
- TG-9 ● Boring Location and Number
- MW-2-12 ◔ Existing Monitoring Well Location and Number
- GS-01 ◑ Gasco Phase 1 Offshore Boring Location and Number
- B-1 ■ Geotechnical Boring Location and Number
- TG — Cross Section Location and Designation

0 150
Scale in Feet

K:\Jobs\000029-GASCO\0000290200002902-214 GEO-XSEC MAP.dwg FIG 2 PreDsgn (TG SERIES)
Oct 03, 2008 4:22pm dholmer

ANCHOR ENVIRONMENTAL, L.L.C.

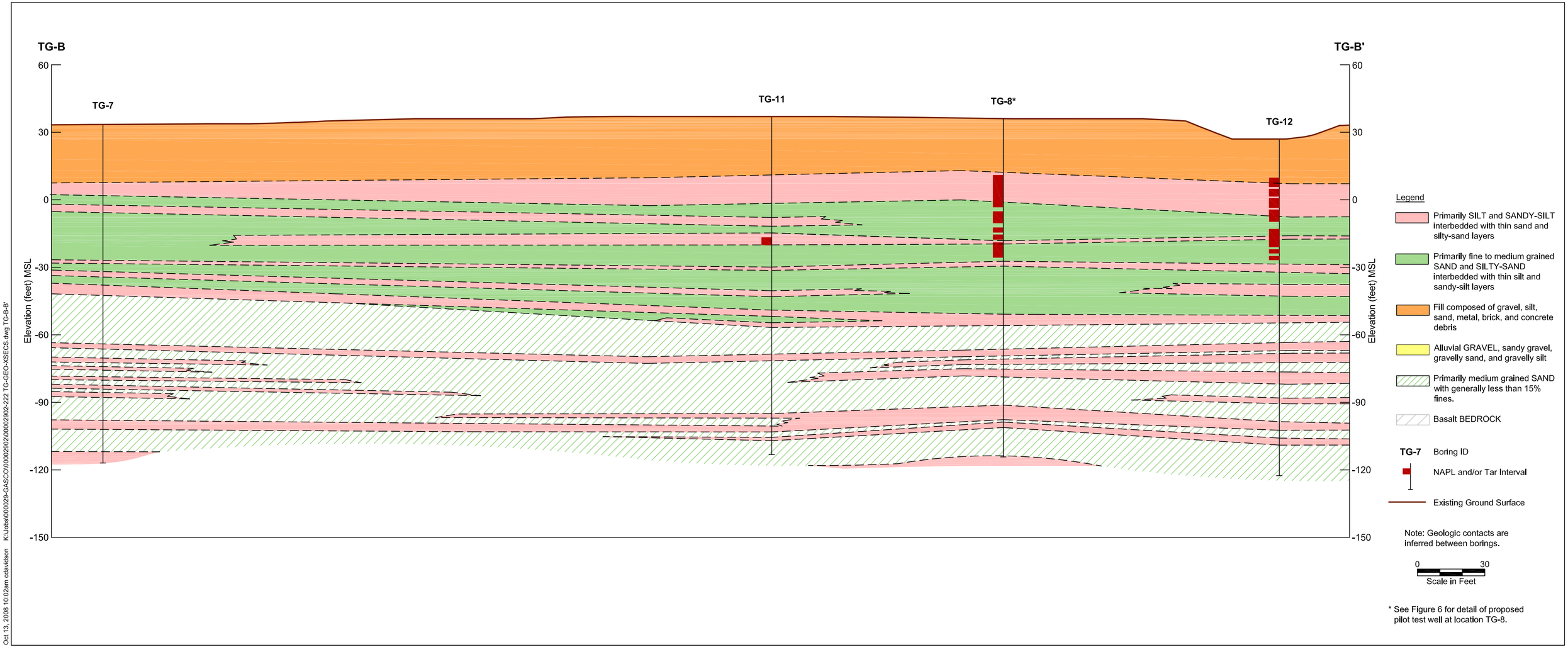
Figure 1
Geologic Profile Location Map
Gasco, Portland, Oregon



Oct 08, 2008 3:09pm dhdmer K:\Jobs\000029-GASCO\0000292\0000292\0000292-222 TG-GEO-XSECS.dwg TG-A-A'

ANCHOR ENVIRONMENTAL, L.L.C.

