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

RECEIVED

3:50 pm, Sep 17, 2012

Alameda County
Environmental Health

RE: **Additional Site Assessment Work Plan**
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 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
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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
Former Chevron Service Station 9-7127
Grant Line Road and I-580
Tracy, California
Case Number RO0000185

Date:
September 14, 2012

Contact:
Tonya R. Russi

Phone:
916.985.2079 ext. 15

Email:
Tonya.Russi@
arcadis-us.com

Our ref:
B0047959.0000

Dear Mr. Detterman:

On behalf of Chevron Environmental Management Company (Chevron), ARCADIS U.S. Inc. (ARCADIS) has prepared this *Additional Site Assessment Work Plan* for the former Chevron service station 9-7127, located at the east side of Grant Line Road, just south of Interstate-580 in a rural area of Tracy, California (Figure 1).

This work plan has been prepared as requested by the Alameda County Environmental Health Department (ACEHD), as indicated in their letter dated July 27, 2012. The ACEHD requested a soil and groundwater investigation work plan and a Feasibility Study (FS)/Corrective Action Plan (CAP). ARCADIS agrees that 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 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. Investigation activities are proposed to adequately characterize site impacts in support of risk-based closure of the site. 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

Fifteen soil vapor samples (V1 through V15) were collected 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, it was 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, seven on-site soil borings (B-1 through B-7) were advanced at 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, water samples were collected 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, further water sampling of the on-site domestic water well and conveyance piping was conducted. During January 1988, water samples were collected from the tap located adjacent to the on-site domestic water well and contained benzene concentrations of 1 and 1.1 µg/L. During February 1988, water samples collected from the water tap located on the south side of the former station building and the on-site domestic well did not contain detectable concentration of benzene. During March 1989, water samples collected from the on-site domestic well, the tap located adjacent to the on-site domestic water well, and a spigot located off-site contained benzene at concentrations of 3.7, 2.7 and 1.4 µg/L, respectively. During April 1989, water samples collected from the spigot located off-site and the on-site domestic well contained a benzene concentrations of 2 and 7 µg/L (GeoStrategies Inc., 1989).

During May 1989, a carbon adsorption water treatment system was installed on the wellhead and weekly sampling commenced. Between August 1989 and March 1991, water samples were collected 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, the service station was demolished. During demolition, 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 were removed. The tanks were all constructed of fiberglass, and no holes were observed during tank 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, the excavated soil was aerated on-site. The aerated excavation soil was subsequently used as backfill (Blaine Tech, 1991).

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

During December 1992, one soil boring (B-1) and three monitoring wells (MW-1 through MW-3) were installed at the site. Soil samples were collected 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, separate phase hydrocarbons (SPH) were observed in monitoring well MW-1 at a thickness of 1.67 feet. 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, SPH was bailed out on a weekly basis from MW-1. Additionally, in January 1993 a passive skimmer was installed 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

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. A grab groundwater sample was collected 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

A comprehensive site evaluation was performed 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

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

June 1997 – Risk-Based Assessment

In June 1997, a Tier-2, Risk-Based Corrective Action (RBCA) assessment was completed. It was 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, Oxygen Release Compound® (ORC) socks were installed in wells MW-1, MW-2 and MW-4 to enhance biodegradation and reduce petroleum hydrocarbon concentrations. A passive skimmer replaced the ORC sock in monitoring well MW-1 in July 2001. (Delta, 2003). The ORC socks in the remaining wells were removed at an unknown date.

December 1999 – Hydrogen Peroxide Injection

Hydrogen peroxide was injected 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, a CAP was submitted which recommended the destruction of the on-site water supply well and monthly bailing of LNAPL from MW-1 for two quarters. Following completion of the recommended activities, the LNAPL thickness would be re-evaluated (Delta, 2001).

2001-2002 – Remedial Activities

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

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

A RAP/FS was submitted in April 2003. Based on data from the report, it was suggested that a perched zone of groundwater was present at approximately 10 to 40 feet bgs. Confining bedrock underlies the perched zone. It was 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, approximately 5,100 gallons of impacted groundwater were removed 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 a CAP was submitted 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, groundwater pumping tests were recommended in the December 2008 CAP Addendum and Proposed FS. The results of the proposed pumping tests would further define the necessary scope for soil and groundwater remediation at the site and to evaluate remedial alternatives to address LNAPL (CRA, 2008).

