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Alameda County Health Care Services
1131 Harbor Bay Parkway, Suite 250
Alameda, California 94502-6577

RE: **Additional Site Assessment Work Plan Addendum**
Former Chevron Service Station 97127
Grant Line Road and Interstate 580
Tracy, California
RWQCB # RO0000185

Dear Mr. Detterman:

ARCADIS U.S., Inc. (ARCADIS), at the request of Chevron Environmental Management Company (Chevron), has prepared the enclosed Additional Site Assessment Work Plan Addendum for Former Chevron Service Station 97127, located at Grant Line Road and Interstate 580 in Tracy, California.

I declare to the best of my knowledge at the present time, that the information and/or recommendations contained in the attached document are true and correct. The enclosed report is submitted pursuant to the requirements of California Water Code Section 13267 (b)(1).

Sincerely,

Catalina Espino Devine
Project Manager

ARCADIS U.S., Inc.
950 Glenn Drive
Suite 125
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Tel 916-985-2079
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ENVIRONMENT

Mr. Mark Detterman, P.G., C.E.G.
Alameda County Environmental Health
1131 Harbor Bay Parkway, Suite 250
Alameda, California 94502-6577

Subject:
Additional Site Assessment Work Plan Addendum
Former Chevron Service Station No. 97127
Grant Line Road and Interstate 580
Tracy, California
RWQCB # RO0000185

Date:
June 26, 2013

Contact:
Tonya R. Russi

Phone:
916.985.2079 ext. 15

Email:
Tonya.Russi@
arcadis-us.com

Our ref:
B0047959.0001

Dear Mr. Detterman:

On behalf of Chevron Environmental Management Company (Chevron), ARCADIS U.S. Inc. (ARCADIS) has prepared this *Additional Site Assessment Work Plan,* dated September 14, 2012 and *Additional Site Assessment Work Plan Addendum* for the former Chevron service station 97127, located at the east side of Grant Line Road, just south of Interstate-580 in a rural area of Tracy, California (Figure 1).

ARCADIS prepared this work plan as requested by the Alameda County Environmental Health Department (ACEHD), as indicated in their letters dated July 27, 2012 and April 29, 2013, respectively. As discussed on the phone with ACEHD on May 30, 2013, the Site Conceptual Model (SCM) and Interim Remedial Action Plan (IRAP) deliverable schedule will be adjusted following submittal of the assessment report. The ACEHD requested a soil and groundwater investigation work plan and a Feasibility Study (FS)/Corrective Action Plan (CAP). A FS/CAP may be necessary in the future for addressing impacted media at the site; however, an effective remedial approach cannot be determined until the contamination at the site (including the light non-aqueous phase liquids [LNAPL] and dissolved phase plume) is more comprehensively delineated.

The purpose of this work plan is for ARCADIS to collect additional data necessary to evaluate transport mechanisms from various media (i.e., soil, groundwater) that may be impacted by releases of petroleum hydrocarbon constituents and to identify potential data gaps in the existing information. ARCADIS will use the shallow soil sample data being collected to evaluate human health exposure risk based on low threat closure criteria and to evaluate shallow soil conditions for site re-development. The details of the investigation are discussed below.

Site Description and Features

The site is a vacant lot located on the east side of Grant Line Road, just south of Interstate-580 in a rural area of Tracy, California (Figure 1). Former service station facilities at the site included fuel underground storage tanks (UST) (two 10,000-gallon capacity and one 1,000-gallon capacity), one steel used oil UST (1,000-gallon capacity), one heating oil UST (750-gallon capacity), product line piping and pump islands, and station building (Figure 2). The USTs and associated piping were removed in April 1991. The station building and pump islands were subsequently razed, and the site is currently a vacant lot.

Previous Investigations

October 1987 – Soil Vapor Investigation

EA Engineering, Science, and Technology, Inc. (EA) collected fifteen soil vapor samples (V1 through V15) from temporary sample points. The soil vapor sample points were located both on- and off-site and ranged in depth from 3 to 12 feet below ground surface (bgs). Based on the soil vapor sample analytical results, EA determined that LNAPL may exist near the USTs and pump island (EA Engineering, Science, and Technology, Inc. (EA), 1987).

1987-1988 – Subsurface Investigation and Well Sampling

During December 1987, Kleinfelder advanced seven on-site soil borings (B-1 through B-7) to depths ranging from 5 to 20 feet bgs. Total petroleum hydrocarbons as gasoline (TPH-GRO) was detected at a maximum concentration of 2,300 milligrams per kilogram (mg/kg) and benzene was detected at a maximum concentration of 19 mg/kg at a depth of 15 feet bgs. In December 1987 and January 1988, Kleinfelder collected water samples from a water tap located on the south side of the former station building and a water tap located adjacent to the on-site domestic water well. Both taps are supplied by the on-site domestic water well located near the southeast corner of the site. The water samples collected from the both taps had detectable concentrations of benzene of 2 and 4 micrograms per liter (µg/L), exceeding the California recommended action level (Kleinfelder, 1988). Water samples were collected as part of the initial site assessment.

1988 through 1991 Domestic Well Monitoring

Due to the benzene concentrations detected during the initial site assessment, GeoStrategies Inc. (GeoStrategies) conducted further water sampling of the on-site domestic water well and conveyance piping. During January 1988, GeoStrategies collected water samples from the tap located adjacent to the on-site domestic water well, benzene was found at concentrations of 1 and 1.1 µg/L. During February 1988, GeoStrategies collected water samples from the water tap located on the south side of the former station building and the on-site domestic, detectable concentration of benzene were not found. During March 1989, Gettler-Ryan (G-R) collected water samples from the on-site domestic well, the tap located adjacent to the on-site domestic water well, and a spigot located off-site, benzene was found at concentrations of 3.7, 2.7 and 1.4 µg/L, respectively. During April 1989, G-R collected water samples from the spigot located off-site and the on-site domestic well, benzene was found at concentrations of 2 and 7 µg/L (GeoStrategies Inc., 1989).

During May 1989, G-R installed a carbon adsorption water treatment system on the wellhead and weekly sampling commenced. Between August 1989 and March 1991, G-R collected water samples from the on-site domestic well. Of the 26 water samples, TPH-GRO and benzene were not detected above their respective laboratory reporting limits with the exception of two samples; one which contained TPH-GRO at a concentration of 320 µg/L and one which contained benzene at a concentration of 0.07 µg/L (Kleinfelder, 1988, 1989, and Pacific Environmental Group’s [PEG], 1993).

April 1991 – Tank, Product Piping, and Dispenser Island Removal

During April 1991, Blaine Tech Services Inc. (Blaine Tech) demolished the service station removing two 10,000-gallon and one 6,000-gallon gasoline USTs, one 1,000-gallon used oil UST, a 750-gallon heating oil UST, two dispenser islands and associated product piping. The USTs were all constructed of fiberglass, and no holes were observed during UST removal activities. Elevated petroleum hydrocarbons were observed during the initial confirmation soil sampling in the UST pit area and the product piping area, therefore, over excavation was conducted to depths ranging from 13 to 18 feet bgs. Final confirmation soil samples contained concentrations of TPH-GRO at 710 mg/kg and benzene at 0.085 mg/kg at depths of 15 and 14 feet bgs, respectively. In an effort to reduce the concentrations of TPH-GRO in excavated soil to less than 10 mg/kg, Blaine Tech aerated the excavated soil on-site. Blaine Tech then used the aerated excavation soil as backfill (Blaine Tech, 1991).

December 1992 – Monitoring Well Installation/1993 – Water-Supply Well Sampling

During December 1992, Pacific Environmental Group (PEG) installed one soil boring (B-1) and three monitoring wells (MW-1 through MW-3) at the site and collected soil samples at various depths. Concentrations of TPH-GRO were detected up to 8,100 mg/kg and concentrations of benzene were detected up to 21 mg/kg. Subsequent to installation, PEG observed separate phase hydrocarbons (SPH) in monitoring well MW-1 at a thickness of 1.67 feet. PEG sampled the water supply well was sampled weekly from January through March 1993. During one event, water samples contained benzene and toluene at concentrations of 3 and 2 µg/L, respectively. Water samples from the remaining events did not contain detectable concentrations of TPH-GRO and BTEX. (PEG, 1993).

1993 – LNAPL Removal

During 1993, PEG bailed SPH on a weekly basis from MW-1. Additionally, in January 1993 installed a passive skimmer in monitoring well MW-1. As of March 1993, approximately 2 gallons of SPH has been recovered from MW-1 (PEG, 1993).

May 1993 – Monitoring Well Installation

PEG advanced one soil boring (B-3) was advanced and two monitoring wells (MW-4 and MW-5) were installed in May 1993. Concentrations of TPH-GRO and benzene were not detected in the soil samples collected from monitoring well MW-5 at 10 and 15 feet bgs. PEG collected a grab groundwater sample from boring B-3. The grab groundwater sample contained concentrations of TPH-GRO at 96 µg/L and benzene at 1 µg/L (PEG, 1993).

October 1994 – Comprehensive Site Evaluation

Weiss Associates (WA) performed a comprehensive site evaluation in October 1994 to address an additional investigation request, summarize investigative and remedial activities performed at the site to date, evaluate whether the site meets non-attainment criteria and outline a future action plan. The historical data suggested that the hydrocarbon source areas had been removed and that the plume was primarily contained on-site. The full extent of the plume was still unknown, and the installation of an additional monitoring well off-site, to the north was recommended (Weiss Associates [WA], 1994).

October 1995 – Monitoring Well Installation

PEG installed three monitoring wells (MW-6 through MW-8) at the site in October 1995 and collected soil samples at multiple depths. TPH-GRO and benzene were not detected in any of the soil samples collected (PEG, 1996).

June 1997 – Risk-Based Assessment

In June 1997, PEG completed a Tier-2, Risk-Based Corrective Action (RBCA) assessment. PEG determined that due to the elevated concentrations of TPH-GRO and benzene in monitoring wells MW-1, MW-3 and MW-4, groundwater ingestion may pose a risk to human health. In addition the RBCA assessment concluded that the on-site water supply well was a potential receptor for residual petroleum hydrocarbons in soil and groundwater beneath the site (PEG, 1997*).*

1998-2001 – Bioremediation

In August 1998, Chevron's subcontractor installed Oxygen Release Compound® (ORC) socks in wells MW-1, MW-2 and MW-4 to enhance biodegradation and reduce petroleum hydrocarbon concentrations. PEG replaced the ORC sock in monitoring well MW-1 in July 2001 with a passive skimmer. (Delta, 2003). Chevron's subcontractor removed the ORC socks in the remaining wells at an unknown date.

December 1999 – Hydrogen Peroxide Injection

Cambria Environmental Technology (Cambria, now CRA) injected hydrogen peroxide at various concentrations in MW-1 and MW-3 during December 1999 to reduce SPH and petroleum hydrocarbon concentrations in groundwater at the site (Cambria, 2000*).*

May 2001 – Corrective Action Plan (CAP)

During May 2001, Delta Environmental Consultants, Inc. (Delta) submitted a CAP which recommended the destruction of the on-site water supply well and monthly bailing of LNAPL from MW-1 for two quarters. (Delta, 2001).

2001-2002 – Remedial Activities

In July 2001, Delta installed a passive skimmer in well MW-1 and seven groundwater vacuum extraction events were conducted through April 2002. During these vacuum extraction events, Delta removed approximately 8,300 gallons of groundwater and 2.19 gallons of SPH from well MW-1. Delta initiated vacuum extraction from well MW-3 in July 2002. Delta terminated vacuum extraction from both wells in October 2002 due to an increase in SPH thickness. (Delta, 2003)

April 2003 – Remedial Action Plan (RAP) and Feasibility Study (FS)

Delta submitted a RAP/FS in April 2003. Based on data presented in the report, Delta suggested that a perched zone of groundwater was present at approximately 10 to 40 feet bgs with confining bedrock underling the perched zone. Delta also suggested that impacted soil is limited in the areas near the former USTs of the capillary fringe zone at approximately 25 to 30 feet bgs. The preferred remedial alternative of this RAP/FS was the use of an active mechanical skimmer with monitored natural attenuation (Delta, 2003).

March and April 2007 – Groundwater Extraction

During March and April, CRA removed approximately 5,100 gallons of impacted groundwater from well MW-1 in a series of three batch groundwater extraction events. LNAPL thickness was 0.5 feet before the first event, 0.36 before the second event, and 0.39 before the third event.

May 2007 – CAP

During May 2007 CRA submitted a CAP which evaluated the following alternatives: oxygen injection, batch groundwater extraction, and surfactant-enhanced recovery. The preferred remedial alternative was surfactant-enhanced recovery with groundwater extraction (CRA, 2007).

October 2007 – Interim Remedial Action Plan (IRAP)

In order to further characterize the hydrocarbon distribution, hydrogeologic conditions, and facilitate the remediation of groundwater and soil vapor from bedrock fracture, the October 2007 IRAP proposed the installation of three monitoring wells surrounding MW-1. In addition, surfactant-enhanced recovery was recommended to remove LNAPL from the pore space of the subsurface (CRA, 2007*).*

December 2008 – CAP Addendum and Proposed Feasibility Study

In order to further evaluate the hydrogeologic conditions and behavior of groundwater at the site, CRA recommended groundwater pumping tests in the December 2008 CAP Addendum and Proposed FS. (CRA, 2008).

May 2010 Vacuum Extraction Event/Pilot Test

In May 2010, CRA performed a vacuum extraction pilot test in order to remove LNAPL and evaluate hydrogeologic conditions to evaluate if surfactant-enhanced recovery would be an effective remedial option for the removal of LNAPL. The results of the pilot test indicated that MW-1 and MW-3 were hydrogeologically connected, as evidence of drawdown and a reduction in LNAPL observed in MW-3. It was also observed that MW-5 through MW-7 were hydrogeological connected with MW-1 and MW-3. It was assumed that if surfactant were placed in MW-1 and MW-3, they could be easily recovered. In addition, surrounding monitoring wells would be useful as observation wells. Surfactant-enhanced recovery was identified as a preferred and feasible alternative. A work plan outlining this method was submitted (CRA, 2010).

Proposed Scope of Work

ARCADIS proposes the following scope of work to further characterize impacts to soil and groundwater on the subject property. The scope of work proposed for this assessment includes the advancement of thirteen soil borings, one offsite monitoring well, and the completion of an additional LNAPL baildown test (Figure 2). As requested by ACEHD in their letter dated April 29, 2013 and in a meeting on June 13, 2013, additional borings and an offsite monitoring wells were added to the proposed scope of work to aid in defining the groundwater plume.

Site Specific Health and Safety Plan

As required by the Occupational Health and Safety Administration (OSHA) Standard “Hazardous Waste Operations and Emergency Response” guidelines (29 Code of Federal Regulations Section 1910.120), and by California Occupational Health and Safety Administration (Cal-OSHA) “Hazardous Waste Operations and Emergency Response” guidelines (California Code of Regulations Title 8, Section 5192), ARCADIS will prepare a site-specific health and safety plan (HASP) prior to commencement of fieldwork. Field staff and contractors will review the HASP before beginning field operations at the site.

Permitting

All applicable permits will be obtained from the ACEHD and the City of Tracy, as necessary, prior to commencing field activities.

Underground Utility Locating

Underground Service Alert (USA) will be notified a minimum of 48 hours prior to commencing field activities to identify any public utility alignments that may be in conflict with the proposed boring. In conjunction with the USA notification, a private utility locating company will be utilized for clearing proposed boring locations for underground utilities. Locations may require field modifications due to onsite utilities and/or field conditions.

Soil Borings

The drilling subcontractor will hand clear fourteen boring locations using either an air knife or hand auger to a minimum depth of 8 feet 1 inch bgs (utility clearance depth) or as conditions permit. ARCADIS will retain and collect soil samples at the (2 feet, 5 feet, and 10 feet) intervals from a slide hammer from the twelve boring locations during utility clearance. In addition, ARCADIS will collect soil samples continuously from the ten foot interval to the total borehole depth for logging purposes and visual classification. The drilling subcontractor will advance boreholes with a 4-inch diameter inner core tube in 2.5 foot sections of 20 foot runs. ARCADIS will log each discrete interval for soil characteristics including soil type, color, moisture content, etc. In addition, visual observations will be noted regarding observed odor, staining, and relative volatile organic compound concentrations as measured with a photo-ionization (PID) from soil head space. Following the inner core run, the drilling subcontractor will advance a temporary outer drive casing (6.375 inch outer diameter) to the depth of the inner core run. After each core run, the resultant soil core will be extruded into a specifically designed clear plastic core bag to ensure no core sample will be lost. The boreholes will be advanced in this manner to approximately 40 feet bgs. A field cross section of the subsurface stratigraphy will be generated to determine the depths of the high permeability zones.

Soil Sample Analysis

ARCADIS will collect undisturbed soil cores to characterize the in-situ conditions that control separate phase hydrocarbon (SPH) migration in the subsurface. The objective of undisturbed soil core collection is to obtain samples that are representative of the in-situ conditions that control SPH migration. Therefore, the collection methods implemented are optimized to maintaining soil pore structure and retaining aquifer fluids (SPH and groundwater) within the core. ARCADIS will collect undisturbed soil cores at two to three sampling depths and up to three soil samples will be collected from each boring and will be submitted to a laboratory for analysis based on PID measurements and or visual characterization (i.e. LNAPL, odors, sheen). ARCADIS will collect the soil sample cores in polyvinyl chloride (PVC) sleeves and the length of the soil core will depend on the extent of the SPH impacts. ARCADIS will choose sampling depths for undisturbed soil core based upon the areal and vertical extent of SPH impact. ARCADIS will collect soil cores from soil borings advanced with a sonic drilling rig in accordance with the ARCADIS *LNAPL Soil Core Collection Standard Operating Procedure (SOP),* provided in Attachment 1. ARCADIS will freeze cores vertically on-site with dry-ice to maintain the integrity of the soil core following methods specified in the SOP (Attachment 1).

ARCADIS will ship frozen soil cores to PTS Laboratories, Inc. in Santa Fe Springs, California, and photographed under natural (white) and ultra-violet (UV) light. Based on a review of soil core photographs and field data, ARCADIS will designate laboratory tests for specific intervals and cores to characterize aquifer matrix properties and pore fluid saturations. Specific laboratory tests for this SPH mobility evaluation may include:

- LNAPL saturation and residual saturation testing via centrifuge by American Society for Testing and Material (ASTM) Method D425 and via water drive by a proprietary method and API RP40

- Air-water drainage capillary pressure-saturation testing by ASTM Method D6836

- Grain size analysis by ASTM Methods D422 and D4464

ARCADIS will utilize the results of these laboratory analyses along with other site-specific information to characterize SPH mobility in the areas of interest at the site.