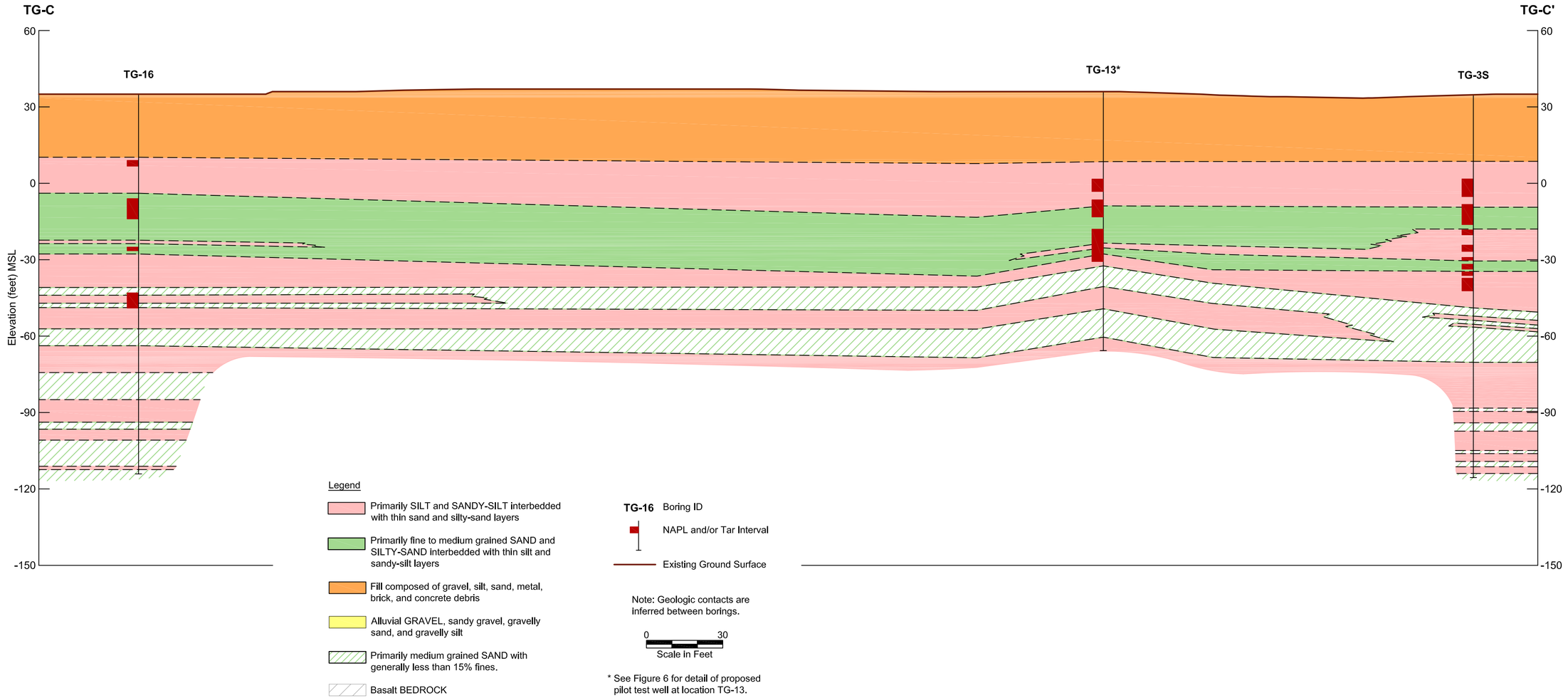
Figure 2
Cross Section TG-A



Oct 13, 2008 10:02am cdavidson K:\Jobs\0000029-GASCO\0000292\000029202\000029202-222 TG-GEO-XSECS.dwg TG-B-B'

ANCHOR ENVIRONMENTAL, L.L.C.