May 2010 Vacuum Extraction Event/Pilot Test

In May 2010, a vacuum extraction pilot test was performed 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

The following scope of work has been prepared to further characterize impacts to soil and groundwater on the subject property. The scope of work proposed for this assessment includes the advancement of eight soil borings as illustrated on Figure 2 to collect soil and groundwater samples and the completion of a LNAPL baildown test.

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

All eight boring locations will be hand cleared 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. Soil samples will be continuously collected, from the eight boring locations, for logging purposes and visual classification from the utility clearance depth to the total borehole depth. The boreholes will be advanced with 4-inch diameter inner core tube in 2.5 foot sections of 20 foot runs. Each discrete interval will be logged 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, a 6.375 inch outer diameter temporary outer drive casing will be advanced 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

Undisturbed soil cores will be collected to characterize the in-situ conditions that control 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. Undisturbed soil cores will be collected at two to three sampling depths. 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). The soil sample cores will be collected in polyvinyl chloride (PVC) sleeves. The length of the soil core will depend on the extent of the SPH impacts. Sampling depths for undisturbed soil core will be chosen, based upon the areal and vertical extent of SPH impact. Undisturbed soil cores will be collected 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. Cores will be frozen vertically on-site with dry-ice to maintain the integrity of the soil core following methods specified in the SOP (Attachment 1).

Frozen soil cores will be shipped 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
- BTEX by USEPA Method 8260B
- Methyl tertiary butyl ether (MTBE) by USEPA Method 8260B

Temporary Wells

Groundwater grab samples will be collected from each boring location 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 1. It is anticipated that the temporary wells will be screened from approximately 30 to 40 feet bgs. The actual screen and depth interval will be determined based on observations in the field. Prior to sample collection, water will be purged (i.e. three casing volumes) from the temporary well to remove sediments accumulated during the drilling activities. 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. Following completion of soil sampling, the boreholes will be tremie grouted to ground surface.

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 (eight 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, a LNAPL baildown test will be conducted. The results of the baildown test will aid in evaluating LNAPL mobility and recoverability at the site. One peristaltic pump, or similar pump, will be installed temporarily in monitoring well MW-1. 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. LNAPL will be removed 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, measuring will begin in five minute increments to monitor changes in hydraulic head. Measurements of LNAPL and depth to water will be collected and recorded. The SOP is presented in Attachment 2. 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. The LNAPL and groundwater collected during the test will be placed in a proper waste management container. 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

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

Report

A report detailing the results of the investigation will be prepared 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
- 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.

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 R. Russi
Associate Project Manager

David W. Lay, P.G., C.P.G.
Principal Geologist

PROFESSIONAL GEOLOGIST
DAVID LAY
No.8545
STATE OF CALIFORNIA

References

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Enclosures:

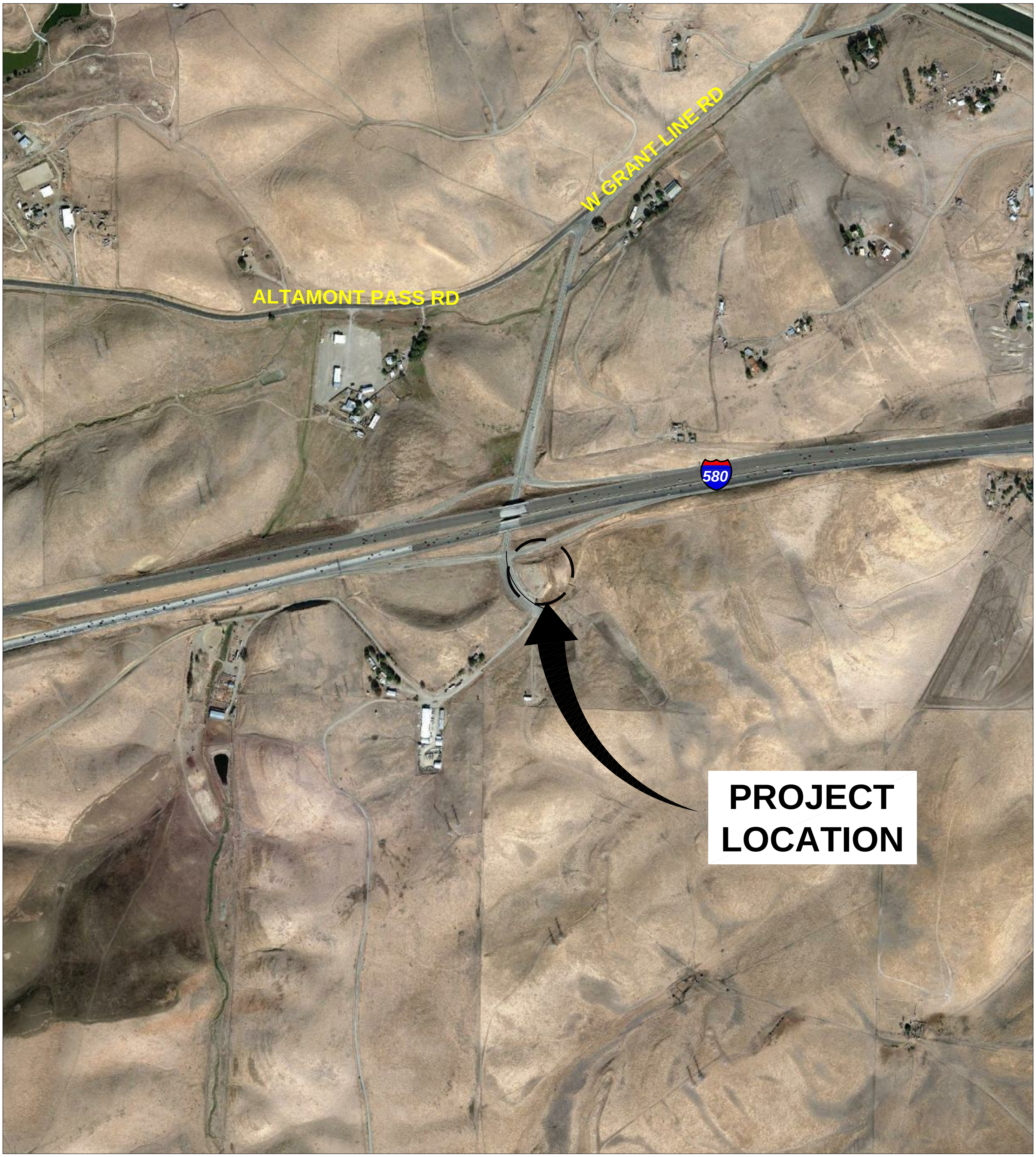
Figure 1	Site Location Map
Figure 2	Site Plan with Proposed Boring Locations
Attachment 1	ARCADIS *LNAPL Soil Core Collection* SOP