Duplicate soil samples will be submitted to Lancaster Laboratories, Incorporated (Lancaster) and analyzed for the presence of:

- TPH-GRO [C_6-C_{12}] by United States Environmental Protection Agency (USEPA) Method 8015B
- Benzene, toluene, ethylbenzene, and total xylenes (BTEX) by USEPA Method 8260B
- Methyl tertiary butyl ether (MTBE) by USEPA Method 8260B

Shallow soil samples (2 feet, 5 feet, and 10 feet) will also be analyzed for the presence of:

- Naphthalene by USEPA Method 8260B

Temporary Wells

ARCADIS will collect groundwater grab samples from thirteen of the fourteen boring locations using temporary wells constructed of 1 inch outside diameter (OD) poly-vinyl chloride (PVC) with a 2.5 inch OD by 10 feet PrePacked screen. The PrePacked screen standard operating procedure (SOP) is included in Attachment 2. It is anticipated that the temporary wells will be screened from approximately 30 to 40 feet bgs. ARCADIS will determine the actual screen and depth interval based on observations in the field. Prior to sample collection, ARCADIS will purge water (i.e. three casing volumes) from the temporary well to remove sediments accumulated during the drilling activities. ARCADIS will collect groundwater samples for analysis with a disposable Teflon® bailer and transfer to the appropriate laboratory-supplied sample container. ARCAIDS will place the samples on ice for transport to the laboratory accompanied by chain-of-custody documentation. Following completion of soil sampling, the drilling subcontractor will be tremie grout the boreholes to ground surface.

Monitoring Well Installation

Upon completion of the soil borings, one monitoring well (MW-16) will be constructed using 2 inch OD PVC casing with approximately 15 feet of 0.020 inch slotted PVC screen. The screen interval will be placed at approximately 19 to 34 feet bgs. A #3 sand filter pack will be placed around the well from the bottom of the borehole to approximately 2 feet above the screen interval followed by approximately 2 feet of hydrated coated bentonite chips. The remainder of the borehole annulus will be grouted using tremie piping to within approximately 1 foot of the ground surface. The well will be completed with a standpipe set in concrete. The actual screen and depth interval will be determined based on observations in the field.

Monitoring Well Development and Sampling

The newly installed well will be developed and sampled a minimum of 48 hours following installation. Prior to sample collection, water will be purged (i.e. ten casing volumes) from the well to remove sediments accumulated during the drilling activities. During the development, field parameter measurements consisting of specific conductance, pH, turbidity, color, odor, dissolved oxygen, oxygen reduction potential and temperature will be measured using a groundwater quality meter. Groundwater samples will be collected for analysis with a disposable Teflon® bailer and transferred to the appropriate laboratory-supplied sample container. The samples will be placed on ice for transport to the laboratory accompanied by chain-of-custody documentation.

The newly installed monitoring wells will be monitored and sampled on a quarterly basis and will be added to the existing monitoring and sampling plan. In accordance with the existing sampling plan, groundwater samples will be collected with new disposable bailers after purging approximately three well volumes.

Laboratory Analysis

Soil and groundwater samples will be submitted to a California Department of Health Services-Certified laboratory under appropriate chain-of-custody protocols. Duplicate soil and groundwater samples will be submitted to an appropriate forensics lab for comparative analysis.

Groundwater Sample Analysis

Groundwater samples will be submitted to Lancaster and analyzed for the presence of:

- TPH-GRO [C_6-C_{12}] by USEPA Method 8015B
- BTEX by USEPA Method 8260B
- MTBE by USEPA Method 8260B

Comparative Analysis

Groundwater samples collected from each boring (thirteen borings) will be analyzed for over 120 paraffin, isoparaffin, aromatic (includes BTEX), naphthene, and olefin (PIANO) compounds in the gasoline range by a modified Method 8260 methodology. The PIANO results will be used to compare compositional characteristics of the samples through pattern recognition and compound class presence/absence. In addition, the results will be used to calculate particular compound diagnostic ratios for use in source identification/differentiation. The gas chromatograms (GC) fingerprints of the total petroleum hydrocarbons (TPH) analysis will be used to identify particular fuel oil products and other material that may be in the samples.

Light Non-Aqueous Phase Liquid Baildown Test

In order to evaluate hydrogeologic conditions at the site, ARCADIS will conduct a LNAPL baildown test. The previously conducted bail down test wasn't conducted with continuous gauging and NAPL recovery wasn't measured. The results of the baildown test will aid ARCADIS in evaluating LNAPL mobility and recoverability at the site. ARCADIS will install one peristaltic pump, or similar pump, temporarily in monitoring well MW-1 and transducers will be placed in monitoring well MW-1 and surrounding wells (MW-9, MW-10, MW-11, and MW-15) in order to record hydraulic head as a function of time during the baildown test. ARCADIS will remove LNAPL from MW-1 with a peristaltic pump, or similar pump. LNAPL removal will not last longer than 5 minutes, thus it will be assumed that LNAPL is being removed from the well instantaneously. When LNAPL has been removed to the extent practical, ARCADIS will begin measuring in five minute increments to monitor changes in hydraulic head. Field staff will collect and record measurements of LNAPL and depth to water. The SOP is presented in Attachment 3. The total time of data collection will be dependent on the LNAPL recovery rates. If recovery rates are fast then data will be collected for two hours. However, if LNAPL recovery rates are slow then measurements will be recorded for eight hours. ARCADIS will place the LNAPL and groundwater collected during the test in a proper waste management container. ARCADIS will collect LNAPL fuel fingerprint samples will be collected to aid in determining the plume source.

- Full scan volatile organic carbon (VOC) by USEPA Method 8260
- Fuel Fingerprint

Investigative Derived Waste

ARCADIS will containerize soil cuttings, drilling fluids, purge water, decontamination water and personal protective equipment (PPE) generated during drilling operations in Department of Transportation (DOT) – approved 55-gallon drums and temporarily stored on the subject property pending characterization and disposal. Upon characterization, a Chevron disposal contractor will transport waste to an appropriate disposal or treatment facility.

Report

ARCADIS will prepare a report detailing the results of the investigation subsequent to the completion of all field activities and the receipt of all analytical data. The report will include at a minimum the following:

- A summary of site conditions and background information
- A scaled site plan illustrating the temporary well locations and other relevant site features
- Documentation of field activities performed in connection with the site assessment
- Geologic boring logs
- Figure illustrating regional groundwater flow direction
- Transect including boring locations
- LNAPL mapping

- Conclusions relevant to the assessment objective

Schedule

ARCADIS is prepared to initiate field work upon the approval of this work plan by the ACEHD and issuance of necessary permits. As requested by ACEHD, a field work implementation schedule is provided in Attachment 4.

If you have any questions or comments regarding the content of this letter, please contact David Lay by telephone at 916.985.2079 ext. 22 or by e-mail at David.Lay@arcadis-us.com or Tonya Russi by telephone at 916.985.2079 ext. 15 or by e-mail at Tonya.Russi@arcadis-us.com

Sincerely,

ARCADIS U.S., Inc.

Tonya Russi

Tonya R. Russi
Associate Project Manager

Melissa Blanchette

Melissa Blanchette, P.G.
Principal Geologist

PROFESSIONAL GEOLOGIST
MELISSA BLANCHETTE
No. 8531
Exp. 10/31/13
STATE OF CALIFORNIA

References

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Enclosures:

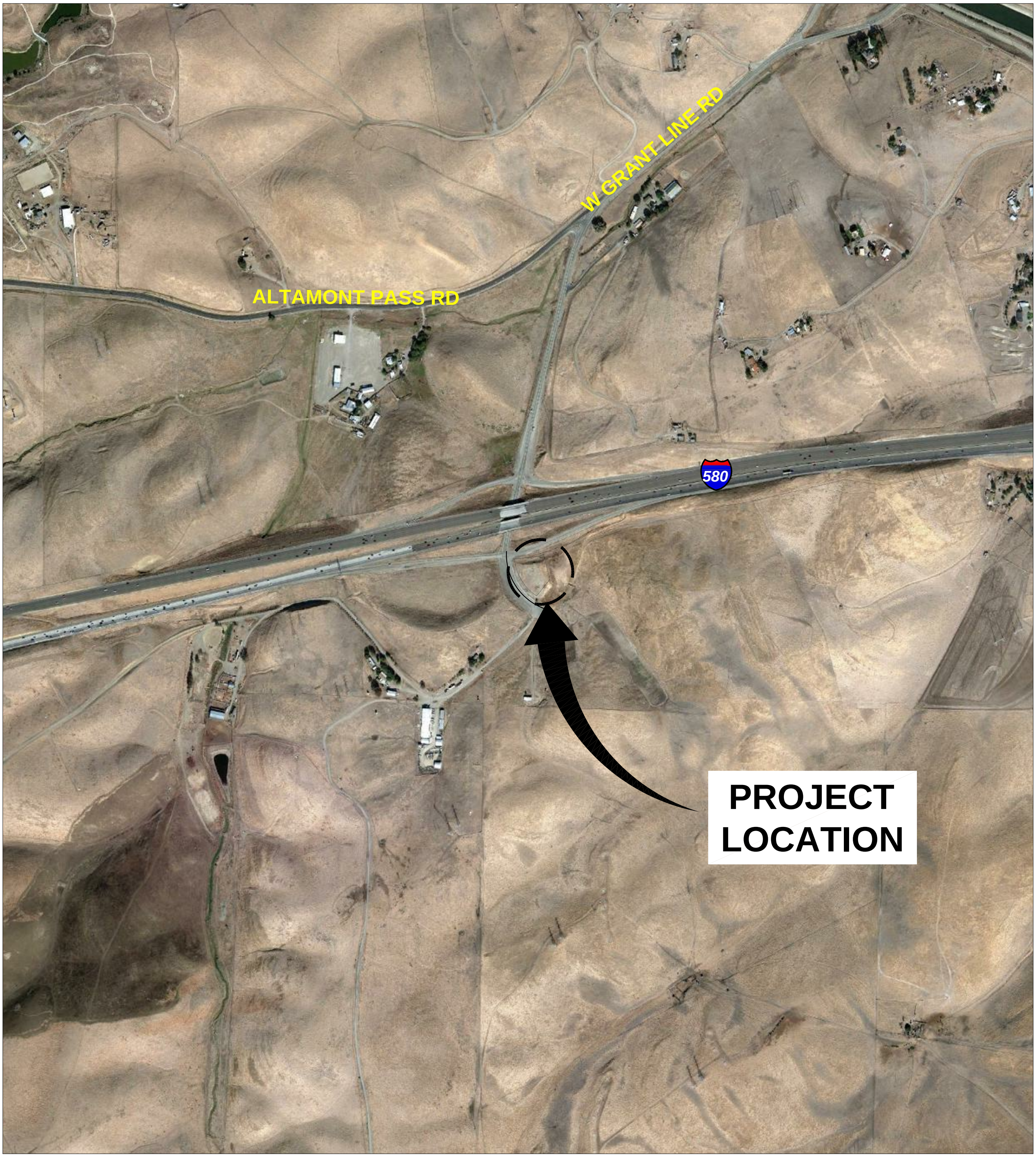
Figure 1	Site Location Map
Figure 2	Site Plan with Proposed Boring and well Locations
Attachment 1	ARCADIS *LNAPL Soil Core Collection* SOP
Attachment 2	ARCADIS *PrePacked Screen* SOP
Attachment 3	ARCADIS *LNAPL Bailbown Test* SOP
Attachment 4	Field Work Implementation Schedule

Copies:

Ms. Catalina Devine, Chevron Environmental Management Company
Mr. Ardavan Onsori, DM Livermore, Inc.
Mr. Wyman Hong, Zone 7 Water Agency

ARCADIS

Figures



MAP SOURCE: Google Earth Pro™ 2009, 37°44'22.01"N, 121°35'6.87"W

0 1000' 2000'
GRAPHIC SCALE

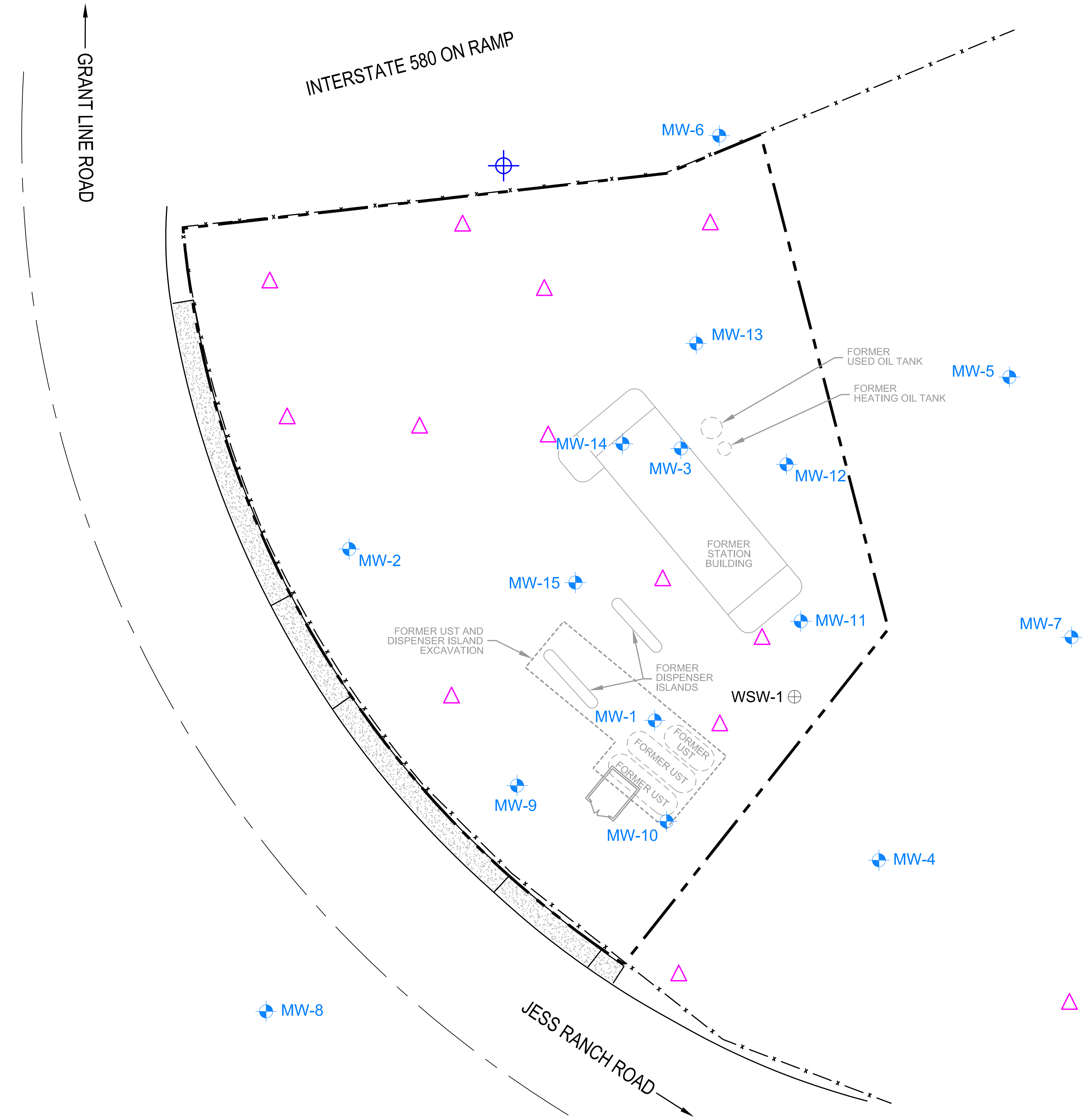
CHEVRON SITE ID 97127
GRANT LINE ROAD AND INTERSTATE 580
TRACY, CALIFORNIA
ADDITIONAL SITE ASSESSMENT WORK PLAN

SITE LOCATION MAP

ARCADIS

FIGURE
1

CITY: PETALUMA, CA DIV/GROUP: ENV DB: J. HARRIS LD:--- PIC:--- PM: D. EVANS TM: D. CATLIN-WRIGHT LYR:(Opt)ON=*;OFF=*REF*
G:\ENVCAD\Roseville-CA\RETURN-TO\Petaluma-CA\B0047959\0000\00100\DWG\47959C01.dwg LAYOUT: 1 SAVED: 8/29/2012 2:26 PM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: ARCADIS.CTB PLOTTED: 8/29/2012 2:27 PM BY: ROBITAILLE, BEVERLY
XREFS: 47959X01 IMAGES: B0047959.0000.00100 google 2790x.jpg PROJECTNAME: ----



LEGEND

- PROPERTY BOUNDARY
- FENCE
- MW-1 MONITORING WELL LOCATION
- WSW-1 WATER SUPPLY WELL (LIVESTOCK)
- PROPOSED BORING
- PROPOSED MONITORING WELL

NOTES:

1. MONITORING WELL LOCATIONS BASED ON SURVEY DATA PROVIDED BY VIRGIL CHAVEZ LAND SURVEYING (SEPTEMBER 2011) DRAWING FILE 305620cad.dwg. MW-6 LOCATION WAS NOT SURVEYED AND IS APPROXIMATE.
2. MAP MODIFIED FROM CONESTOGA-ROVERS & ASSOCIATES (CRA) FIGURE ENTITLED "FIGURE 2 CONCENTRATION MAP" DATED FEBRUARY 21, 2012, DRAWING FILE xsite.dwg. ALL SITE FEATURES AND LOCATIONS ARE APPROXIMATE.
3. MONITORING WELL MW-8 DISCONTINUED FROM MONITORING AND SAMPLING PROGRAM.

0 40' 80'
GRAPHIC SCALE

CHEVRON SITE ID 97127
GRANT LINE ROAD AND INTERSTATE 580
TRACY, CALIFORNIA
ADDITIONAL SITE ASSESSMENT WORK PLAN

SITE PLAN WITH PROPOSED BORING AND MONITORING WELL LOCATIONS

ARCADIS

FIGURE
2

ARCADIS

Attachment 1

ARCADIS *LNAPL Soil Core Collection* SOP

ARCADIS

Infrastructure, environment, buildings

Imagine the result

Standard Operating Procedure for Light Nonaqueous Phase Liquid Soil Core Collection

Rev. #: 1

Rev Date: March 25, 2009

Approval Signatures

Prepared by: ______________________ Date: 3/25/09
Toni Schoen

Reviewed by: ______________________ Date: 3/25/09
Brad Koons (Technical Expert)

I. Scope and Application

The collection of undisturbed soil cores is often required to support Light Nonaqueous Phase Liquid (LNAPL) mobility assessments at petroleum-impacted sites. The undisturbed soil cores are submitted to an analytical laboratory for specialized air/water drainage capillarity and fluid saturation testing. These data are used to support site-specific LNAPL mobility calculations.

The objective of the core collection procedure is to collect samples that are representative of the in-situ conditions that control LNAPL migration. Therefore, the following procedure outlines soil core collection methods that are optimal for:

- Maintaining soil pore structure
- Retaining aquifer fluids (LNAPL and groundwater) within the core

The soil cores are flash frozen in the field prior to shipment to maintain core integrity until it can be analyzed by the receiving laboratory.

This SOP does not address details of soil description or laboratory analysis. Refer to other ARCADIS SOPs and the project work plan, as appropriate.

II. Personnel Qualifications

ARCADIS personnel overseeing, directing, or supervising soil core collection using drilling equipment shall have a previous related experience (minimum of 2 years) under the supervision of an experienced drilling oversight person and a degree in hydrogeology or geology.

III. Equipment List

Below is a list of the equipment and materials that are required for the collection of LNAPL soil cores. Required equipment and materials include:

- personal protective equipment (PPE) including gloves rated for flash freezing, and other items specified by the site Health and Safety Plan (HASP),
- drill rig and other associated equipment based on soil core collection methodology,
- measuring tape,
- indelible ink pens,
- plastic baggies,
- graduated cylinder;
- duct tape,

- saran wrap,
- cleaning equipment/supplies,
- transport container with dry ice,
- foam, bubble wrap, or styrofoam peanuts,
- shippable cooler with inside length greater than soil core sampler,
- 6-inch wide polyvinyl chloride pipe with end cap (length based on length of soil core sampler), and
- logbook.