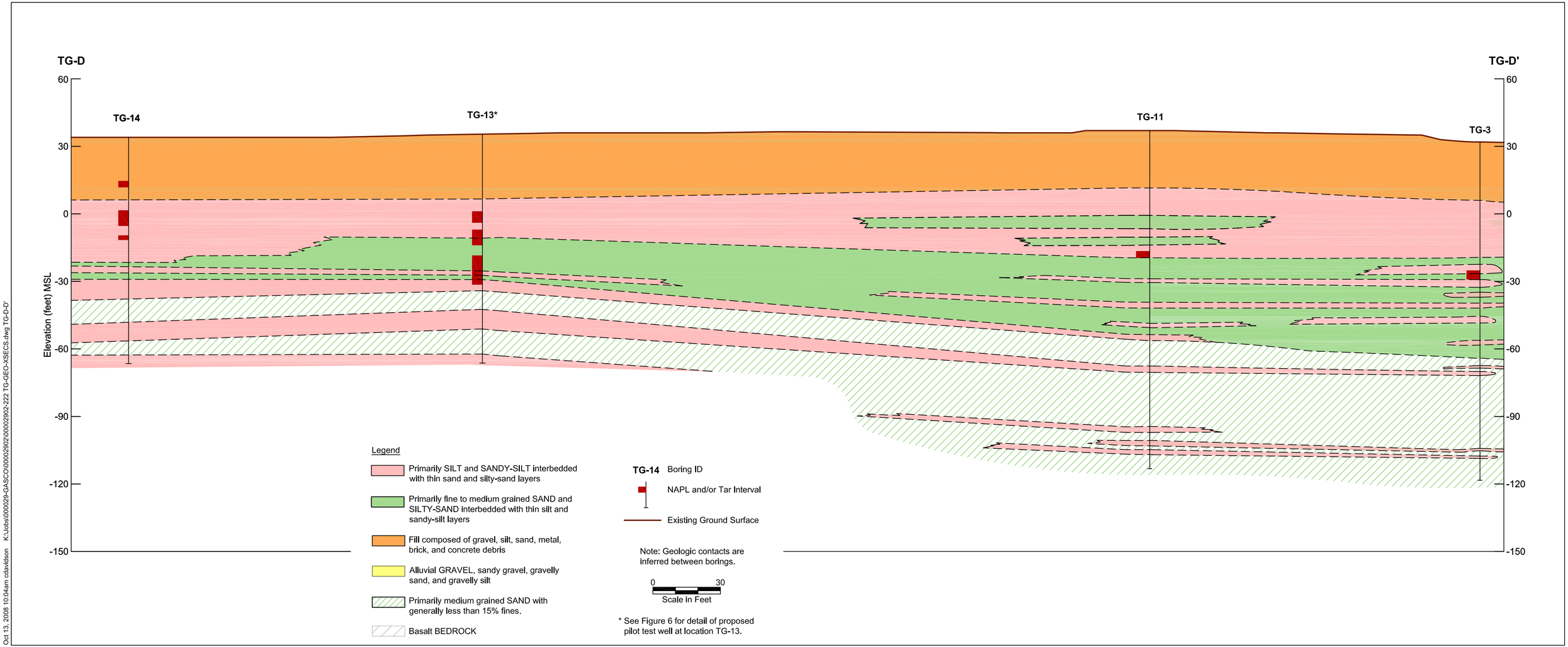
Figure 3
Cross Section TG-B



Oct 13, 2008 9:50am cdavidson K:\Jobs\000029-GASCO\000029802\000029802-222 TG-GEO-XSECS.dwg TG-C-C'

ANCHOR ENVIRONMENTAL, L.L.C.