Attachment 2	ARCADIS *LNAPL Bailbown Test* SOP

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*
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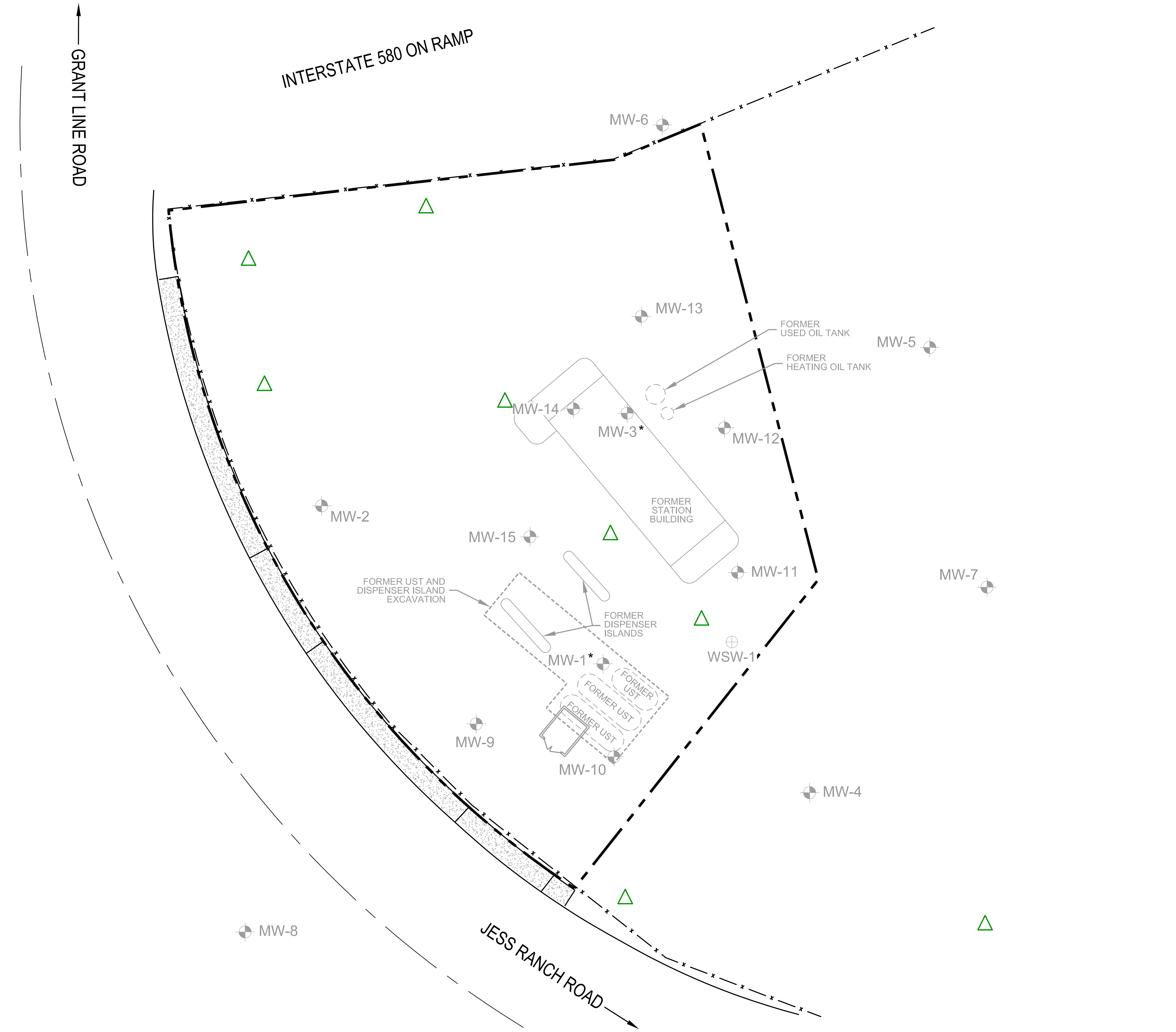