IV. Cautions

Drilling and drilling-related hazards including subsurface utilities are discussed in other SOPs and site specific HASPs and are not discussed herein.

The drilling Contractor is responsible for underground and aboveground utilities clearance by local “Dig Safe,” the owner of easements, and the property owner per the HASP.

V. Health and Safety Considerations

Field activities associated with collection of nonaqueous phase liquid soil cores will be performed in accordance with a site specific HASP, a copy of which will be present on site during such activities. Know what hazardous substances may be present in the soil and nonaqueous phase liquids and understand their hazards.

Prior to mobilization, select an appropriate monitoring device (flame ionization detector, photo-ionization detector, or other detector) based on a review of the sensitivity of the device to the potential constituents of concern.

Dry ice is extremely cold, sublimates into carbon dioxide, and is an asphyxiant (precludes access to oxygen). The site HASP shall contain a copy of the Material Safety Data Sheet (MSDS) for dry ice. Below is a list of health and safety conditions when handling dry ice:

- Store the dry ice in a dry, well ventilated area like a truck bed,
- Wear protective gloves rated for extreme cold/flash freezing,
- Avoid contact with water or other liquid, and
- Dispose of dry ice in a secure ventilated area. Dry ice will create an appearance of “smoke”, which may cause undue attention by site workers or pedestrians.

Communication with the drilling crew is essential to the successful collection of the LNAPL soil cores. The goal of the collection process ("push" sample, smooth steady retrieval by avoiding jarring or jerking during retrieval of the tube from the subsurface, and handling the core in a vertical position until frozen) should be discussed in detail to ensure the drilling crew and geologist are working as a team.

VI. Procedure

The primary objective for the collection of a LNAPL soil core is to collect an undisturbed soil sample with the water and LNAPL entrained in the pore spaces representative of subsurface conditions. This is accomplished by mechanically pushing the core collection device into the subsurface. Avoid using rotation, hammer or vibration when collecting the core. The use of air or drilling water during borehole advancement should be avoided if possible to prevent inadvertently affecting the in-situ fluid saturation profile at or near the coring interval.

The undisturbed soil cores are submitted to a petrophysical laboratory for analysis of soil characteristics such as porosity, capillarity, and LNAPL and water fluid saturations. The lab processes subsamples from the cores that are as small as 1 inch by 1 inch. The scale of the lab analyses and the sensitivity of the parameters being analyzed are two specific reasons why such importance is placed on obtaining cores that are as undisturbed as possible and as representative of in-situ conditions as possible.

The sampler diameter shall not be less than 3-inches in diameter (minimum of 2.5-inch diameter for split barrel sampler). Any sampler will disturb the perimeter of a soil core to some degree. The minimum diameter of 3 inches is based on the need for at least 2 inches in diameter of undisturbed core for the laboratory analysis procedures mentioned above.

Site geology and hydrogeology must be considered to select the most appropriate core collection method. The geology should be evaluated to determine the type of material that will be drilled through to obtain the samples. For example, loose sands or interbedded silt and clay require different sampling methods. Since samples are collected near the groundwater table, an understanding of the depth to water and probability of heaving sands will also influence the selection of a sampling method. Use of rotation, hammer, or vibration will only be utilized if mechanical pushing results in refusal, and the use of these alternative advancement methods should be prioritized as follows: push, rotate, then hammer. Several potential sampling methods are discussed below.

- Split spoon or split barrel samplers are used to collect soil samples across a wide variety of unconsolidated soils (ASTM D-1586). The split spoon consists of a 2-foot to 5-foot long tubular barrel that is split longitudinally into two equal halves. A 3-inch diameter split spoon sampler should be used with a 2.5-inch diameter liner. A retainer at the bottom will limit soils and fluids from falling out the bottom during sample retrieval from the subsurface. The split spoon sampler is attached to the drill rod and advanced into the undisturbed soil approximately the length of the split spoon sampler.

- Standard stationary piston sampler (ASTM D-6519) is a liner attached to a head assembly with a piston at the bottom to prevent soil from entering as the assembly is lowered into the hole. A rod is connected to the piston, and the liner is pressed past the piston into the soil. With a well fitted piston, a vacuum is created that holds the soil and fluids in the liner during core withdrawal.
- Osterberg hydraulic piston sampler is similar to the standard stationary piston sampler but has an actuating piston and a fixed piston. An opening at the head assembly allows for fluid pressure to be applied to the actuating piston which will cause the liner to be pushed past the fixed piston into the soil. This helps eliminate the possibility of over pushing.
- Denison core barrel consists of a rotating outer barrel, a bit with an inner fixed barrel, a liner, and a retainer at the end. During drilling, pressure is applied to the inner barrel while the outer barrel cuts the soil. For this purpose of collecting LNAPL soil cores, a 3.5" diameter by 24" sampler is preferred.
- Shelby tubes consist of a single thin-walled steel tube (ASTM D-1587-08)). The Shelby tube is attached to the lead auger and should be mechanically pushed into the undisturbed soil.

The length of soil core samples can be determined based on the expected height of capillary rise in the soil of interest. By matching core length to the height of capillary rise, drainage of fluids from the samples as they are collected will be minimized. API's technical document 4711 presents the relationship shown in Figure 1, based on an empirical approach developed by McWhorter in 1996. The values shown in the table below are approximations taken from Figure 1 and can be used as a guide to determine core length as a function of site-specific hydraulic conductivity.

Hydraulic Conductivity	0-2.5 ft/day (0-7.5x10^{-4} cm/s)	2.5-10 ft/day (7.5x10^{-4}-3.5x10^{-3} cm/s)	>10 ft/day (>3.5x10^{-3} cm/s)
Core Length	2 ft (70 cm)	1ft (30 cm)	0.5 ft (15 cm)

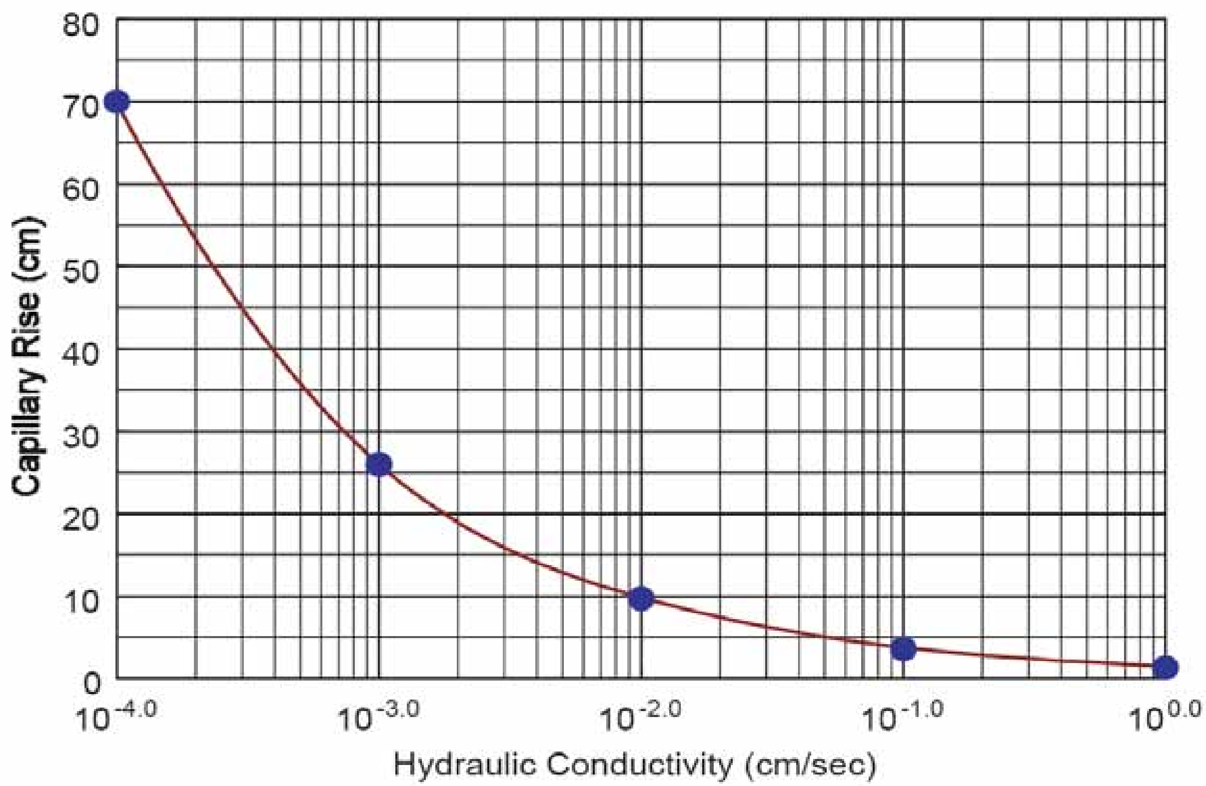


Figure 1 — Capillary rise as function of hydraulic conductivity (API 4711)

Below is the procedure for collection of a LNAPL soil core.

- Gauge a well near the proposed soil boring location for LNAPL soil core collection for depth to LNAPL and depth to water using an interface probe. The proposed soil boring location shall be near the well gauged for LNAPL (approximately 3 to 5 feet).
- Collect soil samples continuously from ground surface to the project-specified distance above the air-LNAPL/water interface using the selected drilling method (typically 1 foot above the groundwater table). Do not use air or water during sampling or drilling advancement.
- Advance the sampler to collect soil from the project-specified vertical extent (typically 1-foot of soil from the vadose zone (unsaturated soil) and approximately 3 feet of LNAPL/water-saturated soil). The sampler shall be mechanically pushed (no rotation, hammer, or vibration shall be applied to the split-barrel). If refusal is encountered using mechanical pushing before advancing the length of the sampler, then hammer or rotation may be applied to advance the sampler.

- Retrieve the sampler at a smooth, steady pace (avoid jarring or jerking of sampler) from the subsurface to minimize loss of fluid from the sampler.
- Maintain the sampler in an **upright position** for the following steps:
  - Place the bottom of the sampler in a plastic bag for collection of fluids while the driller removes any mechanism holding drilling tube holding the sample. Once the soil core sample is released, cap both ends of the liner or tube with water-tight end caps. Capping the top of the liner/tube first will create a vacuum to minimize fluid loss from the soil.
  - Pour liquid from the plastic bag to a graduated cylinder. Measure and record the volume of water and LNAPL loss.
  - If there are any voids in the sample liner/tube, fill with plastic (Saran) wrap to minimize core movement.
  - Wipe the outside of the sample liner/tube and duct tape the end caps (overlap tape a minimum of 2 layers).
  - Label the liner/tube with the boring ID, interval sampled (fractions of a foot should be recorded in tenths), and an arrow pointing toward the top of liner/tube with a permanent marker (do not label duct tape). Each subsequent liner/tube shall be labeled sequentially with A, B, C… etc starting with A on the top (shallowest) sleeve. Also, each liner/tube shall have an arrow pointing toward the top of the tube. (See Figure 2.)

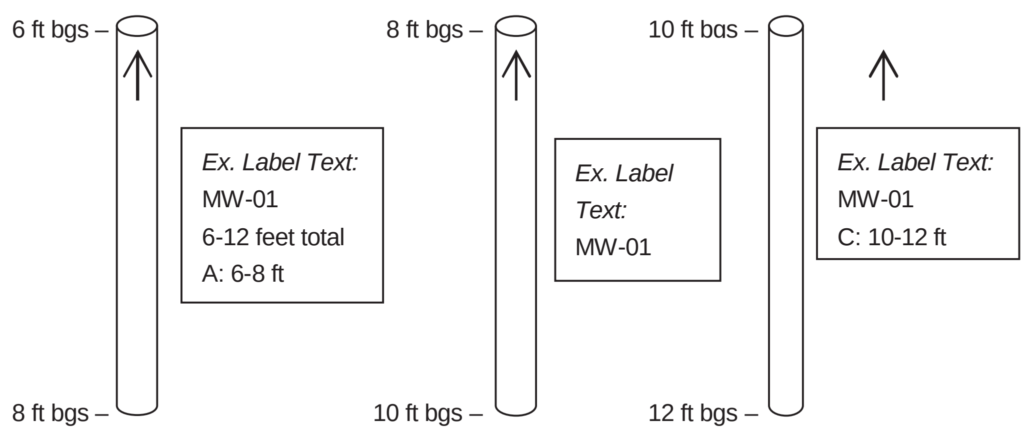


Figure 2 – Schematic showing example of how to label multiple cores per well.

- o Evaluate the integrity of the soil sample, noticing if the soil sample appears undisturbed and how much recovery was achieved. A disturbed soil sample or sample with poor recovery should be discarded. If the first soil core is acceptable, proceed to the core freezing procedure below. If the first soil core is disturbed or had poor recovery, discard it and select a different nearby drilling location for a second attempt. Communicate the change in sampling plan to the project manager.
- o Set the capped, taped, and labeled liner/tube in a vertically-aligned 6-inch Schedule 80 PVC tube or steel pipe surrounded by dry ice for a minimum of 30 minutes. The soil sample should remain in the same vertical direction as it was in the subsurface during freezing. Stabilize the PVC tube or steel pipe to avoid tipping over during the freezing process.
- o Once frozen, wrap core in several layers of plastic bags or 1-2 layers of bubble wrap before placing it into a cooler. A thin, insulative layer is needed between the core and the dry ice.

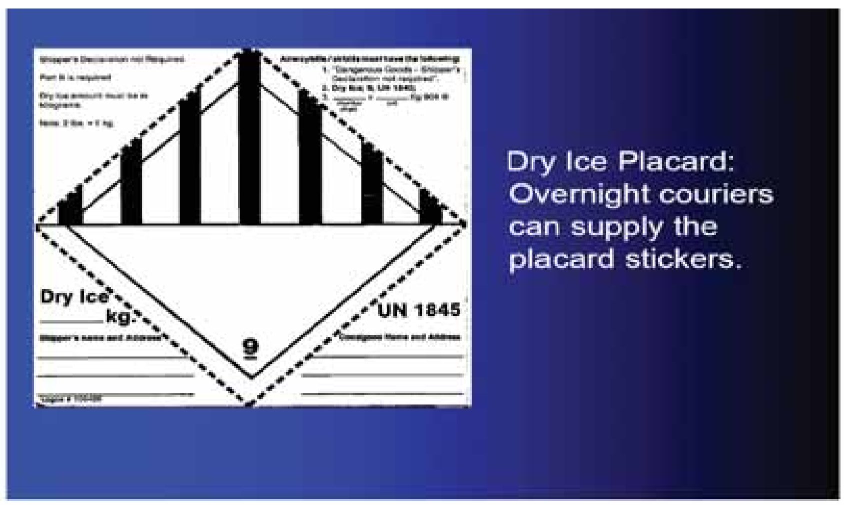
VII. Cooler Preparation and Shipping

Below is a generalized procedure for packing and shipping of frozen LNAPL soil cores. A Shipping Determination must be performed, by DOT-trained personnel, for all environmental and geotechnical samples that are to be shipped, as well as some types of environmental equipment/supplies that are to be shipped.

From the bottom of the cooler up, pack the cooler as follows:

- Place a layer of foam, bubble wrap, or styrofoam peanuts in the bottom of the cooler to absorb shock during transport.
- Place a layer of dry ice over the foam, bubble wrap, or styrofoam peanuts. Do not pack the dry ice in sealable containers.
- Place the core(s) horizontally over the layer of dry ice.
- Place a layer of dry ice over the core. The cooler should contain approximately 30 to 50 pounds of dry ice for shipping. FedEx has a weight limit of 150 pounds for coolers. Up to 22.5 feet of cores can fit into the large marine ice chests with 50-75 feet of ice.
- Fill remainder of cooler with foam, bubble wrap, or styrofoam peanuts.
- Seal the completed chain of custody into a plastic bag and affix to the inside of the lid of the cooler.
- Tape the cooler closed by wrapping two bands of tape around the cooler (overlap tape a minimum of 2 layers). Do not seal the cooler with tape. As the dry ice sublimates to carbon dioxide, the gas needs to escape the cooler.

- Core samples shall not be held overnight onsite. Collect samples early enough to allow time for same-day vertical core freezing, cooler packaging, and FedEx shipping.
- Complete the FedEx airway bill and dry ice placard (see attached examples). Samples shall be shipped for overnight delivery. Arrange shipment so that coolers do not sit in a warehouse or truck for days.
- Use the buddy system for lifting these coolers. The size of the coolers used and volume of dry ice used to maintain a frozen state for the soil cores will result in heavy coolers.
- Notify the laboratory of shipment arrival time and FedEx tracking number(s).



VIII. Data Recording and Management

The supervising geologist will be responsible for documenting drilling events using a logbook to record all relevant information in a clear and concise format. The drilling event record shall include:

- Name and location of project,
- Project number, client, and site location,
- Names of Contractor, Contractor personnel, inspectors, and other people onsite,
- Weather conditions,
- Depth to water and depth to LNAPL from nearby well and distance from sample location,
- Type of drilling method,
- Soil core collection method and sampler dimensions,
- Procedure (noting use or no use of rotation, hammer, or vibration for sample collection),
- Start and finish dates and times of drilling,
- Sample interval, length of unsaturated and saturated soil, and total recovery length,
- Volume of water and LNAPL loss as measured in a graduated cylinder,
- Condition of sampler pre- and post-retrieval from subsurface, and
- Photo document the soil cores, freezing technique, and cooler packaging.

IX. Quality Assurance

Equipment will be cleaned prior to use onsite, between each drilling location, and prior to leaving the site. All drilling equipment and associated tools, including augers, drill rods, sampling equipment, wrenches, and other equipment or tools, that may have come in contact with soils will be cleaned with high-pressure steam cleaning equipment using a clean potable water source. The drilling equipment will be cleaned in an area designated by the supervising geologist that is located outside of the work zone.

X. Waste Management

All dry ice not utilized for freezing the soil cores will be stored in an open container in a well ventilated, secured area and permitted to volatilize. Personal protective equipment (such as gloves, disposable clothing, and other disposable equipment) resulting from cleaning procedures and soil sampling/handling activities will be placed in plastic bags. These bags will be transferred into appropriately labeled 55-gallon drums or disposed of in a designated debris box for disposal. All decontamination water and soil will be placed in separate sealed 55-gallon steel drums and stored in a secured area. Once full, the material will be analyzed to determine the appropriate disposal method.

XI. References

API 4711. Methods for Determining Inputs to Environmental Petroleum Hydrocarbon Mobility and Recovery Models. American Petroleum Institute Publication Number 4711. July 2001.

ASTM. D-1587-08 Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes.

ASTM. D-6282 Standard Guide for Direct Push Soil Sampling for Environmental Site Characterization.

ASTM Method D-1586 Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM D-3550 Practice for Thick-Walled, Ring-Lined. Split Barrel, Drive Sampling of Soils.

ASTM D-6519 Standard Practice for Sampling of Soil Using the Hydraulically Operated Stationary Piston Sampler.