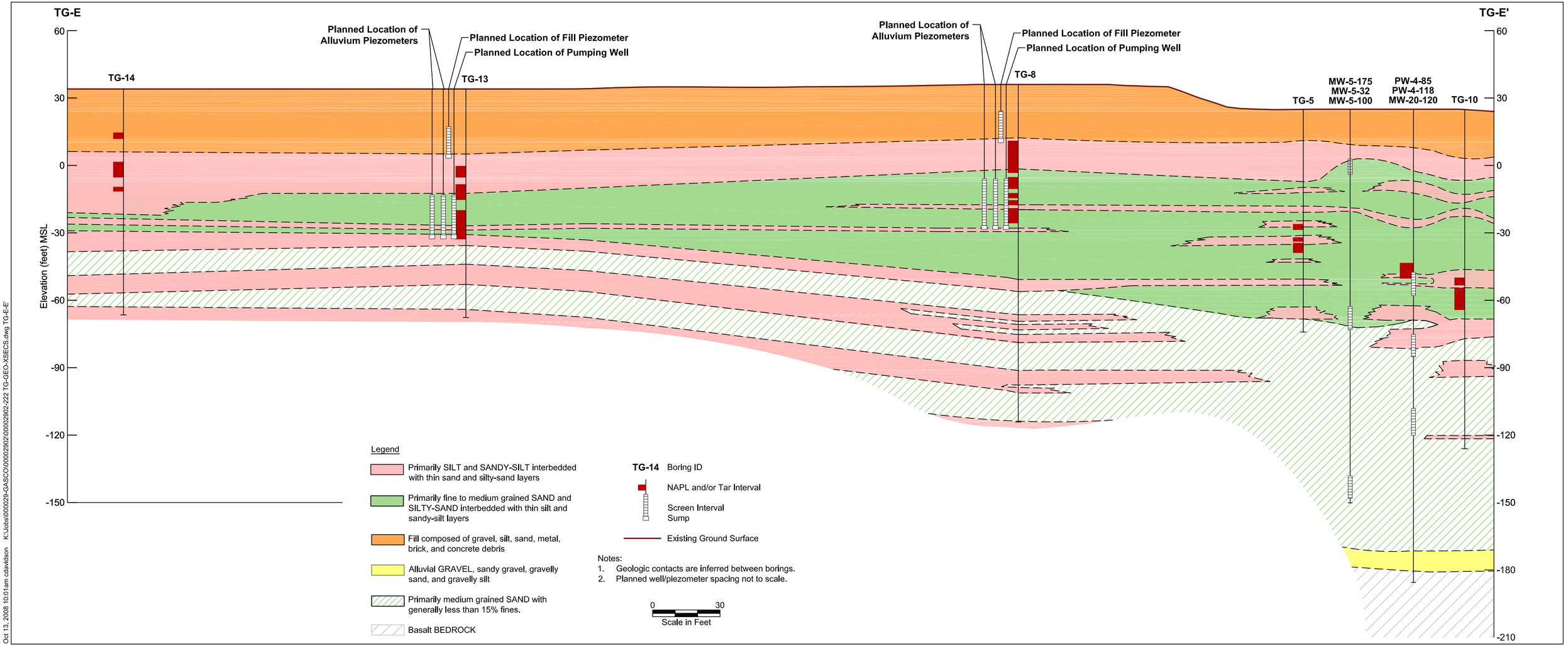
Figure 4
Cross Section TG-C



Oct 13, 2008 10:04am cdavidson K:\Jobs\0000029-GASCO\0000292\00002902-222 TG-GEO-XSECS.dwg TG-D-D'

ANCHOR ENVIRONMENTAL, L.L.C.