LEGEND

PROPERTY BOUNDARY

FENCE

MW-1 MONITORING WELL LOCATION

WSW-1 WATER SUPPLY WELL (LIVESTOCK)

PROPOSED BORING

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 LOCATIONS

ARCADIS

FIGURE
2

CITY: PETALUMA, CA DIV/GROUP: ENV DB: J. HARRIS
G:\ENVCAD\Roseville-CA\RETURN-TO\Petaluma-CA\B0047959\0000\00100\DWG\47959C01.dwg LAYOUT: 2 SAVED: 8/29/2012 2:26 PM ACADVER: 18.1S (LMS TECH) PAGESETUP: SETUP1 PLOTSTYLETABLE: ARCADIS.CTB PLOTTED: 8/29/2012 2:27 PM BY: ROBITAILLE, BEVERLY
XREFS: 47959X01 IMAGES: B0047959.0000.00100 google 2790x.jpg PROJECTNAME: ----

ARCADIS

Attachment 1

ARCADIS *LNAPL Soil Core Collection* SOP

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)

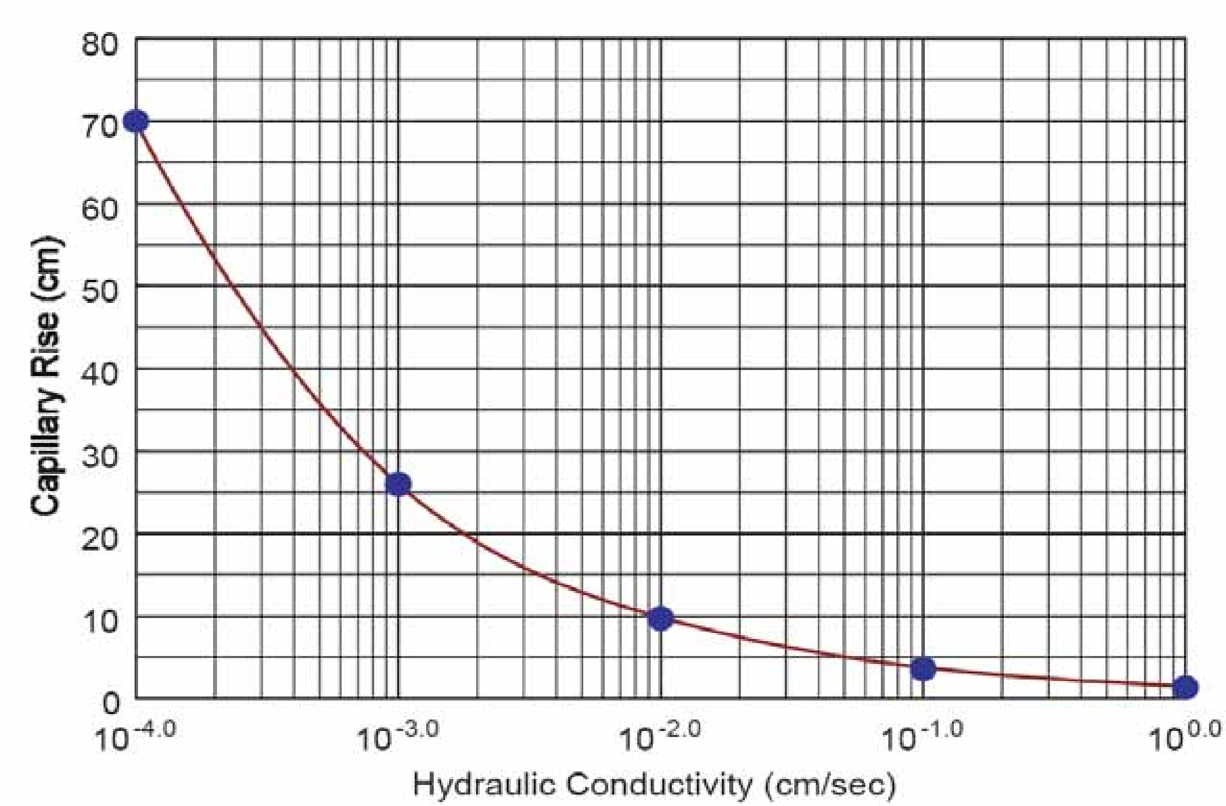


Figure 1 — Capillary rise as function of hydraulic conductivity (API 4711)

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.)

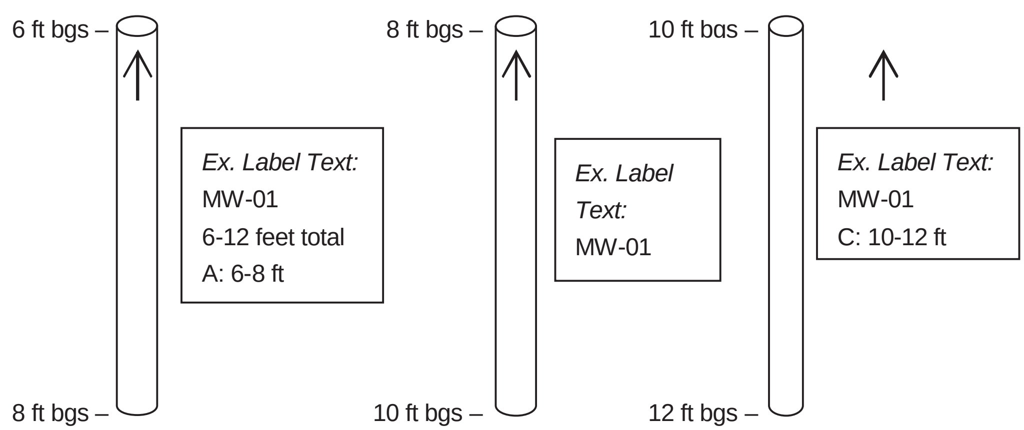


Figure 2 – Schematic showing example of how to label multiple cores per well.

- 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.
- 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.
- 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.

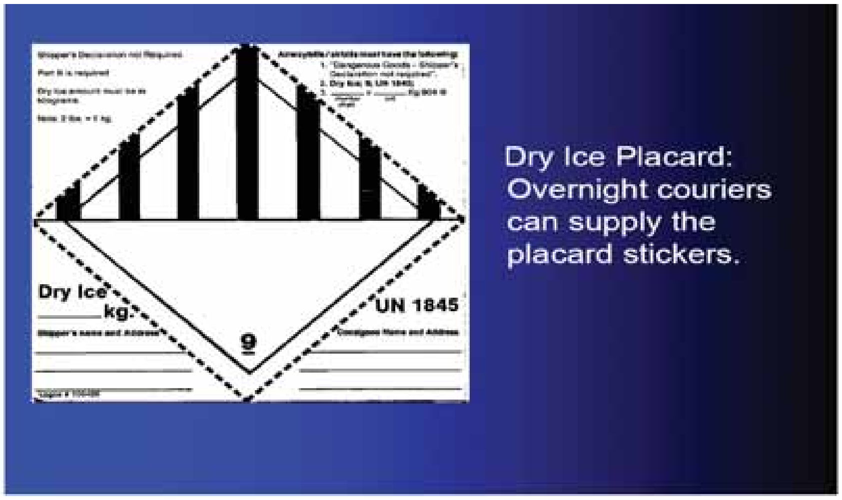
VII. Cooler Preparation and Shipping

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 *LNAPL Bailbown Test* SOP

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