ARCADIS

Attachment 2

ARCADIS *PrePacked Screen* SOP

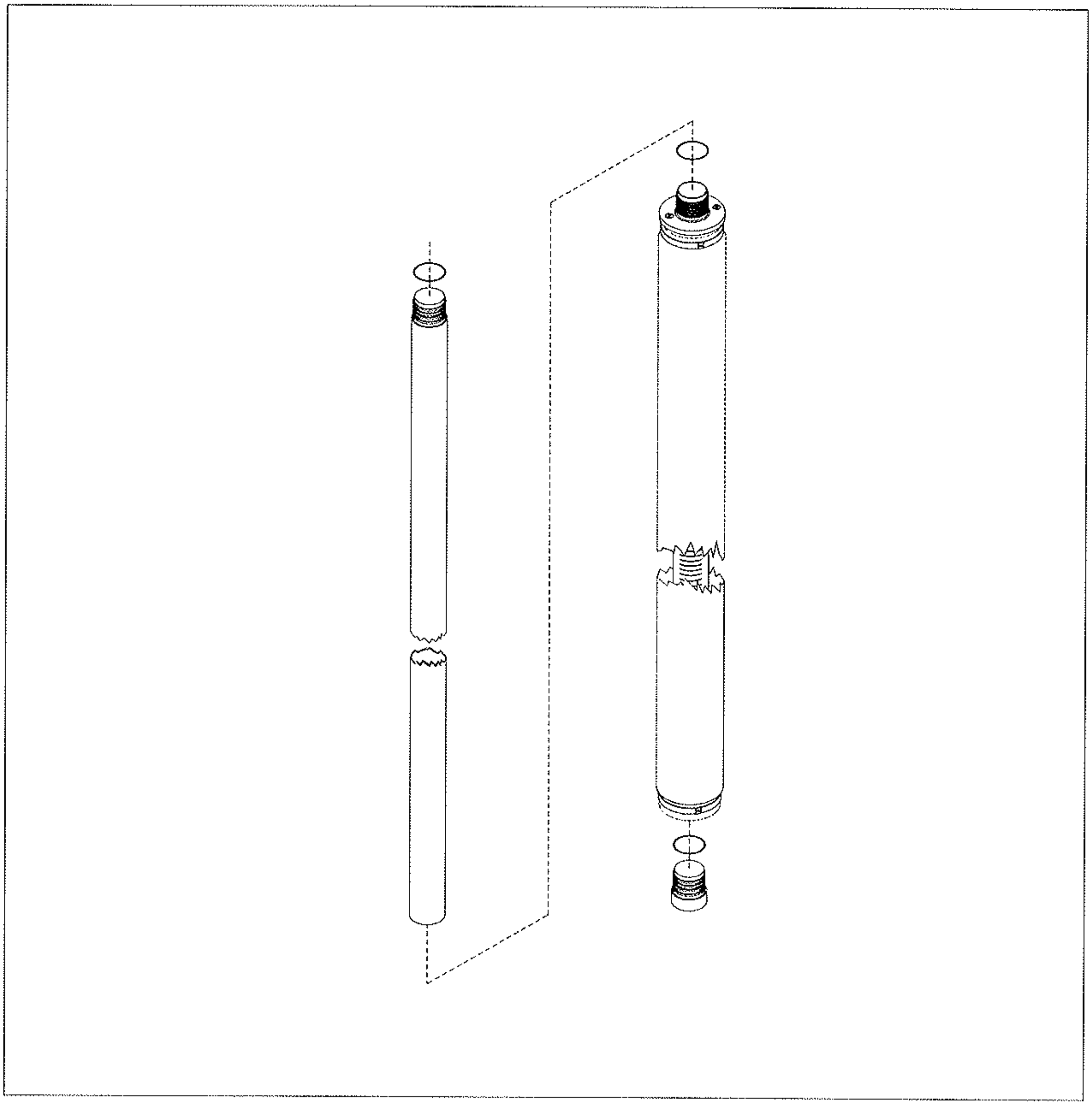
GEOPROBE® 1.0-IN. X 2.5-IN. OD AND 1.5-IN. X 2.5-IN. OD PREPACKED SCREEN MONITORING WELLS

STANDARD OPERATING PROCEDURE

Technical Bulletin No. 992500

PREPARED: August, 1999

REVISED: November, 2006



GEOPROBE® 1.0-in. x 2.5-in. O.D. PREPACKED SCREEN AND PVC RISER

Geoprobe® and Geoprobe Systems®, Macro-Core® and Direct Image® are Registered Trademarks of Kejr, Inc., Salina, Kansas

1.0 OBJECTIVE

The objective of this procedure is to install a permanent, small-diameter groundwater monitoring well that can be used to collect water quality samples, conduct hydrologic and pressure measurements, or perform any other sampling event that does not require large amounts of water over a short period of time (e.g. flow rate > 1 liter/minute). These methods meet or exceed the specifications discussed for direct push installation of permanent monitoring wells with prepacked screens in the U.S. Environmental Protection Agency's guidance document, *Expedited Site Assessment Tools For Underground Storage Tank Sites*, (EPA, 1997) and ASTM Standards *D 6724* (ASTM, 2002) and *D 6725* (ASTM, 2002).

2.0 BACKGROUND

2.1 Definitions

Geoprobe® Direct Push Machine: A vehicle-mounted, hydraulically-powered machine that uses static force and percussion to advance small-diameter sampling tools into the subsurface for collecting soil core, soil gas, or groundwater samples. The Geoprobe® brand name refers to both machines and tools manufactured by Geoprobe Systems®, Salina, Kansas. Geoprobe® tools are used to perform soil core and soil gas sampling, groundwater sampling, soil conductivity and contaminant logging, grouting, materials injection, and to install small-diameter permanent monitoring wells or temporary piezometers.
**Geoprobe® and Geoprobe Systems® are registered trademarks of Kejr, Inc., Salina, Kansas.*

1.0-inch x 2.5-inch OD Prepacked Well Screen (1.0-inch prepack): An assembly consisting of a slotted PVC pipe surrounded by environmental grade sand contained within a stainless steel wire mesh cylinder. The inner component of the prepacked screen is a flush-threaded, 1.0-inch Schedule 40 PVC pipe with 0.01-inch (0.25 mm) slots. Stainless steel wire mesh with a pore size of 0.011 inches (0.28 mm) makes up the outer component of the prepack. The space between the inner slotted pipe and outer wire mesh is filled with 20/40 mesh silica sand. Geoprobe® 1.0-inch x 2.5-inch prepacks are available in 5-foot sections and have an outside diameter of 2.5 inches (64 mm) and a nominal inside diameter of 1.0 inches (25 mm).

The 1.0-inch prepack is also available in a "field pack" configuration in which the user adds sand to the screen prior to installation. This reduces shipping weight by approximately 12.3 pounds (5.6 kg) per screen.

1.5-inch x 2.5-inch OD Prepacked Well Screen (1.5-inch prepack): An assembly consisting of a slotted PVC pipe surrounded by environmental grade sand contained within a stainless steel wire mesh cylinder. The inner component of the prepacked screen is a flush-threaded, 1.5-inch Schedule 40 PVC pipe with 0.01-inch (0.25 mm) slots. Stainless steel wire mesh with a pore size of 0.011 inches (0.28 mm) makes up the outer component of the prepack. The space between the inner slotted pipe and outer wire mesh is filled with 20/40 mesh silica sand. Geoprobe® 1.5-inch x 2.5-inch prepacks are available in 5-foot sections and have an outside diameter of 2.5 inches (64 mm) and a nominal inside diameter of 1.5 inches (38 mm).

2.2 Discussion

Conventional monitoring wells are typically constructed through hollow stem augers by lowering slotted PVC pipe (screen) to depth on the leading end of a string of threaded PVC riser pipe. A filter pack is then installed by pouring clean sand of known particle size through the tool string annulus until the slotted section of the PVC pipe is sufficiently covered.

Installing the entire filter pack through the tool string annulus becomes a delicate and time-consuming process when performed with small-diameter direct push tooling. Sand must be poured very slowly in order to avoid bridging between the riser pipe and probe rod. When bridging does occur, considerable time can be lost in attempting to dislodge the sand or possibly pulling the tool string and starting over.

Prepacked screens greatly decrease the volume of loose sand required for well installation as each screen assembly includes the necessary sand filter pack. Sand must still be delivered through the casing annulus to provide a minimum 2-foot grout barrier, but this volume is significantly less than for the entire screened interval.

The procedures outlined in this document describe construction of a permanent groundwater monitoring well using Geoprobe® 3.25-inch (83 mm) outside diameter (OD) probe rods and 2.5-inch OD prepacked screens. Geoprobe® 2.5-inch OD prepacks are available with either nominal 1.0-inch or 1.5-inch schedule 40 PVC components with a running length of 5 feet.

Installation of a prepack monitoring well begins by advancing 3.25-inch (83 mm) probe rods to depth with a Geoprobe® direct push machine. Prepacked screen(s) are then assembled and installed through the 2.625-inch (67 mm) inside diameter (ID) of the probe rods using corresponding 1.0-inch or 1.5-inch schedule 40 PVC riser (Fig. 2.1). Once the prepacks are lowered to depth, the rod string is slowly retracted until the leading end of the rods is approximately 3 feet above the top prepack.

Regulations generally require a minimum 2-foot grout barrier above the top prepack (Fig. 2.2) to avoid contaminating the well screens with bentonite or cement during installation. In some instances, natural formation collapse will provide the required barrier. If the formation is stable and does not collapse around the riser as the rod string is retracted, environmental grade 20/40 mesh sand may be installed through the probe rods to provide the minimum 2-foot grout barrier.

Granular bentonite or bentonite slurry is then installed in the annulus to form a well seal (Fig. 2.2). A high-pressure grout pump (Geoprobe® Model GS500 or GS1000) may be used to tremie high-solids bentonite slurry or neat cement grout to fill the well annulus as the probe rods are retracted (Fig. 2.3). The grout mixture must be installed with a tremie tube from the bottom up to accomplish a tight seal without voids to meet regulatory requirements.

In certain formation conditions, the prepacked screens may bind inside the probe rods as the rods are retracted. This is most common in sandy formations sometimes called flowing or heaving sands. This binding can generally be overcome by lowering extension rods down the inside of the well riser and gently, but firmly, tapping the extension rods against the base of the well as the rods are slowly retracted. If the binding persists, clean tap water or distilled water may be poured down the annulus of the rods to increase the hydraulic head inside the well. This, combined with the use of the extension rods, will free up the prepacked screen and allow for proper emplacement.

Once the well is set, conventional flush-mount or aboveground well protection can be installed to prevent tampering or damage to the well head (Fig. 2.2). These wells can be sampled by several available methods (mechanical bladder pump, mini-bailer, Geoprobe® tubing check valve, etc.) to obtain high integrity water quality samples. These wells also provide accurate water level measurements and can be used as observation wells during aquifer pump tests.

When installed properly, these small-diameter wells generally meet regulatory requirements for a permanent monitoring well. While a detailed installation procedure is given in this document, it is by no means totally inclusive. **Always check local regulatory requirements and modify the well installation procedure accordingly.** These methods meet or exceed the specifications discussed for direct push installation of permanent monitoring wells with prepacked screens in the U.S. Environmental Protection Agency's guidance document, *Expedited Site Assessment Tools For Underground Storage Tank Sites*, (EPA, 1997) and ASTM Standards *D 6724* (ASTM, 2002) and *D 6725* (ASTM, 2002).

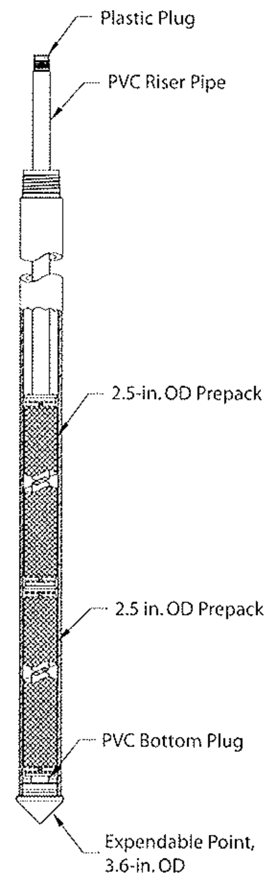


FIGURE 2.1
Insertion of Prepack Screens

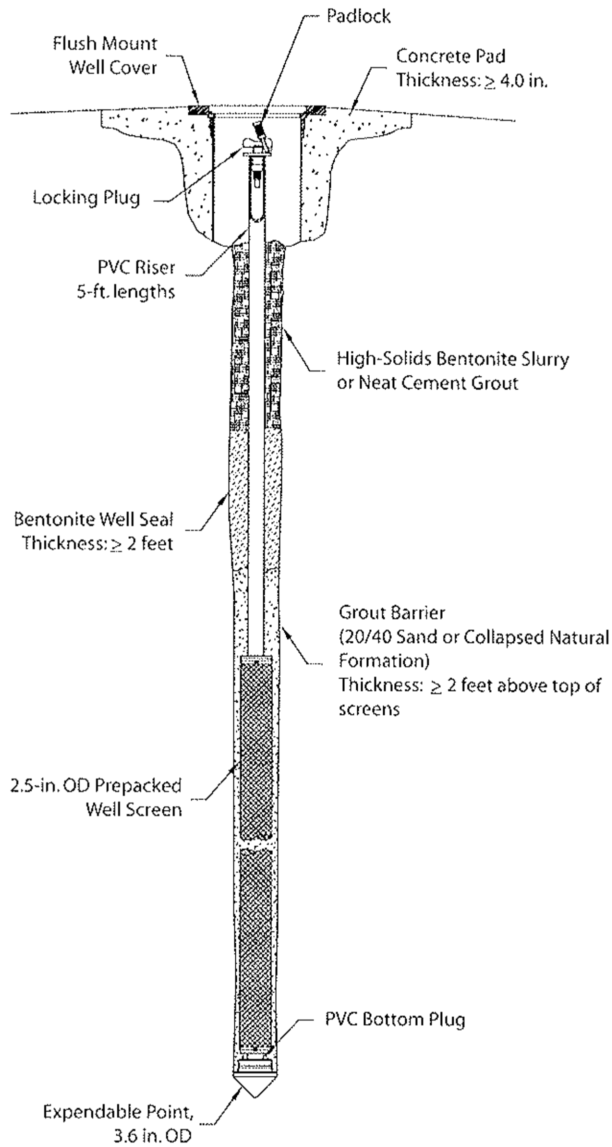


FIGURE 2.2
Installed Geoprobe® 2.5-in. OD Prepacked Screen Monitoring Well

3.0 TOOLS AND EQUIPMENT

The following equipment is required to install a permanent monitoring well with Geoprobe® 2.5-inch OD prepacked screens. Refer to Figures 3.1 and 3.2 for illustrations of well components.

1.0-in. X 2.5-in. Prepack Well Components	**Part Number**
1.0-in. x 2.5-in. Prepacked Screen, 5-ft. length	17467
1.0-in. x 2.5-in. Fieldpacked Screen (w/o sand), 5-ft. length	11679
1.0-in. x 2.5-in. Fieldpacked Screen (w/o sand), 3-ft. length	GW2436
PVC Riser, 1.0-in. sch. 40, 5-ft. length	12876
O-rings for 1.0-in. PVC Riser, Pkg. of 25	13196
PE Top Plug, 1.0-in. sch. 40 riser	13227
Locking Well Plug, for 1.0-in. sch. 40 riser	WP1710
PVC Bottom Plug, 1.0-in. sch. 40 flush thread	12881
Expendable Drive Point, 3.25-in. rods / 3.6-in. OD	AT3215

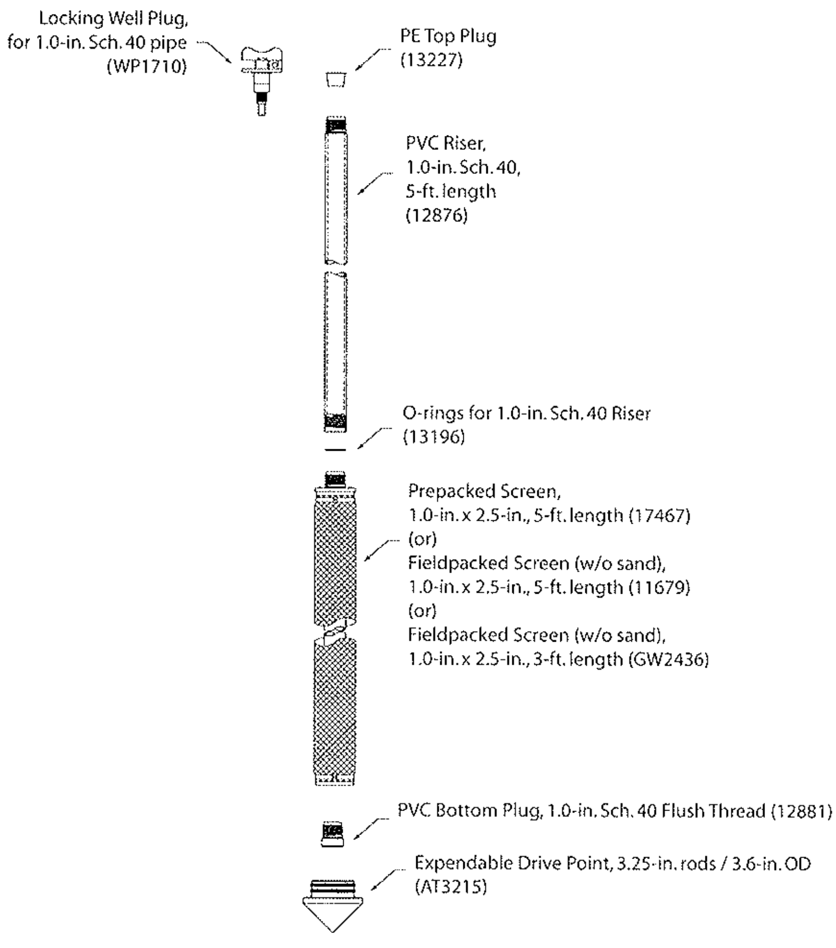


FIGURE 3.1:
1.0-in. x 2.5-in. Prepacked and Fieldpacked Screen Monitoring Well Parts

1.5-in. X 2.5-in. Prepack Well Components	Part Number
1.5-in. x 2.5-in. Prepacked Screen, 5-ft. length	17401
PVC Riser, 1.5-in. sch. 40, 5-ft. length	17405
O-rings for 1.5-in. PVC Riser, Pkg. of 25	18782
PE Top Plug, 1.5-in. sch. 40 riser	21465
Locking Well Plug, for 1.5-in. sch. 40 riser	WP1715
PVC Bottom Plug, 1.5-in. sch. 40 flush thread	17407
Expendable Drive Point, 3.25-in. rods / 3.6-in. OD	AT3215