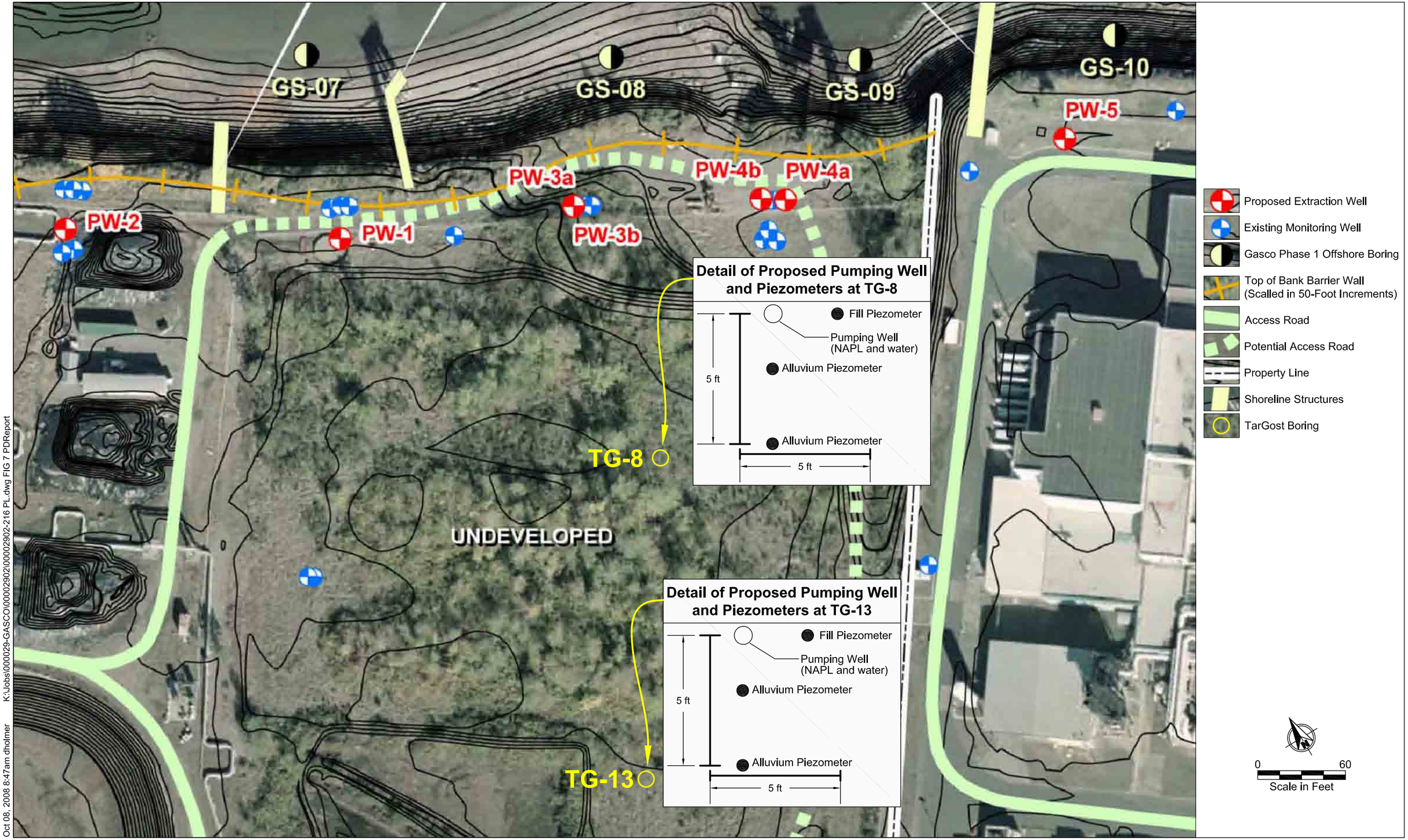
Figure 5
Cross Section TG-D



Oct 13, 2008 10:01am cdavidson K:\Jobs\000029-GASCO\00002902000002902-222 TG-GEO-XSECS.dwg TG-E-E'

ANCHOR ENVIRONMENTAL, L.L.C.