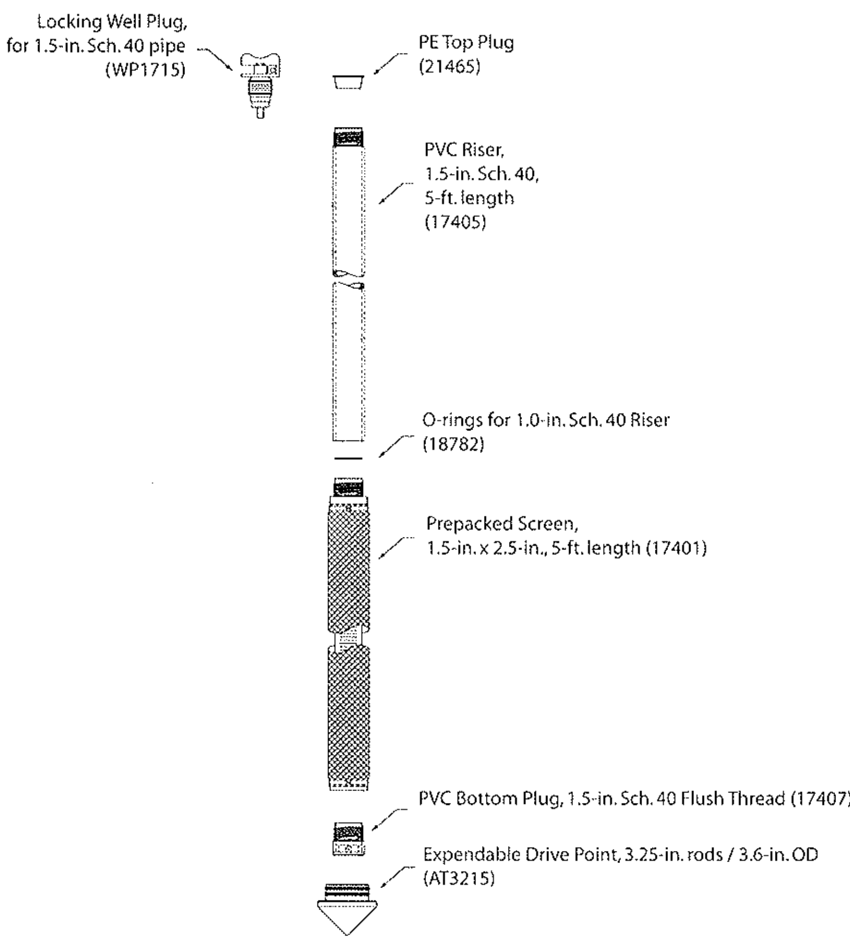


FIGURE 3.2:
1.5-in. x 2.5-in. Prepacked Screen Monitoring Well Parts

Monitoring Well Accessories **Part Number**

	Part Number
Well Cover, flush-mount, 4-in. x 12-in., cast iron / ABS skirt	WP1741
Well Cover, flush-mount, 7-in. x 10-in., cast iron / galvanized skirt	WP1771
Sand, environmental grade (20/40 mesh), 50-lb. bag	AT95
Bentonite, granular (8 mesh), 50-lb. bag	AT91
Bentonite, powdered (200 mesh), 50-lb. bag	AT92

Geoprobe® Tools and Equipment **Part Number**

	Part Number
Probe Rod, 3.25-in. x 48-in. or 60-in.	10594 or 9040
Probe Rod, 3.25 in. x 1 meter (optional)	13925
O-Rings for 3.25-in. Probe Rods (Pkg. of 25)	9960
Expendable Point Holder, 3.25-in. x 48-in. or 60-in.	10596 or 9796
Expendable Point Holder, 3.25 in. x 1 meter (optional)	13926
Expendable Point Assembly, Steel, 3.6-inch OD	AT3215
Drive Cap, Threadless, 3.25-inch Probe Rods (GH40 Hammer)	10605
Drive Cap, Threadless, 3.25-inch Probe Rods (GH60 Hammer)	9742
Rod Grip Pull Handle, 3.25-in. Probe Rods (GH40 Hammer)	12235
Rod Grip Pull Handle, 3.25-in. Probe Rods (GH60 Hammer)	9757
Extension Rod, 48-in. or 60-in.	AT671 or 10073
Extension Rod, 1-meter (optional)	AT675
Extension Rod Coupler	AT68
Extension Rod Handle	AT69
Extension Rod Quick Links Pin	AT695
Extension Rod Quick Link Box	AT696
Screen Push Adapter	GW1535
Grout Machine	GS500 or GS1000
Grout System Accessories, 1.5-in. Rods	GS1015
Water Level Meter, 0.438-in. OD Probe, 100-ft. Cable*	GW2000
Stainless Steel Mini-Bailer (optional)	GW41
Check Valve Assembly, 0.375-in. OD Tubing*	GW4210
Polyethylene Tubing, 0.375-in. OD, 500-ft. (for purging, sampling, etc.)	TB25L
Mechanical Bladder Pump	MB470
Low-Density Polyethylene Tubing, 0.625-in. OD, 100-ft. (for tremie tube grouting)	16857
Grout Tubing Adapter, for 0.625-in. OD Tubing	16893

Additional Tools, Equipment, and Supplies

Locking Pliers
Pipe Wrench
Volumetric Measuring Cup
PVC Cutting Pliers
Weighted Measuring Tape (optional)
Small Funnel or Flexible Container (for pouring sand)
Duct or Electrical Tape Roll
Bucket or Tub (for dry grout material, water, and mixing)
Portland Cement, Type I
Concrete Mix (premixed cement and aggregate)
Clean Water (of suitable quality for exposure to well components)

**Refer to Appendix A for additional tool options.*

***Refer to Standard Operating Procedure (SOP) for the Mechanical Bladder Pump (Technical Bulletin No. MK3013) for additional tooling needs.*

4.0 SAND INSTALLATION IN 1.0 IN. X 2.5-IN. FIELDPACK WELL SCREEN

Due to the significant weight of the sand in a 1.0-in. x 2.5-in. Prepack Well Screen (17467), a 1.0-in. x 2.5-in. OD Fieldpack Screen (11679) is available without sand to reduce shipping costs. It is necessary to add sand to the fieldpack screen prior to installation. A specific packing procedure must be followed in order to prevent the sand from settling in the screen after well installation. This section describes the procedure for properly installing sand in a 1.0-in. x 2.5-in. Fieldpack Well Screen.

4.1 Required Equipment

1 Quart (1 L) Container (1)
Phillips-Head Screwdriver (1)
20-40 Mesh Sand (1gallon / 3.75 L)
Fieldpack Screen Asm., P/N 11679 (1):
- PE Top Plug, (1)
- Stainless Steel Screw, (2)
- Gray PVC Cap, (1)
- Sand Cylinder, (1)

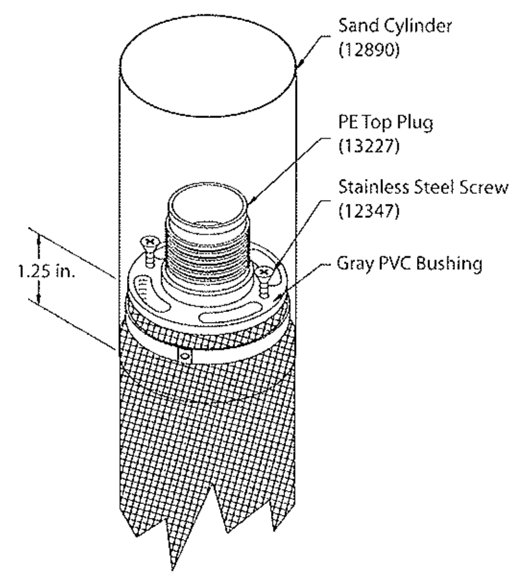


FIGURE 4.1.
Selected components of a 1.0-in. x 2.5-in. OD Fieldpack Well Screen

4.2 Procedure

1. Ensure that the PE top plug is pushed into the top of the PVC riser and both screws are threaded into the gray bushing (Fig. 4.1).

2. Slide the clear sand cylinder over the screen such that the leading end of the cylinder is approximately 1.25 inches below the top of the gray PVC bushing (Fig. 4.1).

IMPORTANT: **Do not push the sand cylinder farther onto the screen than indicated as this will make it difficult to remove once the screen is packed with sand.**

CAUTION: **Use care when handling the screen with bare hands. Small wires protruding from the screen can easily puncture the skin.**

3. Pour 3 quarts (3 L) of sand into the sand cylinder. This will fill the screen approximately 3/4 to 7/8 full.

4. The screen must now be tapped on the ground to settle (pack) the sand.

   a) Gently grasp the screen and raise it approximately 2 inches (5 cm) off the ground.

IMPORTANT: **Be careful when gripping the screen to squeeze it just hard enough to lift it from the ground. The screen may be damaged if too much pressure is applied before the screen is packed with sand.**

   b) Release the screen and allow it to fall back to the ground.

IMPORTANT: **Do not drop the screen more than 2 inches (5 cm) as this can damage the screen.**

c) Repeat Steps 4.2.4-A and B for a total of 15 "drops".

5. Completely fill the screen with sand. Add enough sand to also fill the sand cylinder approximately three/quarters full.

   NOTE: The screen will hold approximately 4 quarts (3.75 L) of sand when all has settled after packing.

6. Lift and drop the screen an additional 60-80 times to finish packing the sand. Remember not to drop the screen from a height of more than 2 inches (5 cm). After this step, the screen should feel very firm.

7. Remove the sand cylinder by rocking it from side-to-side while pulling upward. Let the excess sand drain from the bottom of the cylinder. Brush any remaining sand from the top of the gray bushing.

8. Remove the stainless steel screws (Fig. 4.1) from the gray bushing using the phillips-head screwdriver.

9. Place the gray PVC cap on top of the screen with the countersunk holes "up" as shown in Figure 4.2.

IMPORTANT: Ensure that no sand is trapped between the cap and bushing as this may allow sand to leak from the screen during handling.

10. Attach the PVC cap to the PVC bushing by installing the two stainless steel screws (Figs. 4.2).

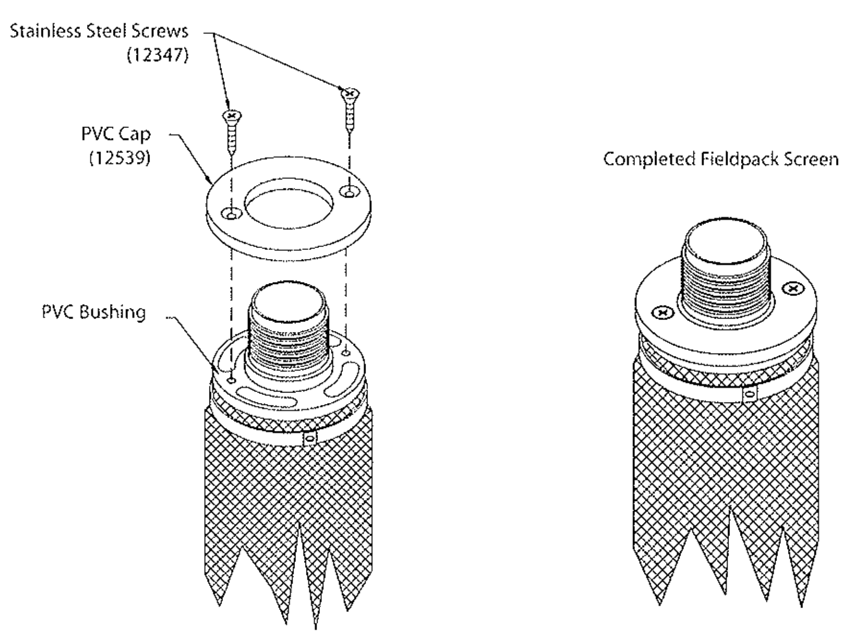
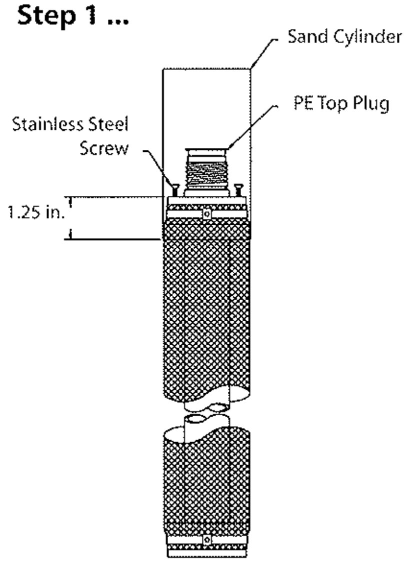


FIGURE 4.2.
The PVC cap is attached to the top of the screen with two stainless steel screws.

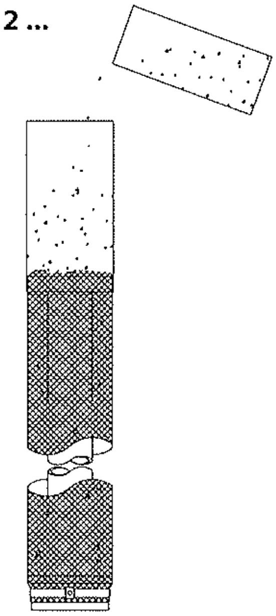
Sand Installation Quick Reference Guide

Step 1 ...



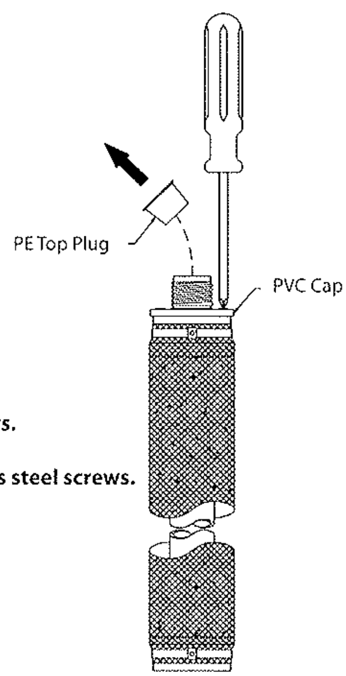
1. Position sand Cylinder.

Step 2 ...



1. Fill screen with sand.
2. Tap screen on ground to pack sand.
3. Add more sand to completely fill screen.
Screen will hold about 4 quarts (3.75 L) of sand.

Step 3 ...



1. Remove sand cylinder.
2. Remove stainless steel screws.
3. Position PVC cap.
4. Replace and tighten stainless steel screws.
5. Remove top plug.

5.0 WELL INSTALLATION

Monitoring well installation can be divided into the six main tasks listed below. This section provides specific instructions for the completion of all six tasks.

- Driving the probe rods to depth
- Deploying the screen(s) and riser pipe
- Installing a sand/grout barrier
- Installing a bentonite seal above the screen
- Grouting the well annulus
- Installing surface protection

NOTE: The many prepacked screen options have resulted in an extensive list of Geoprobe® part numbers. To simplify the instructions presented in this document, part numbers for well components are not specified in the text or illustrations. Refer to Section 3.0 for part numbers and complete descriptions for all well components and accessories.

Installing sand in the 1.0-in. x 2.5-in Fieldpacked Well Screen

The 1.0-inch x 2.5-inch fieldpacks can be packed with sand before arriving at the job site or at the job site. To help make the well installation process more efficient, Geoprobe Systems® recommends packing all well screens with sand before mobilizing to the job site. Each box of 1.0-inch x 2.5-inch Fieldpacked Screens includes a complete set of sand filling instructions. The process of filling the screens with sand is also described in Section 4.0 of this document.

5.1 Driving Probe Rods to Depth

1. Place the Geoprobe® direct push machine at the proposed monitoring well location and unfold the probe assembly into the operating position as instructed in the machine Owner's Manual. Because access to the top of the probe rod string is required, it is important to allow room for derrick retraction when positioning the unit for operation.

2. Insert a 3.6-inch OD Expendable Point Assembly into the unthreaded end of a 3.25-inch Expendable Point Holder. See Figure 5.1.

3. Place a 3.25-inch Drive Cap over the threaded end of the expendable point holder.

4. Place the expendable point holder under the hydraulic hammer in the driving position (refer to direct push machine Owner's Manual). Advance the point holder into the ground, using percussion if necessary. To install an accurately placed monitoring well, it is important to drive the rod string as straight as possible. If the point holder is not straight, retract the assembly from the ground and start over with Step 1.

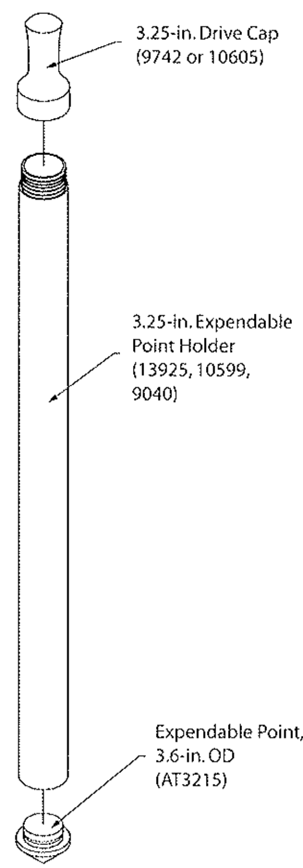


FIGURE 5.1
Drive Cap, Expendable Point Holder and Expendable Point Assembly

5. Remove the drive cap from the expendable point holder. Install an O-ring on the point holder in the groove located at the base of the male threads (Fig. 5.2) Make sure the O-ring groove and O-ring mating surface are clean. Any foreign material located in these areas will prevent the O-ring from sealing properly.

IMPORTANT: O-rings must always be used to seal the 3.25-inch Probe Rod joints.

6. Lubricate the O-ring and O-ring mating surface (Fig. 5.3) with a small amount of clean water. Apply the water with either a moist cloth or a spray bottle.

7. Thread a 3.25-inch Probe Rod onto the expendable point.

8. Place the drive cap on the probe rod and advance the rod string the full stroke of the machine.

9. Remove the drive cap. Again, install an O-ring in the O-ring groove of the probe rod. Lubricate the O-ring and the O-ring mating surface (Fig. 5.3). Add the next probe rod, replace the drive cap, and advance the rod string.

10. Repeat Step 9 until the leading end of the rod string is 1.5 inches (3.8 cm) below the bottom of the desired screen interval. The additional depth adjusts for the extra height created by the expendable point and the PVC Bottom Plug. The top probe rod must also extend at least 15 inches (38 cm) above the ground surface to allow room for the rod grip puller used later in this procedure. (An additional rod may be added if necessary.) Move the machine foot back to provide access to the top of the rod string.

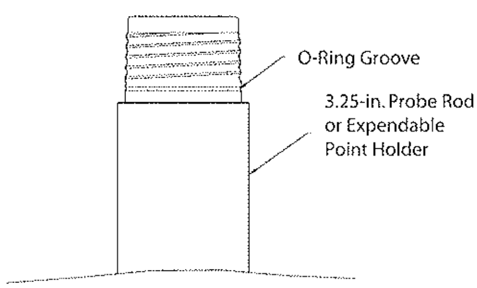


FIGURE 5.2
Probe Rod O-Ring Groove

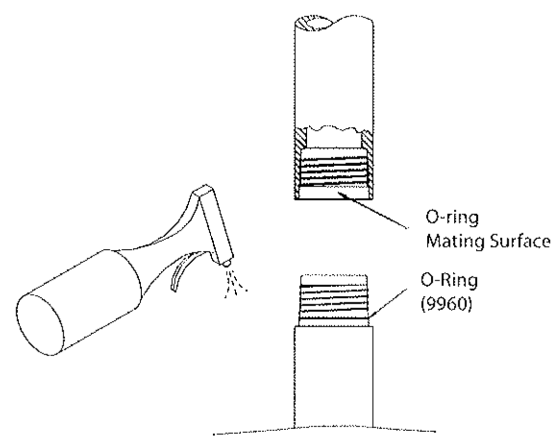


FIGURE 5.3
Lubricating O-Ring and Mating Surface

5.2 Deploying the Screen(s) and Riser Pipe

1. With the probe rods driven to the proper depth, the next step is to deploy the prepacked or field-packed screen(s) and riser pipe. If using fieldpacks, inspect the screens to ensure that:

a) the plastic plug is removed.
b) the stainless steel screws are snug.(See Fig. 5.4)

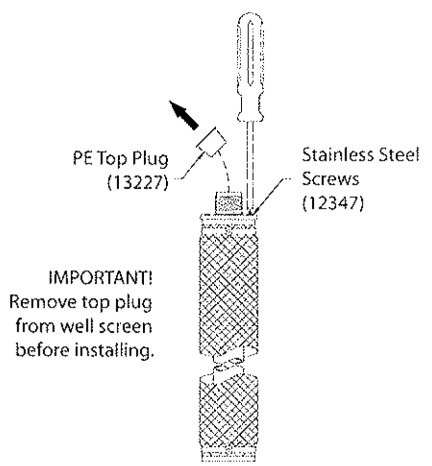


FIGURE 5.4
Inspecting a Fieldpacked Screen

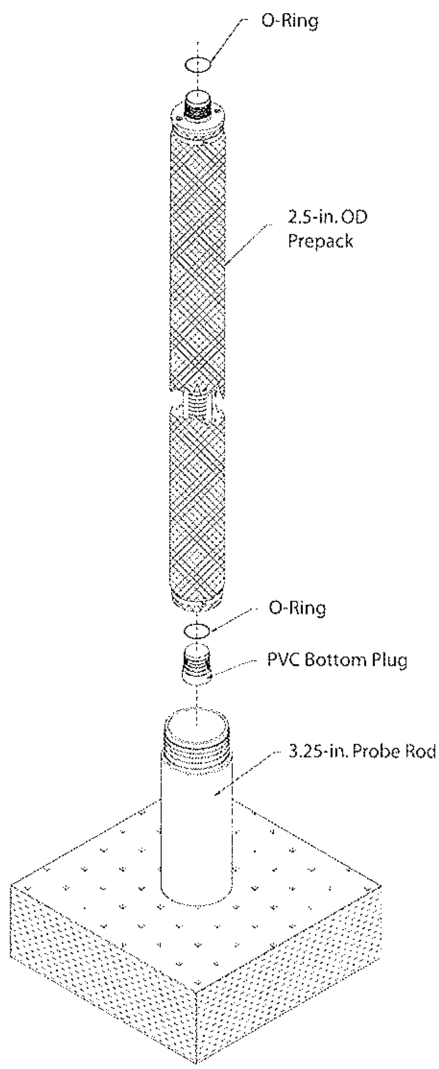


FIGURE 5.5
Prepacked Screen Assembly Inserted Into Rod String

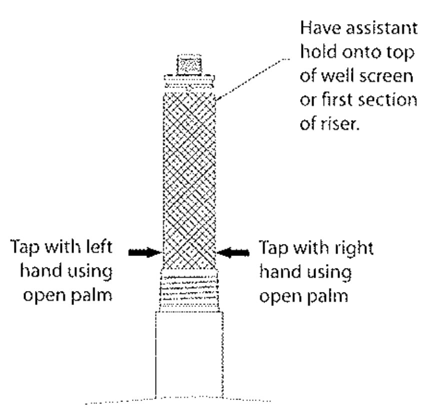


FIGURE 5.6
Tap On Sides of Prepack If Difficult to Install

IMPORTANT: The following installation instructions specify "prepack(s)" and "prepacked screen(s)", but are also applicable to 1.0-in. x 2.5-in. fieldpacked screens.

2. Thread a PVC Bottom Plug into a 2.5-in. OD prepack. An O-ring may be used on the plug if desired.

3. Leading with the bottom plug, insert the prepacked screen assembly into the probe rod string as shown in Figure 5.5. If the prepack does not slide easily into the rods, do not force it. With the lower end of the prepack in the probe rod, hit the screen simultaneously with both hands using a clapping motion (Fig. 5.6). With this technique, the screen will drop by gravity into the probe rods. Have an assistant hold onto the top portion of the screen to prevent the screen from unexpectedly falling downhole.

CAUTION: Be careful when "kneading" the screen. Sudden screen slippage can pinch hands between the screen and the probe rod. To prevent screen slippage, have an assistant hold onto the prepack during the "kneading" operation.

4. Add additional five-foot prepacks to obtain the desired screened interval. O-rings can be installed between the prepack sections if desired.

5. With the assistance of a second person, attach five-foot sections of 1.0-inch Schedule 40 PVC Riser to the top of the screen assembly. O-rings are required at each riser joint to prevent groundwater, located above the desired monitoring interval, from seeping into the well. Continue to add riser sections until the assembly reaches the bottom of the probe rods (Fig. 5.7). At least one foot (0.3 m) of riser should extend past the top probe rod. Place the plastic plug into the top riser. Duct tape may be used to help keep the plug in the riser.

6. It is now time to pull up the probe rods from around the well screen and riser. Reposition the probe unit so that the Rod Grip Puller can be attached to the rod string.

(continued on Page 16)

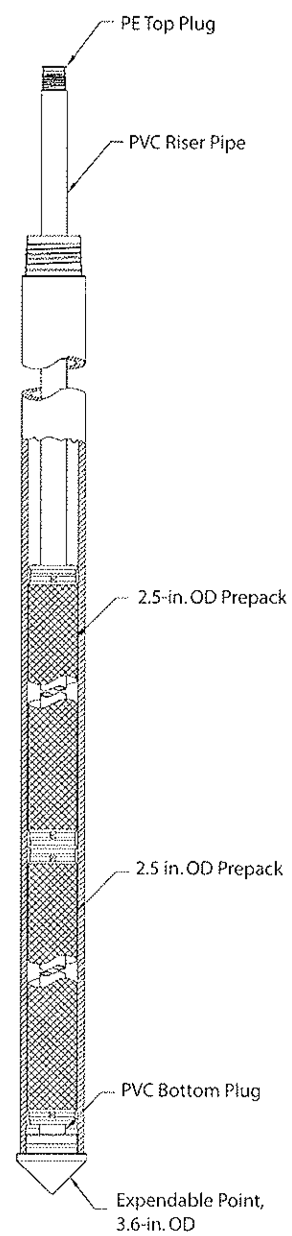


FIGURE 5.7
Prepack Assembly Inside Probe Rods

7. Retract the rod string the total length of all the screens plus an additional 3 feet (1 m). While pulling the rods, observe whether the top PVC riser stays in place or moves up with the rods.

a) If the riser stays in place, stable formation conditions are present. Continue retracting the rods to the depth specified above. Go to Section 4.4.

b) If the riser moves up with the probe rods, have a second person hold it in place while pulling up the rods. An additional section of PVC riser may be helpful. Once the probe rods have cleared the lower section of screen, the screen and riser assembly should stop rising with the rods. Continue retracting to the depth specified above. Go to Section 5.4.

c) If the risers continue to move up with the probe rods and cannot be held in place by hand, sand heave has most likely caused the screen to bind to the inside of the rods. Extension rods are now required. (Refer to Figure 5.8 for an illustration of extension rod accessories.)

d) Place a Screen Push Adapter on the end of an Extension Rod. Insert the adapter and extension rod into the PVC riser and hold either by hand or with an Extension Rod Jig. Attach additional extension rods with Extension Rod Couplers or Extension Rod Quick Links until the push adapter contacts the bottom of the screens (Fig. 5.9). Place an Extension Rod Handle on the top extension rod after leaving 3 to 4 feet (1 to 1.2m) of extra height above the last probe rod.

e) Slowly retract the probe rods while another person pushes and taps on the screen bottom with the extension rods (Fig. 5.9). To ensure proper placement of the screen interval and to prevent well damage, be careful not to get ahead while pulling the probe rods. The risers should stay in place once the probe rods are withdrawn past the screens. Retrieve the extension rods. Place the plug back into the top riser and secure it with duct tape if necessary.

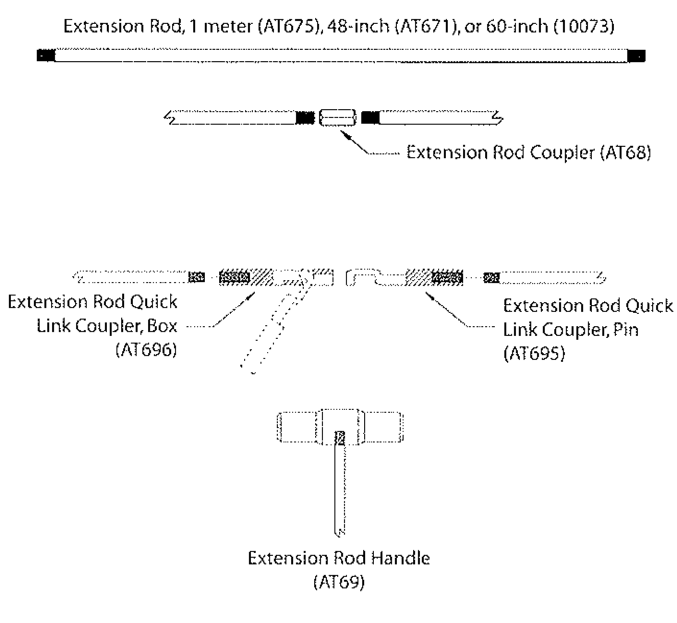


FIGURE 5.8
Geoprobe® Extension Rods and Accessories

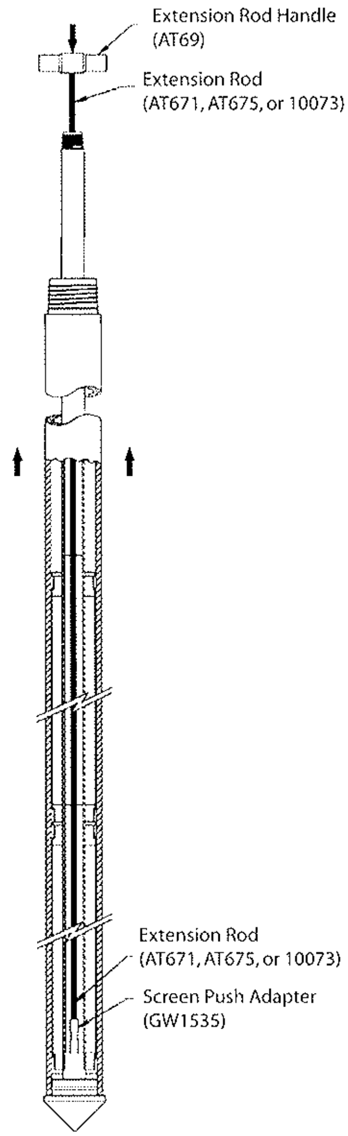


FIGURE 5.9
Using Extension Rods to
Tap Out Wedged Screens

5.3 Installing the Grout Barrier

The natural formation will sometimes collapse around the well screens and PVC riser as the probe rod string is pulled back. This provides an effective barrier between the screens and grout material used to seal the well annulus. If the formation does not collapse, a sand barrier must be installed from the surface. This portion of the well installation procedure is important because an inadequate barrier will allow grout to reach the well screens. Grout contamination can produce non-representative samples and retard groundwater flow into the well.

1. Using a Water Level Indicator or flat tape measure, determine the depth from the top of the PVC riser to the bottom of the riser and probe rod annulus. Two scenarios are possible:

   a) **Measured depth is 2 to 3 feet (0.6 to 0.9 m) less than riser length:** This indicates that unstable conditions have resulted in formation collapse. A natural grout barrier was formed as material collapsed around the PVC riser when the probe rods were retracted. This commonly occurs in sandy formations. No further action is required. Proceed with Section 5.5 and perform Step 2 (unstable formation).

   b) **Measured depth is equal to or greater than riser length:** This indicates that stable conditions are present. The probe hole has remained open and void space exists between the riser (and possibly the screen) and formation material. Clean sand must be placed downhole to provide a suitable grout barrier. Continue with Step 2.

2. Begin slowly pouring 20/40 grade sand down the annulus between the PVC riser and probe rod string. Reduce spillage by using a funnel or flexible container as shown in Figure 5.10. Add approximately 1.4 gal. (5.3 L) for each 5-foot (1.5 m) screen section, plus 0.9 gal. (3.4 L) for a minimum 2-foot (0.6 m) layer of sand above the screen section.

3. Measure the annulus depth after each 1,5 liters of sand. The sand may not fall all the way past the screen due to the tight annulus and possible water intrusion. This is acceptable, however, since the prepacked screens do not require the addition of sand. The important thing is that a sand barrier is provided above the screens.

4. Sand may also bridge within the annulus between the risers and probe rods and consequently fail to reach total depth (Fig. 5.10). This most likely occurs when the sand contacts the water table during deep well installations. Wet probe rods also contribute to sand bridging. If the annulus is open, skip to Section 5.5, Step 1. If bridging is evident, continue with Step 5.

5. In case of a sand bridge above the screens (wet rods, high water table, etc.), insert clean extension rods into the well annulus to break up the sand (Fig. 5.10). Simultaneously retracting the probe rods usually helps. Check annulus depth again. If sand is no longer bridged, proceed to Section 5.5. If bridging is still evident, continue with Step 6.

6. If the sand bridge cannot be broken up with extension rods, inject a small amount of clean water into the annulus using a Geoprobe GS500 or GS1000 Grout Machine and 3/8-in. (9.5mm) OD polyethylene tubing. Simply insert the poly tubing down the well annulus until the sand bridge is contacted. Attach the tubing to the grout machine and pump up to one gallon of clean water while moving the tubing up and down. The jetting action of the water will loosen and remove the sand bridge. Check the annulus depth again. The distance should be 2 to 3 feet (0.6 to 0.9 m) less than the riser length. Proceed with Section 5.5.

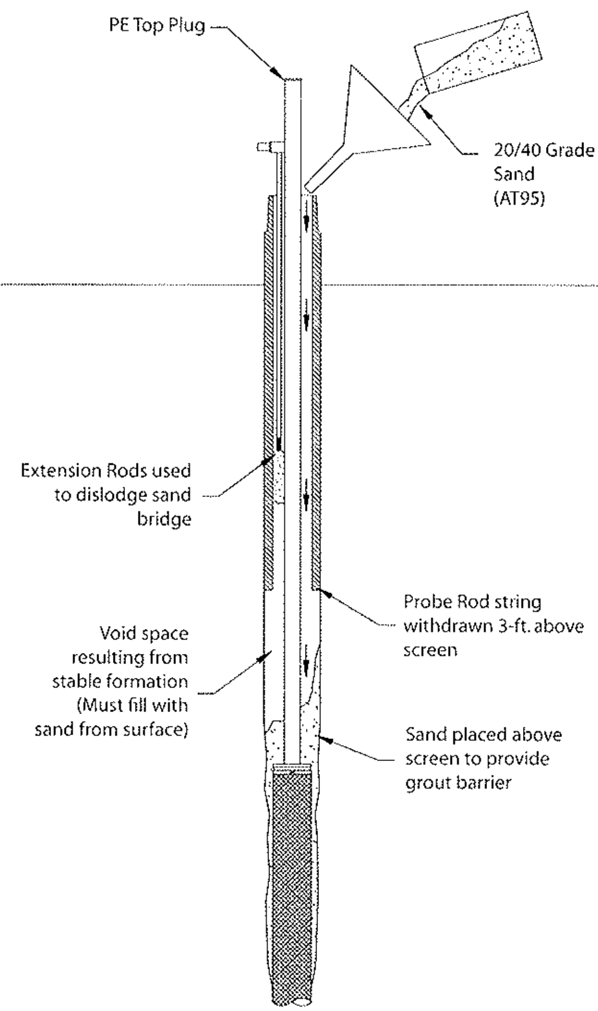


FIGURE 5.10
Installing Grout Barrier from Ground Surface with 20/40 Grade Sand

5.4 Bentonite Seal Above Screen

Bentonite is an expanding clay which exhibits very low permeability. When properly placed, bentonite prevents contaminants from moving into the well screens from above the desired monitoring interval. The seal is formed either by pouring granular bentonite into the annulus from the ground surface, or by injecting a high-solids bentonite slurry directly above the grout barrier. The use of granular bentonite is limited to cases in which the top of the screen ends above the water table (no water is present in the probe rods). Whichever method is used, at least 2 feet (0.6 m) of bentonite must be placed above the sand pack.

1. **Stable Formation.** Granular bentonite is recommended if the following conditions are met:
   - Top of screen interval is above the water table
   - Formation remained open when probe rods were retracted
   - Bridging was not encountered while installing sand for the grout barrier in Section 5.4

   a) Withdraw the probe rod string another 3 to 4 feet (0.9 to 1 m) and ensure that the PVC riser does not lift with the rods. It is important that the bottom of the rod string is above the proposed seal interval. If positioned too low, dry bentonite will backup into the expendable point holder. Bridging then results if moisture is present inside the probe rods.

   b) Pour bentonite between the probe rods and PVC riser as was done with the sand in Section 5.4. To properly hydrate the granular bentonite, it is necessary to periodically add water through a tremie tube while installing the bentonite. To accomplish this, repeat adding six inches of granular bentonite followed by 1.0 gallon (3.8 L) of water through a tremie tube until a minimum 2-foot (0.6 m) bentonite layer is created. Use the following procedure:

      i. Pour 0.8 liters of granular bentonite into the annulus. This volume of bentonite will fill approximately 6 inches (15 cm) of annular space.

      ii. Check for bridging inside the annulus. Measure the riser depth to the bottom of the annulus. The depth should equal the riser length minus the 2-foot sand pack and the added bentonite. If the measured depth is significantly less than expected, the bentonite has more than likely bridged somewhere inside the rod string. A procedure similar to that identified for bridged sand (Section 5.4, Steps 5 and 6) may be used to dislodge the granular bentonite.

      iii. Hydrate the bentonite by adding 1 gallon (3.8 L) of water to the annulus through a tremie tube. Do not pour water directly into the annulus. A tremie tube will help prevent bridging by keeping the rod string dry.

      iv. Repeat this procedure an additional three times or until the 2-foot (0.6 m) thick bentonite layer is completed.

2. **Unstable formation.** A grout machine is required to install the bentonite seal if the formation collapsed when the rods were retracted or the sand bridged when installing the grout barrier. The grout machine can pump a high-solids bentonite slurry under sufficient pressure to displace collapsing soil. Void spaces often develop when poured (gravity installed) granular bentonite is used under these conditions, resulting in an inadequate annular seal. Wet rods will often lead to bridging problems as well. Use the procedure on the following page to install a bentonite seal with a grout pump.

a) Mix 1.5 gallons (5.7 L) of high-solids bentonite (20 to 25 percent by dry weight) and place in the hopper of the grout machine.

b) Insert flexible tubing to the bottom of the annulus between the probe rods and well riser. Leaving at least 25 feet (8 m) extending from the top of the rod string, connect the tubing to the grout machine. This extra length will give needed slack for rod extraction (completed later in the procedure).