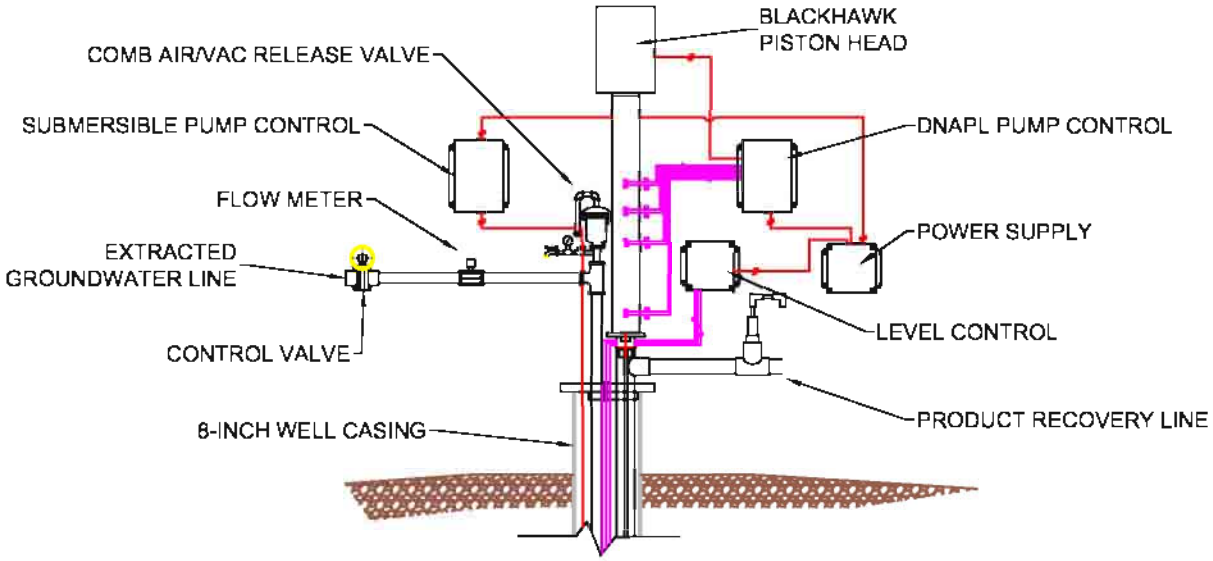
Figure 6
Cross Section TG-E

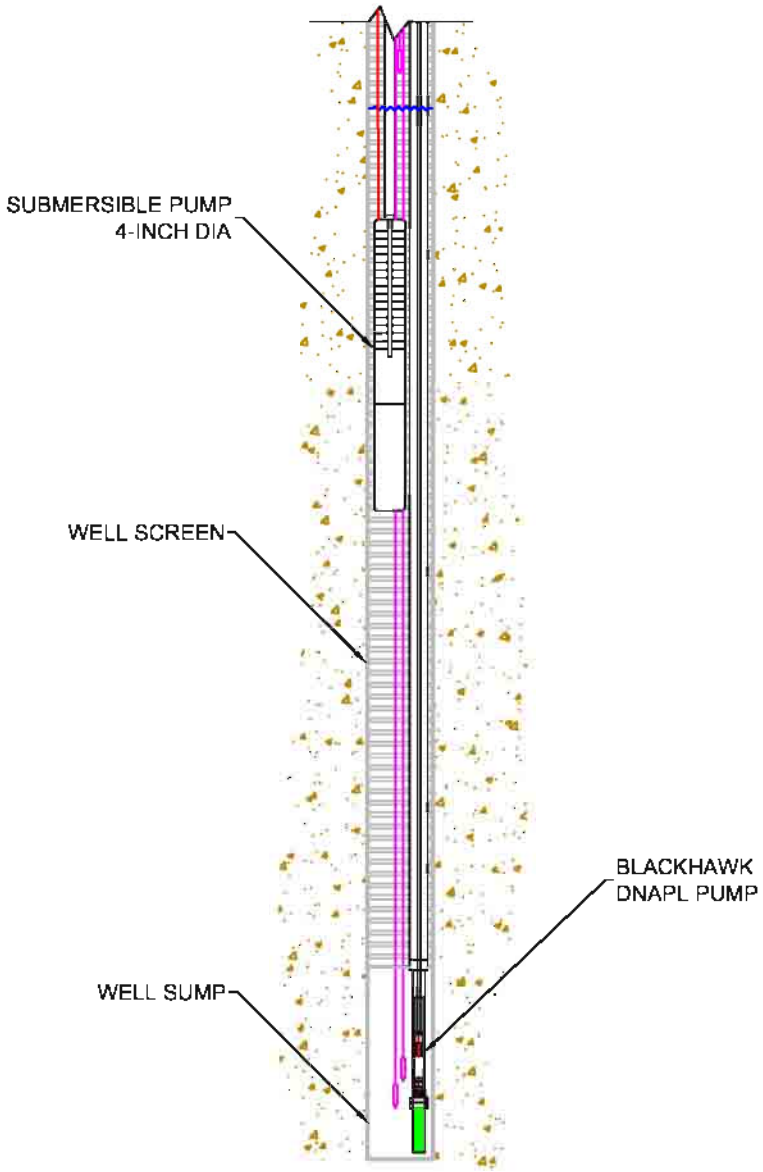


K:\Jobs\000029-GASCO\00002902\00002902-216 PL.dwg FIG 7 PDRep
Oct 08, 2008 8:47am dholmer

ANCHOR ENVIRONMENTAL, L.L.C.

Figure 7
Map of DNAPL Pilot Layout
Gasco/Siltronic, Portland, Oregon





NW NATURAL
GASCO
PORTLAND, OREGON

SCHEMATIC, DUAL PUMP DNAPL RECOVERY

"PARTNERS IN SERVICE"

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

DATE	10/07/08
DRAWN	LAD
DESIGN	LAD
CHECK	KAD
SCALE	NTS
SHEET	1 OF 1