NOTE: The side-port tremie method is recommended to prevent intrusion of grout into the sand barrier. To accomplish side-port discharge of grout, cut a notch approximately one-inch (25 mm) up from the leading end of the tubing and then seal the leading end with a threaded plug of suitable size.

c) Reposition the probe unit and attach the 3.25-inch Rod Grip Puller.

d) Activate the pump and fill the tremie tube with bentonite. Begin slowly pulling the rod string approximately 3 feet (1.0 m) while operating the pump (Fig. 5.11). This will place bentonite in the void left by the retracted rods before it is filled by the collapsing formation. Continue to watch that the PVC riser does not come up with the rod string.

NOTE: When removing the retracted probe rod, slide the rod over the tremie tube and place it on the ground next to the grout machine. This eliminates cutting and reattaching the tubing for each rod removed from the string. Take care not to "kink" the tremie tube during this process as it will create a weak spot which may cause the tubing to burst when pressure is applied.

e) Measure the annulus depth to ensure that at least 2 feet (0.6 m) of bentonite was delivered. Pump additional bentonite slurry if needed.

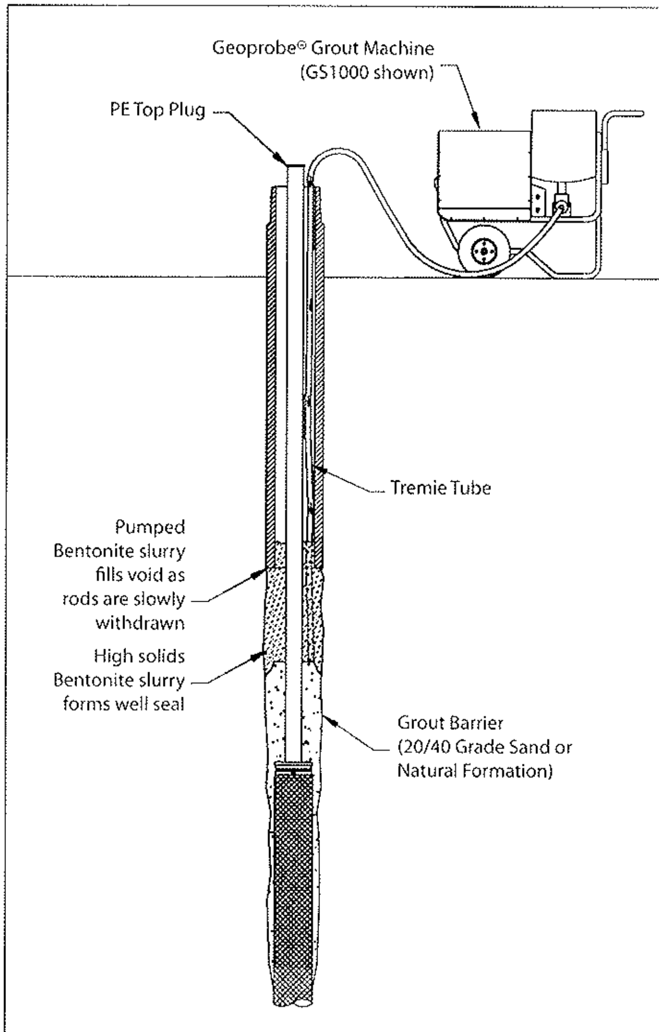


FIGURE 5.11
Installing Bentonite Seal with Geoprobe® GS1000 Grout Machine

5.5 Grouting the well annulus

The placement of grout material within the remaining well annulus provides additional protection from vertical contaminant migration. Most grout mixes are composed of neat cement, high-solids bentonite slurry, or a combination of cement and bentonite. Such mixes must be delivered with a high-pressure grout pump. When stable formations exist, the well may be sealed by pouring dry granular bentonite directly into the annulus from the ground surface. Consult the appropriate regulatory agency to determine approved grouting methods. This section presents the procedure for grouting the well annulus with the Geoprobe Model GS500 or GS1000 Grout Machine. Refer to Figure 5.12 as needed.

1. Mix an appropriate amount of grout material and place it in the hopper of the grout machine.

NOTE: It is recommended that an additional 20 to 25 percent of the calculated annulus volume be added to the total grout volume. This additional amount allows for grout that either remains in the grout hose or moves into the formation during pumping. Including the additional 20 percent, it will take approximately 0.54 gallons (2.0 L) of grout for each foot of riser below ground surface.

2. Insert tremie tube into the well annulus until the end of the flexible tubing reaches the top of the bentonite seal. Ensure that at least 25 feet (8 m) of tubing extends from the top of the rod string. This extra length allows rod retraction with the tubing attached to the pump.

3. Attach the tubing to the grout machine and begin pumping. If the bentonite seal was below the water table (deep well installation), water will be displaced and flow from the probe rods as the annulus is filled with grout. Continue operating the pump until undiluted grout flows from the top probe rod.

4. Reposition the probe unit and prepare to pull rods.

5. Begin pulling the probe rods while continuing to pump grout. Match the pulling speed to grout flow so that the rods remain filled to the ground surface. This maintains hydraulic head within the probe rods and ensures that the void left by the withdrawn rods is completely filled with grout.

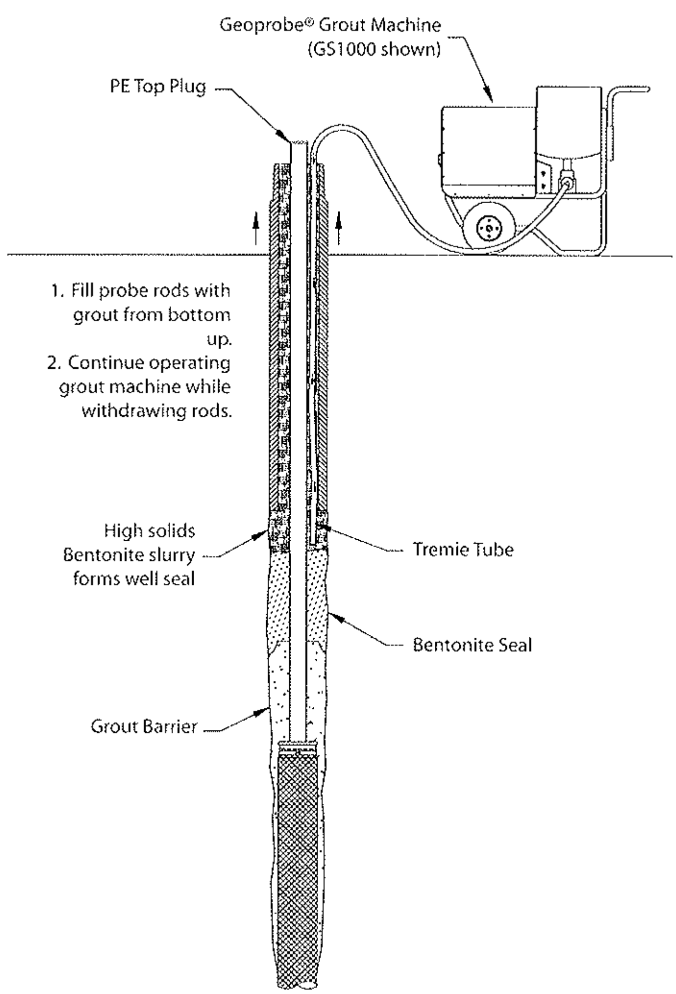


FIGURE 5.12
Grouting Well Annulus with Geoprobe® GS1000 Grout Machine

NOTE: Slide the probe rods over the tremie tube and place neatly on the ground next to the grout machine. Be careful to not pinch or bind the flexible tubing as this forms weak spots which may burst when pressure is applied.

NOTE: Try to avoid filling the upper 12 inches (305 mm) of well annulus with grout when pulling the expendable point holder. This will make for a cleaner well cap installation.

6. When all probe rods have been retrieved and the well is adequately grouted, unstring the tremie tube and begin cleanup. It is important to promptly clean the probe rods, grout machine, and accessories. This is especially true of cement mixes as they quickly set up and are difficult to remove once dried.

5.6 Surface Cover/Well Protection

A surface cover protects the PVC well riser from damage and tampering. Although aboveground and flush-mount well covers may be used, most Geoprobe® monitoring wells have been installed with flush-mount covers (Fig. 5.13 - Page 24). Consult the project planners and/or appropriate regulators to determine the approved well cover configuration for your specific application.

1. In order to fit under a flush-mount cover, the top of the well riser must be below the ground surface. Place the well cover over the riser and push it into the ground to mark the cover diameter. Remove the cover and dig out approximately 6 inches (152 mm) of soil from within the cover mark.

2. Remove the PE top plug from the PVC riser. The top of the riser should be approximately 4 inches (102 mm) above the bottom of the hole. If a joint is near this level, unthread the top riser. If a joint is not positioned near the specified level, cut off the riser with PVC cutters.

IMPORTANT: Do not cut off the riser with a hacksaw as cuttings will fall down into the screens.

3. Insert a locking well plug into the top of the PVC riser. Tighten the center wing-bolt on the plug until it fits snugly within the riser. Secure the well plug by installing a padlock over one side of the wingbolt and through the hole provided on top of the plug.

4. Position the well cover so that it is centered over the PVC pipe. Push the cover into the ground using the machine foot if needed. Provide at least 0.5 inches (13 mm) of space between the top of the locking cap and bottom of the well cover lid. Do not push the cover so deep as to place the top of the lid below the surrounding ground surface.

5. Support the well cover by installing a concrete pad according to project requirements. Pads are commonly square-shaped with a thickness of 4 inches (102 mm) and sides measuring 24 inches (610 mm) or greater. Finish the pad so that the edges slope away from the center to prevent ponding of surface water on the well cover.

6. Fill the inside of the well cover with sand up to approximately 2 to 3 inches (51 to 76 mm) from the top of the PVC riser.

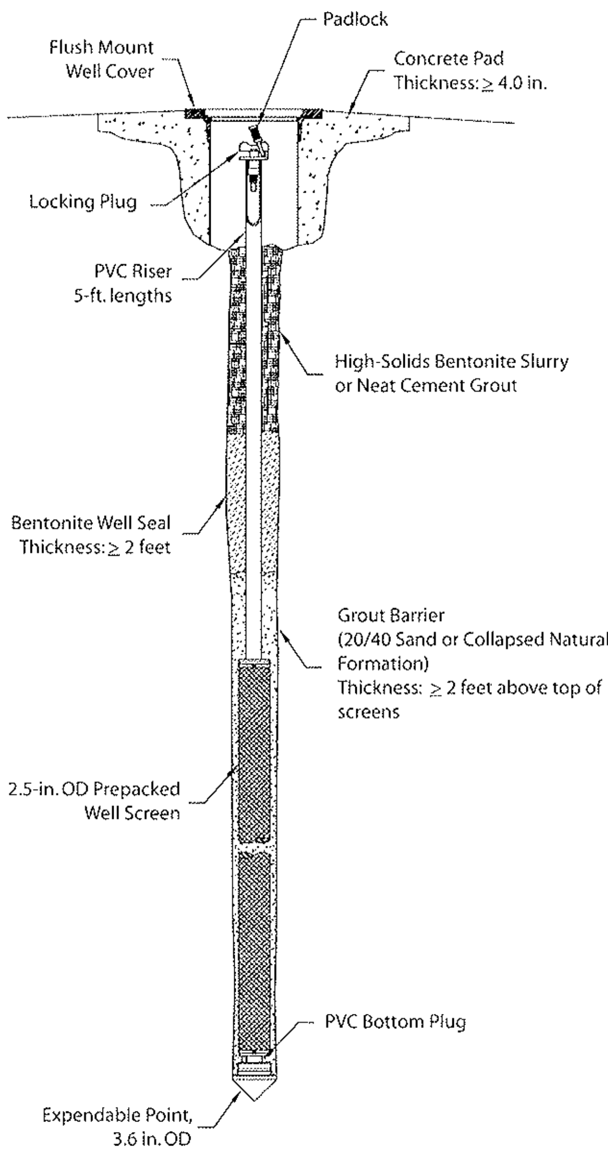


FIGURE 5.13
Properly Installed Geoprobe® 2.5-in. OD Prepacked Screen Monitoring Well

6.0 WELL DEVELOPMENT

"The development serves to remove the finer grained material from the well screen and filter pack that may otherwise interfere with water quality analyses, restore groundwater properties disturbed during the installation (probing) process, and to improve the hydraulic characteristics of the filter pack and hydraulic communication between the well and the hydrologic unit adjacent to the well screen," (ASTM D 5092).

The two most common methods of well development are purging (bailing or pumping) and mechanical surging.

6.1 **Purging** involves removing at least three well volumes of water with either a Tubing Bottom Check Valve (Fig. 6.1), Stainless Steel Mini-Bailer Assembly or Mechanical Bladd Pump. Include the entire 3.6-inch (91 mm) diameter of disturbed soil at the screen interval when calculating the well volume.

6.2 **Mechanical Surging** uses a surge block which is attached to extension rods and lowered inside the riser to the screen interval. The extension rods and surge block are moved up and down, forcing water into and out of the screen. Water and loosened sediments are then removed using one of three methods listed in 6.1.

IMPORTANT: **Mechanical surging may damage the well screen and/or reduce groundwater flow across the filter pack if performed incorrectly or under improper conditions. Refer to ASTM D 5521, "Standard Guide for Development of Groundwater Monitoring Wells in Granular Aquifers" for a detailed discussion of mechanical surging.**

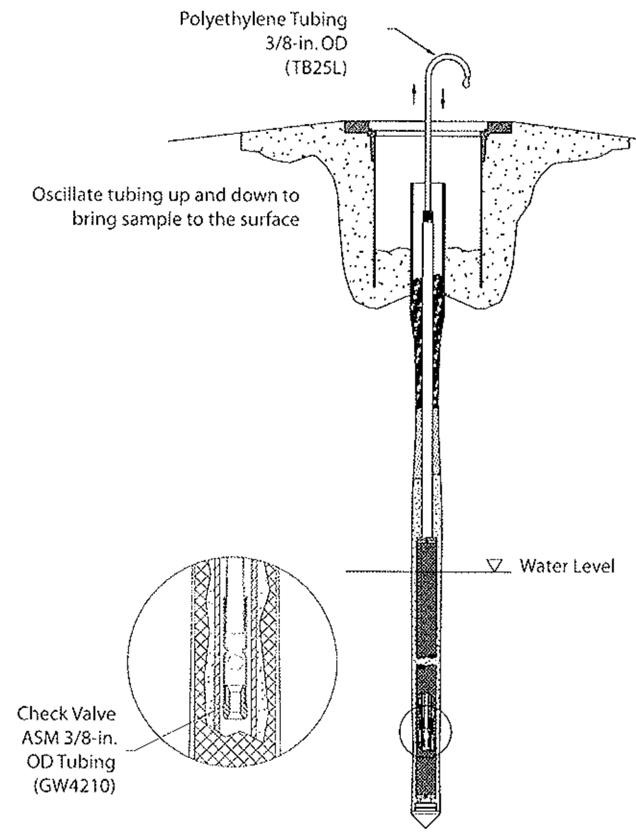


FIGURE 6.1
Sampling with Polyethylene Tubing and a Tubing Bottom Check Valve

Development should continue until consecutive samples yield representative water. "Representative water is assumed to have been obtained when pH, temperature, and specific conductivity readings stabilize and the water is visually clear of suspended solids," (ASTM D 5092).

7.0 SAMPLE COLLECTION

As the federal EPA and more state agencies are recommending or requiring use of the "low-flow" sampling protocol (EPA 1996), the ability to sample small-diameter, direct push (DP) installed monitoring wells with bladder pumps has significantly increased. The latest option for collecting groundwater is to utilize a Geoprobe® MB470 Mechanical Bladder Pump. It may be used to meet requirements of the low-flow sampling protocol (EPA 1996). The low-flow sampling method is preferred when sampling for volatile contaminants or metal analytes. The Mechanical Bladder Pump can be used with any of the available flow-through-cells and water quality monitoring probes. Smaller volume flow-through-cells are recommended when available. Use of the Mechanical Bladder Pump and flow-through-cell allows you to meet the stringent requirements for monitoring pH, specific conductance, DO, and ORP, and obtaining low-turbidity samples for metals analysis.

Groundwater samples may be collected with a check valve assembly (with 3/8-inch OD poly tubing as shown in Fig. 6.1) or a stainless steel mini-bailer assembly when appropriate. While the check valve is the quicker and more economical sampling device, some operators still prefer the traditional mini-bailer.

Before going into the field to sample monitoring wells (or groundwater samplers), be sure to know the level of sample quality that will be required. For high-integrity samples that must meet strict data quality objectives, sampling with a mechanical bladder pump may be required. Conversely, if screening level data is required (is it there and about how much?) a check valve assembly may be sufficient and could save time and money. For further information on this topic, request the Geoprobe® bulletin titled *Groundwater Quality and Turbidity vs. Low Flow*.

8.0 REFERENCES

American Society for Testing and Materials (ASTM), 1992. ASTM D 5092 *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers.* ASTM West Conshohocken, PA.

American Society for Testing and Materials (ASTM), 1995. ASTM D 5521 *Standard Guide for Development of Ground Water Monitoring Wells in Granular Aquifers.* ASTM West Conshohocken, PA.

American Society for Testing and Materials (ASTM), 2002. ASTM D 6724 *Standard Guide for Selection and Installation of Direct Push Ground Water Monitoring Wells.* ASTM West Conshohocken, PA.

American Society for Testing and Materials (ASTM), 2002. ASTM D 6725 *Standard Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers.* ASTM West Conshohocken, PA.

Geoprobe Systems®, 2003. *Tools Catalog, V. 6.*

U.S. Environmental Protection Agency (EPA), 1996. Robert W. Puhls and Michael J. Barcelona. *Ground Water Issue: Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures.* OSWER. EPA/540/S-95/504. April.

U.S. Environmental Protection Agency (EPA), 1997. *Expedited Site Assessment Tools For Underground Storage Tank Sites: A Guide for Regulators.* EPA 510-B-97-001. March, 1997.

APPENDIX A
ALTERNATIVE PARTS

Groundwater Purging and Sampling Accessories	Part Number
Polyethylene Tubing, 0.25-inch OD, 500 ft.	TB17L
Polyethylene Tubing, 0.5-inch OD, 500 ft	TB37L
Polyethylene Tubing, 0.625-inch OD, 50 ft.	TB50L
Check Valve Assembly, 0.25-inch OD Tubing	GW4240
Check Valve Assembly, 0.5-inch OD Tubing	GW4220
Check Valve Assembly, 0.625-inch OD Tubing	GW4230
Water Level Meter, 0.375-inch OD Probe, 100-ft. cable	GW2001
Water Level Meter, 0.438-inch OD Probe, 200 ft. cable	GW2002
Water Level Meter, 0.375-inch OD Probe, 200-ft. cable	GW2003
Water Level Meter, 0.438-inch OD Probe, 30-m cable	GW2005
Water Level Meter, 0.438-inch OD Probe, 60-m cable	GW2007
Water Level Meter, 0.375-inch OD Probe, 60-m cable	GE2008

Geoprobe Systems®

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ARCADIS

Attachment 3

ARCADIS *LNAPL Bailbown Test* SOP

ARCADIS
Infrastructure, environment, facilities

Imagine the result

Standard Operating Procedure for LNAPL Baildown Test

Rev. # 2

Rev. Date: January 14, 2010

Approval Signatures

Prepared by: ______________________ Date: January 14, 2010
Jonathon J. Smith

Reviewed by: ______________________ Date: January 14, 2010
Brad W. Koons, P.E.

I. Scope and Application

The objective of this Standard Operating Procedure (SOP) is to establish uniform procedures for conducting rising-head light non-aqueous-phase liquid (LNAPL) baildown tests to evaluate LNAPL conductivity (K_n) in the subsurface at a specific well location. The data generated from the LNAPL baildown test can be used, along with other site data, to evaluate LNAPL mobility and recoverability at a site. This SOP describes the equipment, field procedures, materials and documentation procedures necessary to determine LNAPL conductivity. The details within this SOP should be used in conjunction with project work plans.

This SOP applies to task orders and projects associated with ARCADIS. This SOP may be modified, as required, depending on site-specific conditions, equipment limitations or limitations imposed by the procedure. The ultimate procedure employed will be documented in the appropriate project work plans or reports. If changes to the testing procedures are required due to unanticipated field conditions, the changes will be discussed with the project manager as soon as practicable and documented in the project report.

II. Personnel Qualifications

Only qualified ARCADIS-related personnel will conduct LNAPL baildown tests. ARCADIS field sampling personnel will have sufficient “hands-on” experience necessary to successfully complete the LNAPL baildown test field work. Training requirements for conducting LNAPL baildown tests include reviewing this SOP and other applicable SOPs and/or guidance documents, instrument calibration training, and health and safety training.

ARCADIS field sampling personnel will have completed current company-required health and safety training (e.g., 40-hour Hazardous Waste Operations training, site-specific training, first aid and cardiopulmonary resuscitation (CPR) training), as needed.

III. Equipment List

Equipment and materials used for conducting the LNAPL baildown tests may include, but are not limited to, the following:

- appropriate personal protective equipment (PPE), as specified in the site Health and Safety Plan (HASP)
- equipment decontamination supplies
- photoionization detector (PID) (see ARCADIS SOP: Photoionization Detector Air Monitoring and Field Screening)
- plastic sheeting
- oil absorbent pads
- stopwatch
- polypropylene rope
- clean disposable bailers
- oil-specific skimmer pump
- vacuum truck
- plastic bucket with lid
- plastic beakers or graduated cylinders (appropriately sized for anticipated NAPL/water recovery volume)
- Calculator
- appropriate field logs/forms
- oil-water interface probe (see ARCADIS SOP: Water Level Measurement)
- data logger and transducer
- white masking tape

- measuring tape with gradation in hundredths of a foot
- indelible ink pen
- monitoring well keys
- bolt cutters
- monitoring well locks
- field log book or PDA or field (computer) notebook

IV. Cautions and Procedure Considerations

Wells containing LNAPL for baildown testing should be selected based on project-specific objectives and a review of historical site data. It is good practice to select several baildown test wells to bracket the range of observed historical apparent LNAPL thickness measurements and LNAPL mobility/recoverability conditions across a given area. As a rule of thumb, apparent LNAPL thicknesses in wells used for baildown tests should be greater than or equal to the borehole diameter (Lundy and Parcher, 2007). Additional guidelines for selecting appropriate wells for LNAPL baildown testing include:

- Select wells located near the interior and exterior portions of the LNAPL plume(s)
- Select wells located in a variety of geologic materials, as feasible
- Consider the position of wells relative to groundwater and LNAPL flow direction
- Consider the potential of wells to exhibit different equilibrated apparent LNAPL thicknesses
- Select wells which contain different types of LNAPL, if present

In addition, understanding the areas affected by recent remediation efforts should be considered because these areas may not be representative of static subsurface conditions. Also, ARCADIS field sampling personnel must be aware of historical fluid levels as they compare to the conditions at the time of testing (i.e., the smear zone).

If higher LNAPL recovery rates are expected, larger diameter wells (4- to 6-inch-diameter casings) are generally preferred. The increased area of the wellbore seepage face for larger diameter wells will provide information that is applicable to a larger, more representative volume of aquifer material. However, if the expected recovery rate is low, smaller diameter wells are often preferred because the volume of the borehole is smaller relative to the formation recovery capacity. Further discussion on accounting for the well filter pack is presented in *A Protocol for Performing Field Tasks and Follow-up Analytical Evaluation for LNAPL Transmissivity using Well Baildown Procedures* (Beckett and Lyverse, 2002).

ARCADIS project personnel must confirm that the test wells have been properly developed. This cannot be overemphasized, as incomplete well development results in underestimates of LNAPL transmissivity (T_n) and LNAPL conductivity (K_n). See the ARCADIS SOP titled *Monitoring Well Development* for additional details.

ARCADIS field sampling personnel must verify that the air/LNAPL and LNAPL/groundwater interfaces occur within the screen interval. At a minimum, the piezometric head elevation in the well should occur below the top of the screen.

ARCADIS field sampling personnel will choose the most appropriate technique to evacuate the LNAPL from the well. These techniques include:

- **Manual bailer** — A 1¾-inch-diameter bailer will be used for 2-inch-diameter wells. For 4-inch-diameter wells, a 3-inch-diameter bailer will be used for LNAPL recovery. ARCADIS highly recommends using product recovery cups, which attach to the bottom of the bailer and maximize the surface area for LNAPL recovery (For example, the Superbailer™, manufactured by EON Products, Inc. has this feature built-in). This will allow for more complete LNAPL removal and more accurate recovery measurements.

- **Pumping** — LNAPL removal can be accomplished by using an oil-specific skimmer pump that operates at a pumping rate which exceeds the LNAPL recharge capacity. For shallow wells (< 25 feet below ground surface), a peristaltic pump may also be a useful, effective and appropriate mode of LNAPL removal.

- **Vacuum Truck** — If large LNAPL volumes are to be removed or extremely rapid recovery rates are anticipated, LNAPL removal can be accomplished using a vacuum truck. The vacuum extraction line is to be outfitted with a small-diameter stinger attachment that will be extended down the well and an in-line site glass to observe extracted fluid color for determination of whether LNAPL or groundwater is being extracted. Begin pumping at the LNAPL/air interface and slowly move the stinger tube downward to extract LNAPL. When groundwater recovery is observed indicating that the LNAPL has been evacuated withdraw the stinger tube and begin fluid level measurements.

Follow the sequential steps below for each baildown test well. Data collection is generally manual using an interface probe, although a data logger can also be used as long as it can sense either the fluid interfaces or the head change only with respect to LNAPL. Before performing an LNAPL baildown test, allow monitoring well water and LNAPL levels to equilibrate with atmospheric pressure. Gauge fluid levels periodically for 5 to 10 minutes to monitor changes in head. Monitoring wells without vents (flush mounts) may require more time to equilibrate with atmospheric pressure following well cap removal.

ARCADIS recommends taking LNAPL measurements initially in one-minute intervals and then adjusting the frequency of measurements thereafter, based on site-specific conditions. The rate of LNAPL recovery will usually slow over time unless the zone of interest is highly conductive. Once the rate of recovery is slow enough, a new baildown test can be initiated at another location, returning to take periodic measurements at the initial test well. Continue this process as long as it is viable based on soil characteristics, field logistics, well locations and data collection needs. Real-time examination of the data curves is the best indicator of data sufficiency. A plot of the change in LNAPL thickness over time may exhibit up to three theoretical segments:

1) initial steep segment that could reflect filter pack drainage

2) main production segment where the formation LNAPL gradient to the wells controls recovery

3) third segment where the diminishing formation LNAPL gradient produces a flatter recovery curve

Repeatedly introducing the oil-water interface indicator may alter the fluid-level measurements. Avoid splashing the probe into the water table or lowering the probe too far beyond the LNAPL-water interface depth. To avoid introducing surface soil or other material into the monitoring well, stage downhole equipment on a clean and dry working surface.

Two field personnel are recommended to adequately perform this test, one person to collect the data and one person to record the data.

V. Health and Safety Considerations

Overall, the Loss Prevention System™ (LPS) tools and the site-specific HASP will be used to guide the performance of LNAPL baildown tests in a safe manner without incident. A Job Safety Analysis (JSA) will be prepared for LNAPL baildown tests. The following specific health and safety issues must be considered when conducting LNAPL baildown tests:

- Monitoring for volatile organic compounds (VOCs) in the monitoring well head space must be conducted with a PID and recorded in the field logbook prior to initiating the LNAPL baildown test. PID readings will be compared to action levels established in the site HASP for appropriate action.

- Appropriate PPE must be worn to avoid contact with LNAPL during the baildown test.

- LNAPL removed from the test well must be managed with caution to avoid igniting the LNAPL material. LNAPL characteristics must be reviewed in the JSA, which will be prepared and reviewed by the project team prior to implementing the baildown test.

- LNAPL generated during the baildown test must be properly managed in accordance with facility and applicable regulatory requirements.

- Well covers must be carefully removed to avoid potential contact with insects or animals nesting in the well casings.

VI. Procedure

Specific procedures for conducting LNAPL baildown tests are presented below:

1. Identify site, well number, date and time on the LNAPL Baildown Test Log and field logbook or PDA, along with other appropriate LNAPL baildown testing information. An example LNAPL Baildown Test Log is provided in Attachment 1 to this SOP.

2. Place clean plastic sheeting and several oil absorbent pads on the ground next to the well.

3. Unlock and open the monitoring well cover while standing upwind from the well.

4. Measure the concentration of detectible organics present in the worker breathing zone immediately after opening the well using a PID. If the PID reading(s) exceed the thresholds provided in the HASP, take appropriate actions per the HASP. After monitoring the worker breathing zone, proceed to

monitor the well head space with the PID and record the PID reading in the field logbook.

5. Prepare a test log to record LNAPL recovery data. Initially, data should be collected very frequently. As time progresses and the LNAPL recovery rate slows, less frequent measurements will be required. In most cases, initial measurement increments of 1 minute are sufficient, with subsequent measurements farther apart as appropriate, based on observed rate of recovery during the first few readings. If LNAPL recovery rates are high, data should be collected more frequently. For lower LNAPL recovery rates, time intervals between measurements can be increased.

6. It is important to monitor rapid LNAPL recovery at a higher frequency, again as indicated by the observed recovery data.

7. Secure one end of the rope to the bailer and the other end to the well casing using a bowline knot.

8. Before beginning the baildown testing, measure and record static fluid levels using the oil/ water interface probe (i.e., depth to LNAPL and depth to groundwater) and document the well construction details. Using the conversion chart at the bottom of the test log, the measured LNAPL thickness and the well diameter, calculate and record the initial LNAPL volume in the well. Gauge fluid levels periodically for 5 to 10 minutes to monitor changes in head. Do not begin the test until the well has equilibrated. Ideally, one person will be responsible for lowering the bailer into the well and recording time intervals in the log, and another person will be responsible for lowering the water-level probe into the well and measuring and communicating water-level depths to the person recording information in the log.

9. To begin baildown testing, slowly lower the bailer or equivalent into the well until it is just below the LNAPL-water interface.

10. Set stopwatch. Wait to start the stopwatch until immediately after LNAPL removal is finished.

11. Evacuate LNAPL from the well by gently bailing, pumping, or vacuum recovery as described in Section IV above while minimizing water production. One of the assumptions employed in the analysis of the baildown test data is that the LNAPL is removed from the well instantaneously. Thus, it is important to avoid spending excessive amounts of time (more than 5 minutes) removing LNAPL from the well.

12. Record the time at which LNAPL removal is complete (or removed to the maximum practical extent) as the test start time. Begin measuring the elapsed time, starting with this point. Monitor depth to LNAPL and depth to water at the appropriate intervals, as discussed above (5). Measure fluid levels to the nearest hundredth of a foot with the oil-water interface probe and record, along with the corresponding time reading in minutes and seconds.

13. Transfer the LNAPL and groundwater evacuated from the well into an appropriately sized beaker or graduated cylinder. Record the volumes of LNAPL and groundwater on the Baildown Test Log (Attachment 1). If an LNAPL/water emulsion was formed during fluid recovery, allow time for LNAPL/water separation and make note of the observed emulsification.

14. Two to eight hours of data collection is usually sufficient. However, faster LNAPL recovery need not be monitored for extended periods, and slow recovering wells may benefit from follow-up readings the next day.

15. Place all LNAPL and groundwater collected during the test into an appropriate container for proper waste management.

16. Decontaminate the oil-water level indicator with a non-phosphate detergent and water scrub, a tap water rinse, a reagent grade methanol rinse, a second tap water rinse, a second methanol rinse, a third tap water rinse, and a triple rinse with distilled water (see SOP titled *Field Equipment Decontamination*).

17. Secure the monitoring well prior to leaving by replacing the well cap and/or cover and locking it.

VII. Waste Management

Rinse water, PPE and other waste materials generated during equipment decontamination must be placed in appropriate containers and labeled. Containerized waste will be disposed of in a manner consistent with appropriate waste management procedures for investigation-derived waste.

VIII. Data Recording and Management

ARCADIS field sampling personnel will record data using the LNAPL Baildown Test Log (Attachment 1). All information relevant to the test data beyond the items identified in the Baildown Test Log will be recorded using the field logbook, PDA or field computer. Field equipment decontamination activities and waste management activities will be recorded in the field logbook. Records generated as a result of implementing this SOP will be controlled and maintained in the project record files in accordance with client-specific requirements.

IX. Quality Assurance/Quality Control

ARCADIS project personnel will review the data set collected during the LNAPL baildown test in the field to determine whether or not the data are reasonable given site-specific conditions. For example, if the data indicates that LNAPL recovery is very rapid in a very low-permeability soil type, this may indicate that there are problems with the data set. If the data are questionable, the field equipment must be checked to confirm it is working properly and the test will be repeated, if possible. Depending on data quality objectives, a duplicate LNAPL baildown test may be conducted as a quality control check 48 hours after the initial test, assuming water levels and apparent LNAPL thicknesses have returned to static conditions.

Any issues that may affect the data must be recorded in the field log book so that analysts can consider those issues when processing the data.

X. References

Beckett, G.D. and Lyverse, M.A. 2002. *A Protocol for Performing Field Tasks and Follow-up Analytical Evaluation for LNAPL Transmissivity using Well Baildown Procedures, August 2002.*

Lundy, D. and Parcher, M. 2007. *Assessment of LNAPL Volume, Mobility and Recoverability for Recovery Systems: Design and Risk-Based Corrective Action. National Ground Water Association Short Course, November 2007.*

ARCADIS SOPs Referenced Herein:

Field Equipment Decontamination, Revision No.1, April, 2009.

Monitoring Well Development, Revision No.2, March, 2008.

Photoionization Detector Air Monitoring and Field Screening, Revision No. 0, July, 2003.

Water Level Measurement, Revision No. 1, March, 2004.

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Attachment 1: LNAPL BAILDOWN TEST LOG

LNAPL Baildown Test Standard Operating Procedure

Site Name		Test Well ID	
Date and Time In		Date and Time Out	
Personnel		Weather	

Well Construction Details

Top of Casing Elevation (ft amsl)		Screen Slot Size (in)	
Total Well Depth (ft)		Filter Pack Type	
Depth to Top of Screen (ft)		Depth to Bottom of Screen (ft)	
Well Casing Diameter (in)		Borehole Diameter (in)	

Initial Test Conditions

Static Depth to LNAPL (ft)		Test Date	
Static Depth to Water (ft)		Start Time	
LNAPL Thickness (ft)		Initial LNAPL Volume in Well (gal)	

LNAPL Removal Information

LNAPL Removal Method/Equipment		Time LNAPL Removal Begins	
Volume of LNAPL Removed (gal)		Time LNAPL Removal is Completed	
Volume of Groundwater Removed (gal)			

Baildown Test Data

Elapsed Time (min)	Depth to LNAPL (ft)	Depth to Water (ft)	Observations

(Modified after Beckett and Lyverse, 2002)

Well Casing Volumes	1-¼" = 0.06	2" = 0.16	3" = 0.37	4" = 0.65
(Gal./Ft.)	1-½" = 0.09	2-½" = 0.26	3-½" = 0.50	6" = 1.47

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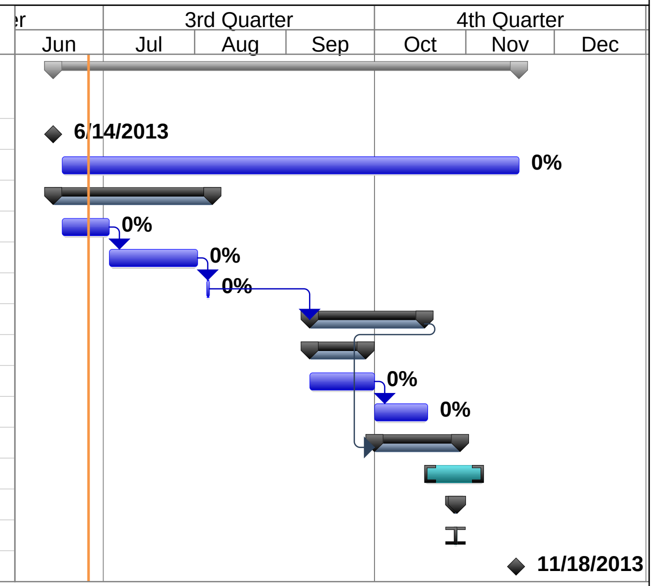
Attachment 4

Field Work Implementation Schedule

97127 (Tracy, CA) Soil and Groundwater Assessment

ID		* ASTM WBS	WBS	Task Name	Duration	Start	Finish
0			**0**	**97127 (Tracy, CA) Assessment - Soil and Groundwater**	**109 days**	**Fri 6/14/13**	**Mon 11/18/13**
1			0	Start	0 days	Fri 6/14/13	Fri 6/14/13
2			3.01	Project Management	109 days	Mon 6/17/13	Mon 11/18/13
3			**0**	**Work Plan**	**37 days**	**Fri 6/14/13**	**Tue 8/6/13**
4		03.01	3.1	Work Plan Preparation and Submittal	12 days	Mon 6/17/13	Tue 7/2/13
5			2.03	Regulator Review	21 days	Wed 7/3/13	Thu 8/1/13
6			2.03	Receive Regulatory Approval	1 day	Mon 8/5/13	Mon 8/5/13
7			**4**	**Field Activities**	**29 days**	**Mon 9/9/13**	**Thu 10/17/13**
8			**0**	**Soil and Groundwater Investigation**	**15 days**	**Mon 9/9/13**	**Fri 9/27/13**
9			7.15	Field Activities	16 days	Mon 9/9/13	Mon 9/30/13
10			8.02	Analytical	14 days	Tue 10/1/13	Fri 10/18/13
11			**0**	**Reporting**	**21 days**	**Tue 10/1/13**	**Tue 10/29/13**
12			5.1	Data Analysis	14 days	Fri 10/18/13	Wed 11/6/13
13			**6**	**Meeting**	**1 day**	**Mon 10/28/13**	**Mon 10/28/13**
14			6.1	Meeting with Alameda County	1 day	Mon 10/28/13	Mon 10/28/13
15			0	Project Complete	0 days	Mon 11/18/13	Mon 11/18/13



Project: 97127 (Tracy, CA)
Date: Wed 6/26/13

Task	External Milestone	Manual Summary Rollup
Split	Inactive Task	Manual Summary
Milestone	Inactive Milestone	Start-only
Summary	Inactive Summary	Finish-only
Project Summary	Manual Task	Progress
External Tasks	Duration-only	Deadline